(1) Engine output

Engine output (metric horsepower: PS) can be found by using the followng formula:

$$\text{Engine output:} \quad Pe \geq \frac{P}{0.736 \times \eta_G} \text{ (P.S.)}$$

where, generator output (P) = 5,000 (kW)

1 (PS) = 0.736 (kW)

Generator efficiency ($\eta_G$) = 96 (%)

$$PG \geq \frac{5,000}{0.736 \times 0.96} \simeq 7,080 \text{ (P.S.)}$$

(2) Rated capacity of the generator

The rated capacity $P_G$ (kVA) of the generator can be found by using the following formula:

$$PG = \frac{P}{P.f} = \frac{5,000}{0.8} = 6,250 \text{ (kVA)}$$

where, power factor of the generator: P.f = 0.8

4.2.2 Step-up Transformer

Two (2) banks of single-phase transformer (Total 6 units, 18.75 MVA) are installed to step-up generated voltage at Bushrod Diesel Plant. As those banks are seriously obsolete and also spare one is already out of order, the total reliability of the plant is assumed very poor, and so one (1) bank of the said banks will be replaced with one 20 MVA transformer, considering the future development plan.

### 4.2.3 Station Service Transformer

Two (2) banks of 500 kVA Transformers are installed for station service purpose at Bushrod diesel plant, but those ones are obsolete. For the above-mentioned reason, one of the transformers will be replaced with one same capacity transformer.

### 4.2.4 Switchboard

The below-mentioned supervisory and control panels must be able to control and supervise the operation of the diesel generating units in this Project:

(1) Main supervisory controls
(2) Generating unit control panels
(3) Neutral point grounding resistor panel
(4) DC distribution panel
(5) AC distribution panels
(6) Excitor panels

### 4.2.5 Circuit Breakers

Switches are required to start and stop the power supply generated by the diesel generating units under this Project to the existing buses through which the power is supplied.

(1) 15 kV circuit breaker

A vacuum circuit breaker (VCB) should be adopted for this purpose since it is very reliable and economical. The function of the CB is to break the current if any troubles occur in protecting the electric equipment and instruments. It is "closed" during normal generation and "opened" during suspecded operation.

(2) 72 kV circuit breaker

A gas circuit breaker (GCB), SF6, which is generally adopted in this class of voltage, should be adopted in this Project.

### 4.2.6 Equipment Schedule

The specifications of the equipment to be granted are outlined below:

(1) Principal Equipment

Principal equipment shows in Table 4-1.

(2) Auxiliary system

As shown in the attached Fig. 3-7 and 3-8, the heavy oil and diesel oil should be branched from the existing system and supplied to the generating units, while the cooling water should be supplied from the nearest water supply pipe.

The new plant should be separated from the existing Bushrod Plants No. 5 and No. 6 to ensure reliability of power supply.

Special consideration should be given to the disposal of waste oil by constructing waste oil tanks and incinerators so that it may be disposed of within the power plant.

Concerning the steam for heating the heavy oil supply system which is presently supplied from the Luke Diesel Plant, consideration should be given to utilizing the steam from the engine to be constructed in this Project so that reliability and stability of the power supply may be enhanced.

(3) Materials for maintenance

(a) Main equipment

To the main equipment to be provided under this Project should be added those materials and spare parts which are required for the daily maintenance of the main equipment for a three-year operation as well as those spare parts which are required for carrying out two overhaulings (mainly of the engine), such as piston rings, gaskets, and bearings.

Table 4-1 Principal Equipment (1/2)

| Item | Specification | Quantity | | |
|---|---|---|---|---|
| | | Phase I | Phase II | Total |
| Diesel Engine | Type : 4-cycle, stationary type, for power generation use<br>Output : Approx. 7080 (PS), continuous<br>Speed : Medium-speed class<br>Cooling method : Radiator<br>Fuel : Heavy Oil C | 1 set | 1 set | 2 sets |
| Generator | Type : Three-phase, Ac, horizontal, synchronous generator<br>Rated output : 5,000 (kW), continuous<br>Rated capacity : 6,250 (kVA), continuous<br>Voltage : 12.5 (kV)<br>No. of poles : 10 (poles)<br>Power factor : 0.8 (delay)<br>Frequency : 60 (Hz)<br>Insulation class : Class F<br>Excitation method : Brushless<br>Cooling method : Air cooling | 1 set | 1 set | 2 sets |
| Set-up Transformer | Type : Outdoor, 3 phases<br>Rated capacity : 20 (MVA)<br>Voltage : 12.5/69 (kV)<br>Frequency : 60 (Hz)<br>Connection : Delta/Y<br>Neutral point : Direct grounding | - | 1 set | 1 set |
| Station Service Transformer | Type : Indoor, 3 phases<br>Rated capacity : 500 (kVA), continuous<br>Voltage : 12.5 (kV)/440 - 254 (V), (3 phases-4 wires)<br>Frequency : 60 (Hz)<br>Connection : Delta/Y<br>Neutral point : Direct grounding | 1 set | - | 1 set |

Table 4-1 Principal Equipment (2/2)

| Item | Specification | Quantity | | |
|---|---|---|---|---|
| | | Phase I | Phase II | Total |
| Circuit Breaker | Type : Outdoor, three-phase gas circuit breaker<br>Rated voltage : 72 kV<br>Rated current : 1,200 (A)<br>Rated breaking current : 20 (kA) | - | 1 set | 1 set |
| Metal Enclosed Cubicle | Type : Indoor, enclosed, self-supported<br>Circuit breaker : Vacuum<br>Rated voltage : 15 kV<br>Rated current : 1,250 A<br>Application : For 12.5 kV circuit | | | |
| | (a) For generators x 2<br>(b) For step-up transformer x 1<br>(c) For 12.5 kV feeder x 1<br>(d) For gas turbine generation x 1<br>(e) Station service transformer x 1 | 5 sets | 1 set | 6 sets |
| Switchboard | Type : Indoor, enclosed, self-supported<br>Application : For control and protection | | | |
| | (a) Main supervisory control panel x 2<br>(b) Generating unit control panel x 2<br>(c) Neutral point grounding resistor panel x 1<br>(d) DC distribution panel (120 V) x 1<br>(e) AC distribution panel (400 V) x 2<br>(f) Excitor panel x 2 | Total<br><br>6 sets | Toatl<br><br>4 sets | Total<br><br>10 sets |
| Power Cable | Type : CV cable<br>Voltage : 15 kV<br>Cable thickness : 250 ($mm^2$), 150 ($mm^2$), 38 ($Mm^2$) | 1 lot | 1 lot | 2 lots |

(b) Switchboards (and others)

It is natural that the types and quantities of spare parts to be porvided should differ between stationary equipment and equipment with movable parts. Spare parts (such as fuses and pilot lamps) which are required for daily maintenance for the three-year operation should be granted together with those spare parts which represent, at least, one item per one type for i) those which are subject to mechanical wear and degradation such as relays, electromagnetic contactor coils, contacts, gaskets, and bearings, and ii) those which cannot be repaired at the site, including bushings, thermometers, oil level gauges, and selector switches.

4.2.7 Affect on the Power System

The power distributing facilities such as transmission lines and substations have ample capacities in the Monrovia Power System. No problems will occur in this system, providing the 10-MW generating units of this project are installed.

# CHAPTER 5 PROJECT IMPLEMENTATION PLAN

# CHAPTER 5 PROJECT IMPLEMENTATION PLAN

## 5.1 IMPLEMENTATION ORGANIZATION

As a result of discussions with the Government of Liberia, the Government of Japan has determined to implement the required work under the below-mentioned organization to carry out this Project under the grant aid cooperation of the Japanes Government. Fig. 5-1 illustrates the principal project implementation system.

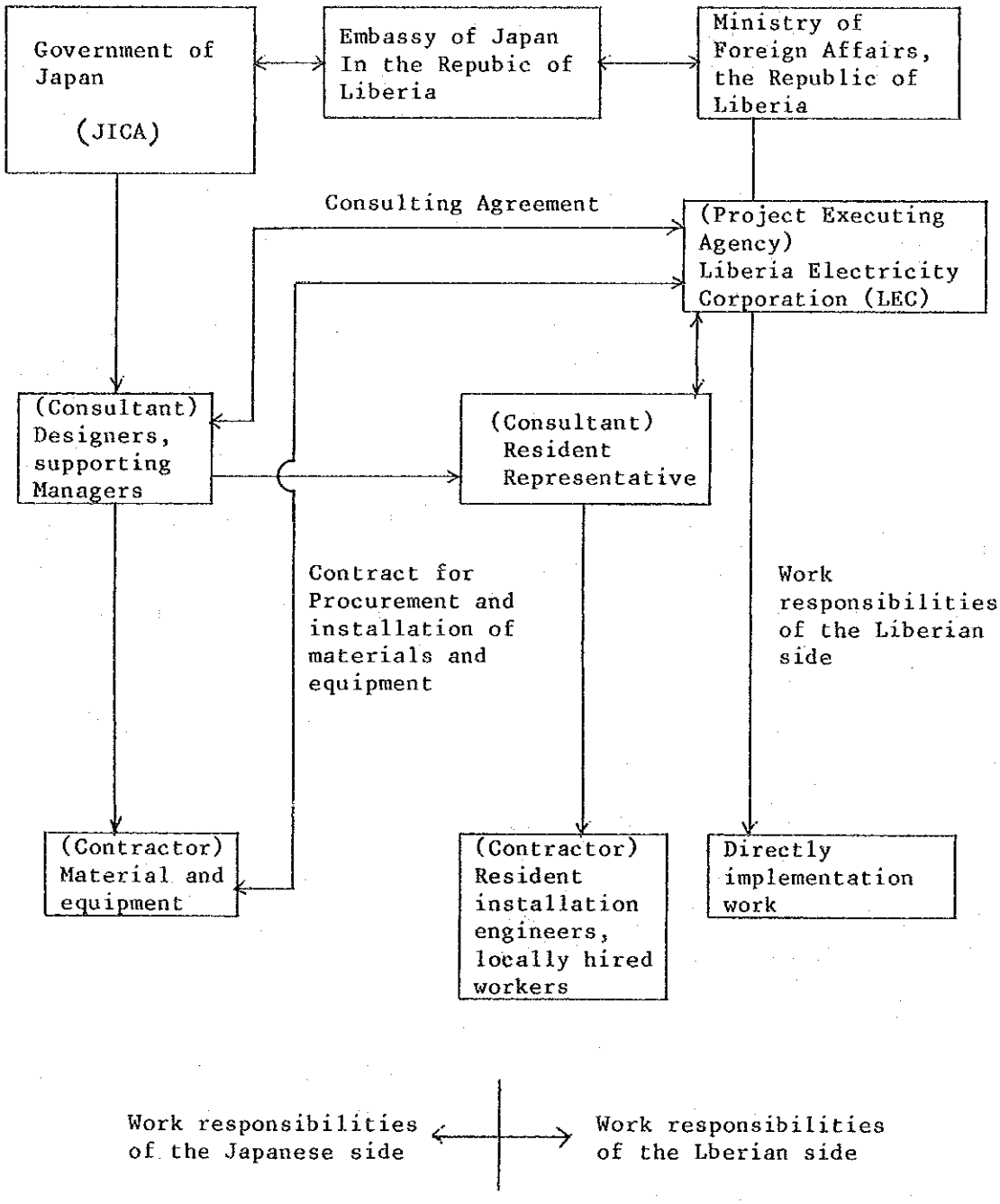
### 5.1.1 Scope of Work on the Liberian Side

After conclusion of the Exchange of Notes (E/N), the LEC will assume responsibility for work items assigned to Liberian side. It will conclude agreements with a Japanese consultant and contractor and proceed with installation work of the grant equipment. The LEC Section in charge of this Project at the implementation stage is the Technical Section, the Corporate Planning and Development Dept., Technical Div. When the implementation stage reaches its peak, however, a project team composed of technical staff will be established.

The LEC is preparing budget for implementing the work that falls within the scope of Liberia's responsibilities.

Conclusion of banking arrangement (B/A) covering disbursements in this Project and the issuance of the authorization to pay (A/P) under the consulting agreement and contractual agreement will be conducted between a bank to be designated by the Liberian side and a Japanese foreign exchange bank.

Fig. 5-1 Project Implementation Organization



### 5.1.2 Scope of the Consultant's Work

After the Japanese Government decides on this Project, the Government of Liberia and the Government of Japan will exchange notes, and a consulting agreement for the Project will be concluded between LEC and a Japanese consulting firm. Detailed design, preparation of tender documents, bidding and supervision of construction work should then be carried out under the said consulting agreement.

(1) Detailed design

The consultant should determine the contractual conditions necessary for contracted work, including but not limited to the general and special conditions, agreement forms, technical specifications and other drawings and formats in accordance with the results of the basic design survey.

(2) Tenders for contractor selection

Before commencing construction, the consultant shall, for the purposes of selecting the contractor, issue a public notice inviting tenders, receive tender requests, convene a meeting to explain the tender conditions, and issue the tender documents. After the tendering period, the consultant shall accept and review the tenders and provide the necessary assistance in the conclusion of a contracting agreement between the LEC and the Japanese contractor.

(3) Review for approval drawings

Any necessary work required to approve the equipment and material manufacturing drawings to be submitted by the contractor shall be conducted by the Japanese consultant who acts on behalf of the LEC, since the drawings are indispensable for the procurement of such equipment and materials and are urgently required.

(4) Shop tests

So-called "shop" tests should be carried out to confirm that the equipment manufactured by the contractor is being or has been manufactured in accordance with the technical specifications designated

in the contracting agreement and the drawings approved by the consultant. These tests should be carried out in the presence of the Japanese consultant who acts for the LEC.

(5) Supervision of site construction work

The consultant shall dispatch its staff to the job site at the critical work stages, such as the discussion meetings prior to commencement of construction, installation of main equipment, equipment adjustment and tests, and delivery in accordance with the consulting agreement to supervise this project in such a manner that it is completed smoothly within the period specified in the E/N.

(6) Reports on Work Progress

The consultant shall send a monthly report, whenever appropriate, to the Government of Japan on the state of progress of this Project during those periods in which the contractor manufactures, transports, installs, adjusts and tests, and delivers the equipment.

5.1.3 Scope of the Contractor's Work

After concluding the contracting agreement with the LEC for the supply and installation of grant aid equipment under this Project, the Japanese contractor shall carry out the below-mentioned work.

(1) Preparation of manufacturing equipment drawings

The contractor shall prepare design drawings for manufacturing equipment to be granted under the conditions of the agreement and apply for approval to the consultant.

(2) Manufacturing of equipment to be provided

The contractor shall manufacture the equipment to be provided in accordance with the drawings duly approved and request the consultant to witness shop tests conducted by the contractor for the purpose of confirming that the equipment being produced or already completed meets the contractual conditions and the requirements specified in the approved drawings.

(3) Transportation

The contractor shall transport the equipment and materials from a port of departure in Japan to Monrovia as the port of destination in the Republic of Liberia and shall carry out land transportation to the Bushrod Power Plant site of the LEC after unloading and completing customs clearance at the port of destination.

(4) Installation

The contractor shall prepare the foundations for installing the equipment to be provided, and undertake installation work including connecting buses to the existing power system, connecting fuel pipes to the existing fuel pipeline, and connecting cooling water pipes to the existing cooling water pipeline.

(5) Adjustments and tests prior to taking-over

The contractor shall carry out a series of adjustments and tests to confirm the performance of the diesel power generators after completing the installation work.

(6) On-the-job training

During the installation of the equipment, the contractor shall provide on-the-job training and maintenance training to the LEC personnel who are expected to take responsibility for the operation and maintenance of the equipment.

## 5.2 SCOPE OF WORK

The scope of work to be performed by the Government of Liberia and the Government of Japan for this Project is stated below:

### 5.2.1 Scope of Work to be Performed by the Government of Japan

(1) Manufacturing of the equipment and materials listed in section 4.2.6 above

(2) Marine and inland transportation of the equipment and materials as specified in the item (1) above

(3) Installation, adjustments, and tests of the said equipment and materials

(4) Consulting work related to detailed design, tendering and administration of construction

5.2.2 Scope of Work to be Performed by the Government of Liberia

(1) Provision and preparation of a construction site

(2) Opening and closing of an entrance into the generator house required for delivering the equipment and materials as specified in Section 5.2.1 (1) above

(3) Removal of the existing power plant and ancillary facilities and cleaning of the site after the removal

(4) Supply of water and electricity during the construction work and supply of fuel for trial operation

(5) All items other than those which are carried out under the grant aid cooperation

The implementation of this grant aid shall be based on the premise that the Government of Liberia is responsible for taking the necessary measures to provide exemption of all taxes and customs duties applicable to equipment, materials, and services to be given by Japanese people related to the construction work and to manage and operate this facility smoothly and promptly.

