# CHAPTER 4

# REHABILITATION PROGRAMS
# FOR
# EXISTING THERMAL POWER STATION

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## 4.1 OUTLINE OF REHABILITATION PROGRAMS

In January, 1985, a British consulting firm named "British Electricity International, Ltd. (BEI) compiled a report on rehabilitation programs of major power plants in GEC's power system. These rehabilitation programs were for the following power generation facilities.

| | |
|---|---|
| Kingston "B" Power Plant: | steam, 10 MW x 3<br>gas turbine, 10 MW x 2 |
| Garden of Eden Power Plant: | diesel; 5.7 MW x 4 |
| Canefield Power Plant: | diesel; 5.8 MW x 2 |
| Onverwagt Power Plant: | diesel; 2.5 MW x 1<br>(new installation) |

A loan from the Inter-American Development Bank (IDB) has been authorized to finance these rehabilitation programs, and the loan agreement was concluded in November 1, 1985. However, the appropriation of 16.1 million U.S. dollars under this agreement was delayed beyond November of 1987, and it was compelled to revise the rehabilitation programs which were scheduled to start in March, 1988.

The reasons that this revision became necessary were as below.

1) Price escalation due to two year's delay.

2) Devaluation of U.S. dollars (the loan was on U.S. dollar basis)

3) New spare parts that were required due to additional aging of facilities.

Under the circumstances, the facilities to be rehabilitated under these programs were changed to the followings.

| | |
|---|---|
| Kingston "B" Power Plant: | steam, 10 MW x 3<br>(guaranteed output; 8.5 MW x 3) |

Garden of Eden Power Plant: diesel; 5.7 MW x 4
(guaranteed output; 3.0 MW x 3)

Canefield Power Plant: diesel; 5.8 MW x 2
(guaranteed output; 4.5 MW x 2)

Onverwagt Power Plant: diesel; 2.5 MW x 1
(guaranteed output; 2.0 MW x 1)
plus a new 2.5 MW x 1

A part of repair parts required for these rehabilitation programs have been ordered, and GEC is now planning to start the rehabilitation works by October of 1988.

GEC has reviewed these rehabilitation programs in August, 1988, and the power generation facilities to be repaired by these programs were changed to the following facilities.

Kingston "B" Power Plant: steam; guaranteed output; 8.5 MW x 3
(No. 1, No. 2 and No. 3 Units)

Garden of Eden Power Plant: diesel; guaranteed output;
4.0 MW x 1 (No. 2 Unit)
5.0 MW x 2 (No. 3, No. 4 Units)
5.0 MW x 1 (No. 5 Unit)
Rehabilitation cancelled

Canefield Power Plant: diesel; guaranteed output;
4.5 MW x 1 (No. 3 Unit)
5.0 MW x 1 (No. 4 Unit)

Onverwagt Power Plant: diesel; guaranteed output;
2.0 MW x 1 (No. 5 Unit)
Installation of a new unit with guaranteed output of 2.0 MW x 1 cancelled.

The approximate schedule is presented in Figure 4.1, "Rehabilitation Work Schedule".

Fig. 4.1 REHABILITATION WORK SCHEDULE

| | 1988 | | | 1989 | | | | | | | | | | | | 1990 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Power plant | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
| **Kingston** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Actual (Expected) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| # 1: 8.5MW (8.5MW) | | | | | | | | | === | === | === | === | | | | | | | | | | | | | | | |
| # 2: 8.5MW (8.5MW) | | | | | | | | | | | | | | | | | | | === | === | === | | | | | | |
| # 3: 8.5MW (8.5MW) | | | | | | | | | | | | | | | | | | | | | | === | === | === | | | |
| **Garden of Eden** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | 4 | | | | | | | | | | | | | | | | | | | | | |
| # 2: 0 MW (4.0MW) * | | | | | === | === | | | 5 | | | | | | | | | | | | | | | | | | |
| # 3: 0 MW (5.0MW) * | | | | | | | | === | === | | | | 2 | | | | | | | | | | | | | | |
| # 4: 3.0MW (5.0MW) | | | | | | | | | | | | === | === | | | | | | | | | | | | | | |
| **Canefield** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| # 3: 4.5MW (4.5MW) | | | | | | | === | === | | | | | | | | | | | | | | | | | | | |
| # 4: 0 MW (5.0MW) * | | | | === | === | 5 | | | | | | | | | | | | | | | | | | | | | |
| **Onverwagt** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| # 5: 0 MW (2.0MW) * | | === | === | | | | | | | | | | | | | | | | | | | | | | | | |
| Total: 33 MW (51 MW) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Increase of capacity** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| - Annual: | | | 2 | | | 5 | | 4 | | | 5 | | | 2 | | | | | | | | | | | | | |
| - Accumulated total | | | 2 | | | 7 | | 11 | | | 16 | | | 18 | | | | | | | | | | | | | |

Note: * shows generating units which are out of order at present due to troubles.

## 4.2 REHABILITATION PROGRAM OF EACH POWER STATION

The contents of rehabilitation programs for each power plant included IDB loan were studied based on the site survey, BEI report, and the report compiled by GIBBS & HILLS/DRAVO SERVICES, INC. (from May, 1988 to July, 1988).

These programs are being implemented after GEC has worked out the details under the advice of GIBBS & HILLS/DRAVO SERVICE, INC.

### 4.2.1 Kingston "B" Power Station

Turbine

The No. 1 turbine and the governors of No. 1, No. 2 and No. 3 Units have to be replaced together with related instruments, and spare parts of these components have to be procured.

According to the statement of the station manager presented when the Study Mission visited this power plant, the replacement of No. 1 turbine rotor and overhaul of the whole unit is scheduled to the third quarter of 1989. The five-year overhauls are scheduled for No. 2 Unit in the second quarter of 1990, and that for No. 3 Unit in second to third quarter of 1990.

Generator

It is required to re-wind the No. 2 Unit's stator coil, to spray insulation varnish to the stator coil, to clean the stator and replace wedges, to replace the exciter armature, and to procure related spare parts.

Boiler System

The boiler tubes of the three units were replaced in early 1980, and all units are operable. However, damages are in progress on the outside equipments due to shortage of spare parts and repair tools.

The instruments are not reliable, and modern equipments must be installed in order to assure reliability and safety of the facilities.

The major items which must be replaced are burners, soot blowers, safety valves, water level sight glasses, blowdown valves, gauges, boiler tubes (spares), repair of fire bricks, high water level and water low level alarms, desuperheater spray valves, boiler water sampling coolers, propane ignition system, fuel oil spill valves, boiler instrumentation, electric analyzer, flame safeguard, igniter system, smoke density recorder, CO2 recorder, flue gas temperature recorders, valves, valves in main and auxiliary steam systems, and related spare parts.

Fuel Oil System

The fuel systems as a whole are operable, but they are not reliable. In particular, there are many problems with the fuel oil unloading facility, and its measuring system and piping have to be replaced, the pier and pump station re-constructed, and the instruments and gauges in both high pressure and low pressure fuel system must be replaced.

Major items which need to be renewed are the oil unloading pumps and piping, low pressure fuel feed pumps, high pressure fuels feed pumps, strainers, measuring gauges, steam traces and heaters, control system of steam heaters, gauges, fuel trip valves, oil unloading pier, measuring instruments, oil unloading hoses and coupling, circuit breakers in 415 V control center, and related spare parts.

Cooling Water System

The cooling water system is in such a state that repair is difficult. As the river water is used as cooling water, the water contains a large amount of silt, and sea water is mixed as the site is at the coast. One water pipe out of three is completely damaged, and so is one band screen out of the two. The remaining band screen is coroded. There is no washing screen and cooling water pump is worn out. Although three pumps out of four are still operable, one of them fail frequently. The condenser, condenser pipes and pipe sheets have been worn out for 6 to 8 years.

The major items to be renewed are band screens, screen washing pumps, cooling water pumps and valves, piping, generator cooler piping, valves, strainers, heat exchangers proper, condenser tubes, turbine sheets, lubrication oil coolers, valves, piping, cooling water pump motors, 415 V circuit breakers, cables, sacrificial anodes, instruments, penstocks, cathodic protection systems, plus related spare parts.

Combustion Air and Flue Gas Systems

These system can be repaired in general, but the instrumentation systems are inferior in reliability and accuracy. The induced draft fans and forced draft fans, their driving motors, dampers, stack coatings, stack insulators, circuit breakers of 415 V control centers and instruments must be renewed, and their spare parts supplied.

Water Treatment System

These systems are usable in general, but they have been exploited to limits, with valves, pumps and piping worn and excessive water leaks observed. This condition makes the city water and demineralized water mix to each other. The dosing pumps are worn, and anion fiber glass tanks have failed often in the past and repaired. The piping and pumps of evaporator systems must be replaced, and the bearing cooling water systems must be re-designed so that chemicals, Nalco39 or Colgan can be injected to prevent rusting, to change it to a recirculating heat exchanger system. It is required to install a demineralized water tank of appropriate capacity so that there will be no trouble when the city water pressure is reduced so that it will not be necessary to transport water by trucks.

The major items which have to be replaced are the low pressure and high pressure dosing pumps, demineralizer tanks, piping and valves for demineralized water and city water systems, PVC pipes and fittings, evaporator raw water pumps, solenoids, timers, valves, filter pumps, instruments, circuit breakers of 415 V control centers, evaporators, bearing cooling water system, city water booster pumps, high pressure drain pumps, recovery pumps, anion supply pumps, cation supply pumps and air compressors, with procurement of related spare parts.

Condenser Systems

These systems are operable in general. However, damages on piping and valves, and erosion of pump casings due to silt and rust are excessive, and water is leaking from the inspection manhole of condenser.

Major items to be replaced are extraction pump piping and valves, side glasses, condenser start main air ejectors condenser flash boxes, control valves, instruments, circuit breakers of 415 control centers, deaerator safety valves, lift pump motors, and related spares.

Boiler Feedwater Systems

These systems are operable in general. As some boiler feedwater pumps have been damaged due to wear, they have to be changed to motor driven systems. Valves, check valves, insulators on piping, gauges and instruments have to be replaced and their spare parts supplied.

Electrical Systems

All electrical systems are approaching the condition from which they cannot be repaired at all. The dilapidation has been caused by shortage of spare parts and aging degradation of circuit breakers.

The major items to be replaced are 11 kV switches, meters, relays, circuit breakers of 415 V control centers, switches and wiring in 110/220 V circuits, unit grounding, frequency meters and frequency recorders, turbine speed remote control systems, as well as related spare parts.

Power Plant Illumination, Communication System, Control Pneumatic System and DC Power Supply

In order to enhance the maintenance activities in power plants, it is required to renew the illumination systems, to introduce modern communication systems, to replace batteries (48 V) and battery chargers, and to procure related spare parts.

Instrumentations

The instruments are generally poor in accuracy. It is required to replace the boiler flue gas monitoring systems, forced draft fan and induced draft fan control systems, oxygen analyzers, recorders, etc. to realize efficient operation of power plants.

Major items to be replaced are the main steam pressure control systems, forced draft fan and induced draft fan control systems, main steam temperature control systems, auxiliary steam pressure control systems, air and gas temperature indicators and recorders, boiler flue gas analyzers, steam temperature indicators, steam pressure indicators, fuel gauges and accounting meters, boiler feedwater flow meters and accounting meters, main steam flow meters and accounting meters, and related spare parts.

Crane

There is a 25/5 ton crane in the main equipment hall, and 1.5 ton crane on the band screen side. The 5 ton hook, brakes, electrical wiring of the main crane, the electrical wiring of the band screen crane, and circuit breakers of 415 V control centers must be replaced and related spare parts supplied.

Other Equipments

Rehabilitation and/or replacement works should be implemented for improvement of working environment, including the power plant building, sump pump of cooling water pump room, grating of cooling water pump room, covers of plant piping ducts, air conditioners in offices and analyzer laboratory, and ventilation systems of main equipment hall, dining hall and first aid room.

Ancillary Facilities

The tools, machine tools and measuring instruments, and test equipments in chemical analysis laboratory must be replenished.

Warehouse

The warehouse building is small and badly damaged. It must be reconstructed.

Fire Extinguisher System

The power plant is not provided with a comprehensive fire extinguisher system. A new fire extinguisher system must be installed.

### 4.2.2 Garden of Eden Power Station

Diesel Engine

No. 2 Unit: This unit is not operating since its crank shaft was damaged in November, 1987. In order to perform an overhaul, the engine was disassembled and maintained, and now a quotation of the spare parts required for an overhaul is being inquired to the manufacturer (Crossley Pielstick Company) through GIBBS & HILL/DRAVO SERVICES, INC. The overhaul will be started as soon as spare parts are procured, and it is expected to be completed by March, 1989.

No. 3 Unit: This unit was damaged at the end of 1985 due to crank shaft failure, and is not operated now. A new crank shaft is needed to repair this unit, which is today disassembled with only the main engine left at the site. The necessary parts and spare parts must be procured for an overhaul. The overhaul of this unit is planned after the overhaul of No. 2 Unit, and this overhaul is scheduled to be completed in June, 1989.

No. 4 Unit: This is the only unit which is in operation at this time and the maximum generating capacity 3 MW (Installed capacity 5.7 MW). After the overhaul of No. 3 Unit is completed, this unit is to be overhauled and scheduled to be completed in October, 1989.

No. 5 Unit: This unit has been damaged since 1986 when the crank shaft bearing failed. The machine is already removed from the site today, and this unit will be scrapped. The remaining foundation was inspected by a civil engineer (a foreign consultant), and it was found out to be in good condition. At present, the surface concrete of the old foundation was removed, placed with new concrete, and the foundation is preserved.

Generator

No. 2 Unit: The stator and rotor of No. 4 Unit have been removed and fitted to on this unit. This unit can be operated if proper cleaning and insulation varnish spray is applied after overhaul.

No. 3 Unit: This unit is left at the site. It is required to be cleaned and insulation varnish is applied in an overhaul.

No. 4 Unit: The stator and rotor of No. 5 Unit were removed and fitted to this unit. Currently, the output is limited at 3 MW. It is required to be cleaned and insulation varnish should be applied in an overhaul.

No. 5 Unit: For this unit, the stator and rotor of No. 2 Unit should have been available, but the stator has been scrapped, and this unit will be scrapped anyway.

Lubrication Oil System

The lubrication oil is cooled by the river water which contain large amount of silt as well as sea water that come from the nearby sea. The heat exchangers and piping of the cooling system are damaged by erosion and corrosion, and there are troubles including ingress of water into lubrication oil.

Major items to be replaced are three (3) heat exchangers, three (3) priming pumps, three (3) lubrication oil purifiers, and one (1) transfer pump, plus procurement of related spare parts.

Cooling Water System

This system is attacked by wear, erosion and corrosion by the same causes as with the lubrication oil cooling system. Two (2) cooling water pumps (with motors changed to fully enclosed type), piping, and three (3) switching type strainers must be replaced and related spare parts procured.

In the engine cooling system, three (3) injector cooling pumps and three (3) jacket cooling pump driving motors (with the type changed to fully enclosed type) must be replaced, and related spare parts procured.

Fuel Oil System

If C-fuel oil is to be used in future for continuous operation, No. 1 fuel oil treatment module must be replaced, and some parts of the No. 2 module must be replaced, together with two (2) booster pumps and two (2) leakage oil tank pumps, and the related spare parts procured.

There are two fuel storage tanks for C-fuel oil, and two tanks for diesel oil. The C-fuel oil tanks must be painted with anti-corrosive paint, and the tanks for C-fuel oil and diesel oil must be improved, including the surrounding protection walls.

Startup Air System (Compressed Air System)

One of the motor driven compressor had its part replaced, and one engine driven compressor is a unit appropriated from other use. These must be replaced and the related spare parts supplied.

Air Intake and Exhaust System

There are eight air intake systems. Their dust prevention screens and louvers are rusted and corroded, and must be replaced.

There are eight exhaust silencers, which are rusted and corroded, and must be replaced.

There are eight exhaust stacks. The direction of exhaust and height are not proper, and the stacks must be replaced.

Electrical Systems

Generator Control Board

The three generator control boards, for No. 2, No. 3 and No. 4 Unit respectively, must be replaced with those having the most advanced designs, and the related spare parts supplied.

Engine Generator Startup Board

The boards are operable, but spare parts must be supplied.

DC Power Supply

48 V DC Supply: The 24 batteries must be replaced and the related spare parts supplied.

125 V DC Supply: Ten alkali batteries must be replaced and the related spare parts supplied.

Control Center: The two circuit breakers must be overhauled and their spare parts supplied.

13.8 kV Switchgear: The closing motor of the circuit breaker of No. 4 Unit must be repaired and its spare parts supplied.

Station Service Transformer: The dryer agent (silica gel) of the two (2) transformers must be replaced and the insulation oil changed. The insulation oil dielectric constant tester and the glass plates of conservator oil level gauges must be cleaned.

Instruments: Accuracy of all instruments is doubtful. As there is no tool and calibration equipment in the repair shop, various test sets must be procured.

Crane: The main equipment crane has a 5-ton auxiliary hoist and 25-ton main hoist. As the 5-ton hoist is not operable, its parts must be replaced. The hoisting cable of the 25-ton hoist must be replaced.

Other Equipments

Black Start Generator: One DC generator must be installed so that the main engine can be started when all power of the station goes off.

Fire Protection System: The manually operated, carbon dioxide fire extinguisher currently available is not sufficient. A new fire protection system with a diesel engine driven pump must be installed.

Station Electric Wiring

Cooling Water Pump House: As the wiring is excessively aged, it has to be replaced.

Station Lighting: The flood lamps in the power plant building and the ceiling of generator hall are badly soiled by soot. The necessary parts and lamps must be replaced, and the spare parts supplied.

Ancillary Facilities

Repair Shop: In order to clean machine parts, the outdoor yard must be expanded, and a movable gantry crane must be installed for transportation of materials and parts.

Warehouse: The warehouse must be expanded so that the storage racks are extended to store parts of its own power plant.

### 4.2.3 Canefield Power Station

Diesel Engine

No. 3 Unit: The 12,000-hour overhaul is scheduled to be conducted from January to April of 1989, and the spare parts will be delivered by November, 1988.

No. 4 Unit: This unit is being shut down as it was damaged in 1987 due to failure of crank shaft. The new crank shaft has been delivered, and overhaul will be completed by January of 1989.

Generator

There is no particular problem on either No. 3 or No. 4 Unit.

Lubrication Oil System

The lubrication oil is cooled by the river water which contain large amount of silt as well as sea water that come from the nearby sea. The heat exchangers and piping of the cooling system are damaged by erosion and corrosion, and there are troubles including ingress of water into lubrication oil.

Two (2) heat exchangers must be replaced and their spare parts supplied.

Cooling Water System

This system is attacked by wear, erosion and corrosion by the same causes as with the lubrication oil cooling system. One (1) cooling water pump out of three must be repaired, two (2) switching type strainers must be replaced, and their spare parts supplied.

In the engine cooling system, four (4) injector cooling pumps and four (4) jacket cooling pump driving motors (with the type changed to fully enclosed type) must be replaced, and related spare parts procured.

Fuel System

Originally, it was planned to use the heavy oil, which has not been realized, but the reason is not clear, i.e., whether the oil characteristics did not match the purifier specification or the capacity of purifier was not sufficient. Anyway, there will be no problem if diesel oil is continued to be used as it is now. Coating of oil tank and piping will be required.

Startup Air System (Compressed Air System)

The motor driven and engine driven compressors must be replaced and their spare parts supplied.

Intake and Exhaust Systems

The intake system must be painted, and the screens must be replaced.

Ancillary Facilities

The repair shop and warehouse must be cleaned, and the storage racks in the warehouse must be expanded.

#### 4.2.4 Onverwagt Power Station

In the original plan for rehabilitation of Onverwagt Power Plant, the repair of existing No. 5 Unit (with installed capacity of 2.5 MW, manufactured by General Motors Company in 1981, and shut down in June, 1988 due to turbo charger failure) and procurement of a new 2.5 MW unit were planned, as the repair costs for No. 1 through No. 4 diesel generator units, which have smaller capacity (1,000 kW x 4, manufactured by Ruston-GEC in 1973) are more expensive. GEC reviewed this plan in August, 1988, and it was then preparing to implement the repair of No. 5 Unit only in December of 1988.