## 5.3 PROCUREMENT, TRANSPORTATION AND CONSTRUCTION PLAN

### 5.3.1 Equipment and Material Procurement Plan

Those items with specific applications required in implementing the construction work are seldom produced in the Republic of Liberia, and so their supply must come from imports from Japan. The table below shows the

plan to procure the main equipment and materials related to implementation of this Project:

| Procurement from Japan | Local procurement |
|---|---|
| Diesel Engine<br>Generator<br>Transformer<br>Switchboard<br>Pump<br>Pipe and valve<br>Cable conduits and cable<br>Steel material<br>Paint<br>Special maintenance tool<br>Other material<br>Spare parts (for three-year normal operation) | Crossties<br>Cement<br>Aggregate (sand and gravel) |

It is necessary to determine the construction stages by fully considering the anticipated progress in inland transportation and delivery of the equipment and materials to the site as well as considering the foundation and installation work.

Presently it is thought appropriate that the marine transportation of equipment and materials should be divided into 2 times; the first vessel shall transport tools and ancillary equipment and materials while the second one shall transport the main equipment and other materials. After the main equipment and materials are unloaded at the port of Monrovia, transported to the site, assembled, and mechanical, and electric work adjustments and tests carried out, the completed diesel power plant shall be handed over to the organization responsible for project implementation.

When taking the above-mentioned factors and the time required for marine and inland transportation into consideration, the second vessel shall have to depart from a Japanese port at least five (5) months before the intended delivery date of the equipment to be provided. It is necessary, therefore, that procurement of the equipment and materials including manufacturing, inspection, packing, and transportation should be completed in time for such departure.

Concerning those items among the main equipment and materials which may be easily damaged by impact or humidity, and/or are sensitive to high temperature, great care should be given to packing and thorough inspections should be applied prior to shipment. For example, a switchboard, which incorporates lots of instruments and may be easily damaged on impact should be securely fixed in position when packed. Both the generator stator and the rotor which may be easily damaged by humidity should be vacuum-packed, and paints which are extremely sensitive to high temperature should be packed in a manner to prevent ignition during transportation.

Since periodic inspection and maintenance should be fully carried out during the management and operation of facilities to be provided after they are handed over to the LEC, it will be necessary for this Project to include an appropriate number of spare parts in addition to the main equipment and materials so that any possible troubles may be quickly and smoothly coped with.

5.3.2 Transportation

Several shipping companies ship from Japan to Monrovia each month. Although full container vessel may be sometimes assigned to this line, cargo to be loaded and unloaded at that port is sometimes so small that regular assignment is not always carried out.

Moreover, some types of equipment included in this Project are so eavy that a vessel equipped with a heavy derrick is required. It is necessary, therefore, to establish a shipping plan at an early stage.

Regarding inland transportation in the Republic of Liberia, transportation of heavy cargo needs particular review. The maximum available trailler in the Republic is 40 tons, and if the cargo exceeds this weight, some transportation means must be procured in a third country and delivered to the Republic. With reference to cranes to be used for unloading and installing equipment and materials at the power plant site, the LEC presently has one 70-ton crane. This has the capacity to unload only, and when hoisting upstairs, the 70-ton crane will have to be assisted by a crane with a lifting capacity of 30 tons or more. Since such a 30-ton crane is not available in the Republic, it is necessary to secure it in a third country.

It is recommended that equipment and materials other than heavy or long items should be housed in a container for the purposes of smooth cargo handling at Monrovia, inland transportation, protection from theft, and storage at the construction site.

### 5.3.3 Implementation Plan

Immediatly after the Exchange of Notes (E/N), the consultant shall conclude a consulting agreement with the LEC, prepare a detailed design in accordance with the plan of the Basic Design, and fully explain the results to the LEC. At the same time, the consultant shall have to confirm detailed schedules of the work to be carried out by the Government of the Republic of Liberia. Among others, the removal of existing equipment, the clearing of the site after removal, and the securing of an entrance for delivering the main equipment must be completed before the Japanese contractor commences installation work of the equipment. This is the key point if the whole work is to be smoothly completed. It is also necessary to devise a plan, as carefully as possible, and to establish concrete construction procedures which do not require any readjustments at a later stage, incorporating the scope of work of the Liberian side, installation and delivery work of equipment and materials, commencement schedules for work items in each stage, and demarcation of work between the parties.

Since this Project includes installation of the equipment in a power plant in which operating power facilities already exist, it is obviously essential to conduct discussions and adjustments between the parties concerned before the Japanese contractor starts such types of work as connection of the buses to the existing power system, connection of the pipes to the existing fuel pipeline, and connection of the pipes to the existing cooling water pipeline. It is hoped that the LEC will manage these works in an appropriate manner so that they may be completed in time.

## 5.4 IMPLEMENTATION SCHEDULE

The implementation schedule for this Project has been prepared as shown in Fig. 5-2 "Project Implementation Schedule", on the assumption that it will take twelve (12) months from the conclusion of the E/N between the Governments concerned to the transfer of the facilities to the Liberian authorities.

Fig. 5-2 Implementation Schedule of the Project for Improvement of Electric Power Supply in Monrovia

| No. | Item / Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Exchange of Notes (E/N) | ☆ | | | | | | | | | | | | The same schedule applies to Phase I & II. |
| 2. | Consultancy Service Contract Detailed Design / Preparation of Tender Documents | △ | ▬ | | | | | | | | | | | |
| 3. | Issue of Tender Documents | | △ | | | | | | | | | | | |
| 4. | Tendering and Signing of Contract/ Verification | | ▬ | △ | | | | | | | | | | |
| 5. | Approval of Drawings | | | | ▬ | ▬ | | | | | | | | |
| 6. | Manufacturing Shop Test | | | | ▬ | ▬ | ▬ | △ | | | | | | |
| 7. | Marine Transportation | | | | | | | ▬ | ▬ | | | | | |
| 8. | Pre-Construction Meeting | | | | | | | | ▬ | ▬ | | | | |
| 9. | Inland Transportation | | | | | | | | ▬ | ▬ | | | | |
| 10. | Removal of Existing Equipment (LEC) | | | | | ▬ | ▬ | ▬ | | | | | | |
| 11. | Installation Work | | | | | | | | ▬ | ▬ | ▬ | ▬ | | |
| 12. | Taking-over Test | | | | | | | | | | | | ▬ | |
| 13. | Technical Transfer | | | | | | | | | ▬ | ▬ | ▬ | | |
| 14. | Commissioning | | | | | | | | | | | | △ | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |

The implementation of this project will be divided into two (2) phases due to the regulation of the grant aid program and in order to make more elaborate technology transfer during installation and testing stages.

## 5.5 OPERATION AND MAINTENANCE PLAN

Periodic inspections as well as daily checkings are indispensable so that the equipment can achieve full performance once operation begins. It is important, therefore, to be able to operate and maintain the equipment through the on-the-job training to be given during the installation stage. It is also important to prepare a maintenance and repair plan covering the operation plan based on the items described in the manual prepared by the manufacturer and to observe the plan without fail.

Presently, the operation and maintenance personnel of the Bushrod diesel plant belong to the common organization of the Luke diesel plant. But after installation of the new diesel generator at Bushrod plant, in order to clarify the responsibility of personnel of each plant, a separate organization of new Bushrod Plant should be set up and form a new management system similar to the present Luke plant.

Presently, the Luke plant is adopting an operation system whereby operation and maintenance is undertaken by Liberian engineers under the guidance of three foreign experts. Therefore, it will be necessary, that the training after the commissioning in operation and maintenance by Japanese experts for the equipment to be provided by the grant aid should be considered.

# CHAPTER 6 PROJECT EVALUATION

# CHAPTER 6 PROJECT EVALUATION

## 6.1 PROJECT BENEFITS

### 6.1.1 Alleviation of the load shedding

Despite the overall decline in power consumption, the load shedding have been, in the recent years, practiced daily in the Monrovia Power System in Liberia. Taking the load shedding during the dry season last year (January to May) for instance it averaged 3.3 hours a day for one feeder of the main substations and sometimes it reached appriximately 5 hours on average at a certain substation. Moreover, in some feeders no electricity was supplied for an entire day. The existing facilities cannot cope with such a grave situation since the facilities are extremely obsolete and even the newly installed facilities break down frequently. Therefore, there is little hope for a reliable supply of electric power under the present circumstances. It is predicted that there will be 6-hour power shortage a day in the 1989/90 and the supply-demand balance will become even more critical.

When the 10-MW generator which is planned to be provided from the Government of Japan commences operation, the shortage time will be reduced greatly, from 6 hours to 1 hour. Yet the problem will not be solved entirely unless additional diesel generators (20 MW) are introduced urgently or a new hydroelectric power plant is constructed. However, Japan's grant aid assistance can be regarded as an emergency measure expected to greatly relieve the intensive load shedding in the Monrovia Power System.

### 6.1.2 Contribution to Financial Position

As already stated, the financial position of the LEC is weak with problems such as uncollected electricity bills, non-technical losses and serious income deficiencies. For the implementation of the "Five-Year Development Plan", the securing of financial sources is a major task. By the implementation of this project, the LEC anticipates 520 GWh of newly generated electric power for 20 years (10 MW x 0.8 x 65,000 hours) and estimates 85 million U.S. dollars in revenue. Even considering a loss

ratio of 28%, the revenue from the electricity supply is expected to amount to 61.8 million U.S. dollars. As a result, the financial condition will be improved by about 309 million U.S. dollars annually. Since the total revenue of the LEC was approximately 35.6 million dollars in the 1984/85, this new revenue is equal to about 9% of the total revenue an amount that can cover almost 60% of the expenditure on fuel.

Even when deducting expenses for personnel, fuel and maintenance required in the operation of this project from the gross revenue, a 2.0 million U.S. dolalrs increase in revenue will be netted to contribute greatly to the LEC's finances.

6.1.3 Savings of the Fuel Expenditure

Oil diesel generation is the LEC's main power source, particularly in the dry season. For this reason, the financial burden represented by fuel expenses is extremely heavy. In 1986 load shedding had to be practiced in larger areas due to budgetary restrictions on fuel purchases. The expenditure on fuel has fluctuated as follows: 9.4 million dollars in 1981/82, 8.6 million dollars in 1982/83, 7.7 million dollars in 1983/84 and an increase to 9.6 million dollars in 1984/85. In 1985/86, the expenditure decreased to 5.3 million dollars according to estimates. This nevertheless, does not mean savings were achieved, what actually took place was that load sheddings were incorporated in the fuel expenses budget for financial reasons. For that reason, substantial power restrictions were implemented.

Accordingly, the reduction of fuel costs is a presing task of the LEC. The corporation intends to restrain as much as possible gas turbine generation, in particular, which has a high fuel-unit price. The generator being considered for introduction in this project uses heavy oil, thus compared to a gas turbine with the same capacity, a total reduction of 44 million U.S. dollars for twenty years will be achieved. Based on the annual expenditures, the introduction of the new generator will enable costs to be saved by 2.2 million U.S. dollars.

As we have seen, by selecting a heavy oil diesel engines with lower operation costs, the LEC's financial burden will be lightened, and the existing gas turbine will be utilized as a reserve power source.

### 6.1.4 Impact on Liberian People and Public Services

The residential consumers of the LEC amount to 36,000 to 37,000 centering around the Greater Monrovia area. There are around 92,000 families, of which only about 40% are served with electricity.

In recent years the use of electric appliances has remarkably spread through ordinary households. It is expected that the power consumption by households will increase rapidly as the demand for TV, radio, refregerator, air-conditioner, etc. grows. Therefore, load shedding implemented over the past two or five years have been directed mainly at ordinary residence. The citizen's daily life has been seriously affected by the load sheddings. On the other hand, the practice of load shedding also adversely affects daily services of the public organizations such as the government offices, telephone and telegraph offices, hospitals, waterworks offices, etc. The suspension of the government office work caused by load shedding restricts seriously the public services to the citizens.

The increase of LEC's power supply capacity through Japanese cooperation will greatly improve the living conditions of citizens in Monrovia and public services in general. So it can be said that the citizens will be able to benefit substantially from electricity with the improvement of the Monrovia Power System.

### 6.1.5 Indirect Benefits to the Industrial Sector

The growth of the manufacturing sector has been falling in the reent past. It fell by an average of almost 6% over the five years from 1980 to 1984. As of 1981, there were 852 industrial establishments in Monrovia. The main type of the manufacturers are: wearing garments (426 companies), furniture (171), block factories (99), bakeries (39), Jewelleries (37), and printing and publishing (31). In addition, most of them are small or medium-sized enterprises.

The growth of the domestic industries has slowed down due to the recent world-wide recession and sluggish international price of primary commodities, but until 1980 industrial sector accounted for 17% of the total power consumption.

The LEC's prolonged outages have seriously affected the major industries. Their financial cost burden has been considerable, since they had to install private and back-up generators by themselves in the event of inadequate power supply.

In fact, in case of the Liberia Industrial Free Zone, established in 1975 by the government, it owns a 113-acre total area, however only five companies have moved in so far. In negotiations with foreign companies, the one of main issues cited is the reliable supply of power. The foreign companies have expressed their concern that their initial investment costs will increase remarkably with the addition of emergency equipment to be used in times of power cuts. These added costs will reduce the viability of their investment.

The LEC supplied 14.64 GWh of power to the manufacturing sector in 1985/86. This accounts for little less than 7% of the total. The LEC, nevertheless, intends to increase to more than 28.51 GWh, or 11% in 1986/87. Under these circumstances, the project is extremely important to ensure full year round supply to the industrial sector and it would contribute to reducing the financial burden on each company.

## 6.2 FINANCIAL EVALUATION

The financial evaluation attempts to analyze the proposed Project of 10 MW diesel units if it has viable financial impact on the LEC. The evaluation assessed the project on the following assumptions regarding the plant operation schedule, projected energy sales, investment costs, operation and maintenance costs, fuel expenses as well as project benefits.

(a) Plant operation schedule

The proposed project is aimed at supplying additional electricity over the present level to the Monrovia Power System during the dry season. Toward the end of the twentieth century it is expected that hydroelectricity power projects will be operational to gradually replace the high cost diesel generation units and to cater to the major energy requirements in the MPS. Thus the said plant operation schedule is envisaged to provide a generation mix and meet rather

medium-term energy needs in view of the current in adequate power generation capacity. Taking the above conditions into account, the plant operation schedule is set as follows:

| | |
|---|---|
| 1990 - 1999 | 3,600 hours operation per annum |
| 2000 - 2009 | 2,900 hours operation per annum |

The gross power generation is computed in that manner accordingly.

(b) Increment in energy sales

The increment in energy sales has been computed by deducting 20% losses in the transmission and distribution systems as well as.8% for auxiliary usage. The total losses of 28% is the projected figure made by the LEC. The present total losses of 39% is also tried as a case in the sensitivity analysis.

(c) Investment Cost

The capital investment cost has been taken from the study team's estimation of the new diesel plant construction cost.

(d) Operation and maintenance costs

The operation and maintenance (O&M) costs are calculated at US$0.01 per kWh including manpower costs, lubrication oil costs, spare-parts and other related overhead costs. In this connection, the LEC's estimation of O&M costs i.e., US$0.012 per kWh is carefully studied for our reference.

(e) Fuel cost

Fuel costs are computed, in this analysis, at the LPRC concession price for fuel oil (US$0.543 per gallon) and gas oil (US$0.708 per gallon) as of March 1987 and fuel usages of 0.0526 and 0.0605 gallon per kWh respectively. As international oil prices cannot be predicted easily at present, a 10% increase in prices is tested in the sensitivity analysis.

(f) Benefits

The project benefits have been worked out by multiplying the increment in sales by the average price of energy paid by the consumers which is almost equivalent to the present power tariff rate of the LEC i.e., US$0.165 per kWh, then collection efficiency which is projected at 87% is applied to complete the Project benefits.

(g) Project life

The project life is taken as twenty (20) years in this evaluation.

The overall financial evaluation, as a result of the above computations, indicates that the financial internal rate of return (or equalizing discount rate) on the project is 19.24%. The net present value is US$4.72 million at a discount factor of 10% and US$3.17 million at 12% respectively. The benefit-cost ratio is 1.32 at a discount factor 10% and 1.24 at 12%.

The sensitivity analysis for the following cases shows:

Case-1 : 10% rise in fuel costs
FIRR is 18.25%

Case-2 : 39% for total losses
FIRR is 13.79%

Case-3 : 77% collection efficiency
FIRR is 15.06%

The financial evaluation described above has indicated that the project is viable and will contribute to improving the financial status of the LEC.

Nevertheless, as the sensitivity analysis indicates, the Project feasibility would be affected by the management efforts of the LEC, particularly commercial losses and collection efficiency problems. It should be reminded therefore that the present LEC strategy toward the above issues e.g. Block Mapping Project should be continued and further strengthened so as to fully accomplish the projected benefits.

# CHAPTER 7 CONCLUSION AND RECOMMENDATIONS

# CHAPTER 7 CONCLUSION AND RECOMMENDATIONS

## 7.1 CONCLUSION

Reliable power supply is indispensable for people's lives, commercial activities and industrial development.

This project aims at alleviating the urgent problem of power shortages in the Monrovia Power System. As a result of the review of details of the Project, it is confirmed that the proposed project is appropriate and viable from the viewpoints of power supply requirements, technical level and, above all, national economy.

Implementation of the Project will contribute to the elimination of the prolonged power blackouts brought about by the shortage in power supply and thereby will lead to improvements in the metropolitan functions in Monrovia, enhancement of the nation's living standard, and the revitalization of industrial activity. It is also believed that the proposed project will consequently contribute to restoring public confidence in the LEC system.

The Government of Liberia has already committed itself to preparations for establishing an implementation organization, operation and maintenance team, administrative restructuring and personnel training for the Project. Therefore, it is convinced that the proposed project is judged to be fully appropriate for the grant aid cooperation of the Government of Japan.

## 7.2 RECOMMENDATIONS

The power generating facilities to be provided under the said project will form an integral part of the Five-Year Development Plan of the Liberia Electricity Corporation. It is recommended that removal of the existing equipment, provision of a new entrance to the present generator house, and other works stipulated under the undertakings of the Government of the Republic of Liberia should be carried out in a timely manner and that the construction work detailed in this project be smoothly undertaken within the proposed implementation schedule after conclusion of the Exchange of Notes.

For the purpose of satisfactory operation of the granted equipment over a long period, the Government of Liberia should enable the LEC technical staff who will be engaged in the operation and maintenance in the new Bushrod Power Station to take an active part in assembling and installation works and testing, as far as opportunities permit, so that they will acquire the necessary technologies from the Japanese experts to be dispatched under the project.

It is also recommended that the Government of Liberia ensure the technical staff to observe the inspection and maintenance procedures described in manuals to be submitted by the Japanese contractor and allocate the appropriate budgets required for procuring spare-parts and fuel for the subsequent diesel operations.

It is desirable, in this connection, that technical assistance by the Japanese Government should be continued for a certain period after commencement of operation so that the LEC staff will be fully accustomed to handling the equipment and develop their own technical knowledge and know-how through on-the-job training.

# ANNEX

# ANNEX PERTINENT DATA AND INFORMATION

ANNEX NUMBER

Key Personnel with whom the Study Team Met

| Organization Name | Name | Position or Title |
|---|---|---|
| Embassy of Japan | Mr. T. Ishidoh | Counselor |
| " | Mr. J. Usui | Third Secretary |
| " | Mr. M. toriumi | Attaché |
| Japan Overseas Cooperation Volunteers/ Liberia, JICA | Mr. M. Yoshimura | Director |
| Liberia Electricity Corporation (LEC) | Mr. D. Allison | Chairman of LEC Board |
| " | Mr. S.N. Burnette | Managing Director (M.D.) |
| " | Mr. C.Z. Neyor | Acting & Dupty M.D. for Technical Services |
| " | Mr. E.L. Clarke | Comptroller, Deputy M.D. for Finance |
| " | Mr. J.T. Mayah | Deputy M.D. for Operations |
| " | Mr. G.B. Coleman | Manager, Corporate Planning Department |
| " | Mr. E.A. Thomas | Assistant Manager, System Study Section |
| Ministry of Foreign Affairs | Mr. Bestman | Assistant Minister for Asian Affairs |
| Ministry of Planning and Economic Affairs | Ms Liberty | Assistant Minister for Statistics |
| " | Mr. Liberty | Assistant Minister for Sectoral Planning |
| Ministry of Land, Mines and Energy | Mr. W. Stewart | Deputy Minister for Planning & Development |
| Ministry of Finance | Dr. A. Sayeh | Advisor to the Ministor of Finance |
| " | Mr. C. Bolu | Chairman |

| Organization Name | Name | Position or Title |
|---|---|---|
| Ministry of Public Works | Mr. A. Ricks | Economist, Planning Department |
| " | Mrs. Belleh | Chief, Planning Department |
| Liberia Central Bank | Mr. Hunder | Economist, Finance Department |
| Ministry of Commerce, Transportation and Industry | Mr. B.T. Collins | Assistant Minister for Insurance |
| Liberia Petroleum Refinary Corporation | Mr. W. Burnette | Deputy Manager for Marketing |
| Liberia Water and Sewerage Corporation | Mr. A.F. Koiguah | Deputy Managing Director for Operation & Outstations |
| International Bank for Reconstruction and Development (IBRD) | Mr. J.C. Kendail | Resident Representative |
| Liberia Industrial Free Zone Authority | Mr. M.W. Dweh | Operation Manager |
| Local Constructor | Mr. P. Pelizzari | Managing Director, BAO |
| " | Mr. P.F.J. Stappers | Marketing Manager, Scanship Inc. |
| " | Mr. P. Manninen | Resident Manager, Lemminkainen OY |
| " | Mr. M. Mathis | General Manager, Fabra Inc. |
| " | Mr. M.S. Hedjazi | General Manager, Hedjazi Steel Works |
| " | Mr. D. Frankfort | General Manager, Nesstra Inc. |
| " | Mr. S.Z. Ghoussainy | General Manager, K&H Construction Company |
| " | Mr. R.T. Barnes | Manager, Lone Star Insurance Inc. |
| " | Mr. R. Schlitt | Superintendent, Electrical Department Bong Mining Company |

| Organization Name | Name | Position or Title |
|---|---|---|
| Educational TV Project (Grant Aid) | Mr. T. Satoh | Chief Engineer, International Division, All Japan Radio & Television Engineering Services Co., Ltd. |
| " | Mr. Tanagashima | Engineer, Broadcast Installation Section, NEC Corporation |

ANNEX - 2

MEMBER LIST OF THE BASIC DESIGN STUDY TEAM, JICA

| NAME | DESIGNATION | ORGANIZATION |
|---|---|---|
| Mr. Seiichi Kanai | General Direction (Leader) | First Basic Design Study Division, Grant Aid Planning & Survey Department Japan International Cooperation Agency (JICA) |
| Mr. Takeshi Ichikawa | Electric Power Planner | EPDC International Limited (EPDCI) |
| Mr. Itsuo Ichinose | Electric & Mechanical Engineer | EPDC International Limited (EPDCI) |
| Mr. Hisashi Takanashi | Economist | EPDC International Limited (EPDCI) |

ITINERARY

| Ordinal Number of Days | Date | Description |
|---|---|---|
| 1 | April 19 (Sun) | Leave Tokyo, SR187 at 20:20 |
| 2 | 20 (Mon) | Arrive in Zurich at 06:35 |
| 3 | 21 (Tue) | Leave Zurich 12:40 - Arrive Monrovia 20:40 SR242 |
| 4 | 22 (Wed) | Visit Japanese Embassy, meet the Counselor, Mr. Ishidoh and brief him on the team's activities and schedule according to the inception report. |
| 5 | 23 (Thu) | Courtesy call to Ministry of Economic Planning, Ministry of Foreign Affairs, Ministry of Finance, Ministry of National Defence (Minister, Chairman of LEC board of directors). |
| 6 | 24 (Fri) | Bushrod Power Plant.<br>To brief the team's activity and schedule by inception report.<br>To survey the Plant. |
| 7 | 25 (Sat) | Survey Mt. Coffee Hydroelectric Power Station |
| 8 | 26 (Sun) | Internal meeting to evaluate the collected data |
| 9 | 27 (Mon) | Visit Bushrod Power Plant.<br>Confirm and discuss the matters of inquiry. |
| 10 | 28 (Tue) | Visit JOCV office. Visit LEC head office, to sign the minute of discussions. |
| 11 | 29 (Wed) | Embassy, intermediate report. (Leader to leave for Japan). Visit Educational TV Project contractor's office (Grant Aid). |
| 12 | 30 (Thu) | Bushrod Power Plant, to collect data and discuss survey schedule. Visit Educational TV Project consultant office (in LBS, Liberia Broadcast Station) |
| 13 | May 1 (Fri) | Visit LEC head office, meet Mr. Burnette, Managing Director.<br>Bushroad Power Plant, to inspect its substation. Visit Ministry of Planning and Economic Affairs to collect economic data. |
| 14 | 2 (Sat) | Visit Bong Mine Co (BMC) to survey electric facility for mining. |

ITINERARY

| Ordinal Number of Days | Date | Description |
|---|---|---|
| 15 | May 3 (Sun) | Study collected data.<br>Preplaration for studies. |
| 16 | 4 (Mon) | Visit Bushrod Power Plant to inspect control room. Visit National Port Authority (NPA) for inspection. Visit transport agencies to collect data. Visit Liberia Petroleum Refinery co (LPRC), to survey oil and fuel prices. Visit United Nations Development and Planning (UNDP) to collect research and development data. |
| 17 | 5 (Tue) | Bushrod Power Plant, basic survey for diesel generating facility. Visit construction companies to collect data. Ministry of Planning and Economic Affairs to collect data. Inspect LEC training center. |
| 18 | 6 (Wed) | Bushrod Power Plant, inspect for auxiliary equipment.<br>Visit assembly companies to collect data.<br>Visit National Energy Committee, NEC, to research energy policy.<br>Visit Ministry of Land, Mine and Energy to examine mining and industrial statistics. |
| 19 | 7 (Thu) | Bushrod Power Plant, inspect pipe routing. Visit glass factories, inspect industrial electric facilities. Visit Industrial Free Zone Agency, IFZA, survey for industrial activities. Visit World Bank office collect information on economic affairs. |
| 20 | 8 (Fri) | Bushrod Power Plant to inspect transportation route for heavy equipment in the site. Survey land transport routes. Visit Ministry of Public Works and research on unit price for construction. Visit Ministry of Finance. Visit Liberia Central Bank, to obtain information on financial affairs, eg., lending rates. |
| 21 | 9 (Sat) | Bushrod Power Plant, supplementary study and photographing. Visit Telecommunications and Telephone Company, to research tariffs. |
| 22 | 10 (Sun) | Visit hotels and rentacar companies to collect information on tariffs. Review collected data. Draft understandings of discussions. |

ITINERARY

| Ordinal Number of Days | Date | Description |
|---|---|---|
| 23 | 11 (Mon) | Visit Bushrod Power Plant to discuss understandings of discussions and request additional data. Visit insurance companies to collect data. Visit National Investment Committee, NIC, to research investment by foreign countries. Visit Liberia Water and Sewage Corporation to collect data for tariff and water quality, LEC Headquarters. Division of Commerce to obtain information on collection of electricity bills. |
| 24 | 12 (Tue) | LEC head office, to sign understandings of discussions and farewell call. Visit Embassy and JOCV office to report. Ministry of Finance to collect data on financial matters. Visit IFZA, UNDP and LEC head office, Department of Personnel Affairs. |
| 25 | 13 (Wed) | Monrovia 10:20 - Amsterdom 22:10, KL578 |
| 26 | 14 (Thu) | Amsterdom 14:20, KL861 |
| 27 | 15 (Fri) | Tokyo 08:50 |

ANNEX - 4

# MINUTES OF DISCUSSION

ON

# THE PROJECT FOR IMPROVEMENT OF ELECTRIC POWER SUPPLY IN MONROVIA

IN

# THE REPUBLIC OF LIBERIA

In response to the request made by the Government of the Republic of Liberia for the Project for Improvement of Electric Power Supply in Monrovia in the Republic of Liberia (hereinafter referred to as "the Project"), the Government of Japan has sent, through the Japan International Cooperation Agency (hereinafter referred to as "JICA") which is an official agency implementing the technical cooperation of the Government of Japan, the team headed Mr. Seiichi Kanai, to conduct the survey for 27 days from April 19 to May 15, 1987.

The team carried out a field survey, held a series of discussions and exchanged views with the authorities concerned of the Government of the Republic of Liberia.

Both parties have agreed to recommend to their respective governments and the authorities concerned to examine the attachment herewith toward the realization of the Project.

April 28, 1987.

Seiichi Kanai

Mr. SEIICHI KANAI
Leader
JICA Study Team

Mr. Chirstopher Z. Neyor
Acting Managing Director
Liberia Electricity Corporation

Attachment

1. The objective of the Project is intended to increase the dry season generating capacity on the Monrovia Power System in order to moderate the intensive load shedding currently being practiced and decrease the dependence on highly expensive gas turbine operations.

2. As one solution of the above-mentioned difficulty, the Government of the Republic of Liberia planned an additional total 10 MW diesel generating unit(s) and requested the Grant Aid to the Government of Japan.

3. The Team will study and propose the most suitable plan for the Project, after careful investigations on the present electrical power system situation.

4. The Team will convey the Government of Japan the desire of the Government of the Republic of Liberia that the former takes necessary measures to cooperate in implementing the Project and bears the cost of the items requested by the latter shown in Annexure-I with in the scope of Japanese economic co-operation program in grant form.

5. The Government of the Republic of Liberia will take necessary measures listed in Annexure-II under the condition that the grant aid assistance by the Government of Japan is extended to the Project.

6. Both parties confirmed that the Survey Team explained Japan's aid programme and the Liberia side has understood it.

ANNEXTURE-I

The Government of Republic of Liberia has requested to install at Bushrod Yard 10 MW of diesel generating capacity as grant aid assistance from Japan.

The Japanese Mission is to compare and contrast the following options:

1) Slow-speed units
2) Medium-speed units

ANNEXTURE-II

Demarcation of Works Between the Government of Liberia and the Government of Japan.

| No. | Description | Covered by Grant Aid | Covered by Government of Liberia |
|---|---|---|---|
| 1. | To remove the defunct diesel engine generators from Bushrod Power Station | | o |
| 2. | To bear the following commissions to the foreign exchange bank for the banking service upon the B/A | | |
| | i) Advising commission of A/P | | o |
| | ii) Payment commission | | o |
| 3. | To ensure unloading and customs clearance at port of disembarkation in Liberia | | |
| | i) Marine transportation of the equipment and devices from Japan to Liberia | o | |
| | ii) Tax exemption and customs clearance of the equipment and devices at the port of dis-embarkation | | o |
| | iii) Inland transportation from the port of disembarkation to project site. | o | |
| 4. | Installation | o | |
| 5. | 1) To accord Japanese nationales whose services may be required in connection with the supply of equipment and devices and the services and the services under the verified contract such facilities as may be required for their entry into Liberia and stay therein for the per-formance of their work. | | o |
| | ii) To exempt Japanese nationals from customs duties, internal taxes and other fiscal levies imposed in Liberia with respect to the supply of equipment, devices and services under the Contracts to to be executed for the Project. | | o |

| No. | Description | Covered by Grant Aid | Covered by Government of Liberia |
|---|---|---|---|
| 6. | To maintain and use properly and effectively the facilities procured and installed under the Grant Aid. | | O |
| 7. | To bear all the expenses other than those to borne by the Grant, necessary for the execution of the Project. | | O |

The Japan International Cooperation Agency (JICA) will send 10 copies of the basic design report to the Government of Liberia around end of August 1987.