The major items which need replacement are, in addition to spare parts for periodical inspections, the turbo charger of No. 5 Unit, governor, instruments, radiator fan motor, 125 V batteries, automatic voltage regulators, plus their spare parts.

#### 4.2.5 Conclusion

Although the rehabilitation programs are currently being implemented by GEC, it is recommended that all efforts of the Company are concentrated to rehabilitation of power plants discussed above, as they are the key power plants in GEC's power system.

# CHAPTER 5

# POWER DEMAND FORECAST
# AND
# SUPPLY BALANCE

# CHAPTER 5 POWER DEMAND FORECAST AND SUPPLY BALANCE

## 5.1 METHODOLOGY

It is well know that there is a close relationship between power demand and economic performance which is represented by gross domestic product (GDP). This relationship is often utilized for power demand forecast.

Demand function for a given commodity consists of price of that commodity and income of the consumers, therefore it is reasonable to use, as the second explanatory variable, electricity price which is represented by average rate per unit sold.

However, in developing countries, serious unbalance is often found between power demand and supply capability and many potential consumers are waiting for electricity supply. Under these conditions, it is often difficult to identify a strong correlation among power demand, GDP and electricity price. In such a case, number of electricity consumers can be used as the third explanatory variable.

In addition to the above macro-economic forecast method, there are analytic forecast methods made on a micro-economic framework which take into account future industrial projects, agricultural projects, large housing estate projects, etc. However, these analytic methods can be used only when sound prospectives are obtained regarding financing and technical aspects of these projects. Otherwise, they lead often to an overestimate of the future demand for electricity.

In this study, linear regression and multiple regression were calculated based on the time-series data of power demand, GDP, average rate per unit sold, and number of consumers over the period from 1974 to 1987, in order to find the most suitable regression model.

Attention was also paid to the fact that in the Demerara and Berbice systems there are many applications for which supplies have not been provided. Undoubtedly these potential consumers will be supplied with electricity after completion of current rehabilitation program for superannuated plants and construction of new power plants. Therefore, these potential demands were added to demand forecasted by regression method.

## 5.2 REGRESSION MODELS

Time-series data given in Tables 2.2.4.(1) to 2.2.4.(5) and Table 5.1 have led to the following regression models:

Symbols

Y : Energy generation (GWh)

X1 : GDP (G$ million at 1980 prices)

X2 : Average rate per unit sold (G$/kWh) or number of consumers

X : Number of consumers

### 5.2.1 Multiple regression

(1) Explanatory variables: GDP and electricity price (See Table 5.2.(1))

$$Y = 0.0135X1 + 242.51041X2 + 122.02$$

Correlation coefficient: $R^2 = 0.61$

This model cannot be used theoretically because price coefficient shows positive (+) sign.

(2) Explanatory variables: GDP and number of consumers (See Table 5.2.(2))

$$Y = 0.03772X1 + 0.00214X2 - 6.36$$

Correlation coefficient: $R^2 = 0.63$

This model is not also suitable because correlation coefficient is very low.

### 5.2.2 Linear regression

Explanatory variable: Number of consumers only (See Table 5.2.(3))

$$Y = 0.00223X + 41.75$$

Correlation coefficient: $r = 0.76$

Standard deviation: $s = 15.38$

Correlation coefficient of 0.76 is not high but it is considered that this model represents fairly the demand relationshp up to the present.

Therefore, this model has been used as the basis for power demand forecast for the future.

The number of consumers in 1987 which is the base year of this study was 101,359. When using this model, the calculated energy generation in 1987 is 30.4 GWh larger than the actual generation of 237.4 GWh. This difference of about 13% (30.4/237.4 = 0.128) would have been caused by shortage of supply capability of GEC power system. In fact, the load shedding carried out during the period from 1985 to 1987 is estimated by GEC as follows (39.6 GWh in 1987):

| | 1985 (MWh) | 1986 (MWh) | 1987 (MWh) |
|---|---|---|---|
| Demerara system | 7,666 | 22,095 | 33,418 |
| Berbice system | N.A. | N.A. | 6,214 |
| Total | - | - | 39,632 |

Note: N.A. ... Not available.

Therefore, it is considered that the power demand will show a rapid growth in around 1988/89 corresponding to the progress of the current rehabilitation program.

## 5.3 CONDITIONS FOR DEMAND FORECAST

### 5.3.1 Increase of consumers

The number of consumers had increased steadily at an average rate of 3.75% per annum from 73,514 in 1974 to 95,152 in 1981, but since then it has become unstable due mainly to shortage of supply capability of GEC power system. This would mean that if there is no large shortage of supply capability, the number of consumers will increase at a rate of this order even under recession of the economy. Assuming that the current rehabilitation program will be completed by the end of 1990 and also new power plants will enter service thereafter, the number of consumers is estimated to grow at an average annual rate of 3.75% in the future.

### 5.3.2 Shares of power demand by system

Shares of power demand of the isolated systems in the total demand have remained almost unchanged up to present.

In the Demerara system the rate of access to electricity is very high, reaching almost saturated situation. This would lead to the consideration that in the future the growth of power demand in the Demerara system will be less rapid than that in the Berbice system. This may be true but it is difficult to make a quantitative estimate. Power demand in the Demerara system will also grow steadily due to increase of inhabitants, caused by immigrants from other areas.

Therefore, on the assumption that shares of power demand by system in the past will not change very much, the following demand shares are used for the future (See Section 2.2.4.(4)).

| Power system | Demand share (%) |
|---|---|
| Demerara | 85.5 |
| Berbice | 10.8 |
| Anna Regina/Wakenaam | 3.0 |
| Bartica | 0.7 |
| Total | 100.0 |

### 5.3.3 Potential power demand

There are many potential consumers in the Demerara and Berbice systems. The current numbers of applications for which supplies have not been provided are as follows.

| | |
|---|---|
| Demerara system | 3,510 |
| Berbice system | 4,200 |

Almost all of the above applications are residential consumers. As stated in Section 2.2.4.(1), the specific energy consumption of residential consumers is 1.13 MWh in the Demerara system and 0.51 MWh in the Berbice system. The system loss factors of Demerara and Berbice systems are estimated to be 27.3% and 37.2% respectively, as shown in Section 2.2.2.(4). Therefore, the required power generation which correspond to these potential power demands are estimated as follows:

| | |
|---|---|
| Demerara: | 3,510 x 1.13/(1 - 0.273) = 5.5 GWh |
| Berbice: | 4,200 x 0.51/(1 - 0.372) = 3.4 GWh |

It is said that in the Berbice area there are eight saw mills having a total demand of about 4MW. These mills are located beyond the end of distribution line of Canefield power station.

The potential demands of 5.5 GWh for the Demerara system and 3.4 GWh for the Berbice system mentioned above are included in this power demand forecast, but saw mills demands are not included in this demand forecast because accurate information about these demands are not available at the moment.

### 5.3.4 Load factor

As described in Section 2.2.4.(3), the load factor of each power system has been almost unchanged over the period from 1974 to 1987, therefore, the average load factor for this period shown below is used for the future.

| Power system | Load factor (%) |
|---|---|
| Demerara | 65.9 |
| Berbice | 40.1 |
| Anna Regina/Wakenaam | 45.9 |
| Bartica | 47.1 |

### 5.3.5 System loss factor

The system loss factor including station service loss, transmission and distribution losses are abnormally high for all of the power systems. Further, no decreasing trend has been found. For the period from 1974 to 1987, the average loss factors were 27.3% for the Demerara system, 37.2% for the Berbice system, 22.4% for the Anna Regina/Wakenaam system and 25.8% for the Bartica system.

These high loss factors would be due either to theft or to accounting difficulties. GEC recognizes its high system loss and is working at reducing these losses by investigation of theft, introducing a new computer billing system, and upgrading its distribution system.

GEC is presently planning to reduce the losses in Demerara and Berbice systems to 24% by 1990. GEC is also projecting that as a result of the

Distribution Master Plan (IDB financed) the distribution losses will be reduced. It is expected that the overall losses will decrease to 18% by 1994 for the entire system.

Taking the above situation into account, the following loss factors are estimated for the planning period from 1988 to 1998:

| Year | Demerara | Berbice | Anna Regina/Wakenaam | Bartica |
|---|---|---|---|---|
| 1988 | 0.273 | 0.372 | 0.224 | 0.258 |
| 1989 | 0.256 | 0.299 | 0.216 | 0.243 |
| 1990 | 0.240 | 0.240 | 0.208 | 0.229 |
| 1991 | 0.223 | 0.223 | 0.200 | 0.216 |
| 1992 | 0.208 | 0.208 | 0.194 | 0.203 |
| 1993 | 0.193 | 0.193 | 0.187 | 0.191 |
| 1994 | 0.180 | 0.180 | 0.180 | 0.180 |
| Thereafter | 0.180 | 0.180 | 0.180 | 0.180 |

### 5.3.6 Required reserve margin

In order to secure a stable supply of electricity, the power system must have a reserve margin to cover capacity drop due to scheduled maintenance and forced outage, and also to sudden increase of power demand.

There are many criteria to determine reserve margin in accordance with scale of power system and load pattern, but most developing countries adopt the larger of the following two:

- Capacity equivalent to the largest and the second largest generating units;

- A certain percentage of the peak load (in general 15 to 20%)

To cover the current shortage of supply capability, fairly large capacity must be added to the GEC power system. For this purpose, GEC will be burdened with large investment in the future. Taking this into account, the reserve margin is to be one (1) largest unit for each power system. Therefore:

| Power system | Reserve margin (%) |
|---|---|
| Demerara | 8.5 (1988-92), 13.0 (1993-98) (Note) |
| Berbice | 5.0 |
| Anna Regina/Wakenaam | 1.5 |
| Bartica | 0.2 |
| Total | 15.7 |

Note: In 1993, Kingston No.1 unit will be retired, and it is planned to install a 13.0 MW unit.

#### 5.3.7 Retirement schedule

Statistically, in most countries the economic service life is estimated to be 25-30 years for steam power plant and 15-20 years for diesel power plant. In this study, the service life is estimated to be 30 years for Kingston steam power plant and 20 years for the other diesel power plants. The current rehabilitation program is expected to prolong the service life of the plants to these limits.

The time-schedule of retirement and decrease of capacity is estimated as shown in Table 5.3

## 5.4 RESULT OF DEMAND FORECAST AND SUPPLY BALANCE

The results of demand forecast are shown in Tables 5.4.(1) to 5.4.(6). These tables include energy consumption, energy sent-out, peak load, reserve margin, required capacity, capacity of existing power plant, retirement, and power demand and supply balance by existing power plants of each power system over the period from 1988 to 1998.

Fig. 5.1 shows power demand in the Demerara and Berbice systems from 1980 to 1998.

Table 5.1 ECONOMIC PARAMETERS FOR POWER DEMAND FORECAST

| | GDP (G$ million) | | | Electricity price (G$/kWh) | | | |
|---|---|---|---|---|---|---|---|
| Year | Market price | Deflator (1980=100) | 1980 price | Current price | C.P.I. (1980=100) | 1980 price | Number of consumers |
| 1974 | 955.0 | 68 | 1,400.0 | 0.13 | 50.8 | 0.256 | 73,514 |
| 1975 | 1,188.0 | 77 | 1,546.0 | 0.19 | 54.7 | 0.347 | 80,088 |
| 1976 | 1,136.0 | 71 | 1,591.0 | 0.21 | 59.7 | 0.352 | 81,014 |
| 1977 | 1,125.0 | 74 | 1,515.0 | 0.24 | 64.4 | 0.372 | 82,478 |
| 1978 | 1,268.0 | 85 | 1,489.0 | 0.24 | 74.4 | 0.363 | 85,840 |
| 1979 | 1,326.0 | 90 | 1,479.0 | 0.27 | 87.7 | 0.308 | 87,266 |
| 1980 | 1,508.0 | 100 | 1,508.0 | 0.37 | 100.0 | 0.370 | 80,900 |
| 1981 | 1,697.0 | 101 | 1,576.0 | 0.58 | 124.7 | 0.465 | 95,152 |
| 1982 | 1,446.0 | 105 | 1,380.0 | 0.59 | 150.0 | 0.393 | 89,758 |
| 1983 | 1,468.0 | 117 | 1,259.0 | 0.59 | 169.9 | 0.347 | 82,876 |
| 1984 | 1,700.0 | - | - | 0.75 | 212.7 | 0.353 | 86,916 |
| 1985 | 1,964.0 | - | - | 0.84 | - | - | 84,770 |
| 1986 | 2,219.0 | - | - | 0.84 | - | - | 85,546 |
| 1987 | - | - | - | - | - | - | 101,359 |

Source: GDP, GDP deflator and C.P.I.(Consumers price index) were taken from International Financial Statistics 1987 (IMF).

Data on average rate per unit sold (Current price) were provided by GEC Planning Department.

Table 5.2.(1) MULTIPLE REGRESSION CALCULATION

Y : Energy generation (GWh)
X1: GDP (G$ Million)
X2: Average rate per unit sold (G$/kWh)

Input Data :

| I | Y(I) | X1(I) | X2(I) |
|---|---|---|---|
| 1974 | 195.5 | 1400.0 | 0.256 |
| 1975 | 208.6 | 1546.0 | 0.347 |
| 1976 | 226.9 | 1591.0 | 0.352 |
| 1977 | 244.2 | 1515.0 | 0.372 |
| 1978 | 223.4 | 1489.0 | 0.363 |
| 1979 | 236.8 | 1479.0 | 0.308 |
| 1980 | 239.4 | 1508.0 | 0.370 |
| 1981 | 256.2 | 1576.0 | 0.465 |
| 1982 | 230.5 | 1380.0 | 0.393 |
| 1983 | 224.3 | 1259.0 | 0.347 |

*** $Y = aX1 + bX2 + c$ ***

a= 0.01351
b= 242.51041
c= 122.01970

Correlation Coefficient: r=0.610
Standard Deviation: s= 17.44

## Table 5.2.(2) MULTIPLE REGRESSION CALCULATION

Y : Energy generation (GWh)
X1: GDP (G$ Million)
X2: Number of consumers

Input Data :

| I | Y(I) | X1(I) | X2(I) |
|---|---|---|---|
| 1974 | 195.5 | 1400.0 | 73514 |
| 1975 | 208.6 | 1546.0 | 80088 |
| 1976 | 226.9 | 1591.0 | 81014 |
| 1977 | 244.2 | 1515.0 | 82478 |
| 1978 | 223.4 | 1489.0 | 85840 |
| 1979 | 236.8 | 1479.0 | 87266 |
| 1980 | 239.4 | 1508.0 | 80900 |
| 1981 | 256.2 | 1576.0 | 95152 |
| 1982 | 230.5 | 1380.0 | 89758 |
| 1983 | 224.3 | 1259.0 | 82876 |

*** Y = aX1 + bX2 + c ***

a= 0.03772
b= 0.00214
c= -6.36052

Correlation Coefficient: r=0.631
Standard Deviation: s= 17.44

Table 5.2.(3) LINEAR REGRESSION CALCULATION

Y : Energy generation (GWh)
X : Number of consumers

Input Data:

| I | Y(I) | X(I) |
|---|---|---|
| 1974 | 195.5 | 73514 |
| 1975 | 208.6 | 80088 |
| 1976 | 226.9 | 81014 |
| 1977 | 244.2 | 82478 |
| 1978 | 223.4 | 85840 |
| 1979 | 236.8 | 87266 |
| 1980 | 239.4 | 80900 |
| 1981 | 256.2 | 95152 |
| 1982 | 230.5 | 89758 |
| 1983 | 224.3 | 82876 |
| 1984 | 235.8 | 86916 |
| 1985 | 235.8 | 84770 |
| 1986 | 226.0 | 85546 |

*** Y = a + bX ***

a= 41.74963
b= 0.00223

Correlation Coefficient: r= 0.758
Standard Deviation: s= 15.38

Table 5.3 DECREASE OF CAPACITY BY RETIREMENT

| Year | Power plant | Demerara (MW) | Demerara Total | Berbice (MW) | Berbice Total | Anna R./WK. (MW) | Anna R./WK. Total | Bartica (MW) | Bartica Total |
|---|---|---|---|---|---|---|---|---|---|
| 1988 | | - | - | - | - | - | - | - | - |
| 1989 | | - | - | - | - | - | - | - | - |
| 1990 | | - | - | - | - | - | - | - | - |
| 1991 | | - | - | - | - | - | - | - | - |
| 1992 | Anna Regina | - | - | - | - | 1.1 | 1.1 | - | - |
| 1993 | Kingston #1 | 8.5 | 8.5 | - | - | - | 1.1 | - | - |
| 1994 | Kingston #2 | 8.5 | 17.0 | - | - | - | 1.1 | - | - |
| 1995 | GOE #2,#4 | 9.0 | 26.0 | - | - | - | 1.1 | - | - |
| 1996 | GOE #3 | 5.0 | 31.0 | - | - | - | 1.1 | - | - |
| 1997 | Kingston #3 | 8.5 | 39.5 | - | - | - | 1.1 | - | - |
| 1998 | Canef'd #3,#4 | - | - | 9.5 | 9.5 | - | 1.1 | 0.4 | 0.4 |
| " | Bartica | | | | | | | | |

Table 5.4.(1) LOAD FORECAST & SUPPLY BALANCE
(By Existing Power Plants)

GEC Whole Power System

| Year (AD) | Energy sold (GWh) | Energy sent out (GWh) | Peak load (MW) | Reserve margin (MW) | Required capacity (MW) | Existing capacity (MW) | Retire-ment (MW) | Supply balance (MW) |
|---|---|---|---|---|---|---|---|---|
| 1988 | 204.5 | 285.2 | 53.9 | 15.2 | 69.1 | 42.2 | 0.0 | -26.9 |
| 1989 | 217.6 | 294.0 | 55.5 | 15.2 | 70.7 | 58.2 | 0.0 | -12.5 |
| 1990 | 230.6 | 303.1 | 57.2 | 15.2 | 72.4 | 58.2 | 0.0 | -14.2 |
| 1991 | 243.1 | 312.5 | 59.0 | 15.2 | 74.2 | 58.2 | 0.0 | -16.0 |
| 1992 | 255.5 | 322.4 | 60.9 | 15.2 | 76.1 | 58.2 | -1.1 | -19.0 |
| 1993 | 268.4 | 332.6 | 62.8 | 19.7 | 82.5 | 58.2 | -9.6 | -33.9 |
| 1994 | 281.4 | 343.1 | 64.8 | 19.7 | 84.5 | 58.2 | -18.1 | -44.4 |
| 1995 | 290.4 | 354.1 | 66.8 | 19.7 | 86.5 | 58.2 | -27.1 | -55.4 |
| 1996 | 299.7 | 365.5 | 69.0 | 19.7 | 88.7 | 58.2 | -32.1 | -62.6 |
| 1997 | 309.4 | 377.3 | 71.2 | 19.7 | 90.9 | 58.2 | -40.6 | -73.3 |
| 1998 | 319.4 | 389.5 | 73.5 | 19.7 | 93.2 | 58.2 | -50.5 | -85.5 |

Note: Overall load factor = 60.7%

Table 5.4.(2) LOAD FORECAST & SUPPLY BALANCE
By Existing Power Plants)

Demerara & Berbice System

| Year (AD) | Energy sold (GWh) | Energy sent out (GWh) | Peak load (MW) | Reserve margin (MW) | Required capacity (MW) | Existing capacity (MW) | Retire-ment (MW) | Supply balance (MW) |
|---|---|---|---|---|---|---|---|---|
| 1988 | 196.6 | 274.9 | 51.3 | 13.5 | 64.8 | 39.2 | 0.0 | -25.6 |
| 1989 | 209.4 | 283.4 | 52.9 | 13.5 | 66.4 | 55.2 | 0.0 | -11.2 |
| 1990 | 222.1 | 292.2 | 54.5 | 13.5 | 68.0 | 55.2 | 0.0 | -12.8 |
| 1991 | 234.1 | 301.3 | 56.2 | 13.5 | 69.7 | 55.2 | 0.0 | -14.5 |
| 1992 | 246.1 | 310.8 | 58.0 | 13.5 | 71.5 | 55.2 | 0.0 | -16.3 |
| 1993 | 258.7 | 320.6 | 59.8 | 18.0 | 77.8 | 55.2 | -8.5 | -31.1 |
| 1994 | 271.2 | 330.8 | 61.7 | 18.0 | 79.7 | 55.2 | -17.0 | -41.5 |
| 1995 | 279.9 | 341.3 | 63.7 | 18.0 | 81.7 | 55.2 | -26.0 | -52.5 |
| 1996 | 288.9 | 352.3 | 65.7 | 18.0 | 83.7 | 55.2 | -31.0 | -59.5 |
| 1997 | 298.2 | 363.6 | 67.8 | 18.0 | 85.8 | 55.2 | -39.5 | -70.1 |
| 1998 | 307.9 | 375.4 | 70.0 | 18.0 | 88.0 | 55.2 | -49.0 | -81.8 |