List of Received Data and Information (1/3)

| No. | Title | Author/Publisher | Date published | Remarks |
|---|---|---|---|---|
| 1. | Country Economic Memorandum Preparated for the Liberia Round Table Meeting | Ministry of Planning and Economic Affairs | Oct., 1983 | |
| 2. | Economic Survey Liberia 1982 | " | Dec., 1983 | |
| 3. | Economic Survey Liberia 1983 | " | Dec., 1984 | |
| 4. | Annual Report of the Ministry of Planning and Economic Affairs to the People's Redemption Conuncil for the Period<br>April 12 - December 31, 1980 | " | Jan., 1981 | |
| 5. | "<br>January 1 - December 31, 1982 | " | Jan. 1983 | |
| 6. | A Study on Public Foreign Assistance and Development Expenditure in Liberia (19868 - 72) | " | Jan. 1974 | |
| 7. | External Trade of Liberia Imports 1980 | " | Oct. 1981 | |
| 8. | Annual Report<br>Jan. 1, 1982 - Dec. 31, 1982 | Libelia Electricity Corporation | | |
| 9. | 1979 Annual Report<br>Jan. 1 - DEc. 31, 1979 | " | | |

List of Received Data and Information (2/3)

| No. | Title | Author/Publisher | Date published | Remarks |
|---|---|---|---|---|
| 10. | Annual Report<br>Jan. 1, 1981 - Dec. 31, 1981 | Libelia Electricity Corporation<br>" | | |
| 11. | Annual Report<br>Jan. 1, 1980 - Dec. 31, 1980 | " | | |
| 12. | Annual Report<br>Jan. 1, 1983 - June 1984 | " | | |
| 13. | External Trade of Liberia Exports 1980 | Ministryu of Planning & Economic Affairs | Oct. 1981 | |
| 14. | 1974 Population and Housing Census of Liberia | " | 1977 | |
| 15. | Statistical Bulletin of Liberia Vol.1, No.2 | " | Nov. 1986 | |
| 16. | Planning and Development Atlas | " | 1983 | |
| 17. | Topographical Map of Liberia<br>1 : 1,000,000 | ITC, The netherlands | 1982 | |
| 18. | Tourist Map of Monrovia<br>1 : 25,000 | Ministry of Lands and Mines | - | |
| 19. | Five-Year Development Plan (1987-1991) | Corporate Planning and Development Department (LEC) | Mar. 1987 | |
| 20. | 1974 Population & Housing Census | Ministry of Planning and Economic Affairs | 1977 | |

List of Received Data and Information (3/3)

| No. | Title | Author/Publisher | Date published | Remarks |
|---|---|---|---|---|
| 21. | Statistical Bulletin of Liberia, 1986 No.2 | Ministry of Planning and Economic Affairs | Nov., 1986 | |
| 22. | Country Economic Memorandum, 1983 | " | Oct., 1983 | |
| 23. | Second National Development Plan 1981 - 85 | " | Jan., 1985 | |
| 24. | External Trade, 1980 | " | Oct., 1981 | |
| 25. | Economic Survey of Liberia, 1982 | " | Dec., 1983 | |
| 26. | " 1983 | " | Dec., 1984 | |
| 27. | " 1984 | " | Aug., 1985 | |
| 28. | Annual Report, 1980 | " | Jan., 1981 | |
| 29. | " 1982 | " | Jan., 1983 | |
| 30. | " 1984 | " | Jan., 1985 | |
| 31. | " 1986 | " | Dec., 1986 | |
| 32. | Foreign Assistance and Development Expenditure in Liberia, 1968 - 72 | " | Jan., 1974 | |
| 33. | Planning and Development Atlas | " | 1983 | |

# Selection of Diesel Engine Type

## 1. Purpose

To select the most suitable diesel-engine type after comparing low-speed and medium-speed engines technically and economically.

## 2. Conditions

| | | | |
|---|---|---|---|
| (1) | Output | : | 10 MW (5 MW (7,080 PS) x 2 units) |
| (2) | Fuel Oil | : | Heavy oil - Class C |
| (3) | Place to be installed | : | On No.2 and 3 foundations in the existing power house |
| (4) | Starting year of operation | : | Each engine will start operating by the end of fiscal 1988 and 1989. |
| (5) | Budget | : | There is a budgetary limitation for the Japanese Government grant. |

## 3. Sample of Diesel Engine

A sample is shown in Table 1.

## 4. Limitation of Existing Overhead Travelling Crane

Height from floor level to existing crane rail: approx. 6.5 m

The low-speed engine cannot be serviced by the existing crane as the crane requires 7.7 m from the floor level to pull out the piston (see Table 1). The medium "L" and "V" type engines can be serviced by the existing crane as the height is within the limitation (see Table 1).

## 5. Weight Limitation of the Existing Foundation

Weight of the existing foundation (see Fig. 1): approx. 400 ton

The following equation is used to calculate the weight limitation for the foundation:

$$Wf = 0.15\ W/\sqrt{N}$$

Wf : Foundation weight (ton)
W : Engine-generator weight (ton)
N : Engine revolving speed (rpm)

The rough estimation of the necessary foundation weight is as follows:

| | | |
|---|---|---|
| Medium speed "V" engine | : | approximately 260 ton<br>No problem |
| Medium speed "L" engine | : | approximately 410 ton<br>to be studied for details |
| Low speed engine | : | approximately 450 ton<br>impossible to use foundation |

For a low-speed type, the existing foundation should be reinforced, though reconstruction or reinforcement is very difficult.

## 6. Size Limitation of the Existing Foundation

The engine anchor bolt size of the existing foundation is approximately 1.8 m wide by 7.2 m long. Therefore, the low-speed engine is not suitable because its base is too wide. The same is true of the medium-speed "L" engine (see Table 1).

## 7. Running Cost Comparison

For operation and maintenance conditions, see Table 2. Assuming that the personnel cost and lubricant consumption are equal, the spare parts cost is estimated as shown below for 75,000 operating hours and 5,500 startup/shutdown operations.

| Item (US$) | Medium speed "V" | Medium speed "L" | Low speed |
|---|---|---|---|
| Spare parts cost | 662,000<br>(¥98,000,000) | 622,000<br>(¥92,000,000) | 702,000<br>(¥104,000,000) |
| Spare parts cost /year | 33,100<br>(¥4,900,000) | 31,100<br>(¥4,600,000) | 35,100<br>(¥5,200,000) |
| Difference | ±0<br>(±0) | -40,000<br>(-¥6,000,000) | +40,000<br>(+¥6,000,000) |

On the other hand, Table 3 shows the fuel consumption based on the basis of medium speed "V":

| | |
|---|---|
| Medium speed "L" | Increase of US$31,000 (¥4.6 M) |
| Low speed engine | Decrease of US$872,000 (¥129.1 M) |

## 8. Operation/Maintenance Technology

Low speed engines, such as Bushrod, Luke, etc. are already familiar to the operators and therefore advantageous in operation and maintenance. However, it is the first time that this type of engine of a Japanese

engine of this type is introduced, so operation/maintenance technology will have to be learned for any type of engine. Operation/maintenance technology can be gained by training the instructors after installation, test running and operation startup. Whatever type of engine may be adopted for this Project, it should be considered to arrange for instructor(s) to be stationed in Bushrod New Plant before and until the maintenance staff of LEC may acquire techniques of operating and maintaining the diesel-engine set to be provided under the grant aid.

9. Comparison of Construction Expenses

As shown in Table 4, the construction expenses are approximately US$10^3 x 4,289 (¥635 M) for the medium speed "V" engine. Based on this figure, the construction expense increas will be:

| | |
|---|---|
| Medium speed "L" | US$10^3 x 1,069 (¥158 M) |
| Low speed engine | US$10^3 x 3,996 (¥591 M) |

10. Simple Comparison of Total Expenses

Taking the medium speed "V" type as standard, expense increases will be:

| | |
|---|---|
| Medium speed "L" | US$10^3 x 1,060 (¥156 M) |
| Low speed engine | US$10^3 x 3,164 (¥468 M) |

11. Expediency

As shown in Fig. 2, alleviation of electric power shortage is of prime importance. To adopt the low speed engine, it is necessary to modify the power house and foundations on a large scale or construct new ones. Consideration the various preparations invoilved, we estimate that there will be a delay of about one year.

12. General Evaluation

Considering the gratuitous donation budget, the above comparison and investigation lead, to the conclusion that it is very difficult to adopt the low speed engine and that either a medium speed "V" or "L" engine should be adopted, as shown in Table 5.

It is difficult to transport the medium speed "L" type with full accessories because of its height. This type of engine should therefore be transported as a knock-down kit, thus being disassembled after the plant test-run. This fact imply the necessity of a test-run to confirm the performance prior to the normal field test after reassembly. This disassembly and reassembly will increase cost and time.

13. Suggestion

It is believed appropriate that a "medium speed" and "V" type engine be taken up for the Project. Even if any type of engine is selected, it will be essential that necessary guidance be made in operation and maintenance of the diesel-engine set for a reasonable period of time with the full-fledged cooperation of parties concerned.

Table 1 Comparison of Diesel Engine Generator (Example)

| Item | Medium Speed "V" Type Engine | Medium Speed "L" Type Engine | Low Speed Engine (1) | Low Speed Engine (2) |
|---|---|---|---|---|
| Capacity Class (kW) | 5,000 | 5,000 | | 5,000 |
| Engine Speed (rpm) | 720 class | 500 to 600 class | 277 to 400 class | 150 to 160 class |
| Total Weight (ton) | 76 | 110 | | 240 |
| Necessary Installation Space (m) | | | | |
| Length | 10.3 | 11.5 | Not available in Japan | 10.5 |
| Width | 1.3 | 2.0 | | 2.6 |
| Height from Common Bed for Piston Overhaul | 2.8 | 4.5 | | 7.7 |
| Fuel Consumption Rate | | | | |
| Engine End (g/ps.h) at 80% output | 137.5 | 138.0 | | 124.0 |
| Generator end (g/kW.h) at 80% output | 194.7 | 195.4 | | 175.6 |
| Generator Efficiency (%) | 96 | 96 | | 96 |
| Lub. Oil Consumption Rate (g/ps.h) | 1.0 | 1.0 | | 0.8 |

Table 2 Operation & Maintenance Condition (Example)

| Ordinal Number of Year | Operation Hours | Aggregate of Operation Hours (Hour) | Midterm Inspection (After-Hour) | Overhaul (After-Hour) | Load Factor (%) | Capacity Factor (%) | Energy Generation ($\times 10^6$ kWh) | Number of Start-Stop (Time) |
|---|---|---|---|---|---|---|---|---|
| 1 | | 3,600 | 2,500 | | 80 | 32.8767 | 14.4 | 3 |
| 2 | | 7,200 | 5,000 | | | | | |
| 3 | | 10,800 | 10,000 | 7,500 | | | | |
| 4 | | 14,400 | 12,500 | | | | | |
| 5 | Jan. to May; | 18,000 | 17,500 | 15,000 | | | | |
| 6 | 24 hours/day | 21,600 | 20,000 | | | | | |
| 7 | 3,600 hours/year | 25,200 | 25,000 | 22,500 | | | | |
| 8 | | 28,800 | 27,500 | | | | | |
| 9 | | 32,400 | 32,500 | 30,000 | | | | |
| 10 | | 36,000 | 35,000 | | | | | |
| | | | | 37,500 | | | | |
| 11 | | 38,900 | 40,000 | | | 26.484 | 11.6 | 365 |
| 12 | | 41,800 | | | | | | |
| 13 | Feb. to May; | 44,700 | 42,500 | | | | | |
| 14 | 12 hours/day | 47,600 | 47,500 | 45,000 | | | | |
| 15 | Jun. to Jan.; | 50,500 | 50,000 | | | | | |
| 16 | 6 hours/day | 53,400 | | 52,500 | | | | |
| 17 | 2,900 hours/year | 56,300 | 55,000 | | | | | |
| 18 | | 59,200 | 57,500 | | | | | |
| 19 | | 62,100 | | 60,000 | | | | |
| 20 | | 65,000 | 62,500 | | | | | |
| | | | 65,000 | | | | | |
| 21 | | 66,450 | | | | 13.242 | 5.8 | 365 |
| 22 | Jan. to Dec.; | 67,900 | | 67,500 | | | | |
| 23 | 4 hours/day | 69,350 | | | | | | |
| 24 | 1,450 hours/year | 70,800 | 70,000 | | | | | |
| 25 | | 72,250 | 72,500 | | | | | |
| Total No. of Times | | (72,250) | 20 | 9 | (Average 80) | (Average 26.393) | (289) | 5,505 |

Table 3 Comparison of Fuel Cost (Example) 1/2

US$1 = ¥148

| No. | Item | Explanation | Equation | Unit | Medium Speed "V" Type Engine | Medium Speed "L" Type Engine | Low Speed Engine | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | Engine Output | | | PS | 7,080 | 7,080 | 7,080 | |
| 2 | Generator Output | 1 PS = 0.7355 kW | $\eta$ = 0.96 | kW | 5,000 | 5,000 | 5,000 | |
| 3 | Engine Fuel Consumption Rate | at 80% load factor | | g/ps.h | 137.5 | 138.0 | 124.0 | Average of Each Company |
| 4 | " (PS - kW) | 1 kW = 1.35962 PS | | g/kW.h | 186.9 | 187.6 | 168.6 | France horse power |
| 5 | Generator Efficiency | | | % | 96 | 96 | 96 | |
| 6 | Fuel Consumption Rate at Generator end | | 4 / 5 | g/kW.h | 194.7 | 195.4 | 175.6 | |
| 7 | Total Operation Hour | for 25 years | | Hour | 75,000 | 75,000 | 75,000 | |
| 8 | Number of Starting Times | | | Time | 5,500 | 5,500 | 5,500 | |
| 9 | Operating Hour by Diesel Oil/Time | | | Hour | 1 | 1 | 1 | |
| 10 | Total Operating Hour by Diesel Oil | | | Hour | 5,500 | 5,500 | 5,500 | |
| 11 | Total Operating Hour by Heavy Oil | | 7 - 10 | Hour | 69,500 | 69,500 | 69,500 | |
| 12 | Average Load Factor | | | % | 80 | 80 | 80 | |
| 13 | Total Energy Generation | | 2x7x12 | $\times 10^6$ kWh | 300 | 300 | 300 | |
| 14 | Energy Generation by Diesel Oil | | 2x8x12 | $\times 10^6$ kWh | 22 | 22 | 22 | |
| 15 | Energy Generation by Heavy Oil | | 2x8x12 | $\times 10^6$ kWh | 278 | 278 | 278 | |
| 16 | Heavy Oil Consumption | | 6 x 15 | $\times 10^6$ kg | 54.127 | 54.321 | 48.817 | |
| 17 | Heavy Oil Gravity | | | kg/ℓ | 0.9775 | 0.9775 | 0.9775 | |
| 18 | Heavy Oil Consumption (kg - ℓ) | | 16 / 17 | x $10^6$ ℓ | 55.373 | 55.571 | 49.941 | |

Table 3 Comparison of Fuel Cost (Example) 2/2

US$1 = ¥148

| No. | Item | Explanation | Equation | Unit | Medium Speed "V" Type Engine | Medium Speed "L" Type Engine | Low Speed Engine | Remarks |
|---|---|---|---|---|---|---|---|---|
| 19 | Heavy Oil ("C" class) Price | | | US$/gal | 0.543 | 0.543 | 0.543 | Price in 1987, US gal |
| 20 | " (gal - ℓ) | 1 gal = 3.785 ℓ | | US$/ℓ | 0.1435 | 0.1435 | 0.1435 | |
| 21 | Total Cost of Heavy Oil Consumption | (for 25 years) | 18 x 20 | $x10^6$ US$ | 7.946 | 7.974 | 7.167 | |
| 22 | Diesel Oil Consumption | | 6 x 14 | $x10^6$ kg | 4.283 | 4.299 | 3.863 | |
| 23 | Diesel Oil Gravity | | | kg/ℓ | 0.85 | 0.85 | 0.85 | |
| 24 | Diesel Oil Consumption (kg/ℓ) | | 22 / 23 | $x10^6$ ℓ | 5.039 | 5.058 | 4.5450 | |
| 25 | Diesel Oil Price | | | US$/gal | 0.708 | 0.708 | 0.708 | |
| 26 | Diesel Oil (gal - ℓ) | 1 gal = 3.785 ℓ | | US$/ℓ | 0.1871 | 0.1871 | 0.1871 | |
| 27 | Total Cost of Diesel Oil Consumption | (for 25 years) | 24 x 26 | $x10^6$ US$ | 0.943 | 0.946 | 0.850 | |
| 28 | Total Cost of Fuel Oil Consumption | | 21 + 27 | $x10^6$ US$ | 8.889 ($1,315.6x10^6$ Yen) | 8.920 ($1,320.2x10^6$ Yen) | 8.017 ($1,186.5x10^6$ Yen) | |
| 29 | Surplus of Fuel Cost | | | $x10^6$ US$ | ±0 | +0.031 ($+4,588x10^3$ Yen) | -0.872 ($-126,056x10^3$ Yen) | |
| 30 | Fuel Cost for Two Units | | 28 x 2 | $x10^6$ US$ | 17.778 | 17.840 | 16.034 | |

Table 4 Comparison of Construction Cost (Example)