Note: Overall load factor = 61,4%

Table 5.4.(3) LOAD FORECAST & SUPPLY BALANCE
(By Existing Power Plants)

Demerara System

| Year (AD) | Energy sold (GWh) | Energy sent out (GWh) | Peak load (MW) | Reserve margin (MW) | Required capacity (MW) | Existing capacity (MW) | Retire-ment (MW) | Supply balance (MW) |
|---|---|---|---|---|---|---|---|---|
| 1988 | 175.7 | 241.7 | 41.9 | 8.5 | 50.4 | 32.7 | 0.0 | -17.7 |
| 1989 | 185.4 | 249.2 | 43.2 | 8.5 | 51.7 | 43.7 | 0.0 | -8.0 |
| 1990 | 195.3 | 257.0 | 44.5 | 8.5 | 53.0 | 43.7 | 0.0 | -9.3 |
| 1991 | 206.0 | 265.1 | 45.9 | 8.5 | 54.4 | 43.7 | 0.0 | -10.7 |
| 1992 | 216.6 | 273.5 | 47.4 | 8.5 | 55.9 | 43.7 | 0.0 | -12.2 |
| 1993 | 227.8 | 282.2 | 48.9 | 13.0 | 61.9 | 43.7 | -8.5 | -26.7 |
| 1994 | 238.8 | 291.3 | 50.5 | 13.0 | 63.5 | 43.7 | -17.0 | -36.8 |
| 1995 | 246.5 | 300.6 | 52.1 | 13.0 | 65.1 | 43.7 | -26.0 | -47.4 |
| 1996 | 254.5 | 310.4 | 53.8 | 13.0 | 66.8 | 43.7 | -31.0 | -54.1 |
| 1997 | 262.8 | 320.5 | 55.5 | 13.0 | 68.5 | 43.7 | -39.5 | -64.3 |
| 1998 | 271.4 | 330.9 | 57.3 | 13.0 | 70.3 | 43.7 | -39.5 | -66.1 |

Note: Load factor = 65.9%

Table 5.4.(4) LOAD FORECAST & SUPPLY BALANCE
(By Existing Power Plants)

Berbice System

| Year (AD) | Energy sold (GWh) | Energy sent out (GWh) | Peak load (MW) | Reserve margin (MW) | Required capacity (MW) | Existing capacity (MW) | Retire-ment (MW) | Supply balance (MW) |
|---|---|---|---|---|---|---|---|---|
| 1988 | 20.9 | 33.2 | 9.5 | 5.0 | 14.5 | 6.5 | 0.0 | -8.0 |
| 1989 | 24.0 | 34.2 | 9.7 | 5.0 | 14.7 | 11.5 | 0.0 | -3.2 |
| 1990 | 26.7 | 35.2 | 10.0 | 5.0 | 15.0 | 11.5 | 0.0 | -3.5 |
| 1991 | 28.1 | 36.2 | 10.3 | 5.0 | 15.3 | 11.5 | 0.0 | -3.8 |
| 1992 | 29.5 | 37.3 | 10.6 | 5.0 | 15.6 | 11.5 | 0.0 | -4.1 |
| 1993 | 31.0 | 38.4 | 10.9 | 5.0 | 15.9 | 11.5 | 0.0 | -4.4 |
| 1994 | 32.4 | 39.5 | 11.2 | 5.0 | 16.2 | 11.5 | 0.0 | -4.7 |
| 1995 | 33.4 | 40.7 | 11.6 | 5.0 | 16.6 | 11.5 | 0.0 | -5.1 |
| 1996 | 34.4 | 41.9 | 11.9 | 5.0 | 16.9 | 11.5 | 0.0 | -5.4 |
| 1997 | 35.4 | 43.2 | 12.3 | 5.0 | 17.3 | 11.5 | 0.0 | -5.8 |
| 1998 | 36.5 | 44.5 | 12.7 | 5.0 | 17.7 | 11.5 | -9.5 | -15.7 |

Note: Load factor = 40.1%

Table 5.4.(5) LOAD FORECAST & SUPPLY BALANCE
(By Existing Power Plants)

Anna Regina & Wakenaam System

| Year (AD) | Energy sold (GWh) | Energy sent out (GWh) | Peak load (MW) | Reserve margin (MW) | Required capacity (MW) | Existing capacity (MW) | Retire-ment (MW) | Supply balance (MW) |
|---|---|---|---|---|---|---|---|---|
| 1988 | 6.4 | 8.3 | 2.1 | 1.5 | 3.6 | 2.6 | 0.0 | -1.0 |
| 1989 | 6.7 | 8.6 | 2.1 | 1.5 | 3.6 | 2.6 | 0.0 | -1.0 |
| 1990 | 7.0 | 8.8 | 2.2 | 1.5 | 3.7 | 2.6 | 0.0 | -1.1 |
| 1991 | 7.3 | 9.1 | 2.3 | 1.5 | 3.8 | 2.6 | 0.0 | -1.2 |
| 1992 | 7.6 | 9.4 | 2.3 | 1.5 | 3.8 | 2.6 | -1.1 | -2.3 |
| 1993 | 7.9 | 9.7 | 2.4 | 1.5 | 3.9 | 2.6 | -1.1 | -2.4 |
| 1994 | 8.2 | 10.0 | 2.5 | 1.5 | 4.0 | 2.6 | -1.1 | -2.5 |
| 1995 | 8.5 | 10.4 | 2.6 | 1.5 | 4.1 | 2.6 | -1.1 | -2.6 |
| 1996 | 8.8 | 10.7 | 2.7 | 1.5 | 4.2 | 2.6 | -1.1 | -2.7 |
| 1997 | 9.1 | 11.1 | 2.7 | 1.5 | 4.2 | 2.6 | -1.1 | -2.7 |
| 1998 | 9.4 | 11.4 | 2.8 | 1.5 | 4.3 | 2.6 | -1.1 | -2.8 |

Note: Load factor = 45.9%

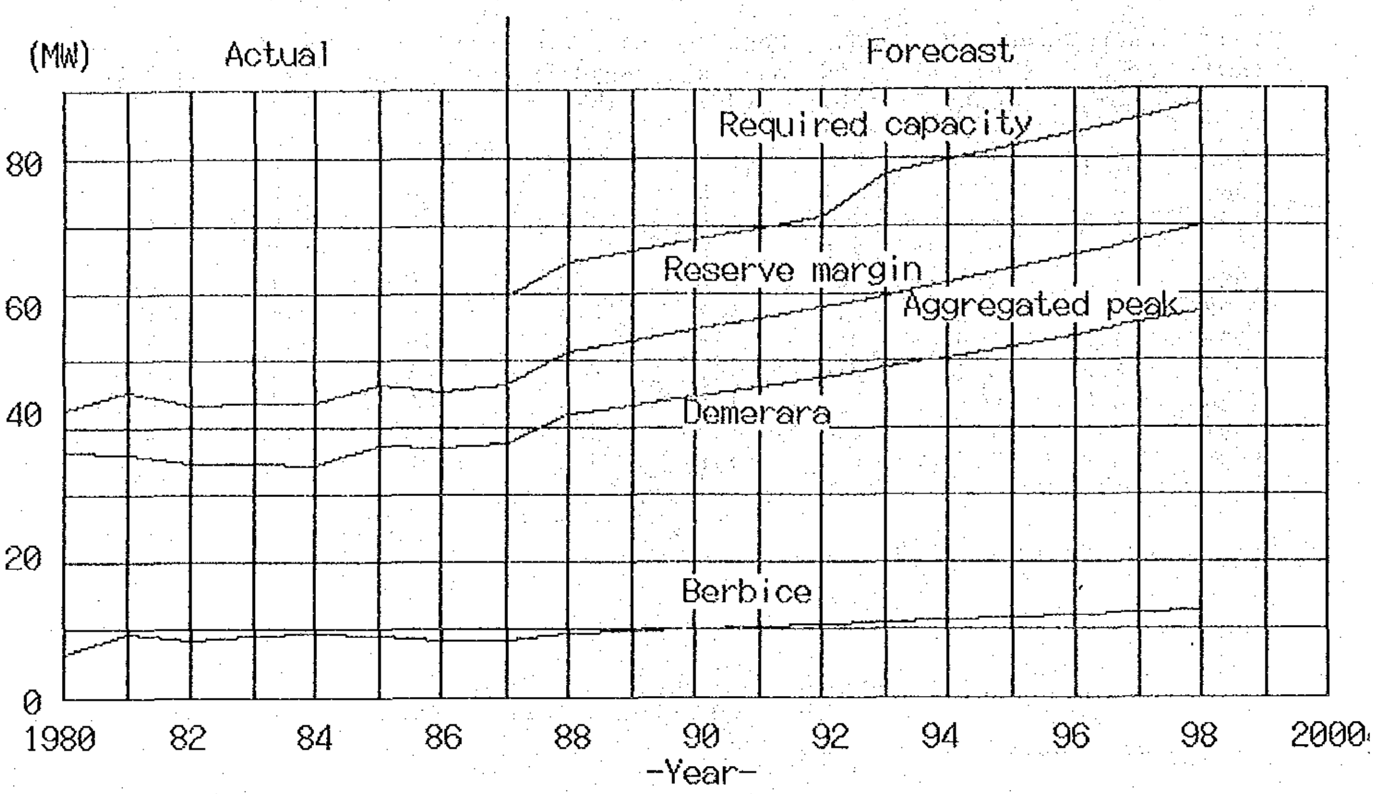
Table 5.4.(6) LOAD FORECAST & SUPPLY BALANCE
(By Existing Power Plants)

Bartica System

| Year (AD) | Energy sold (GWh) | Energy sent out (GWh) | Peak load (MW) | Reserve margin (MW) | Required capacity (MW) | Existing capacity (MW) | Retire-ment (MW) | Supply balance (MW) |
|---|---|---|---|---|---|---|---|---|
| 1988 | 1.4 | 1.9 | 0.5 | 0.2 | 0.7 | 0.4 | 0.0 | -0.3 |
| 1989 | 1.5 | 2.0 | 0.5 | 0.2 | 0.7 | 0.4 | 0.0 | -0.3 |
| 1990 | 1.6 | 2.1 | 0.5 | 0.2 | 0.7 | 0.4 | 0.0 | -0.3 |
| 1991 | 1.7 | 2.1 | 0.5 | 0.2 | 0.7 | 0.4 | 0.0 | -0.3 |
| 1992 | 1.7 | 2.2 | 0.5 | 0.2 | 0.7 | 0.4 | 0.0 | -0.3 |
| 1993 | 1.8 | 2.3 | 0.5 | 0.2 | 0.7 | 0.4 | 0.0 | -0.3 |
| 1994 | 1.9 | 2.3 | 0.6 | 0.2 | 0.8 | 0.4 | 0.0 | -0.4 |
| 1995 | 2.0 | 2.4 | 0.6 | 0.2 | 0.8 | 0.4 | 0.0 | -0.4 |
| 1996 | 2.0 | 2.5 | 0.6 | 0.2 | 0.8 | 0.4 | 0.0 | -0.4 |
| 1997 | 2.1 | 2.6 | 0.6 | 0.2 | 0.8 | 0.4 | 0.0 | -0.4 |
| 1998 | 2.2 | 2.7 | 0.6 | 0.2 | 0.8 | 0.4 | -0.4 | -0.8 |

Note: Load factor = 47.1%

Fig. 5.1 LOAD FORECAST FOR DEMERARA & BERBICE SYSTEMS



# CHAPTER 6

# POWER SUPPLY ENHANCEMENT PLAN

# CHAPTER 6 POWER SUPPLY ENHANCEMENT PLAN

## 6.1 GENERAL

The power supply/demand balance of Guyana is seriously stringent even if the power plant rehabilitation programs currently in progress are fully implemented, and the specific plan for overall improvement of this situation must be immediately formulated.

In addition, when we take into account the eventual decommissioning of existing power plants, which will be forced as the service life of these plants expire, formulation of future plan for expansion of power supply facilities is urgently needed today.

As specifically described in Chapter 5, the shortage of the total power supply capacity today is indeed serious, and the remaining life of existing power facilities are short, as most generators are very old and aged. That is, although the objective of this study has been defined as the improvement of situation for the coming 10 years, it must be noted that, during this period of 10 years, all power generation facilities, with the exception of Versailles and Onverwagt Power Plants (with the total output of 6.2 MW) will reach the age where they have to be replaced.

Therefore, it is mandatory to study not only the improvised measures for tentative improvement of the power supply situation but also the power supply development programs of the future in formulating this master plan.

In this Chapter, we shall discuss the power supply enhancement plan by the following steps.

1) Emergency measures to be enforced immediately.
2) Construction programs of major thermal power plants.
3) Programs for replacement of existing diesel generators.
4) Hydroelectric power development programs.

## 6.2 EMERGENT POWER SUPPLY ENHANCEMENT PLAN

(1) Recovery of Power Supply Capability of Existing Facilities by Rehabilitation

The rehabilitation programs for existing thermal power plants under the IDB loan is being implemented, and these programs must be completed as soon as possible.

The specific contents of these rehabilitation programs are described in Chapter 4. As shown in Table 4.1, a substantial recovery of power supply capacity can be realized when these rehabilitation programs are completed.

(2) Urgent Measures for Construction of New Power Sources

Currently, there is a substantial shortage in power supply capability, as indicated in Table 6.2. Urgent measures for construction of new power supply sources are needed. In this respect, GEC is giving the first priority to a reinforcement project which is to add one new unit at Garden of Eden Power Plant as the most feasible and realistic measure.
It must be noted, however, that this additional unit at Garden of Eden Power Plant can be commissioned only by the end of 1990, even if this program is authorized immediately.

The power supply capability must rely only on the rehabilitated capacity of existing power stations until the unit mentioned above is realized. The power shortage in 1988 and 1989 will amount to 12.2 or 2.7 MW, even if the rehabilitation programs are fully implemented and all units are operated and connected to the grid. Therefore, the load restrictions to be enforced in 1988 and 1989 will continue to be of similar extent as it is today.

If an additional 5.7 MW of power supply is deployed in Demerara Power System by the additional unit in Garden of Eden Power Plant, and if all the exiting units are operated, a certain excess in power supply capacity will be secured in Demerara Power System. However, this situation cannot be regarded as a balance in supply and demand, because a certain amount of reserve capacity will always be needed in the power system.

In addition, the supply capacity in Berbice Power System, which is inter-connected to Demerara Power System, is in serious shortage when any one unit in the system fails, and development of additional 7 MW supply source will be required for the whole power system.

That is, a power source development of approximately 7 MW will be urgently required in addition to the installation of an additional unit in Garden of Eden Power Plant. This additional power source must be commissioned by 1991 at the latest.

In the event that these additional units are completed, the load restrictions of current scale will no longer be required, except under such special circumstances as an extensive large equipment failure.

Therefore, it is recommended that GEC and the governmental authorities concerned authorize the new project of installing three units (with total capacity of 7.8 MW), in addition to the plan of installing a new unit (5.7 MW) in Garden of Eden Power Plant, as a nationally authorized plan, and make appropriate financial and technical preparations.

We propose the above two plans as the urgent programs of electric power development, and expect prompt and energetic actions of the authorities concerned.

(3) Study of appropriateness of concrete plan for emergency measures

1) Replacement of one unit of Garden of Eden Power Station

The Garden of Eden Power Station is the major station in the 60 Hz power system of Guyana. Location-wise, the station is situated at a stragetic point to receive power from GUYMINE power system.

At present, out of the 4 existing units, only 1 unit (No. 4 unit) is operating at 3 MW while the other units are out of service due to mechanical trouble. GEC is planning to rehabilitate units Nos. 2, 3 and 4, and expects to reinstate 15 MW of generating capacity during 1989.

The remaining 1 unit (No. 5 unit) is beyond rehabilitation. At present, there is only the foundation of this unit, and all components and parts of this unit have been transferred and used in the other units.

As an emergency measure to reinforce the supply capability in the shortest time, GEC is giving the highest priority to replace this unit with a new generating equipment and has requested the assistance of the Government of Japan. The study team has also given the first priority to this plan as an emergency measure for the following reasons.

- No. 5 unit, except for the foundation, has been completely dismantled. By installing a new unit of appropriate size at this site, most of the existing fuel supply system and electrical system can be used, resulting in an economic and most shortest time required to reinforce supply capability.

- The existing foundation has adequate strength and weight, making it possible to use this foundation for the new unit.

- The existing powerhouse building and overhead travelling crane can be used.

- Since this is a replacement with a new unit, no new work are required to the power system.

- Measures other than this scheme to reinforce supply capability would mean construction of a new power station, and would result in the basic studies of site selection. Therefore, economically and from the standpoint of time schedule, such scheme would not coincide with the objective of emergency measure to reinforce supply capability.

In the light of foregoing reasons, top priority project to replace No. 5 unit of Garden of Eden Power Station with a new unit is most appropriate as an emergency measure.

The details of the project features are given in Chapter 8.

2) Reinforcement of supply capability of Onverwagt Power Station

As the second step of the emergency measure to reinforce supply capability, the appropriate approach would be to consider reinforcing the capability of Onverwagt Power Station for the following reasons.

- After reinforcing the supply capability of Garden of Eden Power Station by the addition of a new unit, the next step required is to mitigate of power supply condition of Berbice power system. (If one unit of Canefield Power Station drops out, there will arise a power shortage of 30% of Berbice power system.)

- At Onverwagt Power Station, there remain foundations for 3 units of 1 MW units that were retired from service. These foundations can be used.
- It is possible to install on these foundations one unit each of 2.6 MW high speed diesel engine generator. The existing powerhouse building, fuel supply system, electrical system, crane, etc. can be used. Therefore, if compared to constructing a new power station, great saving can be achieved.
- In the installation of new small size unit, the adoption of high speed machine is most economical. As there is a similar machine installed at Versailles Power Station which is operating in good condition, there should be no problem of maintenance and repair.
- Considering the financing possibilities of Guyana, this scheme is recommended as the second priority for the emergency measure to reinforce supply capability.

The details of the project features are given in Chapter 8.

## 6.3 DEVELOPMENT PROGRAM OF NEW MAJOR THERMAL POWER PLANT

(1) Necessity

Kingston-B Power Plant, which is currently the major power supply source in Guyana, has been operated for more than 20 plus several years since its commissioning, and aging of the facility is serious. The mechanical efficiencies of the equipment are also substantially deteriorated.

The serious problem here is that this power plant happens to be the major power supply source of this country which accounts for 65% of the total power generation capacity.

In the event that the major equipment of this power plant fails, an extensive blackout is inevitable, which may even lead to a serious social disturbance.

In this master plan, it has been tentatively assumed that the service life of this steam power plant is 30 years, with the life of the units ending in 1992 and 1993. Considering the poor operating performance of this power plant, however, the above assumption may be too optimistic.

Nevertheless, this power plant is the most important power supply source, and all efforts must be focused on proper maintenance of this facility to sustain sound operation of the plant.

It is absolutely necessary to have a new major power plant which can replace Kingston-B by some time in 1993 or 1994. As this new power plant will then have to play the role of the major power supply source for the whole power system, the plan must be formulated meticulously, based on the real needs of the power system, and not based on easy compromise with such problems as financing or convenience of adapting to existing facilities.

The plan of this new major power plant is different from those for Garden of Eden or Onverwagt discussed above in that its financial and technical scales are much larger. Therefore, the preparation of the plan must be started immediately, even if the date of commissioning may be somewhat further away.

(2) Outline of major power plant plan

In this chapter, the general features of this new power plant as the major power source in the system will be discussed. The details on this subject is presented in Chapter 8.