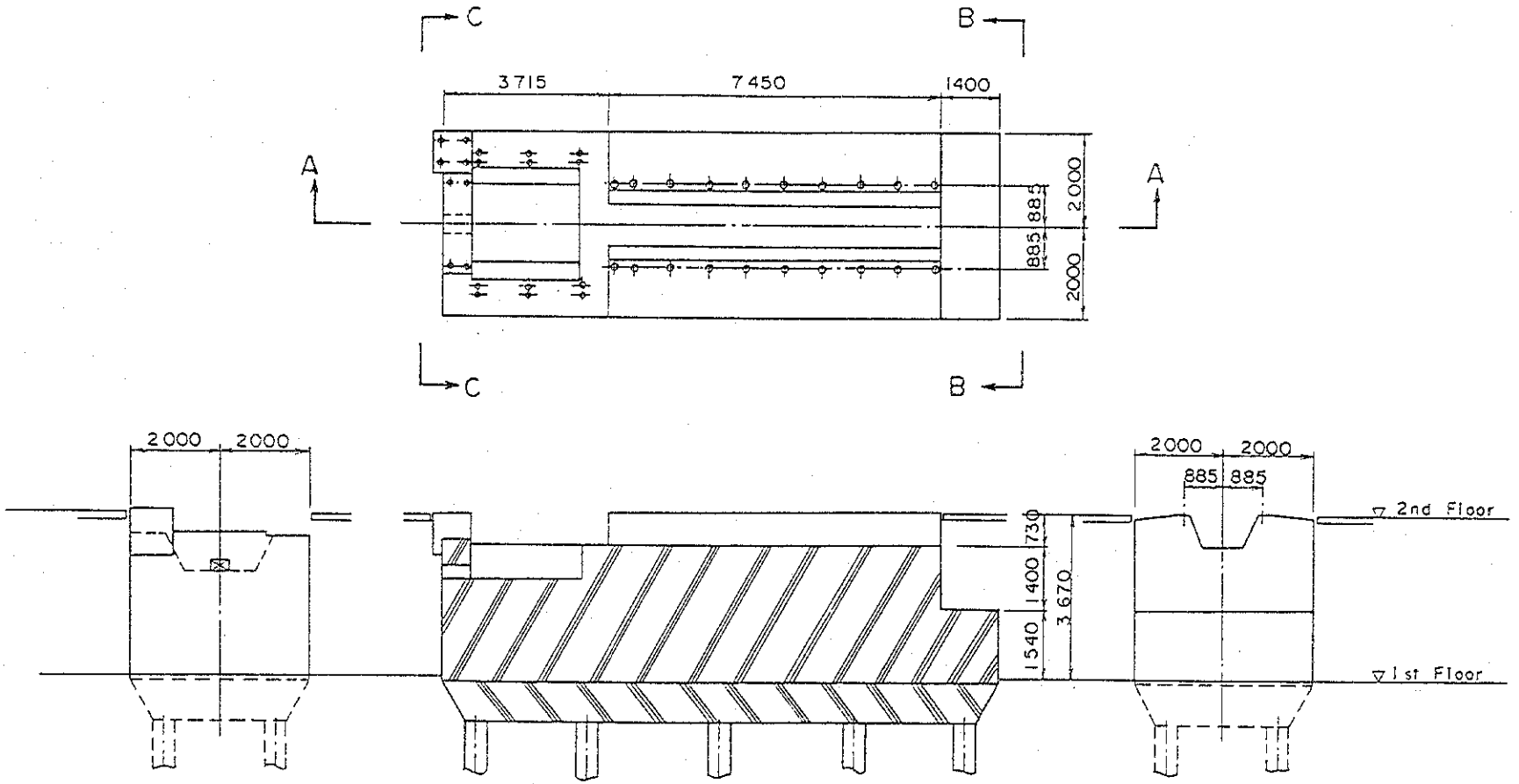
US$1 = ¥148

| Item | Medium Speed "V" Type Engine (x $10^3$ US$) | Medium Speed "L" Type Engine (x $10^3$ US$) | Low Speed Engine (x $10^3$ US$) |
|---|---|---|---|
| Engine & Aux. Equipment | 1,980 | 2,575 | 3,169 |
| Generator & Aux. Equipment | 729 | 878 | 1,460 |
| Packing Cost | 142 | 176 | 244 |
| Insurance & Sea Transportation | 581 | 695 | 872 |
| Inland Transportation | 88 | 109 | 135 |
| Installation Work | 405 | 486 | 608 |
| Civil & Architectural Work | 67 | 81 | 1,351 |
| Design & Supervising | 297 | 358 | 446 |
| Total Construction Cost | 4,289 | 5,358 | 8,285 |
| | (635 x $10^6$Yen) | (793 x $10^6$Yen) | (1,226x$10^6$Yen) |
| Surplus | ±0 | 1,069 | 3,996 |
| | (±0) | (158.1x$10^6$Yen) | (591.3x$10^6$Yen) |

Table 5 Comparison of Each Item

| Item | Medium Speed "V" Type Engine | Medium Speed "L" Type Engine | Low Speed Engine |
|---|---|---|---|
| 1. Ext. Crane | Possible | Possible | Impossible |
| 2. Ext. Foundation | Possible | Possible | Impossible |
| 3. Suitability of Size of Ext. Foundation | Good | Wide is no good | No good |
| 4. Comparison of Fuel Cost (%) | 100 | 101 | 90 |
| 5. Comparison of Construction Cost (%) | 100 | 125 | 190 |
| 6. Surplus of Total Cost ($\times 10^3$ US$) ($\times 10^6$ Yen) | ±0 (±0) | +1,254 (+186) | +3,182 (+471) |
| 7. Urgent Repair | Possible | Possible | Impossible |
| 8. Budget Ceiling | In | Over | Way over |
| 9. Overall Judgement | Suitable | There are some problems | Unsuitable |

Fig. 1 BUSHROD No. 2 , No. 3 D.G. FOUNDATION

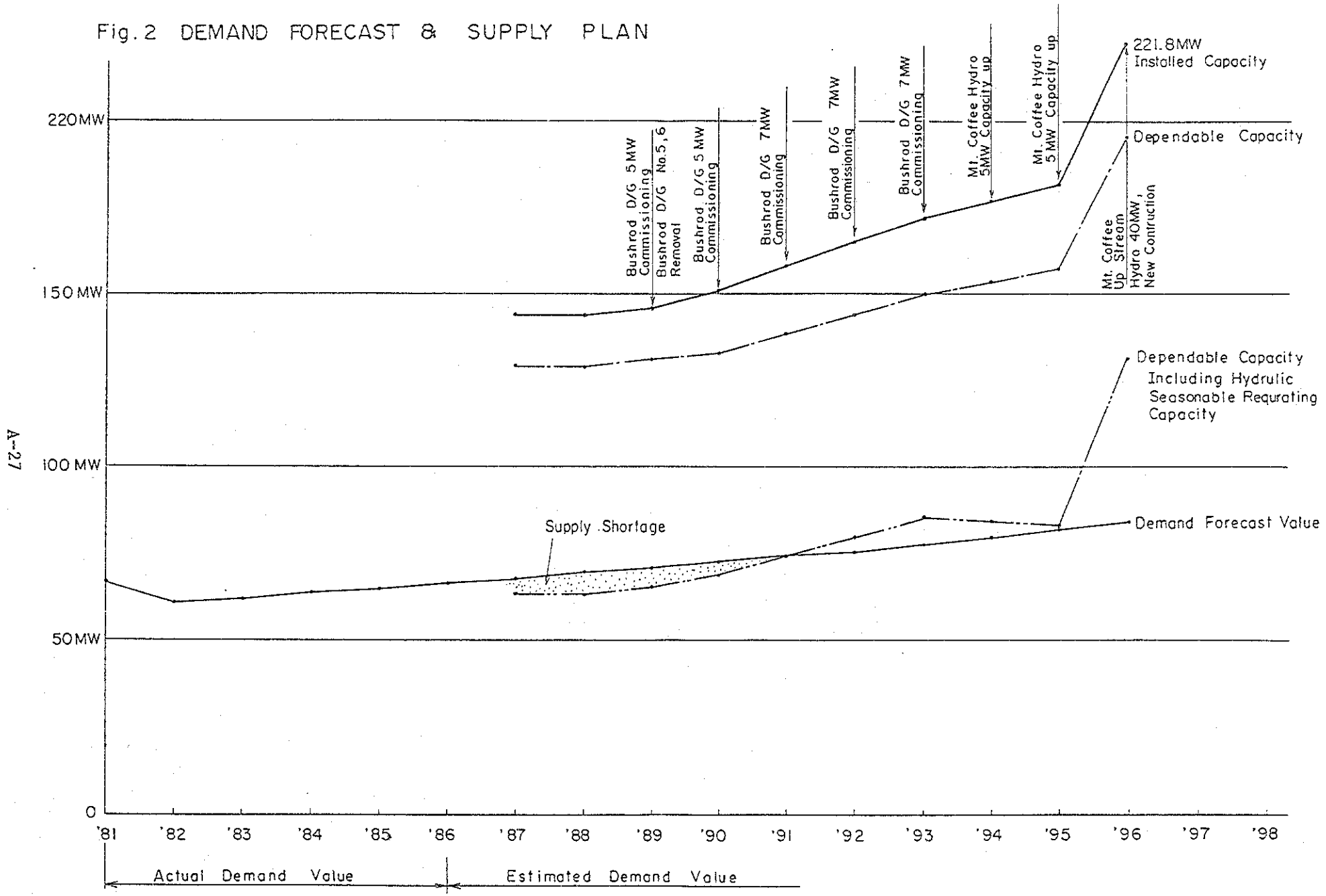



C - C Section

A - A Section

B - B Section

Fig. 2 DEMAND FORECAST & SUPPLY PLAN



# Evaluation of the Existing Concrete Foundations

Sufficient data are not available to explain how the existing concrete foundations were designed and built, since they were constructed about 25 years ago.

Therefore we must include our own opinions in our evaluation of their design and construction.

The field surveys did not reveal anything apparently abnormal such as unequal sinking or structural failure.

We assume that the said foundations can be used again, by taking of the following observations.

(a) Structure and weight of the concrete foundation

The outline of the concrete foundations is as follows:

1. Size (width x length x height): 4.0 x 12.5 x 4.5 (m) approxi.
2. Volume and weight : 180 $m^3$ & 400 tons approxi.
3. Ferroconcrete:

   We assume half-inch iron bars were buried in 6-12 inch pitches around the foundation.

4. Concrete-made supporting pile:

   Although their width and length are unknown, we assume eighteen piles were used in each foundation.

5. The soil strength:

   The result of studies on the soil surrounding the building indicates that an efficient supporting layer is about fifteen meters below the surface.

(b) Weight of the existing engine generator

The weight of each of the existing No. 4, 5 and 6 diesel engine generators has been recorded as 140 tons. We can assume from this that the weight of the No. 2 and 3 diesel generators is around 110 tons on average.

(c) Adaptability of the existing foundations to a new engine generator

Although there are various theories, the required weight of the foundatiuon should be three to five times the equipment weight. As a guideline, this weight can be calculated by the following formula:

$$Wf = 0.15W/\sqrt{N}$$

where,

Wf: foundation's weight (ton)
W : equipment's weight (ton)
N : engine rotation speed (rpm)

The required weight of the foundation is as follows, based on the estimated total weight of the engine generators in our draft.

| Item | Medium-speed V type engine | Medium-speed L type engine | Low-speed engine |
|---|---|---|---|
| 1. Diesel engine generator's total weight (ton) | 65 | 110 | 240 |
| 2. Rotation speed (rpm) | 720 class | 500-600 class | 150-160 class |
| 3. Foundation's required weight (ton) | 260 | 400 | 460 |
| 4. Estimated existing foundation's weight | 400 | 400 | 400 |
| 5. Evaluation | Satis-factory | Needs detailed study | Must be rein-forced |

As is obvious from the above chart, the low-speed engine will require the foundation either to be renewed or to be reinforced, thus involving problems in construction.

The Medium-speed V or L-type engine is feasible as far as the foundation volume is concerned. However, the Medium-speed L-type is not recommended in view of its size.

As a conclusion, it is most appropriate to adopt the Medium-speed V-type engine because of the foundation's limitations.

As for the foundation for the equipment provided by this paper, if both the engine and the generator are assembled on the same frame, at least the existing anchor bolt on the engine side can be reused. With regard to the foundation on the generator side, we plan to use the existing concrete and anchor bolts as much as possible. However, minor renovations may occur if necessary.

# A N N E X – 8

# Table 2-14 OPERATION STATE OF EACH POWER STATION (1/4)

CORPORATE PLANNING & DEVELOPMENT DEPT. MONTHLY GROSS GENERATION DURING 1984

SYSTEM STUDY SECTION:

| Plant | Unit | GROSS GENERATION X 1000 K.W.H. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | JAN. | FEB. | MARCH | APRIL | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. | TOTAL |
| HYDRO MT. COFFEE | 1 | 2,080 | 800.00 | 430.0 | 460.0 | 4,020.00 | 8,420.0 | 9,880.0 | 10,140.0 | 8,560.0 | 7,820.0 | 7,280 | 5,650 | 63,540.0 |
| | 2 | 3,700 | 1,560.0 | 1,890.0 | 5,210.0 | 10,520.00 | 8,830.0 | 9,930.0 | 9,330.0 | 10,600.0 | 11,130.0 | 10,033 | 9,360 | 92,093.0 |
| | 3 | 900 | - | - | 1,670.0 | 10,180.00 | 9,410.0 | 6,660.0 | 10,990.0 | 10,950.0 | 11,330.0 | 9,870 | 410 | 72,370.0 |
| | 4 | 10 | - | - | 20.0 | - | 10.00 | 260.0 | 6,680.0 | 10,590.0 | 11,330.0 | 9,940 | 4,580 | 54,050.0 |
| | Total | 6,690 | 2,360.0 | 2,340.0 | 7,340.00 | 24,730.00 | 26,920.0 | 33,150.0 | 41,050.0 | 40,740.0 | 41,610.0 | 37,123 | 18,000 | 282,053.0 |
| GAS TURBINES | 1 | 4,968 | 6,539.0 | 7,239.0 | 5,903.00 | 969.0 | 469.0 | 65.0 | 34.0 | 3.0 | - | - | - | 26,189.0 |
| | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 3 | - | - | - | 1,713.00 | 2,994.0 | 1,376.0 | 51.0 | 224.0 | 71.0 | 52.0 | 854.0 | 6,444 | 13,779.0 |
| | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Total | 4,968 | 6,539.0 | 7,239.0 | 7,616.00 | 3,963.0 | 1,845.0 | 116.0 | 258.0 | 74.0 | 52.0 | 854.0 | 6,444 | 39,968.0 |
| LUKE | 1 | 6,129.2 | 6,214.20 | 6,456.2 | 5,803.10 | 3,975.0 | 3,322.6 | 98.29 | 118.56 | - | - | - | 1,635.5 | 42,245.25 |
| | 2 | 3,509.0 | 5,871.80 | 3,628.4 | - | - | - | - | - | - | - | - | 1,635.5 | 14,644.76 |
| | 3 | 5,519.0 | 58.98 | - | - | - | - | - | - | - | - | - | | 5,577.98 |
| | Total | 15,157.20 | 12,144.98 | 10,093.6 | 5,803.10 | 3,975.0 | 3,322.60 | 98.29 | 118.56 | 1,778.0 | 9.3 | 397.20 | 9,570.10 | 62,467.93 |
| BUSHROD OLD DIESELS | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 5 | - | - | - | - | - | - | 4.8 | 48.0 | 148.8 | 180.0 | 129.6 | 105.6 | 616.8 |
| | 6 | 256.80 | 878.4 | 14.4 | 2.4 | 4.8 | 21.6 | | | | | 9.6 | 108.0 | 1,912.80 |
| | TOTAL | 256.8 | 878.4 | 14.4 | 2.4 | 4.8 | 21.6 | 4.8 | 48.0 | 148.8 | 180.0 | 139.2 | 213.6 | 1,912.80 |
| GRAND TOTAL | | 27,072.00 | 21,922.38 | 19,687.00 | 20,761.50 | 32,672.80 | 32,109.20 | 33,369.09 | 41,474.56 | 42,740.8 | 41,851.3 | 38,513.4 | 34,227.7 | 386,401.73 |

# Table 2-14 OPERATION STATE OF EACH POWER STATION (2/4)

CORPORATE PLANNING & DEVELOPMENT DEPT. MONTHLY GROSS GENERATION DURING 1985

SYSTEM STUDY SECTION:

| Plant | Unit | GROSS GENERATION X 1000 K.W.H. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | JAN. | FEB. | MARCH | APRIL | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. | TOTAL |
| HYDRO MT. COFFEE | 1 | 1,290.00 | - | - | 420.00 | 3,560.00 | 10,290.00 | 10,420.00 | 10,230.00 | 9,800.00 | 10,830.00 | 9,840.00 | 6,950.00 | 3,590.00 |
| | 2 | 3,460.00 | 1,440.00 | 2,390.00 | 2,390.00 | 7,670.00 | 8,210.00 | 10,010.00 | 10,270.00 | 9,900.00 | 10,990.00 | 10,080.00 | 6,920.00 | 82,570.00 |
| | 3 | - | - | - | - | - | - | 6,320.00 | 10,660.00 | 10,440.00 | 11,430.00 | 10,190.00 | 6,740.00 | 55,780.00 |
| | 4 | 2,360.00 | 1,550.00 | 140.00 | 810.00 | 300.00 | 5,830.00 | 10,460.00 | 10,280.00 | 9,890.00 | 10,840.00 | 9,840.00 | 2,110.00 | 64,410.00 |
| | Total | 7,090.00 | 2,780.00 | 1,680.00 | 3,620.00 | 11,530.00 | 24,310.00 | 37,210.00 | 41,440.00 | 40,030.00 | 44,090.00 | 39,950.00 | 22,720.00 | 276,350.00 |
| GAS TURBINES | 1 | - | 5,409.00 | 5,792.00 | 5,510.00 | 8,936.00 | 3,193.00 | - | - | - | - | - | - | 28,840.00 |
| | 2 | - | - | - | - | - | - | - | 351.0 | - | 1.0 | - | 55.0 | 407.0 |
| | 3 | 8,066.00 | 2,952.00 | 4,311.00 | 3,112.00 | - | - | - | - | - | - | - | - | 18,441.0 |
| | 4 | - | - | - | - | - | - | - | - | - | - | - | -- | - |
| | Total | 8,066.00 | 8,361.00 | 10,103.00 | 8,622.00 | 8,936.00 | 3,193.00 | - | 351.00 | - | 1.0 | - | 55.0 | 47,688.00 |
| [illegible] | 1 | 5,246.00 | 6,710.60 | 5,205.90 | 5,093.50 | 2,334.80 | 1,681.20 | 612.30 | - | - | - | - | 4,691.0 | 31,575.8 |
| | 2 | 7,971.50 | 5,717.60 | 6,725.50 | 4,527.00 | 572.00 | 380.10 | - | - | - | - | --- | - | 28,894.1 |
| | 3 | - | - | - | - | - | - | - | - | 388.3 | 2.9 | - | 412.150 | 803.35 |
| | Total | 13,217.50 | 12,428.20 | 11,931.40 | 9,620.90 | 2,906.80 | 2,061.30 | 612.30 | - | 388.3 | 2.9 | --- | 5,103.15 | 58,272.75 |
| BUSHROD OLD DIESELS | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 5 | 19.20 | 43.20 | 234.20 | 379.20 | 393.60 | 316.80 | 57.60 | - | - | 36.0 | 19.2 | 28.8 | 1,528.8 |
| | 6 | 307.20 | 249.6 | 254.40 | 446.40 | 348.00 | 321.60 | 26.40 | - | - | 36.0 | 29.2 | 14.4 | 1,968.0 |
| | TOTAL | 326.40 | 292.80 | 489.60 | 825.60 | 741.60 | 638.40 | 84.00 | - | - | 36.0 | 49.2 | 43.2 | 3,496.8 |
| GRAND TOTAL | | 28,699.90 | 23,862.00 | 24,104.00 | 22,686.50 | 24,114.40 | 30,202.70 | 37,906.30 | 41,791.00 | 40,418.3 | 44,129.9 | 39,969.2 | 27,921.35 | 385,807.55 |

# Table 2-14 OPERATION STATE OF EACH POWER STATION (3/4)

LIBERIA ELECTRICITY CORPORATION
CORPORATE PLANNING & DEVELOPMENT DEPT. MONTHLY GROSS GENERATION DURING 198

SYSTEM STUDY SECTION:

| Plant | Unit | GROSS GENERATION X 1000 K.W.H. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | JAN. | FEB. | MARCH | APRIL | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. | TOTAL |
| HYDRO MT. COFFEE | 1 | - | - | - | - | - | 2,860.0 | 7,280.0 | 10,510.0 | 10,430.0 | 10,650.0 | 10,030.0 | 3,740.0 | 65,500 |
| | 2 | 6,120.0 | 1,380.0 | 2,540.0 | 4,580.0 | 6,290.0 | 8,800.0 | 8,750.0 | 9,830.0 | 9,730.0 | 10,010.0 | 10,070 | 6,850.0 | 84,950 |
| | 3 | 1,170.0 | 1,270.0 | 2,270.0 | 1,140.0 | 5,980.0 | 6,810.0 | 6,780.0 | 11,130.0 | 11,100.0 | 11,470.0 | 10,860.0 | 8,030.0 | 78,010 |
| | 4 | 450.0 | 3.0 | 30.0 | - | 3,830.0 | 6,100.0 | 7,730.0 | 10,520.0 | 10,330.0 | 10,770.0 | 9,530.0 | 2,000.0 | 61,293 |
| | Total | 7,740.0 | 2,653.0 | 4,840.0 | 5,720.0 | 16,100.0 | 24,570.0 | 30,540.0 | 41,990.0 | 41,590.0 | 42,900.0 | 40,490.0 | 20,620.0 | 279,753.0 |
| GAS TURBINES | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 2 | 850.0 | 1,315.0 | 278.0 | 2,723.0 | 1,132 | 1,748.0 | 2,522 | 2.0 | - | - | 1.3 | 3,043.0 | 13,614.3 |
| | 3 | - | - | - | 281.0 | 10 | 31.0 | 86 | - | - | 18.0 | 1.0 | 422.0 | 849.0 |
| | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Total | 850.0 | 1,315.0 | 278.0 | 3,004.0 | 1,142.0 | 1,779.0 | 2,608.0 | 2.0 | - | 18.0 | 2.3 | 3,465.0 | 14,463.3 |
| LUKE | 1 | 6,511.4 | 4,479.6 | 3,065.5 | 225.5 | 344.8 | - | - | - | - | - | - | 6,303.7 | 20,930.5 |
| | 2 | - | 3,069.3 | 6,511.6 | 6,625.5 | 3,509.6 | 922 | 159.3 | - | - | - | - | - | 20,797.3 |
| | 3 | 5,955.2 | 6,142.8 | 6,580.5 | 7,241.0 | 6,450.3 | 5,219.3 | 2,066.5 | - | - | - | - | 26.8 | 39,682.4 |
| | Total | 12,466.6 | 13,691.7 | 16,157.6 | 14,092.0 | 10,304.7 | 6,141.3 | 2,225.8 | - | - | - | - | 6,330.5 | 81,410.2 |
| BUSHROD OLD DIESELS | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 5 | 93.6 | 13.2 | - | 9.6 | 33.6 | 45.6 | 33.6 | 2.4 | - | 16.8 | 45.6 | 48.0 | 342 |
| | 6 | 14.4 | 26.4 | - | - | - | - | - | - | - | - | - | - | 40.8 |
| | Total | 108.0 | 39.6 | - | 9.6 | 33.6 | 45.6 | 33.6 | 2.4 | - | 16.8 | 45/6 | 48.0 | 382.8 |
| GRAND TOTAL | | 21,164.6 | 17,699.3 | 21,275.6 | 22,825.6 | 27,580.3 | 32,535.9 | 35,407.4 | 41,994.4 | 41,590.0 | 42,934.8 | 40,537.9 | 30,463.5 | 376,009.3 |

Table 2-14 OPERATION STATE OF EACH POWER STATION (4/4)

Operation Hours, Consumption of Heavy Oil & Gas Oil (1984-1986)

| | | Operation Hours (Hrs) | | | | Heavy Oil (Gals) | | | | Gas Oil (Gals) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1984 | 1985 | 1986 | Total | 1984 | 1985 | 1986 | Total | 1984 | 1985 | 1986 | Total |
| Mt. Coffee | #1G | 5,563 | 5,368 | 3,984 | 14,915 | | | | | | | | |
| | #2G | 6,789 | 6,417 | 6,844 | 20,050 | | | | | | | | |
| | #3G | 5,188 | 3,820 | 5,403 | 14,411 | | | | | | | | |
| | #4G | 3,734 | 4,664 | 4,221 | 12,619 | | | | | | | | |
| | Total | 21,274 | 20,269 | 20,452 | 61,995 | | | | | | | | |
| Bushrod | #5G | 477 | 1,090 | 228 | 1,795 | | | | | 53,933 | 141,543 | 48,517 | 243,993 |
| | #6G | 846 | 1,430 | 29 | 2,305 | | | | | 122,236 | 263,964 | 13,514 | 399,714 |
| | Total | 1,323 | 2,520 | 257 | 4,100 | | | | | 176,169 | 405,507 | 68,031 | 649,707 |
| Gas Turbine | #1G | 2,661 | 2,258 | — | 4,919 | | | | | 3,651,000 | 3,495,400 | — | 7,146,400 |
| | #2G | — | 108 | 1,101 | 1,209 | | | | | — | 9,900 | 1,767,800 | 1,777,700 |
| | #3G | 1,046 | 1,357 | 77 | 2,480 | | | | | 1,928,700 | 2,576,100 | 141,300 | 4,646,100 |
| | #4G | — | — | — | — | | | | | — | — | — | — |
| | Total | 3,707 | 3,723 | 1,178 | 8,608 | | | | | 5,579,700 | 6,081,400 | 1,909,100 | 13,570,200 |
| Luke | #1G | 4,959 | 3,379 | 2,112 | 10,450 | 2,935,349 | 2,278,049 | 986,083 | 6,199,481 | 93,298 | 227,220 | 502,504 | 823,022 |
| | #2G | 1,371 | 2,581 | 2,100 | 6,052 | 1,024,312 | 1,803,446 | 1,413,682 | 4,241,440 | 31,807 | 21,856 | 33,835 | 87,498 |
| | #3G | 766 | 499 | 3,504 | 4,769 | 375,099 | 31,350 | 2,284,163 | 2,690,612 | 9,306 | 41,918 | 484,498 | 535,722 |
| | Total | 7,096 | 6,459 | 7,716 | 21,271 | 4,334,760 | 4,112,845 | 4,683,928 | 13,131,533 | 134,411 | 290,994 | 1,020,837 | 1,446,242 |
| Grand Total | | 33,400 | 32,971 | 29,603 | 95,974 | 4,334,760 | 4,112,845 | 4,683,928 | 13,131,533 | 5,890,280 | 6,777,901 | 2,997,968 | 15,666,149 |

Table 2-15 69kV OVERHEAD TRANSMISSION LINES FOR MONROVIA GRID AND ITS ENVIRONMENTS

| Serial No. | FEEDER NAME | No. of Circuits | LENGTH IN KM | | | Conductor Size & Type | REMARKS |
|---|---|---|---|---|---|---|---|
| | | | Wood Pole | Steel Lattice | Steel Tubular | | |
| 1 | Bushrod - Krutown | 2 | — | 6.3 | — | AAAC 158.6 mm² | Equivalent to 266.8 MCM |
| 2 | Bushrod - Capitol | 1 | — | 8.2 | — | 158.6 mm² | 〃 〃 〃 |
| 3 | Bushrod - Capitol through Stockton Creek Junction | 1 | 3.1 | 4.5 | — | 266.6 MCM 158.6 mm² | 〃 〃 〃 |
| 4 | Stockton Crk.-Gardnersville | 1 | 5 | — | — | 266.8 MCM | |
| 5 | Gardnersville-Paynesville | 1 | 5 | 1 | — | 266.8 MCM | |
| 6 | Bushrod - Mt. Coffee | 1 | 26.4 | — | — | AAAC 266.8 MCM | |
| 7 | Bushrod - Mt. Coffee through Caldwell Junction | 1 | 26.4 | — | — | AAAC 266.8 MCM | |
| 8 | Bushrod - Kle through Virginia Substation | 1 | 42.6 | — | — | AAAC 266.8 MCM | |
| 9 | Kle - Boni Hills | 1 | 29 | — | — | 266.8 MCM | |
| 10 | Mt. Coffee - Todee | 1 | 37 | — | — | 266.8 MCM | |
| 11 | Todee - Bong Mines | 1 | 19 | — | — | 266.8 MCM | |
| 12 | Mt. Coffee - Paynesville | 2 | — | 26.3 | — | AAAC 266.8 MCM | |
| 13 | Capitol - Congotown | 1 | — | 4.6 | — | 158.6 mm² | Equivalent to 266.8 MCM |
| 14 | Congotown - Paynesville | 1 | — | — | 8.7 | AAAC 266.8 MCM | |
| 15 | Paynesville - Kakata through Mt. Barclay | 1 | 56.6 | — | — | AAAC 266.8 MCM | |
| 16 | Mt. Barclay - Caldwell | 1 | 11.3 | — | — | 266.8 MCM | |
| 17* | Paynesville - Robertsfield | 1 | 46 | — | — | AAAC 3/0 AWG* | |
| 18 | Robertsfield - Buchanan | 1 | 75 | — | — | AAAC 266.8 MCM | |
| | Sub-total | | 382.4 | 50.9 | 8.7 | | |
| | Grand Total | | 442 | | | | |

Transmission lines with conductor size = 266.8 MCM or equivalent have a rating capacity (MVA) = 42
* Rating capacity (MVA) = 30

## Table 2-23 LOAD SHEDDINGS IN MONROVIA POWER SYSTEM ( JAN. - MAY , 1986 )

| Substation | | Bushrod | Virginia | Krutown | Newport | Capitol | Congotown | Gardners-Ville | Paynes-Ville | Total | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Feeders (A) | | 3 | 4 | 6 | 4 | 5 | 3 | 3 | 5 | 33 | |
| Number of Switchings | JAN. | 46 | 96 | 322 | 34 | 102 | * | 68 | 194 | 862 | * Not Avairable |
| | FEB. | 128 | 358 | 472 | 152 | 230 | 112 | 70 | 154 | 1,676 | |
| | MAR. | 76 | 264 | 524 | 102 | 162 | 94 | 56 | 194 | 1,472 | |
| | APR. | 82 | 260 | 406 | 166 | 192 | 134 | 32 | 165 | 1,437 | |
| | MAY | 62 | 112 | 220 | 32 | 156 | 6 | 48 | 26 | 662 | |
| | Total (B) | 394 | 1,090 | 1,944 | 486 | 842 | 346 | 274 | 733 | 6,109 | |
| | ① | 0.87 | 1.80 | 2.15 | 0.80 | 1.12 | 0.96 | 0.60 | 0.97 | 1.23 | |
| Accumulated Shedded Hours ( Hours ) | JAN. | 129 | 189 | 870 | 200 | 321 | * | 268 | 812 | 2,789 | * Not Available |
| | FEB. | 313 | 982 | 1,085 | 547 | 613 | 243 | 372 | 464 | 4,619 | |
| | MAR. | 174 | 494 | 999 | 306 | 359 | 393 | 322 | 583 | 3,630 | |
| | APR. | 282 | 755 | 1,050 | 523 | 568 | 278 | 123 | 630 | 4,209 | |
| | MAY | 110 | 200 | 299 | 69 | 282 | 11 | 147 | 107 | 1,225 | |
| | Total (C) | 1,008 | 2,620 | 4,303 | 1,645 | 2,143 | 925 | 1,232 | 2,596 | 16,472 | |
| | ② | 2.22 | 4.34 | 4.75 | 2.72 | 2.84 | 2.60 | 2.72 | 3.44 | 3.30 | |
| Shedded Energy ( MWh ) | JAN. | 238.37 | 106.43 | 846.44 | 187.67 | 357.77 | * | 509.11 | 1,135.98 | 3,381.77 | * Not Available |
| | FEB. | 553.69 | 591.67 | 1 103.61 | 542.34 | 791.45 | 408.78 | 583.14 | 656.22 | 5,230.90 | |
| | MAR. | 301.56 | 302.06 | 951.08 | 353.27 | 488.07 | 678.66 | 736.28 | 703.70 | 4,514.68 | |
| | APR. | 483.16 | 473.84 | 943.01 | 516.72 | 675.17 | 456.09 | 287.82 | 898.73 | 4,734.54 | |
| | MAY | 198.26 | 117.77 | 304.83 | 66.87 | 394.55 | 19.5 | 331.20 | 128.95 | 1,561.93 | |
| | Total (D) | 1,775.04 | 1,591.77 | 4,148.97 | 1,666.87 | 2,707.01 | 1,563.03 | 2,447.55 | 3,523.58 | 19,423.82 | |
| | | | | | | | | | | | |
| ③ | | 22,650 | 7,936.6 | 21,852.7 | 11,451.8 | 25,476.7 | 14,083.2 | 10,002.2 | 21,744 | 135,197.2 | |
| Ratio of Shedded Energy (D/E) (%) | | 7.8 | 20.0 | 19.0 | 14.6 | 10.6 | 11.1 | 24.5 | 16.2 | 14.4 | |
| Max. Shedded Hours / Day | | 19 | 21 | 22 | 22 | 24 | 20 | 23 | 24 | — | |
| | | | | | | | | | | | |