1) Power plant capacity

It is anticipated that the existing No. 1 Unit and No. 2 Unit of Kingston-B Power Plant will be decommissioned in 1992, and 2 units of "New Kingston" Power Plant, having 13 MW capacity each, will be commissioned into the system, in place of the old units in 1993.

It is also anticipated that No. 3 Unit of existing Kingston-B Power Plant will be decommissioned in 1996, and No. 3 Unit and No. 4 Unit of the new power plant will be commissioned in 1995.

[Note] Study of Unit Capacity of New Kingston Power Plant
Refer to Chapter 8 and
Table 6-1 Alternatives for Development Plan
Table 6-2 Power Supply/Demand Balance and Required Power Development

The plan presented above is the main plan for the capacity of New Kingston Power Plant, and there is an alternative plan in which only one unit is constructed in the second phase. This alternative plan is suggested because the excess supply power becomes too large in 1995 according to the main plan. However, as presented in Chapter 12 for discussion of economic comparison, the difference in total costs between the main plan and the alternative plan is small. In addition, there is little possibility that all of existing power plant units will maintain the current power supply capability until the end of their service lives, and it may be wiser to move up the timing of new development. Based on these reasoning, "Plan 2" in Table 6-1 has been selected as the main plan.

| | | |
|---|---|---|
| 1993: | No. 1 Unit; | 13 MW |
| | No. 2 Unit; | 13 MW |
| 1995: | No. 3 Unit; | 13 MW |
| | No. 4 Unit; | 13 MW |
| Total Plant Capacity; | | 52 MW |

2) Power plant location

The premises of decommissioned Kingston-A Power Plant.

3) Power plant facility type

60 Hz synchronous generator driven by low speed diesel engine.

4) Fuel

Heavy oil only.

## 6.4 REPLACEMENT PROGRAMS FOR EXISTING DIESEL GENERATORS

(1) Study of required power development

Refer to the following documents.

Table 6-1 Alternaves for Development Plans
Table 6-2 Power Supply/Demand Balance and Required Power Development
Table 6-3 Power Exchange between Demerara and Berbice Power Systems

The draft power development programs for the power supply sources which are sufficient to meet the demands in the coming 10 years, that have been formulated based on the power supply/demand balance described in Chapter 5, are presented in Table 6-1.

Each development program has been developed in such a manner that the total amount of power sources to be developed up to 1998 is the same, so that they are amenable to economic comparison. (Such development programs are eventually subjected to minor changes according to actual development in power supply/demand conditions for the later years. Therefore, no contradiction is introduced by the assumption that the amount of total power development is the same in each plan.)

In Plan I, the power development for the second phase of the New Kingston Power Plant is assumed to be only one 13 MW unit. Thereafter, the three units in Garden of Eden Power Plant are to be replaced, one after another in 1996 and 1997. When the retirement of the existing units at Canefiled becomes imminent, two 6.5 MW units will be installed at the Canefield Power Plant in 1998.

In Plan III, the timing of Phase 2 construction of the New Kingston Power Plant and the installation of the two units at Garden of Eden Power Plant, as defined in Plan I, are interchanged. In this plan, the power supply excess that occurs in 1996 in Plan II is thereby reduced to improve the total economy.

In Plan II, the Phase 2 project of New Kingston Power Plant consists of two units of 13 MW. This reduces the amount of replacements of existing diesel power units.

Although Plan II is slightly costly in construction finance among the three plans, this is the most appropriate plan due to the following reasons.

* It is desirable to secure reliable power supply capability in the earlier phase of the plan, because it is too optimistic to assume that the current levels of output from existing power plants can be maintained until the end of their service lives.

* The construction cost of the Phase 2 project of the New Kingston Power Plant is cheaper per kW if two units are installed, rather than one by one.

* As the unit capacity occupies a very big portion in the power system capacity, convenience in operation and maintenance can be enhanced if more units having the same capacity can be installed.

* As performance of medium capacity diesel engines have not been satisfactory in Guyana, it is advisable to rely on the sturdiness of low speed, large capacity diesel engines.

(2) Plans for replacement of existing diesel generators

Although the No. 5 Unit of the Garden of Eden Power Plant will have been replaced by an emergency power supply enhancement plan, the life of No. 2, No. 3 and No. 4 Units will expire by 1995 or 1996, and will have to be replaced. The units in Canefield Power Plant will have to be replaced by 1998.

In coordinating the timings of these replacements with the construction of the New Kingston Power Plant, three plans have been developed. These draft plans are presented in Table 6-1.

(3) Evaluation of each replacement plan

Overall development plan and alternatives are shown in Table 6-1.
Urgent measures for construction of new power sources (1990: Garden of Eden 5.7 MW, 1991: Onverwagt 7.8 MW) and 1st stage development of the New Kingston (1993: 26 MW) are common in all alternative plans.

Accordingly, in this paragraph, evaluation will be studied for three development alternatives in and after 1995.

1) Plan I

The two units of the New Kingston Phase I project (26 MW total) will be commissioned in 1993, and the one unit of Phase 2 (13 MW) will be commissioned in 1995. Then, No. 2 and No. 4 Units of Garden of Eden Power Plant will be replaced with two units having the same capacity (5.7 MW).

When No. 3 Unit of this power plant is decommissioned by 1997, it will be replaced with a unit of same capacity. Two 5.7 MW units will be installed as the two units in Canefield Power Plant (4 MW and 5 MW) are decommissioned.

This plan is based on the most commonplace concept that the unit capacities in each existing power plants are not changed drastically, and they are expanded as the power demand grows.

The total construction cost is the lowest in this Plan.

Refer to Table 6-2 (1), Table 6-3 (1), Table 6-4 (1)

2) Plan II

Two units with a total capacity of 26 MW will be installed in 1995 in the Phase 2 Project of New Kingston, and the replacement of 2 units in Garden of Eden, scheduled in 1996 in Plan I will not be implemented.

In this plan, the power supply surplus in the year 1995 is large, and this plan looks exaggerated in terms of supply/demand balance. Its total construction cost is also the highest. However, a safety margin, which may be required if the current output levels of existing units can not be assured to the end of their service life, which is quite likely considering the present state of deterioration, is provided in this Plan.

As it is postulated that the final amount of development capacity is the same for all Plans, for the convenience of economic comparison, the replacement schedules of existing diesel units after 1995 are as shown in the Table 6-5.

In other Plans, the development schedules will have to be modified earlier, as anticipated reductions in the output levels of existing units become apparent. In this Plan, such modification will be compelled only in later years of the schedule.

One of the features of this plan is that the proportion of low speed diesel engines is higher in terms of their total output than in Plan I.

It is our opinion that it is important for the interest of the Republic of Guyana to commission the key power generation facility supplying base load, such as the New Kingston Power Plant, at the earliest possible moment to assure stable power system operation, and therefore, we propose this Plan as the "main plan".

Refer to Table 6-2 (2), Table 6-3 (2), Table 6-4 (2).

3) Plan III

In this plan, it is intended to reduce the surplus power supply capacity that occurs in 1995 as much as possible, i.e., the two units in Garden of Eden Power Plant are replaced in 1995, and the new units in the New Kingston Power Plant is commissioned at such a pace that one unit is completed in 1996 and another in 1998. The total construction cost of this plan comes somewhere between those of Plan I and Plan II.

The proportion of the low speed diesels is high, as in Plan II. However, as these units are to be deployed in later years, the modification of the plan in response to reduction of output levels of existing units is not so easy as in Plan II.

In this Plan, the generators to be replaced are concentrated in the Demerara Power System due to the decommissioning schedule of the existing diesel generators. But this would not present a serious problem, because the interlink capacity between the systems will have been strengthened, and the most firm power is supplied from the New Kingston Power Plant.

Refer to Table 6-2 (3), Table 6-3 (3), Table 6-4 (3).

4) Conclusion of evaluation

Plan II will be adopted as the main plan due to the following reasons. The economical evaluation in Chapter 12 shows this plan to be only slightly more costly than plan III

Since new major power sources are deployed into the system early in this plan, it is easy to manoeuvre any risks into a rational modification in the development schedule if decreasing output and low efficiency from the deterioration of existing units cause their performance to become unsatisfactory.

Refer to Fig. 6, Table 6-5.

## 6.5 HYDROELECTRIC POWER DEVELOPMENT PLAN

The Cooperative Republic of Guyana is blessed with abundant water resources, and there are many promising potential hydroelectric power generation sites. It is quite important for this country to implement adequate hydroelectric power development programs as soon as possible and to establish self-sufficient national energy supply systems.

However, hydroelectric power development demands a large amount of funds and long lead time, and it is not appropriate to incorporate a specific hydroelectric power development program into the terms of this master plan, as a concrete power source which will improve the power balance by 1998.

Consequently, in this report, it is necessary to only propose a specific hydroelectric development program for the Tiger Hills site, which has the best possibility to develop at the moment.

As it is required to conduct a set of surveys during the terms of this master plan in order to make this project a realistic one, we describe the contents of such surveys, survey schedules and the necessary preparatory works in detail in this report, and proposed implementation of such preparatory tasks.

The only hydroelectric power development site on which development work can be started in the near future is the Tiger Hills which happens to be in the area of this study. For this reason, the feasibility of hydroelectric power development of this site has been studied to the pre-feasibility report level.

The content of this study is presented:
(in Chapter 9 in detail.)

| | | |
|---|---|---|
| Planned Output | : | Phase I, 56 MW (28 MW x 2 units) |
| Year of Commissioning | : | Around 2000 (as soon as possible). |
| Annual Energy Generation | : | 265 GWh |
| Phase II | : | One additional 28 MW unit around 2005 |

When this hydroelectric power plant is commissioned, certain other power plants, especially medium size diesel plants, will have to be operated only as reserves.

It is recommended, therefore, to review the replacement programs of the existing diesel generators discussed above in the later years in the terms of this master plan, considering the possibility of this hydro project.

Table 6-1 Alternatives for Development Plan

| Commissioning Year | Plan I | | | Plan II | | | Plan III | | |
|---|---|---|---|---|---|---|---|---|---|
| | Power Plant | Capacity (MW) | Area/ Type | Power Plant | Capacity (MW) | Area/ Type | Power Plant | Capacity (MW) | Area/ Type |
| 1988 | | | | | | | | | |
| 1989 | | | | | | | | | |
| 1990 | GOE | 5.7 | D, M | GOE | 5.7 | D, M | GOE | 5.7 | D, M |
| 1991 | OVW | 7.8 | B, H | OVW | 7.8 | B, H | OVW | 7.8 | B, H |
| 1992 | | | | | | | | | |
| 1993 | N.KGS1 | 26.0 | D, L | N.KGS1 | 26.0 | D, L | N.KGS1 | 26.0 | D, L |
| 1994 | | | | | | | | | |
| 1995 | N.KGS2 | 13.0 | D, L | N.KGS2 | 26.0 | D, L | GOE | 11.4 | D, M |
| 1996 | GOE | 11.4 | D, M | | | | N.KGS2 | 13.0 | D, L |
| 1997 | GOE | 5.7 | D, M | GOE | 5.7 | D, M | GOE | 5.7 | D, M |
| 1998 | CF | 13.0 | B, M | CF | 11.4 | B, M | N.KGS3 | 13.0 | D, L |
| Total | | 82.6 | | | 82.6 | | | 82.6 | |

| Breakdown by areas (MW) | Plan I | Plan II | Plan III |
|---|---|---|---|
| DEMERARA | 61.8 | 61.8 | 74.8 |
| BERBICE | 20.8 | 20.8 | 7.8 |

| Breakdown by types | (MW) | Share | (MW) | Share | (MW) | Share |
|---|---|---|---|---|---|---|
| High Speed Diesel | 7.8 | 9.4% | 7.8 | 9.4% | 7.8 | 9.4% |
| Middle Speed Diesel | 35.8 | 43.3% | 22.8 | 27.6% | 22.8 | 27.6% |
| Low Speed Diesel | 39.0 | 47.2% | 52.0 | 63.0% | 52.0 | 63.0% |

Index of area
D: Demerara
B: Berbice & Corentyne

Index of power plant name
GOE: Garden of Eden
OVW: Onverwagt
N.KGS1: New Kingston 1st stage
N.KGS2: New Kingston 2nd stage
N.KGS3: New Kingston 3rd stage
CF: Canefield

Index of plant type
H: High speed diesel
M: Middle speed diesel
L: Low speed diesel

Table 6-2 (1)

Study on Power Balance of each Development Plan

For Plan I

(MW)

| Year | Peak Load | Reserve Margin | Required capacity | Rha. & Retire-ment | Develop-ment | Develop-ment (sum) | System capacity | Power Balance |
|---|---|---|---|---|---|---|---|---|
| 1988 | 51.3 | 13.5 | 64.8 | 2.0 | | 0.0 | 39.2 | -25.6 |
| 1989 | 52.9 | 13.5 | 66.4 | 16.0 | | 0.0 | 55.2 | -11.2 |
| 1990 | 54.5 | 13.5 | 68.0 | 0.0 | 5.7 | 5.7 | 60.9 | -7.1 |
| 1991 | 56.2 | 13.5 | 69.7 | 0.0 | 7.8 | 13.5 | 68.7 | -1.0 |
| 1992 | 58.0 | 13.5 | 71.5 | 0.0 | | 13.5 | 68.7 | -2.8 |
| 1993 | 59.8 | 18.0 | 77.8 | -8.5 | 26.0 | 39.5 | 86.2 | 8.4 |
| 1994 | 61.7 | 18.0 | 79.7 | -8.5 | | 39.5 | 77.7 | -2.0 |
| 1995 | 63.7 | 18.0 | 81.7 | -9.0 | 13.0 | 52.5 | 81.7 | 0.0 |
| 1996 | 65.7 | 18.0 | 83.7 | -5.0 | 11.4 | 63.9 | 88.1 | 4.4 |
| 1997 | 67.8 | 18.0 | 85.8 | -8.5 | 5.7 | 69.6 | 85.3 | -0.5 |
| 1998 | 70.0 | 18.0 | 88.0 | -9.5 | 13.0 | 82.6 | 88.8 | 0.8 |

Fig.6-1 POWER BALANCE AND REQUIRED DEVELOPMENT PLAN-I

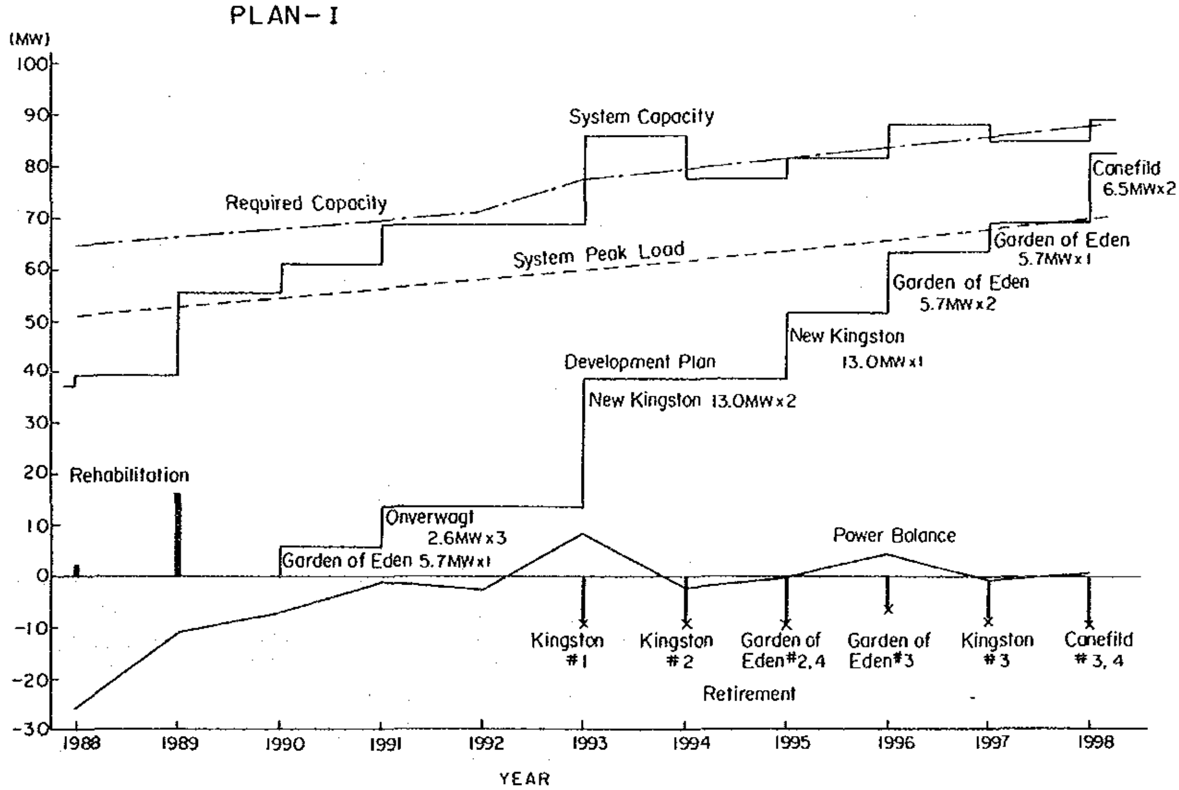


Table 6-2 (2)

Study on Power Balance of each Development Plan

For Plan II

(MW)

| Year | Peak Load | Reserve Margin | Required capacity | Rha. & Retire-ment | Develop-ment | Develop-ment (sum) | System capacity | Power Balance |
|---|---|---|---|---|---|---|---|---|
| 1988 | 51.3 | 13.5 | 64.8 | 2.0 | | 0.0 | 39.2 | -25.6 |
| 1989 | 52.9 | 13.5 | 66.4 | 16.0 | | 0.0 | 55.2 | -11.2 |
| 1990 | 54.5 | 13.5 | 68.0 | 0.0 | 5.7 | 5.7 | 60.9 | -7.1 |
| 1991 | 56.2 | 13.5 | 69.7 | 0.0 | 7.8 | 13.5 | 68.7 | -1.0 |
| 1992 | 58.0 | 13.5 | 71.5 | 0.0 | | 13.5 | 68.7 | -2.8 |
| 1993 | 59.8 | 18.0 | 77.8 | -8.5 | 26.0 | 39.5 | 86.2 | 8.4 |
| 1994 | 61.7 | 18.0 | 79.7 | -8.5 | | 39.5 | 77.7 | -2.0 |
| 1995 | 63.7 | 18.0 | 81.7 | -9.0 | 26.0 | 65.5 | 94.7 | 13.0 |
| 1996 | 65.7 | 18.0 | 83.7 | -5.0 | | 65.5 | 89.7 | 6.0 |
| 1997 | 67.8 | 18.0 | 85.8 | -8.5 | 5.7 | 71.2 | 86.9 | 1.1 |
| 1998 | 70.0 | 18.0 | 88.0 | -9.5 | 11.4 | 82.6 | 88.8 | 0.8 |

Fig.6-2 POWER BALANCE AND REQUIRED DEVELOPMENT PLAN-II

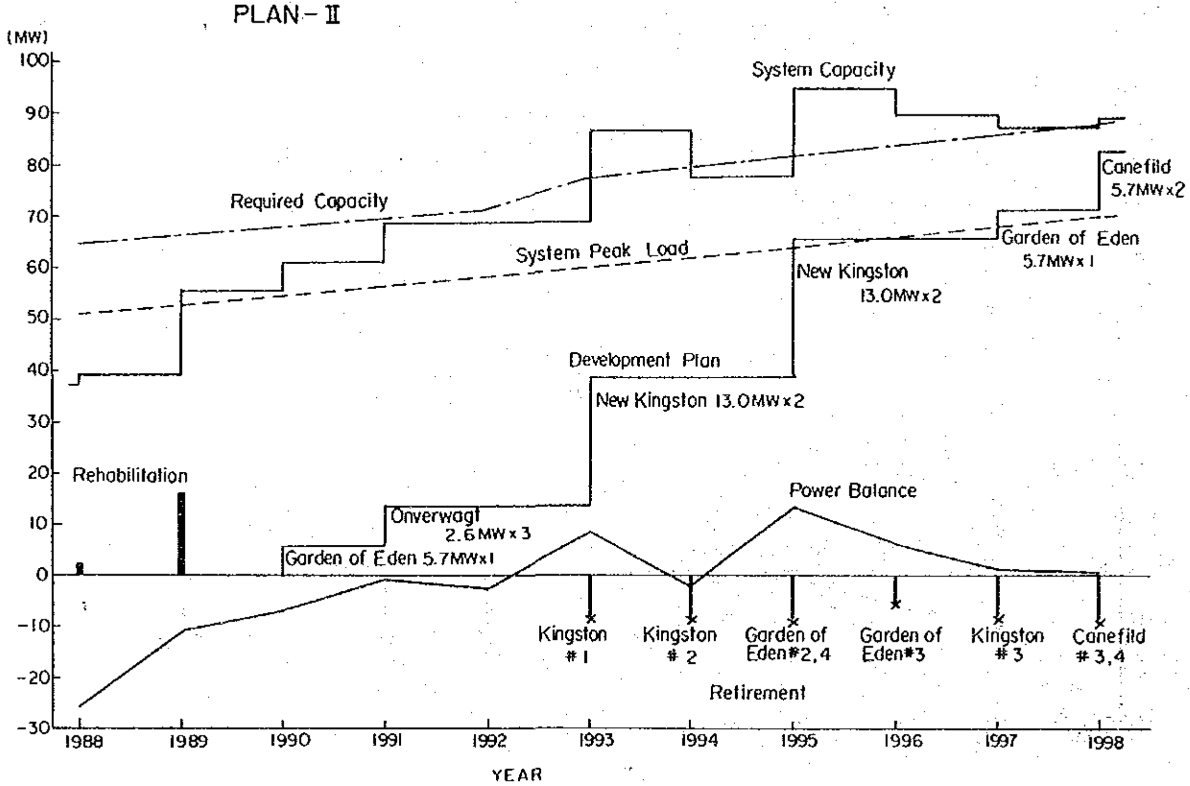


Table 6-2 (3)

Study on Power Balance of each Development Plan

For Plan III

(MW)

| Year | Peak Load | Reserve Margin | Required capacity | Rha. & Retire-ment | Develop-ment | Develop-ment (sum) | System capacity | Power Balance |
|---|---|---|---|---|---|---|---|---|
| 1988 | 51.3 | 13.5 | 64.8 | 2.0 | | 0.0 | 39.2 | -25.6 |
| 1989 | 52.9 | 13.5 | 66.4 | 16.0 | | 0.0 | 55.2 | -11.2 |
| 1990 | 54.5 | 13.5 | 68.0 | 0.0 | 5.7 | 5.7 | 60.9 | -7.1 |
| 1991 | 56.2 | 13.5 | 69.7 | 0.0 | 7.8 | 13.5 | 68.7 | -1.0 |
| 1992 | 58.0 | 13.5 | 71.5 | 0.0 | | 13.5 | 68.7 | -2.8 |
| 1993 | 59.8 | 18.0 | 77.8 | -8.5 | 26.0 | 39.5 | 86.2 | 8.4 |
| 1994 | 61.7 | 18.0 | 79.7 | -8.5 | | 39.5 | 77.7 | -2.0 |
| 1995 | 63.7 | 18.0 | 81.7 | -9.0 | 11.4 | 50.9 | 80.1 | -1.6 |
| 1996 | 65.7 | 18.0 | 83.7 | -5.0 | 13.0 | 63.9 | 88.1 | 4.4 |
| 1997 | 67.8 | 18.0 | 85.8 | -8.5 | 5.7 | 69.6 | 85.3 | -0.5 |
| 1998 | 70.0 | 18.0 | 88.0 | -9.5 | 13.0 | 82.6 | 88.8 | 0.8 |

Fig.6-3 POWER BALANCE AND REQUIRED DEVELOPMENT PLAN-III

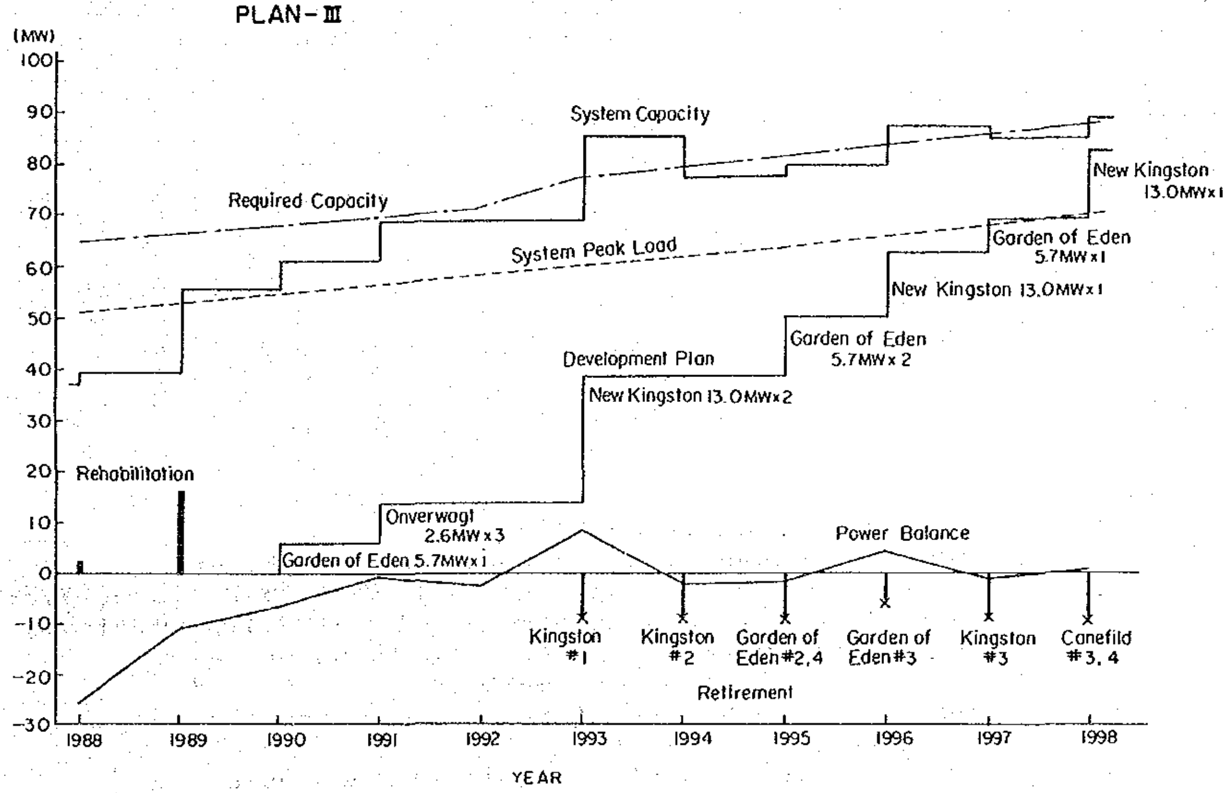


Table 6-3 (1) (F:D-B(1))
Study on inter-link capability between D & B Sys.
For Plan I

(MW)

1. Demerara Power Balance

| Year | Peak Load | Init. Capa. | Rehb. Retr. | Dev. Plan | Gen. Cap. | Powr. Balan. | KGS Out | Surpl. Berb. | Total Sys. Surplus Abnor. | Total Sys. Surplus Nor. | Abnor. B-> D | ok /D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 41.9 | 32.7 | | | 32.7 | -9.2 | -17.7 | -3.0 | -20.7 | -12.2 | x | |
| 1989 | 43.2 | 32.7 | 11.0 | | 43.7 | 0.5 | -8.0 | 1.8 | -6.2 | 2.3 | 1.8 | D |
| 1990 | 44.5 | 43.7 | | 5.7 | 49.4 | 4.9 | -3.6 | 1.5 | -2.1 | 6.4 | 1.5 | D |
| 1991 | 45.9 | 49.4 | | | 49.4 | 3.5 | -5.0 | 9.0 | 4.0 | 12.5 | 5.0 | ok |
| 1992 | 47.4 | 49.4 | | | 49.4 | 2.0 | -6.5 | 8.7 | 2.2 | 10.7 | 6.5 | ok |
| 1993 | 48.9 | 49.4 | -8.5 | 26.0 | 66.9 | 18.0 | 5.0 | 8.4 | 13.4 | 26.4 | | ok |
| 1994 | 50.5 | 66.9 | -8.5 | | 58.4 | 7.9 | -5.1 | 8.1 | 3.0 | 16.0 | 5.1 | ok |
| 1995 | 52.1 | 58.4 | -9.0 | 13.0 | 62.4 | 10.3 | -2.7 | 7.7 | 5.0 | 18.0 | 2.7 | ok |
| 1996 | 53.8 | 62.4 | -5.0 | 11.4 | 68.8 | 15.0 | 2.0 | 7.4 | 9.4 | 22.4 | | ok |
| 1997 | 55.5 | 68.8 | -8.5 | 5.7 | 66.0 | 10.5 | -2.5 | 7.0 | 4.5 | 17.5 | 2.5 | ok |
| 1998 | 57.3 | 66.0 | | | 66.0 | 8.7 | -4.3 | 10.1 | 5.8 | 18.8 | 4.3 | ok |

(MW)

2. Berbice Power Balance

| Year | Peak Load | Init. Capa. | Rehb. Retr. | Dev. Plan | Gen. Cap. | Powr. Balan. | CF Out | Surpl. Deme. | Total Sys. Surplus Abnor. | Total Sys. Surplus Nor. | Abnor. D-> B | ok /D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 9.5 | 4.5 | 2.0 | | 6.5 | -3.0 | -8.0 | -9.2 | -17.2 | -12.2 | x | |
| 1989 | 9.7 | 6.5 | 5.0 | | 11.5 | 1.8 | -3.2 | 0.5 | -2.7 | 2.3 | 0.5 | D |
| 1990 | 10.0 | 11.5 | | | 11.5 | 1.5 | -3.5 | 4.9 | 1.4 | 6.4 | 3.5 | ok |
| 1991 | 10.3 | 11.5 | | 7.8 | 19.3 | 9.0 | 4.0 | 3.5 | 7.5 | 12.5 | | ok |
| 1992 | 10.6 | 19.3 | | | 19.3 | 8.7 | 3.7 | 2.0 | 5.7 | 10.7 | | ok |
| 1993 | 10.9 | 19.3 | | | 19.3 | 8.4 | 3.4 | 18.0 | 21.4 | 26.4 | | ok |
| 1994 | 11.2 | 19.3 | | | 19.3 | 8.1 | 3.1 | 7.9 | 11.0 | 16.0 | | ok |
| 1995 | 11.6 | 19.3 | | | 19.3 | 7.7 | 2.7 | 10.3 | 13.0 | 18.0 | | ok |
| 1996 | 11.9 | 19.3 | | | 19.3 | 7.4 | 2.4 | 15.0 | 17.4 | 22.4 | | ok |
| 1997 | 12.3 | 19.3 | | | 19.3 | 7.0 | 2.0 | 10.5 | 12.5 | 17.5 | | ok |
| 1998 | 12.7 | 19.3 | -9.5 | 13.0 | 22.8 | 10.1 | 3.6 | 8.7 | 12.3 | 18.8 | | ok |

Index
- Nor. : Case of all units working
- Abnor. : Case of outage of a max capa.unit in the sys.
  For Demerara, KGS unit down: 8.5MW(-1992),13MW(1993-98)
  For Berbice, CF unit down : 5MW( -1997),6.5MW(1998)
- B->D : Power from Berbice to Demerara in abnor.case.
- D->B : " " Demerara to Berbice " "
- x : No power can be transfered because any surplus exists in another sys.
- D : Power deficit exists even if maximum power be transfered from another sys.
- ok : Shows ok if power indicated in the left column be transfered from another sys.

Table 6-3 (2) (F:D-B(2))

Study on Inter-link capability between D & B Sys.

For Plan II

(MW)

1. Demerara Power Balance

| Year | Peak Load | Init. Capa. | Rehb. Retr. | Dev. Plan | Gen. Cap. | Powr. Balan. | KGS Out | Surpl. Berb. | Total Sys. Surplus Abnor. | Total Sys. Surplus Nor. | Abnor. B-> D | ok /D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 41.9 | 32.7 | | | 32.7 | -9.2 | -17.7 | -3.0 | -20.7 | -12.2 | x | |
| 1989 | 43.2 | 32.7 | 11.0 | | 43.7 | 0.5 | -8.0 | 1.8 | -6.2 | 2.3 | 1.8 | D |
| 1990 | 44.5 | 43.7 | | 5.7 | 49.4 | 4.9 | -3.6 | 1.5 | -2.1 | 6.4 | 1.5 | D |
| 1991 | 45.9 | 49.4 | | | 49.4 | 3.5 | -5.0 | 9.0 | 4.0 | 12.5 | 5.0 | ok |
| 1992 | 47.4 | 49.4 | | | 49.4 | 2.0 | -6.5 | 8.7 | 2.2 | 10.7 | 6.5 | ok |
| 1993 | 48.9 | 49.4 | -8.5 | 26.0 | 66.9 | 18.0 | 5.0 | 8.4 | 13.4 | 26.4 | | ok |
| 1994 | 50.5 | 66.9 | -8.5 | | 58.4 | 7.9 | -5.1 | 8.1 | 3.0 | 16.0 | 5.1 | ok |
| 1995 | 52.1 | 58.4 | -9.0 | 26.0 | 75.4 | 23.3 | 10.3 | 7.7 | 18.0 | 31.0 | | ok |
| 1996 | 53.8 | 75.4 | -5.0 | | 70.4 | 16.6 | 3.6 | 7.4 | 11.0 | 24.0 | | ok |
| 1997 | 55.5 | 70.4 | -8.5 | 5.7 | 67.6 | 12.1 | -0.9 | 7.0 | 6.1 | 19.1 | 0.9 | ok |
| 1998 | 57.3 | 67.6 | | | 67.6 | 10.3 | -2.7 | 8.5 | 5.8 | 18.8 | 2.7 | ok |

(MW)

2. Berbice Power Balance

| Year | Peak Load | Init. Capa. | Rehb. Retr. | Dev. Plan | Gen. Cap. | Powr. Balan. | CF Out | Surpl. Deme. | Total Sys. Surplus Abnor. | Total Sys. Surplus Nor. | Abnor. D-> B | ok /D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 9.5 | 4.5 | 2.0 | | 6.5 | -3.0 | -8.0 | -9.2 | -17.2 | -12.2 | x | |
| 1989 | 9.7 | 6.5 | 5.0 | | 11.5 | 1.8 | -3.2 | 0.5 | -2.7 | 2.3 | 0.5 | D |
| 1990 | 10.0 | 11.5 | | | 11.5 | 1.5 | -3.5 | 4.9 | 1.4 | 6.4 | 3.5 | ok |
| 1991 | 10.3 | 11.5 | | 7.8 | 19.3 | 9.0 | 4.0 | 3.5 | 7.5 | 12.5 | | ok |
| 1992 | 10.6 | 19.3 | | | 19.3 | 8.7 | 3.7 | 2.0 | 5.7 | 10.7 | | ok |
| 1993 | 10.9 | 19.3 | | | 19.3 | 8.4 | 3.4 | 18.0 | 21.4 | 26.4 | | ok |
| 1994 | 11.2 | 19.3 | | | 19.3 | 8.1 | 3.1 | 7.9 | 11.0 | 16.0 | | ok |
| 1995 | 11.6 | 19.3 | | | 19.3 | 7.7 | 2.7 | 23.3 | 26.0 | 31.0 | | ok |
| 1996 | 11.9 | 19.3 | | | 19.3 | 7.4 | 2.4 | 16.6 | 19.0 | 24.0 | | ok |
| 1997 | 12.3 | 19.3 | | | 19.3 | 7.0 | 2.0 | 12.1 | 14.1 | 19.1 | | ok |
| 1998 | 12.7 | 19.3 | -9.5 | 11.4 | 21.2 | 8.5 | 2.8 | 10.3 | 13.1 | 18.8 | | ok |

Index

- Nor. : Case of all units working
- Abnor.: Case of outage of a max capa.unit in the sys.
  For Demerara, KGS unit down:8.5MW(-1992),13MW(1993-98)
  For Berbice, CF unit down: 5MW(-1997),5,7MW(1998)
- B->D : Power from Berbice to Demerara in abnor.case.
- D->B : 〃 〃 Demerara to Berbice 〃 〃
- x : No power can be transfered because any surplus exists in another sys.
- D : Power deficit exists even if maximum power be transfered from another sys.
- ok : Shows ok if power indicated in the left column be transfered from another sys.

Table 6-3 (3) (F:D-B(3))

Study on inter-link capability between D & B Sys.

For plan III

(MW)

1. Demerara Power Balance

| Year | Peak Load | Init. Capa. | Rehb. Retr. | Dev. Plan | Gen. Cap. | Powr. Balan. | KGS Out | Surpl. Berb. | Total Sys. Surplus Abnor. | Total Sys. Surplus Nor. | Abnor. B-> D | ok /D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 41.9 | 32.7 | | | 32.7 | -9.2 | -17.7 | -3.0 | -20.7 | -12.2 | x | |
| 1989 | 43.2 | 32.7 | 11.0 | | 43.7 | 0.5 | -8.0 | 1.8 | -6.2 | 2.3 | 1.8 | D |
| 1990 | 44.5 | 43.7 | | 5.7 | 49.4 | 4.9 | -3.6 | 1.5 | -2.1 | 6.4 | 1.5 | D |
| 1991 | 45.9 | 49.4 | | | 49.4 | 3.5 | -5.0 | 9.0 | 4.0 | 12.5 | 5.0 | ok |
| 1992 | 47.4 | 49.4 | | | 49.4 | 2.0 | -6.5 | 8.7 | 2.2 | 10.7 | 6.5 | ok |
| 1993 | 48.9 | 49.4 | -8.5 | 26.0 | 66.9 | 18.0 | 5.0 | 8.4 | 13.4 | 26.4 | | ok |
| 1994 | 50.5 | 66.9 | -8.5 | | 58.4 | 7.9 | -5.1 | 8.1 | 3.0 | 16.0 | 5.1 | ok |
| 1995 | 52.1 | 58.4 | -9.0 | 11.4 | 60.8 | 8.7 | -4.3 | 7.7 | 3.4 | 16.4 | 4.3 | ok |
| 1996 | 53.8 | 60.8 | -5.0 | 13.0 | 68.8 | 15.0 | 2.0 | 7.4 | 9.4 | 22.4 | | ok |
| 1997 | 55.5 | 68.8 | -8.5 | 5.7 | 66.0 | 10.5 | -2.5 | 7.0 | 4.5 | 17.5 | 2.5 | ok |
| 1998 | 57.3 | 66.0 | | 13.0 | 79.0 | 21.7 | 8.7 | -2.9 | 5.8 | 18.8 | x | ok |

(MW)

2. Berbice Power Balance

| Year | Peak Load | Init. Capa. | Rehb. Retr. | Dev. Plan | Gen. Cap. | Powr. Balan. | CF Out | Surpl. Deme. | Total Sys. Surplus Abnor. | Total Sys. Surplus Nor. | Abnor. D-> B | ok /D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 9.5 | 4.5 | 2.0 | | 6.5 | -3.0 | -8.0 | -9.2 | -17.2 | -12.2 | x | |
| 1989 | 9.7 | 6.5 | 5.0 | | 11.5 | 1.8 | -3.2 | 0.5 | -2.7 | 2.3 | 0.5 | D |
| 1990 | 10.0 | 11.5 | | | 11.5 | 1.5 | -3.5 | 4.9 | 1.4 | 6.4 | 3.5 | ok |
| 1991 | 10.3 | 11.5 | | 7.8 | 19.3 | 9.0 | 4.0 | 3.5 | 7.5 | 12.5 | | ok |
| 1992 | 10.6 | 19.3 | | | 19.3 | 8.7 | 3.7 | 2.0 | 5.7 | 10.7 | | ok |
| 1993 | 10.9 | 19.3 | | | 19.3 | 8.4 | 3.4 | 18.0 | 21.4 | 26.4 | | ok |
| 1994 | 11.2 | 19.3 | | | 19.3 | 8.1 | 3.1 | 7.9 | 11.0 | 16.0 | | ok |
| 1995 | 11.6 | 19.3 | | | 19.3 | 7.7 | 2.7 | 8.7 | 11.4 | 16.4 | | ok |
| 1996 | 11.9 | 19.3 | | | 19.3 | 7.4 | 2.4 | 15.0 | 17.4 | 22.4 | | ok |
| 1997 | 12.3 | 19.3 | | | 19.3 | 7.0 | 2.0 | 10.5 | 12.5 | 17.5 | | ok |
| 1998 | 12.7 | 19.3 | -9.5 | | 9.8 | -2.9 | -5.5 | 21.7 | 16.2 | 18.8 | 5.5 | ok |

Index

- Nor. : Case of all units working
- Abnor. : Case of outage of a max capa.unit in the sys.
  For Demerara, KGS unit down: 8.5MW(-1992),13MW(1993-98)
  For Berbice, CF down: 5MW( -1997),OVW down 2,6MW(1998)
- B->D : Power from Berbice to Demerara in abnor.case.
- D->B : " " Demerara to Berbice " "
- x : No power can be transfered because any surplus exists in another sys.
- D : Power deficit exists even if maximum power be transfered from another sys.
- ok : Shows ok if power indicated in the left column be transfered from another sys.