NOTE : ** Total Days = 151 Days except Congotown
= 120 Days for Congotown

① $\frac{\text{Number of Switching}}{\text{Day} \cdot \text{Feeder}} \left( \frac{B}{A \cdot \text{Total Days } **} \right)$

② $\frac{\text{Shedded Hours}}{\text{Day} \cdot \text{Feeder}} \left( \frac{C}{A \cdot \text{Total Days } **} \right)$

③ Estimated Energy will be transmitted through all Feeders during JAN. - MAY 1986 (E) (MWh)

Table 2-27 SPECIFICATION OF BUSHROD POWER STATION FACILITIES

| Plant / Unit No. | | Bushrod Diesel Unit | | Gas Turbine Generator Units | | | | Luke Diesel Units |
|---|---|---|---|---|---|---|---|---|
| | | 2 & 3 | 4, 5, 6 | 1 | 2 | 3 | 4 | 1, 2, 3 |
| Type | | Fairbanks-Morse TGZO | Fairbanks-Morse TGZO | BBC WT521 | BBC WT521 | BBC WT521 | BBC WT521 | ASEA |
| Generator apparent power | kVA | 2,500 | 3,445 | 23,000 | 23,000 | 23,000 | 23,000 | 16,000 |
| Generator active power | kW | 22,000 | 2,500 | 15,500 | 14,700 | 19,100 | 19,100 | 13,600 |
| Power factor | cos $\phi$ | 0.80 | 0.72 | 0.67 | 0.64 | 0.83 | 0.83 | 0.849 |
| Rated voltage | V | 12,500 | 12,500 | 13,800 | 13,800 | 13,800 | 13,800 | 13,800 |
| Rated current | A | 115.5 | 159.0 | 965.0 | 965.0 | 965.0 | 965.0 | 669.4 ± 10 % |
| Engine type | | Fairbanks-Morse 31A18 | Fairbanks-Morse 31A18 | BBC GT11L | BBC GT11L | BBC GT 9 | BBC GT 9 | Gotaverken Motor B & W 10K67GS |
| Power at coupling | HP | 2,800 | 3,500 | 20,785 | 19,712 | 25,613 | 25,613 | 14,000 kW |
| Rated speed | rpm | 277 | 277 | 3,600 | 3,600 | 3,600 | 3,600 | 150 |
| Number of cylinders | | 8 | 10 | — | — | — | — | 10 |
| Number of strokes | | 2 | 2 | — | — | — | — | 2 |
| Year installed | | 1961 | 1963 | 1966 | 1969 | 1973 | 1973 | No. 1, 2 1980<br>No. 3 1982 |

## Table 2-28 LEC EXPERITIES

| No. | N A M E | SPECIALITY | POSITION | COUNTRY/COMPANY | EXPERIENCE | L E C | COMM/GRANT (1)/(2) |
|---|---|---|---|---|---|---|---|
| 1 | N. K. Gupra | Power System | General Manager | India-TATA | 21 Years | 6 Yrs | (1) |
| 2 | T. S. Raman | Electrical | Power System Sp | 〃 〃 | 24 〃 | 3 〃 | (1) |
| 3 | S. Dattatrega | Gas Turbine | Mec. Engineer Sr. | 〃 〃 | 18 〃 | 3 〃 | (1) |
| 4 | M. B. Rao | Elec Meter Sp. | Meter-SP | 〃 〃 | 15 〃 | 8 〃 | (1) |
| 5 | G. S. Ram | Commercial | Commercial Sp. O. Manager | 〃 〃 | 17 〃 | 2-5 〃 | (1) |
| 6 | A. Rammle | Computers | Commercial D. Pt | 〃 〃 | 12 〃 | 3 〃 | (1) |
| 7 | J. L. Petersen | Diesel Engineer | Supt. Luke Plant | Demark-BMW | 20 〃 | 1 〃 | (1) |
| 8 | J. L. Sorensen | 〃 〃 | Maintenance Mech Luke Plant | Demark-BMW | 20 〃 | 1 〃 | (1) |
| 9 | S. Joseph | Elec. Maintenance | Elect. Maint. | Sweeden | 6 〃 | 1 〃 | (1) |
| 10 | Silvio Secchi | Civil | Snr. Civil Eng. | Italy-Inpresit CPDD | 50 〃 | 18 〃 | (1) |
| 11 | M. S. Ali | Civil | Civil Engineer CPDD Consultant | Egypt-Arabfund Arab Contries League | 19 〃 | 6 〃 | (2) |
| 12 | William A. Botrous | Electrical | System Study Consultant | 〃 〃 | 21 〃 | 6 〃 | (2) |
| 13 | I. M. Omar | Mechanical | Mech. Engineer Consultant, CPDD | 〃 〃 | 16 〃 | 2 monthes | (2) |
| 14 | George | Traiying Elect/Mech | Training Instractor | India | | 1 manth | (1) |

# A N N E X — 9

# Fig. 2-1-1 OPERATION STATE OF GENERATING FACILITIES

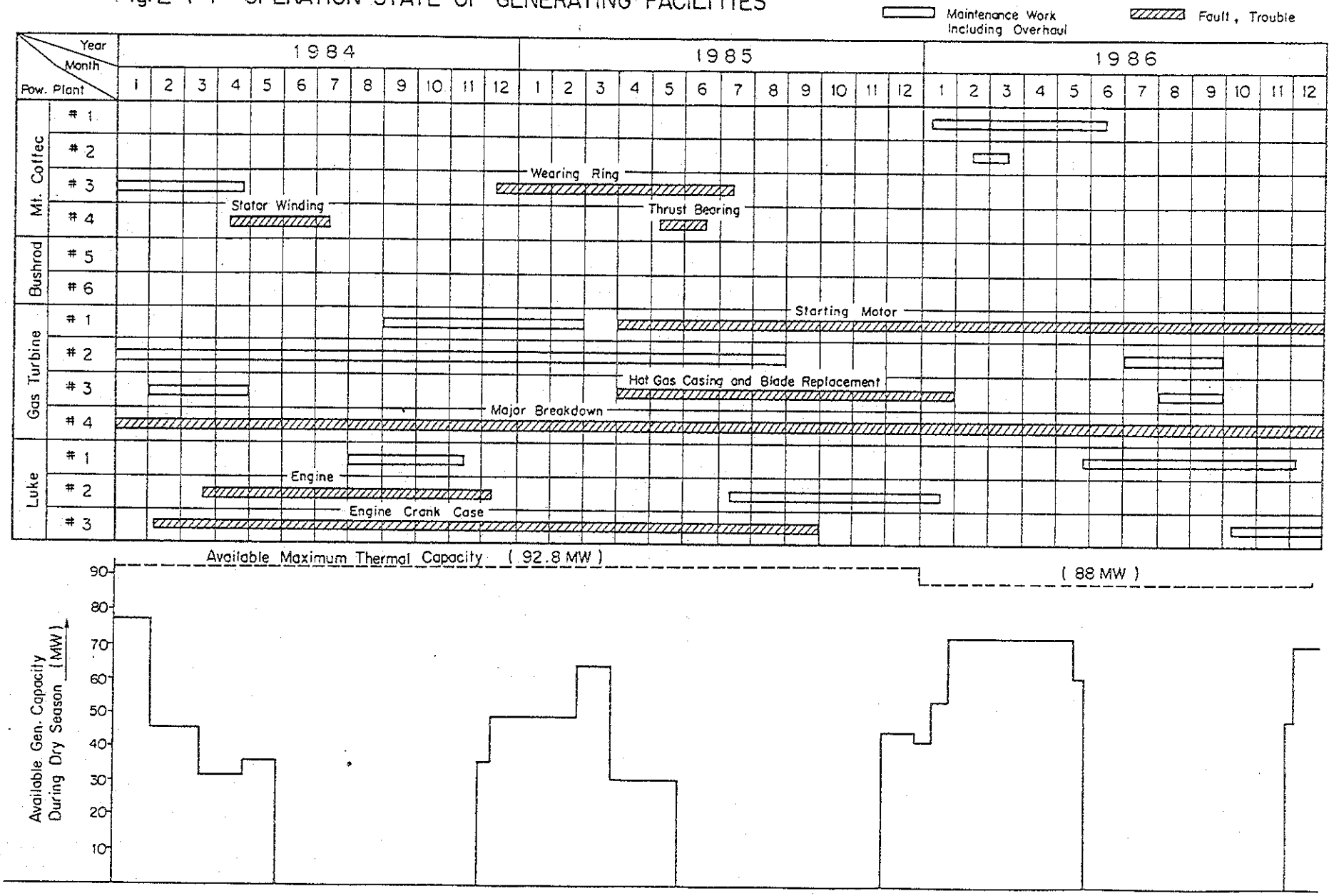


Fig. 2-1-2 Luke Diesel Plant Generated Energy and Consumed Fuel (1984 - 1986)

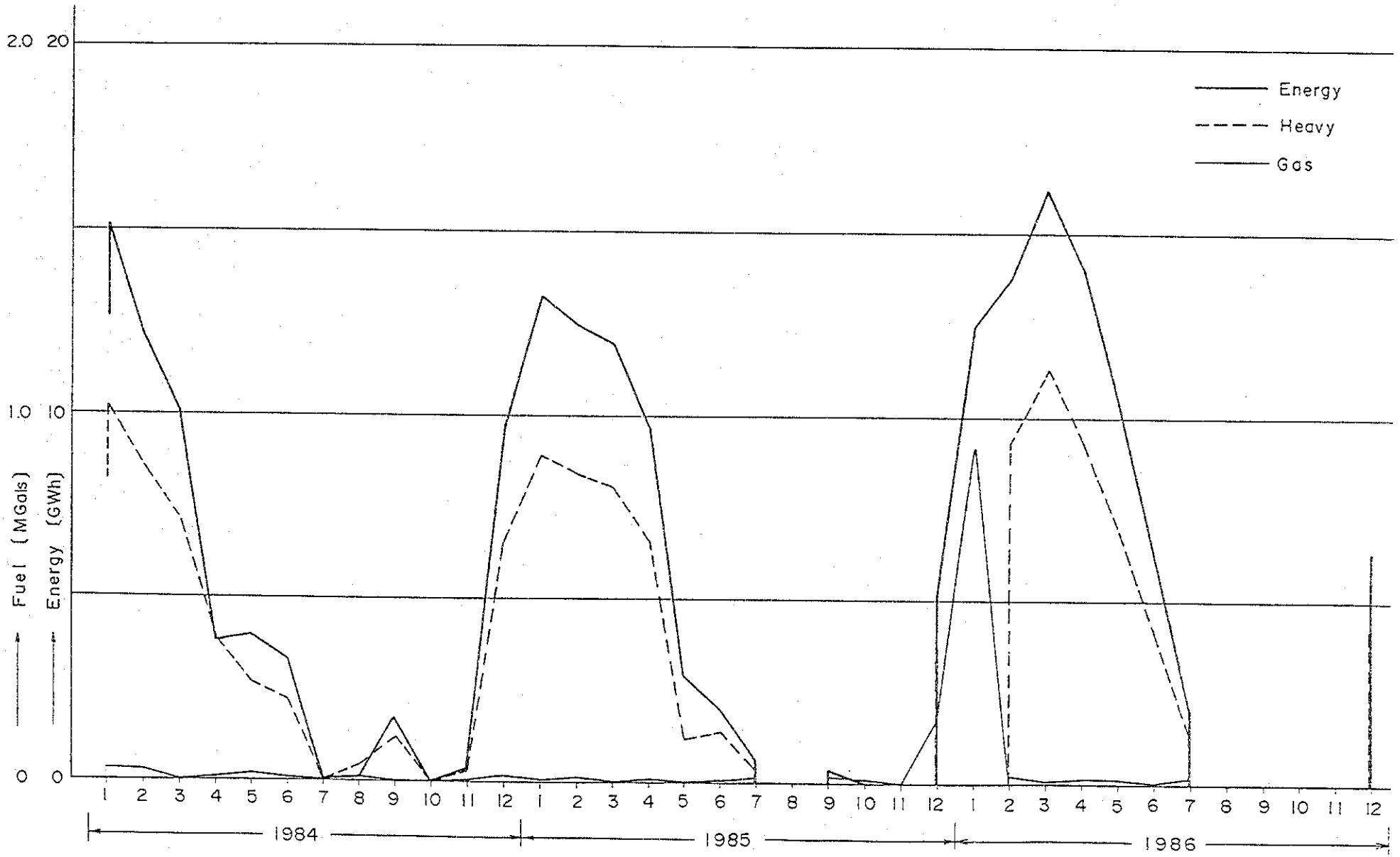


Fig. 2-1-3 Gas Turbine Plant Generated Energy and Consumed Fuel (1984 - 1986)