Table 6-4 (1) (F:PSCAP-1R)

Changes of plant capacity of each power station
For Plan I

1. Demerara

| | Kingston | | | Garden of Eden | | | | New KGS | | | | Vers. | Deme. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | #1 | #2 | #3 | #2 | #3 | #4 | #5 | #1 | #2 | #3 | #4 | 123 | Total |
| 1988 | 8.5 | 8.5 | 8.5 | 0.0 | 0.0 | 3.0 | | | | | | 4.2 | 32.7 |
| 1989 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | | | | | | 4.2 | 43.7 |
| 1990 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | | | | | 4.2 | 49.4 |
| 1991 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | | | | | 4.2 | 49.4 |
| 1992 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | | | | | 4.2 | 49.4 |
| 1993 | | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | 13.0 | 13.0 | | | 4.2 | 66.9 |
| 1994 | | | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | 13.0 | 13.0 | | | 4.2 | 58.4 |
| 1995 | | | 8.5 | | 5.0 | | 5.7 | 13.0 | 13.0 | 13.0 | | 4.2 | 62.4 |
| 1996 | | | 8.5 | 5.7 | | 5.7 | 5.7 | 13.0 | 13.0 | 13.0 | | 4.2 | 68.8 |
| 1997 | | | | 5.7 | 5.7 | 5.7 | 5.7 | 13.0 | 13.0 | 13.0 | | 4.2 | 66.0 |
| 1998 | | | | 5.7 | 5.7 | 5.7 | 5.7 | 13.0 | 13.0 | 13.0 | | 4.2 | 66.0 |

2. Berbice

| | Onverwgt. | | Canefld. | | Berb. |
|---|---|---|---|---|---|
| | #5 | 123 | #3 | #4 | Total |
| 1988 | 2.0 | | 4.5 | 0.0 | 6.5 |
| 1989 | 2.0 | | 4.5 | 5.0 | 11.5 |
| 1990 | 2.0 | | 4.5 | 5.0 | 11.5 |
| 1991 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1992 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1993 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1994 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1995 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1996 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1997 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1998 | 2.0 | 7.8 | 6.5 | 6.5 | 22.8 |

3. All System

| Year | Total |
|---|---|
| 1988 | 39.2 |
| 1989 | 55.2 |
| 1990 | 60.9 |
| 1991 | 68.7 |
| 1992 | 68.7 |
| 1993 | 86.2 |
| 1994 | 77.7 |
| 1995 | 81.7 |
| 1996 | 88.1 |
| 1997 | 85.3 |
| 1998 | 88.8 |

Table 6-4 (2) (F:PSCAP-2R)

Changes of plant capacity of each power station

For Plan II

1. Demerara

| | Kingston | | | Garden of Eden | | | | New KGS | | | | Vers. | Deme. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | #1 | #2 | #3 | #2 | #3 | #4 | #5 | #1 | #2 | #3 | #4 | 123 | Total |
| 1988 | 8.5 | 8.5 | 8.5 | 0.0 | 0.0 | 3.0 | | | | | | 4.2 | 32.7 |
| 1989 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | | | | | | 4.2 | 43.7 |
| 1990 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | | | | | 4.2 | 49.4 |
| 1991 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | | | | | 4.2 | 49.4 |
| 1992 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | | | | | 4.2 | 49.4 |
| 1993 | | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | 13.0 | 13.0 | | | 4.2 | 66.9 |
| 1994 | | | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | 13.0 | 13.0 | | | 4.2 | 58.4 |
| 1995 | | | 8.5 | | 5.0 | | 5.7 | 13.0 | 13.0 | 13.0 | 13.0 | 4.2 | 75.4 |
| 1996 | | | 8.5 | | | | 5.7 | 13.0 | 13.0 | 13.0 | 13.0 | 4.2 | 70.4 |
| 1997 | | | | | 5.7 | | 5.7 | 13.0 | 13.0 | 13.0 | 13.0 | 4.2 | 67.6 |
| 1998 | | | | | 5.7 | | 5.7 | 13.0 | 13.0 | 13.0 | 13.0 | 4.2 | 67.6 |

2. Berbice

| | Onverwgt. | | Canefld. | | Berb. |
|---|---|---|---|---|---|
| | #5 | 123 | #3 | #4 | Total |
| 1988 | 2.0 | | 4.5 | 0.0 | 6.5 |
| 1989 | 2.0 | | 4.5 | 5.0 | 11.5 |
| 1990 | 2.0 | | 4.5 | 5.0 | 11.5 |
| 1991 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1992 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1993 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1994 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1995 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1996 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1997 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1998 | 2.0 | 7.8 | 5.7 | 5.7 | 21.2 |

3. All System

| Year | Total |
|---|---|
| 1988 | 39.2 |
| 1989 | 55.2 |
| 1990 | 60.9 |
| 1991 | 68.7 |
| 1992 | 68.7 |
| 1993 | 86.2 |
| 1994 | 77.7 |
| 1995 | 94.7 |
| 1996 | 89.7 |
| 1997 | 86.9 |
| 1998 | 88.8 |

Table 6-4 (3) (F:PSCAP-3R)

Changes of plant capacity of each power station

For Plan III

1. Demerara

| | Kingston | | | Garden of Eden | | | | New KGS | | | | Vers. | Deme. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | #1 | #2 | #3 | #2 | #3 | #4 | #5 | #1 | #2 | #3 | #4 | 123 | Total |
| 1988 | 8.5 | 8.5 | 8.5 | 0.0 | 0.0 | 3.0 | | | | | | 4.2 | 32.7 |
| 1989 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | | | | | | 4.2 | 43.7 |
| 1990 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | | | | | 4.2 | 49.4 |
| 1991 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | | | | | 4.2 | 49.4 |
| 1992 | 8.5 | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | | | | | 4.2 | 49.4 |
| 1993 | | 8.5 | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | 13.0 | 13.0 | | | 4.2 | 66.9 |
| 1994 | | | 8.5 | 4.0 | 5.0 | 5.0 | 5.7 | 13.0 | 13.0 | | | 4.2 | 58.4 |
| 1995 | | | 8.5 | 5.7 | 5.0 | 5.7 | 5.7 | 13.0 | 13.0 | | | 4.2 | 60.8 |
| 1996 | | | 8.5 | 5.7 | | 5.7 | 5.7 | 13.0 | 13.0 | 13.0 | | 4.2 | 68.8 |
| 1997 | | | | 5.7 | 5.7 | 5.7 | 5.7 | 13.0 | 13.0 | 13.0 | | 4.2 | 66.0 |
| 1998 | | | | 5.7 | 5.7 | 5.7 | 5.7 | 13.0 | 13.0 | 13.0 | 13.0 | 4.2 | 79.0 |

2. Berbice

| | Onverwgt. | | Canefld. | | Berb. |
|---|---|---|---|---|---|
| | #5 | 123 | #3 | #4 | Total |
| 1988 | 2.0 | | 4.5 | 0.0 | 6.5 |
| 1989 | 2.0 | | 4.5 | 5.0 | 11.5 |
| 1990 | 2.0 | | 4.5 | 5.0 | 11.5 |
| 1991 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1992 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1993 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1994 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1995 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1996 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1997 | 2.0 | 7.8 | 4.5 | 5.0 | 19.3 |
| 1998 | 2.0 | 7.8 | | | 9.8 |

3. All System

| Year | Total |
|---|---|
| 1988 | 39.2 |
| 1989 | 55.2 |
| 1990 | 60.9 |
| 1991 | 68.7 |
| 1992 | 68.7 |
| 1993 | 86.2 |
| 1994 | 77.7 |
| 1995 | 80.1 |
| 1996 | 88.1 |
| 1997 | 85.3 |
| 1998 | 88.8 |

(F: MAJORPLN))

Table 6-5

Major Development Plan

| Commiss. Year | Power Plant Name | Unit | Capacity (MW) | Total (MW) | Remarks |
|---|---|---|---|---|---|
| 1. Emergent Power Supply Enhancement Plan | | | | | |
| 1990 | GOE | #5 | 5.7 | 5.7 | |
| 1991 | OVW | #1 | 2.6 | | |
| | | #2 | 2.6 | | |
| | | #3 | 2.6 | 7.8 | |
| 2. Development Program of Major Power Plant | | | | | |
| 1993 | KGS I | #1 | 13.0 | | |
| | | #2 | 13.0 | 26.0 | |
| 1995 | KGS II | #3 | 13.0 | | |
| | | #4 | 13.0 | 26.0 | |
| 3. Replacement Programs for Diesel Generators | | | | | |
| 1997 | GOE | #3 | 5.7 | 5.7 | |
| 1998 | CF | #3 | 5.7 | | |
| | | #4 | 5.7 | 11.4 | |
| | Total | | | 82.6 | |

Note 1

Expectant Recovery of power supply capability of existing plant by Rehabilitation Work

| Year | P.S | | Work | Recovery (MW) |
|---|---|---|---|---|
| 1988 | OVW | #5 | 0->2.0 | 2.0 |
| 1989 | GOE | #2 | 0->4.0 | |
| | | #3 | 0->5.0 | |
| | | #4 | 3->5.0 | |
| | CF | #4 | 0->5.0 | 16.0 |
| | Total | | | 18.0 |

Note 2

Assumption of Retiring Year of existing plants

| Year | P.S | | Retir.Capa (MW) | Year Total (MW) |
|---|---|---|---|---|
| 1993 | KGS | #1 | 8.5 | 8.5 |
| 1994 | KGS | #2 | 8.5 | 8.5 |
| 1995 | GOE | #2 | 4.0 | |
| | | #4 | 5.0 | 9.0 |
| 1996 | GOE | #3 | 5.0 | 5.0 |
| 1997 | KGS | #3 | 8.5 | 8.5 |
| 1998 | CF | #3 | 4.5 | |
| | | #4 | 5.0 | 9.5 |
| | Total | | | 49.0 |

# CHAPTER 7

# REPLACEMENT PROGRAM
# OF
# GARDEN OF EDEN POWER STATION

# CHAPTER 7 REPLACEMENT PROGRAM OF GARDEN OF EDEN POWER STATION

## 7.1 CURRENT STATUS OF GARDEN OF EDEN POWER STATION AND CURRENT PROBLEMS

### 7.1.1 Current status of Garden of Eden Power Station

Garden of Eden Power Station is located on the eastern bank of Demerara River approximately 22 km to the south of the capital city of Georgetown. This power plant is connected to the 69 kV Demerara Power System, and supplies power to the City of Georgetown, International Air Port and other important load centers by 13.8 kV distribution lines.

The power generating facility of Garden of Eden Power Station consists of 4 units of diesel generators, with a total installed capacity of 22.8 MW (5.7 MW x 4). No. 2 and No. 3 Units started commercial service in 1975, and No. 4 and No. 5 Units in 1976 (there is no No. 1 Unit). Garden of Eden Power Station is the largest diesel power plant owned by GEC.

(1) Current status of facilities

No. 2 Unit: The stator winding of this unit was damaged, and the generator of No. 4 Unit was transferred to this unit, and operation was continued for some time. However, this unit became inoperable in September, 1987, due to failure of crank shaft bearing.

No. 3 Unit: This unit became inoperable in 1986 due to failure of crank shaft bearing. The unit is currently disassembled and usable parts are used in other units.

No. 4 Unit: The stator winding of this unit was damaged in 1986, and the generator of No. 5 Unit has been transferred to this unit to continue operation. This unit is obsolete, and it is being barely operated by limiting the output to 3 MW while the rated output of this unit is 5.7 MW.

No. 5 Unit: This unit became inoperable in 1986 due to failure of crank shaft bearing. Today, both the main unit and auxiliary equipment have been dismantled with only the foundation left.

Specification of Diesel Engine

| | |
|---|---|
| Manufacturer: | Crossly Pielstick, U.K. |
| Type: | KVMAJOR |
| Output: | 7,920 HP (8,030 PS) |
| Rotating speed: | 514 rpm |
| Weight: | Approximately 100 tons |

Specification of Generator

| | |
|---|---|
| Manufacturer: | General Electric Company, U.K. |
| Capacity: | 7,170 kVA |
| Voltage: | 13.8 kV |
| Current: | 300 A |
| Power factor: | 0.8 (lag) |
| Frequency: | 60 Hz |

(2) Past performance records

The performance records of each unit from 1978 to August, 1988 are presented in Table 7-1. The operating performance records for the period from 1975 to 1977 have already been discarded and are not available today. The available performance records reveal that there are large differences in the operating hours between each unit for the period from 1978 to 1980. It can also be surmised that some units were shut down for long periods after 1981 due to trouble.

(3) Power plant facilities

The premises of the power plant have an area of 57,600 $m^3$, where the following facilities are located.

1) *Powerhouse building (approx. 1,300* $m^2$*)*

This building accommodates 4 diesel generators, the control room, cubicle room, etc.

2) Switchyard (approx. 5,800 $m^2$)

Main transformers (69/13.8 kV, 16.7 MVA) and 69 kV switchgears are installed in this switchyard.

3) Fuel storage tank

Two tanks having 250,000 Imperial gallon (1,136.5 kl) capacity each and two tanks having 20,000 Imperial gallon (90.9 kl) capacity each are installed.

4) Workshop and storehouse (approx. 700 $m^2$)

There is a building accommodating a workshop and a storehouse separately from the powerhouse building. The workshop is equipped with lathes, drilling machines and welding machines. The storehouse contains large spare parts of other power stations, including Versailles, Wakenaam, Anna Regina, Bartica, in addition to those of this power plants.

5) Administration office (approx. 160 $m^2$ + 150 $m^2$)

(2) Operation and maintenance organization

The organization for operation and maintenance of Garden of Eden Power Plant is illustrated in Figure 7.1. As of September, 1988, 52 persons are assigned to this power plant under the command of the station manager.

### 7.1.2 Current Problems with Garden of Eden Power Station

(1) Problems concerning operation and maintenance

Concerning inspection and repair of power plant equipment, shortage of foreign currency for procurement of necessary parts, and chronic power supply shortage have created a situation in which proper preventive maintenance activities, such as scheduled maintenance and overhauling, could not be conducted. The most serious problem with this power plant is that equipment are subjected to severe operating conditions without adequate inspection and repair.

As the equipment in operation are aged and deteriorated, there are many leakages of oil and water. The maintenance staff are too busily occupied with repair work leaving no time to perform cleaning of generating facilities, auxiliary equipment and pits in the floor.

The lighting equipment inside power plant and control room are only partially lit, and the illumination inside the power plant is not sufficient for proper operation, monitoring, patrol and inspection duties.

(2) Causes of failures

The causes of failures are presumably due to a great extent by the operation of equipment without performing proper maintenance, repair, and replacement of parts due to the shortage of spare parts resulting in delayed inspection and preventative maintence.

(3) Feasibility of rehabilitation

According to the rehabilitation program of GEC, repair programs are in progress to complete rehabilitation of No. 2, No. 3 and No. 4 Units by the end of October, 1989.

All usuable parts of No. 5 Unit have been transferred elsewhere, and the engine has been dismantled leaving only its foundation the site. Therefore, the cost of rehabilitating No. 5 Unit will be almost equal to that of procuring a new unit. This No. 5 Unit is not included in GEC's rehabilitation program, and this unit has been abandaned.

(4) Future problems

In order that new power generating facilities maintain their original performance levels over a long period, it is necessary that GEC personnels who are in charge of plant operation and maintenance acquire the necessary skills and knowledges for routine operation and maintenance.

Concerning spare parts, it is required to keep inventories which are sufficient for 3 years of plant operation plus the first overhauling of all equipment, if we consider the economic status of Guyana. In addition, detailed operation and maintenance manuals must be formulated, and daily inspections, periodical inspections and overhauling works must be conducted properly.

## 7.2 REQUEST FOR ASSISTANCE OF THE GOVERNMENT OF JAPAN FOR THE IMPLEMENTATION OF THE PROJECT

GEC, which is the sole utility supplying electric power to consumers in the Republic of Guyana, owns 4 diesel power plants and 1 steam power plant in its Demerara/Berbice Power System. The system consists of a total of 12 power generation units (67.2 MW installed capacity) which are installed in these power plants. As of September, 1988, 4 of these units (19.7 MW installed capacity) are inoperable and shut down. The remaining power generation units (47.5 MW installed capacity) cannot generate their rated output and they are being operated by limiting the output to 37.2 MW. This situation is caused by the shortage of fund, making it difficult to import necessary parts and to perform repair of power generation facilities.

Under such circumstances, the Demerara/Berbice Power System is in chronic shortage of power supply capability, and scheduled load sheddings are enforced.

The Government of Guyana is concerned with the current status of power supply shortage which is greatly hampering the normal activities of people and industry, and as a measrue to remedy this situation, it is making serious efforts to rehabilitate the existing power generation facilities. However, the current situation of power supply shortage can not be completely eliminated and forced load sheddings must be enforced even after the existing facilities are rehabilitated according to the current plan. For these reasons, the Government of Guyana has requested a grant cooperation of the Japanese Government for construction of one 5.7 MW diesel generator unit at Garden of Eden Power Station.

## 7.3 CONTENT OF PROJECT

### 7.3.1 Objective of project

The objective of this Project is to urgently reinforce the power supply capability of Demerara/Berbice Power System in order to mitigate the power shortage of this area.

Specifically, the No. 5 power generating unit of existing Garden of Eden Power Station is to be a new unit to increase the supply capability of this power plant, thereby improving the function of this power plant as the power supply source to the capital city of Georgetown so that the livelihood of the citizens is improved and the local industry is vitalized.

7.3.2 Examination of the request

The request of the Government of Guyana has been carefully examined to evaluate its suitability, and to establish the basic project plan for this grant cooperation, including the scale of project, location of installing a new generating unit, and the basic specification of the unit such as rating and speed of diesel engine.

(1) Scale of project

The rehabilitation program for the existing power generation facilities which is being implemented by GEC will be completed by 1990, and the available power supply capacity in Demerara/Berbice Power System will be recovered to 55.2 MW from the current 37.2 MW. Power demand forecast predict that the peak load of this system at that time will be 54.5 MW, and the power supply shortage can be solved when the rehabilitation program is fully implemented and all generating facilities are operated. In reality, however, these power generating facilities must be subjected to periodical shutdowns for inspection in order that satisfactory operation and maintenance can be performed. Although there are 12 power generation units in this power system, it must be anticipated that one or two of these units are always shut down throughout a year. This will result in the continuation of the current power supply shortage, and the scheduled load shedding currently being practiced must be continued. To mitigate this shortage of power supply, the scale of this project has been determined tc be one unit of 5.7 MW by taking into account the following factors.

1) Standard size diesel engine can be adopted power plant.
2) The foundation of the dismantled No. 5 Unit can be utilized.

If a unit size of 5.7 MW is selected, the scheduled load shedding can be eliminated even when one of the existing diesel generator units (5 MW) is shut down for inspection. In addition, scheduled load shedding of approximately 3.8% is required for 1 to 2 hours at peak time even when one of steam power units (8.5 MW) at Kingston Power Station is shut down.

Based on the above analyses and evaluations, it is concluded that the plan of installing one 5.7 MW unit, which the Government of Guyana has requested, is an optimum plan.

(2) Study of location of installation

In this project, it is planned to expand the generating capacity of Garden of Eden by installing the new unit in the generating building of this plant.