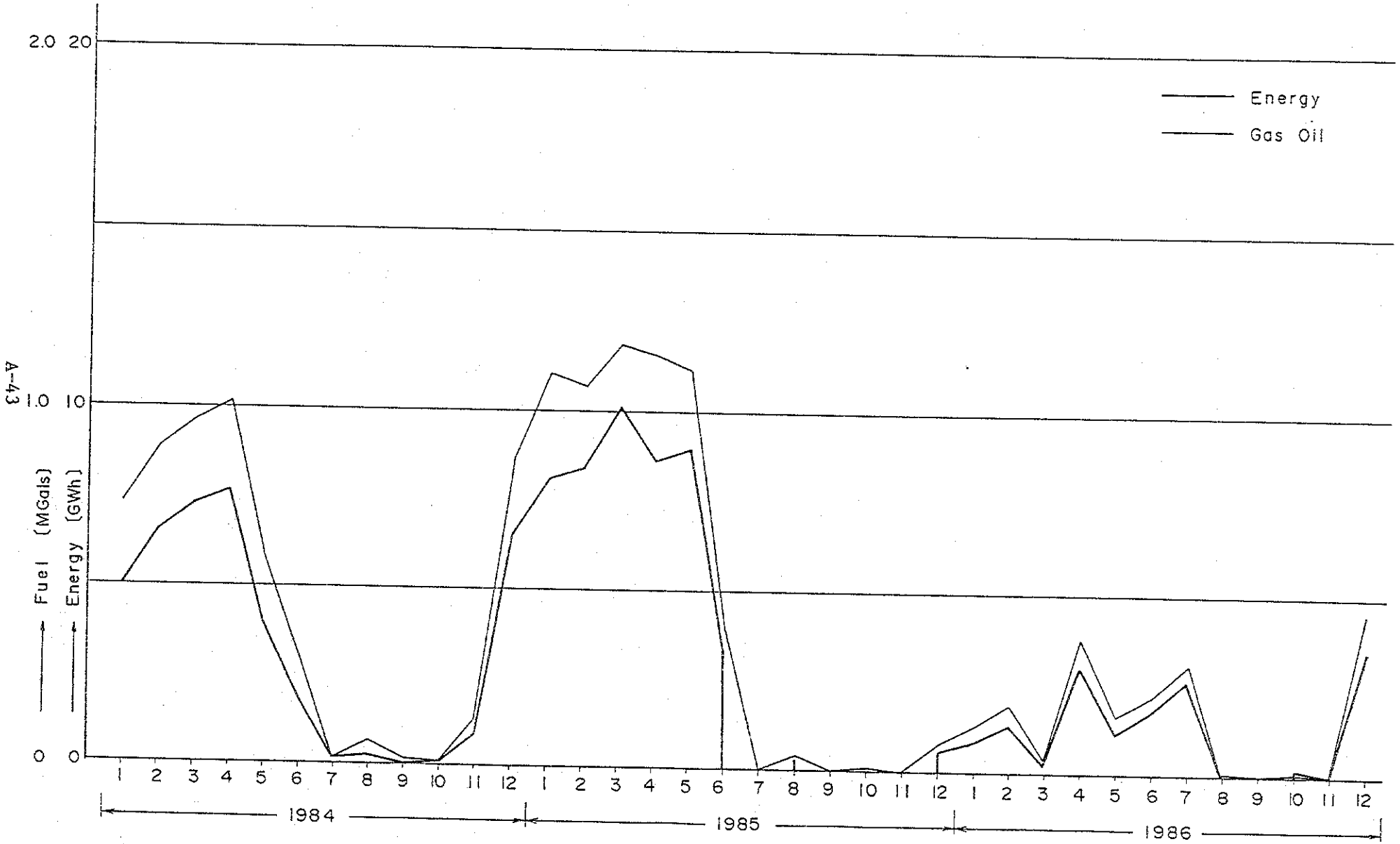
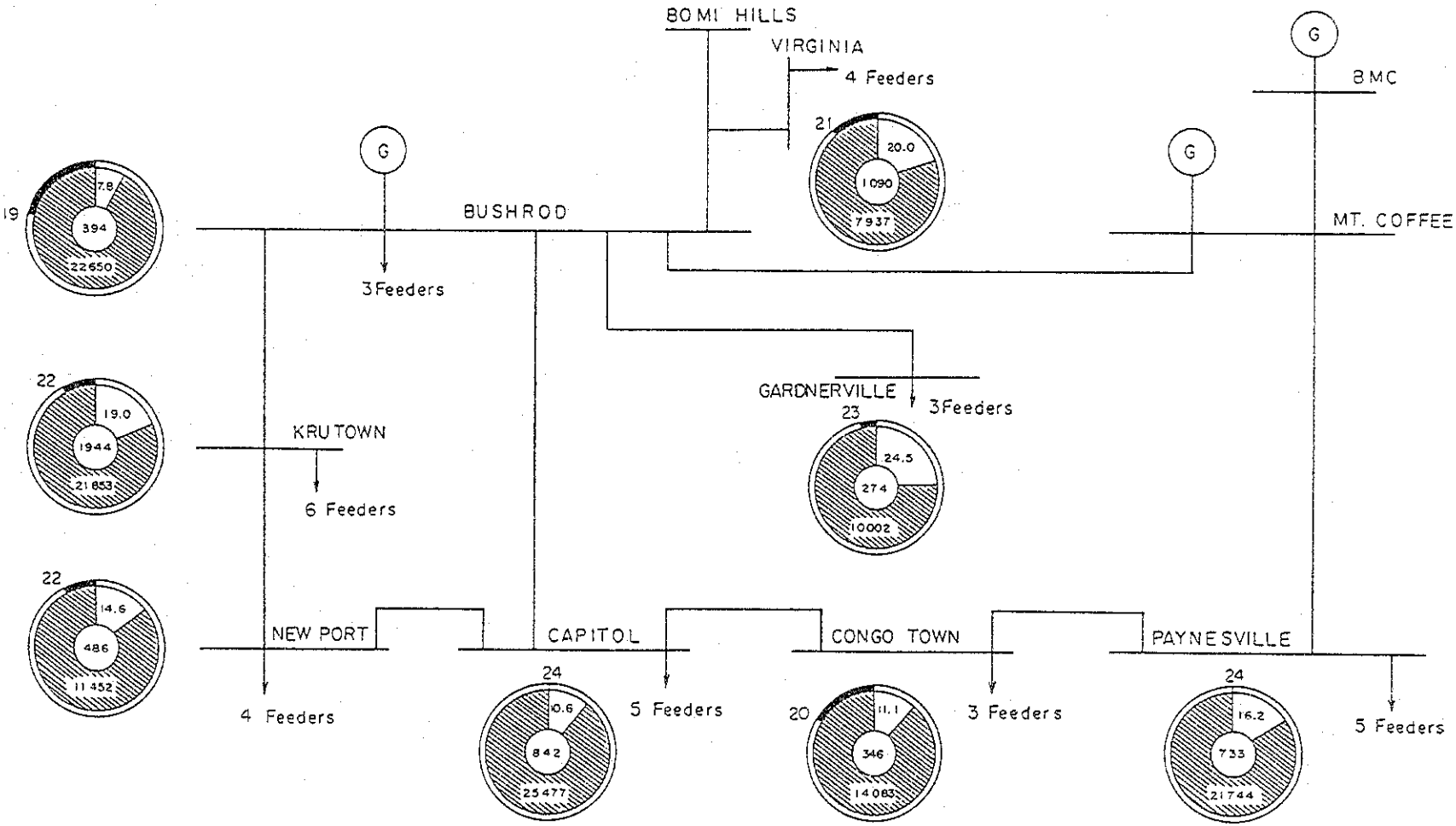


Fig. 2-8 LOAD SHEDDINGS IN MONROVIA POWER SYSTEM (JAN. THRU MAY, 1986)



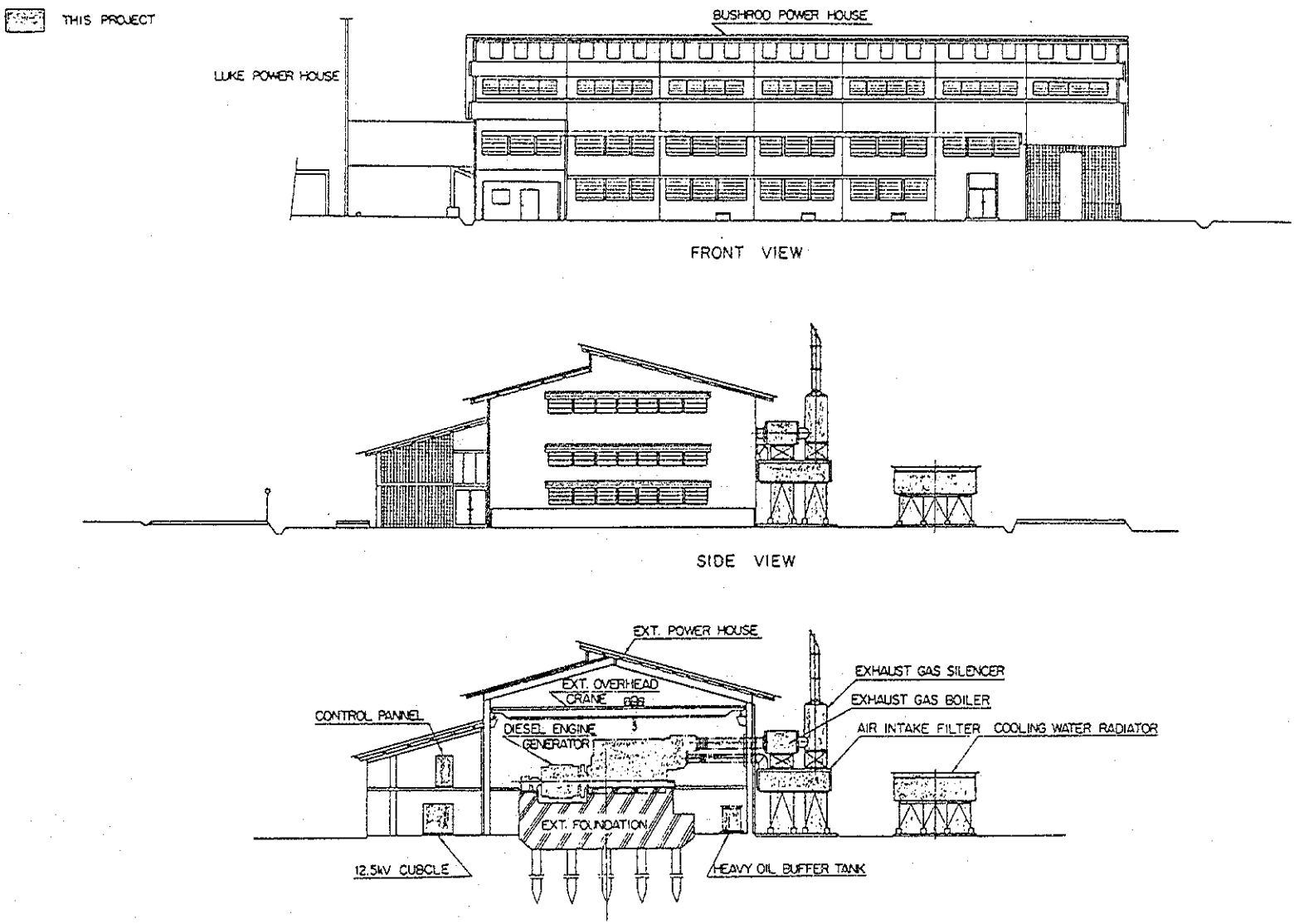



Fig. 2-11 BUSHROD POWER PLANT ( PLAN )

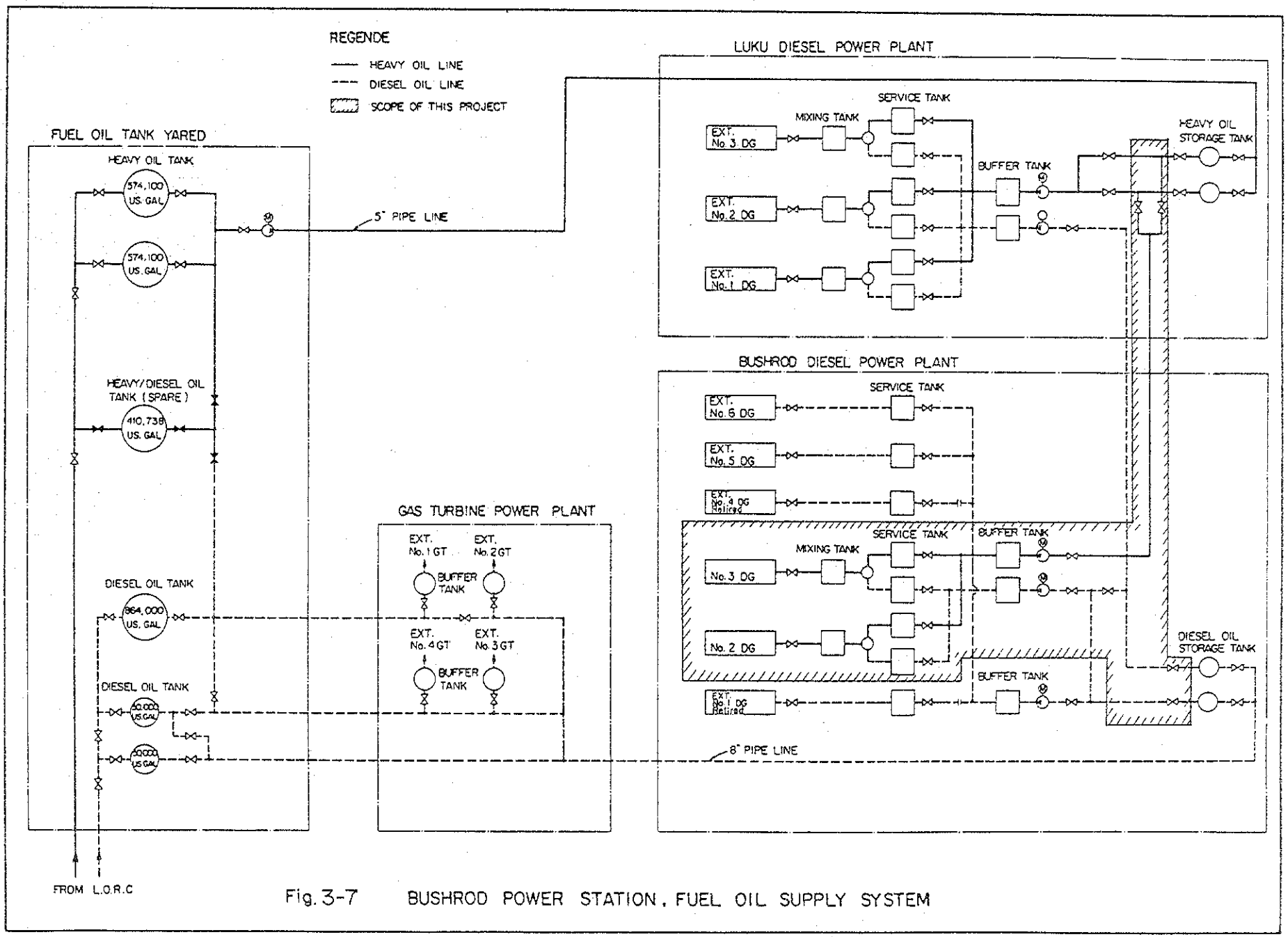



Fig. 3-7 BUSHROD POWER STATION, FUEL OIL SUPPLY SYSTEM

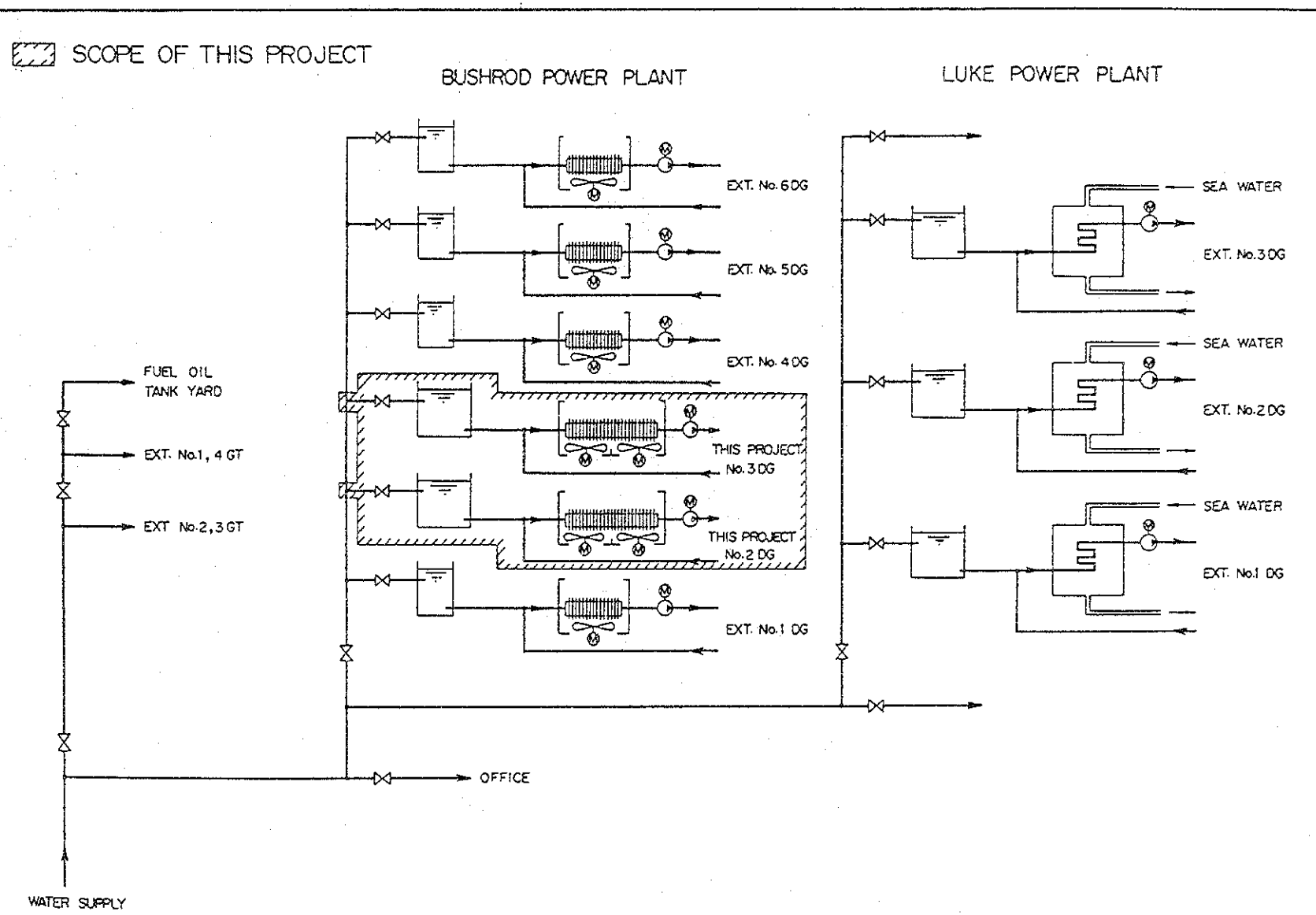



Fig. 3-8 BUSHROD POWER STATION, WATER SUPPLY LINE