No. 5 Unit of Garden of Eden Power Plant is not included in GEC's rehabilitation program, and the engine of the old No. 5 Unit has been removed, and the generator transferred to No. 4 Unit, with only the foundation of No. 5 Unit left.

It is possible to install the new generating unit in other places in this power plant compound. But in such case, larger investment and longer construction period will be required as new building and foundation must also be constructed, which is not appropriate for this project which is quite urgent. As it is judged that the foundation of the old No. 5 Unit can be utilized, it is proposed to install the new unit on this foundation.

(3) Study of existing foundation

1) According to the survey conducted at the site, no abnormal condition is visually observed on the foundation of the old No. 5 Unit, and no abnormal vibration has been observed in past on this foundation.

2) The concrete foundation is an independent structure from the generating building, and its approximate weight is estimated at 335 tons.

3) Information on the weight of the removed engine, which had been manufactured by Crossley Pielstick, is not found in existing documents, but is can be estimated to be around 100 tons from its output (7,920 HP), rotating speed (514 rpm) and the date of manufacturing (1975).

4) Evaluation:

It is a general rule that the foundation must have a weight which is more than 3 times the weight of the equipment to be installed. The weight of the existing foundation is estimated to be approximately 335 tons, while the total weight of the new diesel generator unit in assembled conditions will be approximately 87 tons. This gives the foundation to equipment weight ratio of 3.9, and this foundation is suitable for use for the new generating unit.

To increase the height of this foundation, it is quite practicable to do so by chipping the existing concrete surface to upper end of existing reinforcing steel bars, welding new reinforcing bars to the existing ones and placing new concrete to the required height.

(4) Rated speed of diesel engine

The rated speed of the old No. 5 engine was 514 rpm. A medium speed engine of rated speed of 720 rpm is adopted for the new unit based on the following considerations.

1) Smaller size, lighter weight resulting in lower cost.

2) The ratio of foundation weight to machine weight is 3.9, thereby permitting the utilization of the existing foundation. Generally, a ratio of more than 3.0 is required, and values between 3.5 to 4 is generally used in foundation design.

3) The maximum weight of a component to be shipped is 25 tons, enabling the use of unloading facility in Georgetown harbor (25 tons maximum).

4) A rated speed of 720 rpm is adopted in many 5 MW class engines of modern designs, all of which demonstrate good performance. A comparison between 514 rpm engine and 720 rpm engine is given in Table 7.2.

Table 7.2 Comparison of 514 rpm engine and 720 rpm engine

| | | 514 rpm Design | 720 rpm Design | Note |
|---|---|---|---|---|
| 1. | Weight<br>(1) Engine<br>(2) Generator<br><br>Total | <br>80 tons<br>34 tons<br><br>114 tons | <br>60 tons<br>27 tons<br><br>87 tons | |
| 2. | Ratio of foundation weight to machine weight | 335/114 = 2.9 | 335/87 = 3.9 | Foundation; 335 tons |
| 3. | Engine weight as shipped | 40 tons | 25 tons | Split into 2 or more pieces |
| 4. | Price | 126% | 100% | |

(5) Type of fuel

The existing units in this power plant is designed for heavy oil (Bunker C), and units were operated with the fuel oil purifier system (centrifugal type) in the early phases of plant operation. Later on, the fuel oil clarifier system was added, but frequent troubles were encountered. The fuel was switched to diesel oil due to these troubles, and the fuel oil purifier system is not used today.

The cause of the trouble is presumably the incompatibility of the properties of the fuel oil which was imported from Venezuela, and the low level of operation and maintenance technique of the fuel oil purifier system. Consequently, it is planned to use diesel oil for this project based on the following considerations.

1) It can be presumed that the properties of heavy oil imported from Venezuela in the past is problematic, and not suitable for medium to high speed diesel engines.

2) The cost of operation and maintenance of fuel oil purifier system is expensive.

3) The existing engines are already operated on diesel oil.

(6) Overhead traveling crane

The existing overhead traveling crane of this power plant has a main hook with maximum hoisting capacity is 25 tons, and the hoisting height above the floor is 7.5 meters. The auxiliary hook of this crane has a maximum hoisting capacity of 5 tons and maximum hoisting height of 7.0 meters above the floor. It is possible to use this crane for disassembly, assembly and installation of the new generating unit.

7.3.3 Outline of the project

(1) Operation and maintenance organization

The current operation and maintenance organization of Garden of Eden Power Station has been presented in Paragraph (4) of Section 7.1.1 When the new power generation unit under this project is commissioned, Garden of Eden Power Station will account for 45% of the total power output in Demerara Power System and becomes the important power station for the operation of the whole system. Therefore, further enhancement of the operation and maintenance system of this power plant is recommended.

It is recommended that the quality of the operation and maintenance personnels be improved through the on-the-job training which will be provided during the period of installation of the new power unit under this Project, and have specialists stationed in the power plant for some time after commissioning of the new unit so that additional guidance is provided.

(2) Major equipment to be supplied

The major equipment required for implementation of thie Project are listed below.

<1> Diesel engine
<2> Engine control system
<3> Air compressor
<4> Fuel supply system
<5> Cooling system
<6> Exhaust system
<7> Generator
<8> Exciter

<9> Supervisory and control board
<10> Station service transformer
<11> Station service power source board
<12> DC Power supply system for controls
<13> 15 kV Switchgear
<14> Power cables and related materials
<15> Spare parts and tools

In addition, the following existing facilities will be utilized in implementing this Project.

<1> Generating building for generator (including control room)
<2> Overhead traveling crane
<3> Fuel storage tank
<4> Cooling water

The one-line diagram, general plan, equipment layout drawing, cooling water system piping diagram, fuel piping diagram, lubricating oil system diagram, as well as the drawing describing the branches from the existing equipment piping systems to the piping system of the new unit under this Project, are presented in drawings Fig.7.4 to Fig. 7.13.

(3) Outline of project site

1) Garden of Eden Power Station

Garden of Eden Power Station is located on the eastern bank of Demerara River approximately 22 km from the center of the capital city of Georgetown.

The power generated by this power station is stepped up to 69 kV, and is transmitted to Sophia Converter Station and Linden Substation in the Demerara Power System. This power station is also an important supply center as it is situated near large load centers, and its output is also supplied to the urban districts of Georgetown City, International Air Port, and other loads by 13.8 kV distribution lines.

Transportation of heavy items from Georgetown Harbor to the power station is not a problem as there are no obstacles. The unloading facility located on Demerara River, which was used when the existing facilities of this power station were constructed, can also be utilized if it is repaired. As the plant's premises are wide and there is no dwellings nearby, there is no environmental problems such as noise, vibration and exhaust gas. Therefore, this power plant is located at an ideal site.

2) Georgetown Harbor

Georgetown Harbor, where the equipment of this project is to be unloaded from ships, is adjacent to the urban districts of Georgetown city. This harbor is the main gateway for international trade of Guyana, where various goods such as food, daily commodities and construction machines are imported and from where bauxite is exported.

3) Roads

The road from Georgetown Harbor to Garden of Eden Power Plant is paved and there seems to be no obstacles such as a bridge for transportation of equipment.

(4) Guidance in operation and maintenance

Experienced and technically qualified personnel in the operation and maintenance of the equipment to be installed are required. Therefore, training and recruiting operation and maintenance personnel are very important. Specifically, technology transfer in the routine operation and maintenance through on-the-job training which can be provided by the manufacturer during the construction period is essential.

## 7.4 BASIC DESIGN

### 7.4.1 Basic principles of design

As the objective of this Project is to urgently increase the power supply capability, it is the principle of this project that the existing generating building is not expanded for this particular purpose and the existing facilities are utilized as much as possible so that an economical project is completed in a short time. Specifically, the power generation facilities and auxiliary facilities of the old No. 5 Unit are removed, its foundation is utilized, and the new unit is to be installed in the existing generating building.

As the existing unit were installed in the period from 1974 to 1976, the auxiliary equipment as well as main units are quite aged and deteriorated, and their specifications are different from those of the new unit. Therefore, there is the risk that faults and other factors occurring in the old facilities may interfere with the efficiency of the new unit. For this reason, dedicated auxiliary power supply, DC control power supply and 13.8 kV switchgears for the exclusive use of new unit are to be installed.

The existing facilities which are to be utilized in this Project are as listed below.

(1) Concrete foundation for engine and generator

The existing foundation of No. 5 Unit shall be utilized, as stated in Paragraph (3), Section 7.3.2 "Study of Existing Foundation".

(2) Generating building

As the new unit is to be installed at the location of the old No. 5 unit which has been removed, the new unit will be equipped inside the existing generating building.

(3) Overhead traveling crane

The hoisting capacities of the existing overhead traveling crane are 25 tons for the main hook and 5 tons for the auxiliary hook. These capacities are sufficient for disassembly and assembly of the new unit under this Project.

(4) Fuel storage tank

The new generating unit under this Project is to be operated with diesel oil which is the same as the fuel used for the existing units. The fuel shall be supplied from the exiting fuel supply piping from the existing fuel storage tank.

The capacity of the existing fuel storage tank is 2,455 kl (1,136.5 kl x 2 and 90.9 kl x 2). When the unit under this Project as well as the rehabilitation of the existing 3 units is completed, the total fuel consumption will be about 3,000 kl per month assuming a load factor of 80%. That is, the fuel storage tank has a capacity of storing 25 days of fuel. According to GEC, the fuel of this power plant is imported from Venezuela by Guyana National Energy Authority (GNEA), a governmental corporation, and can be delivered within 11 to 12 days after an order is placed. Considering this status, there seems to be no need to increase the capacity of fuel storage tanks.

### 7.4.2 Design conditions

(1) Meteorology (in Georgetown City)

| | | |
|---|---|---|
| Temperature: | annual average highest temperature; | 30.4°C |
| | annual average lowest temperature; | 24.0°C |
| Atmospheric pressure: | annual average; | 1,013.6 mbar |
| Humidity: | annual average; | 82.5% |
| Precipitation: | annual maximum; | 2,744.3 mm |
| | annual average; | 2,303 mm |
| | monthly maximum; | 509.5 mm |

The meteorological data for the period from 1968 to 1987 are presented in Table 7.3. There is no need to consider seismic activity in the equipment design.

(2) Fuel characteristics

The diesel oil which is currently used at Garden of Eden Power Station has the following characteristics.

| | |
|---|---|
| Specific gravity: | 0.8667 at 15°C |
| Viscosity: | 3.6 mm2/sec at 40°C |
| Flash point: | 76°C |
| Sulfur content: | 0.4%M |
| Water content: | 0.05%V or less |
| Sediments: | 0.01%M or less |
| Cetane: | 46 |

(3) Characteristics of cooling water

The cooling water which is currently used by Garden of Eden Power Station has been analyzed, and the following results have been obtained.

| | | Fresh Water | Raw Water |
|---|---|---|---|
| PH | | 6.3 | 5.7 |
| M alkalinity | ppm | 40 | 12 |
| Electric conductivity | μΩ/cm | 90 | 3700 |
| Chloride | ppm | 12 | 1101 |
| Total hardness | ppm | 2.52 | 106.5 |
| Silica | ppm | 5.17 | 31.4 |
| Suspended solids | ppm | 30 | 2910 |

(4) Applicable standards

The following standards have been applied in the design of the equipment for this Project.

Japanese Industrial Standard (JIS)
Standard of The Japanese Electrotechnical Committee (JEC)
Japan Electrical Manufacturers Association Standard (JEM)
Japanese Electrical Wire and Cable Makers' Association Standard (JCS)

### 7.4.3 Fundamental designs

(1) Engine output and generator capacity

The generator rated output is selected at 5,700 kW, and the required engine output and generator capacity are calculated as follow:

1) Engine output

Engine output (French horsepower; PS) is calculated by the following equation.

engine output: $Pe \geq \dfrac{P}{0.736 \times \eta g}$ (PS)

where:

generator output : $P = 5700$ (kW)

$1$ PS $= 0.736$ (kW)

generator efficiency: $\eta g = 96\%$

$$Pe \geq \frac{5700}{0.736 \times 0.96} \simeq 8070 \text{ (PS)}$$

2) Generator rated capacity

The generator rated capacity is obtained by the following equation:

generator output: $Pg = \dfrac{P}{Pf}$

where:

generator power factor: $Pf = 0.8$

$$Pg = \frac{5700}{0.8} = 7125 \text{ (kVA)}$$

(2) Station service transformer

The existing station service transformers consists of two 1500 kVA units. According to the design principle of this Project, the equipment related to the new unit are to be independent insofar as possible from the existing facilities. With this principle, a new station service transformer, which supplies power to the auxiliary equipment of the new diesel generator under this Project and the related systems, are to be installed. The required capacity of this station service transformer is from 3 to 4% of the main equipment capacity, or 250 kVA.

(3) Supervisory and control boards (Monitor and Control Board)

The following supervisory and control boards are required for operation, control and monitoring of the diesel generator unit under this Project.

1) Main supervisory and control board
2) Generating unit control board
3) Generator neutral grounding resister (NGR) board
4) Station service power board
5) DC control power switchboard

(4) Circuit breaker board

The diesel generator unit to be installed under this Project shall be connected to the existing 13.8 kV bus, and shall be equipped with a circuit breaker to connect or disconnect the generator from the power system.

Vacuum circuit breaker (VCB), which has high reliability and which is low in cost, is to be installed for this purpose. This circuit breaker protects the related electrical equipment by cutting off fault current in the event of fault. The circuit breaker is closed when the generator is supplying power, and opened when the generator is shut down.

(5) Power cable

The electrical connections between the generator and the vacuum circuit breaker, and between the station service transformer and the line switch are to be made by 15 kV power cables as illustrated in the attached one-line diagram.

### 7.4.4 Equipment/Material procurement plan

(1) Equipments/Materials for new power generation unit

The items of equipment/material to be procured for new power generation unit and their specifications are listed below.

| Item | Outline Specification |
|---|---|
| Diesel Engine | Number: 1<br>Type: 4 cycle, stationary type, power generation duty<br>Output: Approximately 8,070 PS, continuous duty.<br>Rotating speed: 720 rpm<br>Cooling system: Circulating water, with cooling tower<br>Fuel: Diesel oil |
| Generator | Number: 1<br>Type: 3-phase, horizontal shaft AC synchronous generator.<br>Rated output: 5,700 kW, continuous<br>Rated capacity: 7,125 kVA, continuous<br>Voltage: 13.8 kV<br>Current: 298 A<br>Power factor: 0.8 (lag)<br>Frequency: 60 Hz<br>Number of poles: 10<br>Insulation class: Class F<br>Excitation method: Brushless<br>Cooling system: Open air cooled. |
| Station Service Transformer | Number: 1<br>Type: Outdoor, 3-phase, oil filled, self cooled.<br>Rated capacity: 250 kVA, continuous<br>Voltage: Primary; 13.8 kV, secondary; 480 V.<br>Frequency: 60 Hz<br>Connection: Primary; delta, secondary; star.<br>Neutral: Directly grounded. |
| Supervisory and Control Boards (Supervisory, Control, Protection and Power Supply Boards) | Type: Indoor, enclosed, self-standing type.<br>Application: Control and protection.<br>(a) Main supervisory and control board; 1<br>(b) Generating unit control board; 1<br>(c) Neutral grounding resistor board; 1<br>(d) DC control power supply board; 1<br>(with battery charger, alkali batteries, and DC control system) |

| Item | Outline Specification |
|---|---|
| Circuit Breaker Board | Number: 1<br>Type: Indoor, enclosed, self-standing type.<br>Circuit breaker: Vacuum circuit breaker.<br>Rated voltage: 15 kV<br>Rated current: 600 A |
| Power Cable | Type: Cross-linked polyethylene insulated power cable.<br>Voltage: 15 kV<br>Conductor size: 150 $mm^2$, 60 $mm^2$. |

(2) Materials for maintenance and spare parts

1) Materials for maintenance of main unit and auxiliary equipment

Materials and spare parts which are required for 3 years of routine maintenance of the main unit and auxiliary equipment for the first three years, as well as the spare parts (piston rings, gaskets, bearings, etc.) required for the first overhaul (mainly the engine) of the unit are required.

2) Control boards and others

The kinds and quantities of materials and spare parts required for routine maintenance of control boards, circuit breakers, transformers, etc. will differ depending on whether the equipment is a stationary equipment or it has moving parts. Spare parts for 3 years of routine maintenance (including fuses and pilot lamps) will be required, and in addition, for components which are subjected to mechanical wear or deterioration such as coils of relays and magnetic contactors, contacts, gaskets and bearings, and those items which can not be repaired locally, such as thermometers, oil level gauges and switches, at least one spare for each item will be required.

## 7.5 IMPLEMENTATION PROGRAM

### 7.5.1 Facility operation and supervisory plans

(1) Operation and maintenance plans

In order to demonstrate the functions to the fullest of the equipment to be supplied under this Project, it is necessary to exercise due care in operation and maintenance of the equipment once it is commissioned, and conduct daily routine and periodical inspections. It is important for this purpose that the personnels of the power plant acquire the skill and capability required for good operation and maintenance practices through on-the-job training. It is also necessary to develop operation, inspection and repair schedules based on the manuals to be supplied by the manufacturers, and have the plant personnels strictly observe these schedules.

(2) Fuel procurement program

Smooth procurement of fuel is essential for operation of Garden of Eden Power Station. The fuel requirements for operation of the diesel generator unit to be installed by this Project have been calculated and presented below for the equipment load factors of 60%, 70% and 80%.

1) Diesel oil consumption (per horsepower and per hour)

$$\text{fuel consumption} = \text{fuel rate} \times \text{engine output} \times \frac{1}{\text{fuel specific gravity}}$$

$$= 0.143 \text{ kg/PS.h} \times 8{,}070 \text{ PS.} \times \frac{1}{0.86 \text{ kg/l}}$$

$$= 1{,}342 \text{ l/h}$$

<1> 60% load factor:

1 month: 1,342 l/h x 24 h/day x 30 day/month x 0.6

= 579,744 l/month

≈ 580,000 l/month

1 year: 580,000 l/month x 12 months = 6,960,000 l/year

<2> 70% load factor:

1 month: 1,342 l/h x 24 h/day x 30 day/month x 0.7

= 676,368 l/month

≃ 676,000 l/month

1 year: 676,000 l/month x 12 months = 8,112,000 l/year

<3> 80% load factor:

1 month: 1,342 l/h x 24 h/day x 30 day/month x 0.8

= 772,992 l/month

≃ 773,000 l/month

1 year: 773,000 l/month x 12 months = 9,276,000 l/year

2) Lubricating oil consumption

Considering the structure of the diesel generator, the lubricating oil consumption is increased by 10%.

$$0.83 \text{ g/PS.h} \times 1.1 \times 8{,}070 \text{ PS.} \times \frac{1}{1{,}000 \text{ g/kg}} \times \frac{1}{0.9 \text{ kg/l}} = 8.19 \text{ l/h}$$

<1> 60% load factor:

1 month: 8.19 l/h x 24 h/day x 30 day/month x 0.6

= 3,538 l/month

1 year: 3,538 l/month x 12 months = 42,456 l/year

<2> 70% load factor:

1 month: 8.19 l/h x 24 h/day x 30 day/month x 0.7

= 4,128 l/month

1 year: 4,128 l/month x 12 months = 49,536 l/year

<3> 80% load factor:

1 month: 8.19 l/h x 24 h/day x 30 day/month x 0.8

= 4,717 l/month

1 year: 4,717 l/month x 12 months = 56,604 l/year

As indicated by the above calculations, the Guyanan Government must procure at least 7,000 kl of diesel oil and 40 kl of lubricating oil per year in order to maintain smooth operation of the 5,700 kW diesel generator unit to be installed at Garden of Eden Power Station under this Project.

Currently, a total of approximately 19,700 kl of diesel oil is being consumed by the diesel power plants owned by GEC, and Garden of Eden Power

Station is consuming 45% of this amount, or 8,660 kl. GEC procures this fuel by importing it from Venezuela through the Guyana National Energy Authority (GNEA).

### 7.5.2 Implementation schedule

The implementation schedule for this Project has been prepared as shown in Fig. 7.14. It will take eighteen (18) months after the preparation of bidding documents is started. Therefore, the necessary financial and technical preparations must be started immediately so that the Project can be completed by 1990.

### 7.5.3 Approximate project cost

The approximate Project Costs are presented below.

| Item | Price ($10^3$ US$) |
|---|---|
| Equipments | 3830 |
| Transportation (Marine and Land) | 540 |
| Intallation and Removal Works | 1050 |
| Others | 350 |
| Total | 5770 |

## 7.6 STUDY OF OPERATION AND SUPERVISORY COSTS

The average annual cost per kWh, including depreciation, and operation/maintenance cost throughout the economic life of the new diesel generating equipment have been calculated. Then, the amount of power consumed or loss were assumed based on the past data to calculate the saleable power in order to judge whether the abovementioned average annual cost per kWh can be absorbed in the present average selling price kWh as a means to study if GEC can sustain the operation and maintenance cost of the new diesel generating equipment.

Although no information is available on the the ratios of generation, transmission/distribution and overhead costs to the unit selling price of GEC, they were assumed for the new unit at a load factor of 70%. The calculations are presented below.

| | |
|---|---|
| power generation cost: | 70% |
| transmission and distribution cost: | 15% |
| *overhead and others:* | 15% |
| | 100% |

annual energy generation = 5.7 MW x 8760 hours x 0.7 = 34.95 GWh

power generation cost = 0.04616 US$/kWh x 34.95 GWh

= 1,613,292 US$

transmission and distribution cost $= 1{,}613{,}292 \times \frac{15}{70}$

= 345,705 US$

overhead expense and others $= 1{,}613{,}292 \times \frac{15}{70}$ = 345,705 US$

Total 2,304,702 US$

The total loss is estimated to be 18% in the future, and this gives the energy at load end as:

*energy at load end = 34,95 GWh x (1 - 0.18) = 28.66 GWh*

cost/kWh = 2,304,702/28.66 GWh = 0.0804 US$/kWh

As indicated by the above calculations, the cost per kWh of generation by the new diesel generator unit of Garden of Eden Power Station is 0.0804 US$ (0.804 G$), which is below the current kWh rate of GEC of 0.84 G$. Therefore, the operation and maintenance cost of this new equipment can be absorbed by the current electricity rate.

Table 7.1 OPERATION RECORDS OF GARDEN-OF-EDEN POWER STATION

| Year | OPERATION HOURS AND ENERGY GENERATED | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. 2 Unit | | No. 3 Unit | | No. 4 Unit | | No. 5 Unit | | Total |
| | Hours | M.W.H. | Hours | M.W.H. | Hours | M.W.H. | Hours | M.W.H. | M.W.H. |
| 1978 | 6822 | 28361.22 | 3189 | 13760.28 | 6101.78 | 25712.76 | 5430.5 | 22097.37 | 89,931.63 |
| 1979 | 5804 | 24499.28 | 3875.2 | 16170.24 | 4280.5 | 16483.47 | 5630 | 23064.05 | 80,217.04 |
| 1980 | 2600.7 | 9584.11 | 5892.3 | 22710.70 | 3869.3 | 14064.67 | 1455.3 | 6858.02 | 53,217.50 |
| 1981 | - | - | 3692.1 | 13,737.31 | 2209.4 | 7871.55 | 5056.6 | 19330.55 | 40,939.41 |
| 1982 | 2201.8 | 6671.76 | 1484 | 4771.60 | 4521.29 | 13786.39 | 2437.40 | 7887.58 | 33,117.33 |
| 1983 | 5254.1 | 20,096.44 | 3799.5 | 14,295.37 | - | - | 978.75 | 2555.93 | 36,947.74 |
| 1984 | 3490.6 | 12,983.34 | 3277.80 | 12,210.47 | - | - | 3784.2 | 14,082.53 | 39,276.34 |
| 1985 | 3668.29 | 11,332.50 | 4059.8 | 12,588.69 | - | - | 5174 | 17,058.94 | 40,980.13 |
| 1986 | 5671.70 | 11,445.68 | 1669.64 | 3188.81 | 306.40 | 376.47 | 67.9 | 136.53 | 15,147.49 |
| 1987 | 2172.4 | 3205.54 | - | - | 7193.60 | 21,233.22 | - | - | 24,438.76 |
| 1988 | - | - | - | - | 4988 | 14,406.80 | - | - | 14,406.80<br>August 1986 |
| TOTAL | 37685.59 | 128179.87 | 30939.34 | 113433.47 | 33470.27 | 113935.33 | 30014.65 | 113071.5 | 468620.17 |

Table 7.3. METEOROLOGICAL DATA (1)

## MEAN MAXIMUM TEMPERATURE (℃)

STATION NAME:GEORGETOWN BOTANIC GARDENS

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 28.9 | 28.9 | 28.9 | 30.6 | 30.0 | 30.0 | 30.0 | 31.1 | 32.2 | 32.8 | 31.1 | 29.4 |
| 1969 | 29.4 | 30.0 | 30.6 | 31.7 | 30.6 | 30.6 | 31.1 | 32.2 | 32.2 | 32.8 | 31.1 | 31.1 |
| 1970 | 30.0 | 29.4 | 30.0 | 30.0 | 31.1 | 30.6 | 31.1 | 31.1 | 31.1 | 32.2 | 31.1 | 30.0 |
| 1971 | 29.4 | 28.9 | 30.0 | 30.6 | 30.0 | 30.0 | 30.0 | 31.1 | 31.1 | 31.1 | 31.1 | 29.4 |
| 1972 | 29.4 | 28.9 | 30.6 | 30.6 | 30.0 | 30.0 | 30.6 | 31.1 | 32.2 | 32.8 | 30.8 | 30.0 |
| 1973 | 30.0 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 30.6 | 35.0 | 31.7 | 30.6 | 30.6 | 30.0 |
| 1974 | 28.9 | 32.2 | 31.1 | 29.4 | 30.0 | 30.6 | 31.7 | 30.6 | 32.2 | 31.7 | 31.1 | 31.7 |
| 1975 | 30.6 | 29.4 | 30.0 | 31.1 | 30.6 | 31.1 | 31.7 | 30.6 | 31.1 | 31.7 | 31.1 | 30.6 |
| 1976 | 28.3 | 28.3 | 28.3 | 28.9 | 28.9 | 28.3 | 29.4 | 30.6 | 31.7 | 31.7 | 31.1 | 29.4 |
| 1977 | 28.9 | 29.4 | 29.4 | 29.4 | 29.4 | 28.9 | 29.4 | 30.6 | 31.1 | 30.6 | 31.1 | 29.4 |
| 1978 | 28.9 | 29.4 | 30.0 | 30.6 | 29.4 | 29.4 | 30.0 | 30.0 | 31.1 | 31.1 | 31.1 | 30.0 |
| 1979 | 28.9 | 28.5 | 28.9 | 30.0 | 30.0 | 30.6 | 30.6 | 30.6 | 31.7 | 31.7 | 31.7 | 30.0 |
| 1980 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.6 | 31.1 | 31.7 | 31.1 | 30.0 | 29.4 |
| 1981 | 30.0 | 29.5 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.6 | 31.1 | 31.1 | 31.7 | 30.0 |
| 1982 | 28.9 | 29.5 | 28.9 | 29.4 | 30.0 | 28.9 | 30.0 | 30.6 | 31.7 | 31.1 | 31.1 | 30.6 |
| 1983 | 28.9 | 29.5 | 30.6 | 30.0 | 30.0 | 30.0 | 30.6 | 30.6 | 31.1 | 31.7 | 31.7 | 29.4 |
| 1984 | 28.9 | 28.9 | 29.4 | 30.0 | 28.9 | 39.4 | 30.0 | 30.6 | 30.6 | 30.6 | 30.0 | 28.9 |
| 1985 | 28.9 | 29.5 | 28.9 | 30.0 | 30.0 | 30.0 | 30.6 | 30.6 | 30.6 | 30.6 | 30.6 | 29.4 |
| 1986 | 28.9 | 28.9 | 29.4 | 30.0 | 29.4 | 27.8 | 30.0 | 29.4 | 31.7 | 30.6 | 30.6 | 28.9 |
| 1987 | 28.9 | 29.4 | 30.6 | 30.6 | 30.6 | 30.6 | 30.6 | 31.1 | 31.7 | 31.7 | 31.1 | 30.6 |
| 1988 | 28.9 | 29.4 | 30.0 | 30.6 | 30.6 | 30.6 | 30.6 | | | | | |

Table 7.3. METEOROLOGICAL DATA (2)

MEAN MINIMUM TEMPERATURE (℃)

STATION NAME:GEORGETOWN BOTANIC GARDENS

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 23.6 | 23.3 | 23.5 | 23.5 | 23.4 | 23.3 | 23.4 | 23.8 | 24.2 | 24.6 | 23.9 | 23.8 |
| 1969 | 23.8 | 24.4 | 25.1 | 24.9 | 24.5 | 24.3 | 23.6 | 23.7 | 24.7 | 24.7 | 25.3 | 24.3 |
| 1970 | 23.9 | 24.3 | 24.8 | 24.4 | 24.1 | 23.8 | 23.2 | 23.7 | 24.1 | 24.4 | 23.8 | 23.7 |
| 1971 | 23.9 | 23.5 | 24.0 | 24.8 | 23.7 | 23.7 | 23.2 | 23.0 | 23.8 | 23.7 | 23.7 | 22.6 |
| 1972 | 23.1 | 23.5 | 23.9 | 24.1 | 24.0 | 23.5 | 23.9 | 24.1 | 24.5 | 25.2 | 24.1 | 23.8 |
| 1973 | 24.2 | 24.4 | 24.9 | 25.2 | 24.8 | 23.9 | 23.6 | 23.6 | 23.3 | 24.0 | 23.9 | 23.1 |
| 1974 | 23.4 | 23.7 | 23.9 | 23.6 | 24.0 | 23.4 | 23.1 | 23.7 | 23.4 | 23.8 | 23.8 | 23.6 |
| 1975 | 22.8 | 23.1 | 24.0 | 23.7 | 23.7 | 23.3 | 22.7 | 23.1 | 23.8 | 23.9 | 22.4 | 22.8 |
| 1976 | 22.5 | 22.7 | 23.4 | 23.1 | 23.3 | 23.4 | 23.2 | 23.6 | 24.1 | 24.1 | 24.0 | 23.4 |
| 1977 | 22.9 | 23.4 | 23.8 | 23.7 | 23.3 | 23.2 | 22.9 | 23.6 | 23.7 | 24.0 | 24.5 | 23.4 |
| 1978 | 22.9 | 23.7 | 24.2 | 24.7 | 23.7 | 23.2 | 23.3 | 23.3 | 23.8 | 23.9 | 24.2 | 23.6 |
| 1979 | 23.3 | 24.6 | 24.2 | 24.5 | 24.6 | 23.2 | 23.1 | 24.0 | 24.6 | 24.4 | 24.8 | 23.6 |
| 1980 | 24.1 | 24.4 | 24.1 | 24.5 | 23.7 | 24.2 | 24.0 | 24.3 | 24.9 | 24.1 | 24.3 | 23.6 |
| 1981 | 23.9 | 24.1 | 24.4 | 24.2 | 24.1 | 24.6 | 23.4 | 23.9 | 24.3 | 24.5 | 24.8 | 24.5 |
| 1982 | 24.0 | 24.2 | 24.0 | 24.1 | 24.5 | 24.2 | 23.7 | 23.7 | 24.9 | 24.4 | 24.8 | 24.3 |
| 1983 | 24.9 | 24.3 | 24.6 | 24.8 | 24.5 | 24.3 | 24.1 | 24.2 | 24.9 | 25.0 | 24.1 | 23.3 |
| 1984 | 22.9 | 24.1 | 24.2 | 24.2 | 23.9 | 24.1 | 23.2 | 24.0 | 23.7 | 23.8 | 23.7 | 23.9 |
| 1985 | 23.6 | 23.9 | 23.6 | 24.7 | 24.4 | 24.0 | 23.5 | 23.5 | 24.2 | 24.4 | 24.0 | 23.8 |
| 1986 | 23.9 | 22.7 | 24.2 | 25.1 | 24.4 | 24.1 | 23.8 | 25.2 | 25.1 | 24.4 | 24.2 | 23.6 |
| 1987 | 23.8 | 24.7 | 24.9 | 25.5 | 24.9 | 24.8 | 24.2 | 24.8 | 24.9 | 25.5 | 25.4 | 25.0 |
| 1988 | 24.2 | 24.5 | 24.9 | 25.7 | 25.1 | 24.2 | 23.7 | | | | | |

Table 7.3 METEOROLOGICAL DATA (3)

PRECIPITATION (MONTHLY TOTALS) (mm)

STATION NAME : GEORGETOWN BOTANIC GARDENS

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | TOTAL | MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 139.4 | 225.3 | 185.7 | 261.6 | 208.0 | 442.2 | 261.1 | 96.3 | 115.1 | 91.7 | 201.2 | 135.9 | 2363.5 | 197.0 |
| 1969 | 235.2 | 111.0 | 22.1 | 103.1 | 392.9 | 191.5 | 242.6 | 316.0 | 52.3 | 93.7 | 53.3 | 189.5 | 2003.2 | 166.9 |
| 1970 | 384.0 | 96.7 | 69.3 | 204.2 | 239.5 | 369.6 | 414.0 | 266.7 | 106.9 | 96.0 | 332.2 | 148.8 | 2727.9 | 227.3 |
| 1971 | 120.1 | 79.0 | 80.3 | 127.0 | 374.7 | 401.3 | 296.9 | 347.7 | 108.5 | 162.8 | 306.3 | 447.8 | 2852.4 | 237.7 |
| 1972 | 293.9 | 111.8 | 151.9 | 366.5 | 493.5 | 294.3 | 197.1 | 127.0 | 73.7 | 143.5 | 318.5 | 86.9 | 2658.6 | 221.6 |
| 1973 | 54.9 | 22.9 | 15.7 | 102.6 | 131.6 | 294.1 | 222.8 | 209.6 | 380.7 | 348.5 | 245.6 | 715.3 | 2744.3 | 228.7 |
| 1974 | 285.8 | 124.2 | 135.6 | 110.5 | 84.6 | 337.3 | 289.0 | 290.6 | 205.0 | 85.9 | 235.5 | 240.5 | 2424.5 | 202.0 |
| 1975 | 183.4 | 77.7 | 66.3 | 115.8 | 376.7 | 296.4 | 348.7 | 252.5 | 140.5 | 89.7 | 209.8 | 509.5 | 2667.0 | 222.3 |
| 1976 | 459.0 | 422.4 | 280.4 | 196.6 | 306.1 | 459.7 | 131.8 | 108.0 | 16.3 | 8.9 | 244.1 | 281.7 | 2915.0 | 242.9 |
| 1977 | 65.5 | 37.3 | 25.1 | 250.0 | 306.3 | 231.6 | 293.9 | 160.8 | 112.8 | 69.9 | 118.6 | 184.2 | 1856.0 | 154.7 |
| 1978 | 146.8 | 30.5 | 34.8 | 75.7 | 444.8 | 395.7 | 279.7 | 289.3 | 109.7 | 68.1 | 119.4 | 201.7 | 2196.2 | 183.0 |
| 1979 | 108.5 | 47.2 | 249.7 | 152.9 | 395.5 | 340.6 | 355.6 | 200.7 | 77.0 | 74.9 | 111.3 | 228.9 | 2342.8 | 195.2 |
| 1980 | 60.2 | 9.7 | 136.4 | 127.3 | 252.7 | 297.2 | 307.3 | 126.5 | 55.1 | 197.4 | 373.1 | 266.2 | 2209.1 | 184.1 |
| 1981 | 177.7 | 190.4 | 25.5 | 388.5 | 448.5 | 236.8 | 280.5 | 319.7 | 108.0 | 223.1 | 22.7 | 198.2 | 2619.6 | 218.3 |
| 1982 | 164.7 | 93.0 | 342.1 | 201.5 | 272.3 | 152.8 | 254.3 | 100.8 | 32.6 | 38.5 | 46.5 | 148.8 | 1807.9 | 150.7 |
| 1983 | 88.4 | 49.7 | 118.8 | 241.4 | 232.4 | 233.2 | 90.9 | 249.7 | 97.7 | 49.2 | 19.0 | 409.8 | 1880.2 | 156.9 |
| 1984 | 364.3 | 28.3 | 63.9 | 27.2 | 317.1 | 334.8 | 343.1 | 247.5 | 71.3 | 256.1 | 232.5 | 237.3 | 2523.4 | 210.3 |
| 1985 | 94.8 | 27.0 | 187.7 | 10.1 | 163.5 | 205.5 | 135.8 | 275.3 | 147.2 | 128.3 | 279.5 | 158.8 | 1813.5 | 151.1 |
| 1986 | 52.8 | 116.5 | 33.7 | 52.5 | 224.5 | 403.1 | 164.4 | 111.8 | 29.0 | 206.4 | 142.8 | 191.1 | 1728.6 | 144.1 |
| 1987 | 71.6 | 29.2 | 20.2 | 113.7 | 210.7 | 436.4 | 358.1 | 86.1 | 96.2 | 77.0 | 159.9 | 69.7 | 1728.8 | 144.1 |
| 1988 | 125.1 | 29.8 | 15.8 | 27.3 | 264.0 | 299.0 | 296.7 | | | | | | | |

Table 7.3 METEOROLOGICAL DATA (4)

## MEAN RELATIVE HUMIDITY (%)

STATION NAME : GEORGETOWN BOTANIC GARDENS

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 84 | 83 | 77 | 86 | 84 | 90 | 87 | 84 | 81 | 79 | 84 | 83 |
| 1969 | 84 | 82 | 75 | 81 | 86 | 87 | 88 | 88 | 80 | 78 | 77 | 83 |
| 1970 | 84 | 80 | 78 | 79 | 87 | 87 | 90 | 87 | 81 | 81 | 86 | 85 |
| 1971 | 82 | 77 | 78 | 79 | 86 | 87 | 87 | 88 | 80 | 84 | 84 | 88 |
| 1972 | 84 | 79 | 82 | 80 | 86 | 88 | 84 | 81 | 79 | 78 | 83 | 82 |
| 1973 | 78 | 76 | 74 | 75 | 76 | 87 | 86 | 86 | 88 | 84 | 82 | 86 |
| 1974 | 75 | 79 | 79 | 80 | 77 | 84 | 86 | 84 | 84 | 78 | 82 | 80 |
| 1975 | 84 | 78 | 75 | 78 | 82 | 86 | 87 | 87 | 82 | 81 | 82 | 87 |
| 1976 | 84 | 82 | 81 | 84 | 87 | 90 | 86 | 83 | 78 | 74 | 80 | 82 |
| 1977 | 78 | 77 | 76 | 78 | 86 | 86 | 88 | 85 | 82 | 82 | 79 | 80 |
| 1978 | 80 | 77 | 77 | 80 | 89 | 91 | 87 | 90 | 82 | 82 | 84 | 84 |
| 1979 | 80 | 75 | 82 | 83 | 87 | 92 | 88 | 88 | 82 | 82 | 83 | 89 |
| 1980 | 81 | 77 | 78 | 83 | 83 | 88 | 90 | 86 | 80 | 82 | 85 | 86 |
| 1981 | 81 | 84 | 79 | 88 | 89 | 89 | 90 | 89 | 83 | 78 | 79 | 82 |
| 1982 | 81 | 82 | 83 | 83 | 85 | 88 | 83 | 83 | 75 | 75 | 77 | 83 |
| 1983 | 80 | 79 | 79 | 80 | 83 | 82 | 81 | – | 80 | 74 | 77 | 89 |
| 1984 | 89 | 80 | 76 | 73 | 81 | 89 | 89 | 85 | 84 | 86 | 86 | 82 |
| 1985 | – | – | – | – | – | – | – | – | – | – | – | – |
| 1986 | 80 | 79 | 76 | 79 | 88 | 90 | 88 | 83 | 80 | 82 | 83 | 81 |
| 1987 | 81 | 78 | 77 | 77 | 86 | 86 | 88 | 84 | 80 | 77 | 77 | 81 |
| 1988 | 80 | 77 | 76 | 77 | 83 | 89 | 94 | | | | | |

Table 7.3 METEOROLOGICAL DATA (5)

## MEAN ATMOSPHERIC PRESSURE (mb)

STATION NAME : GEORGETOWN BOTANIC GARDENS

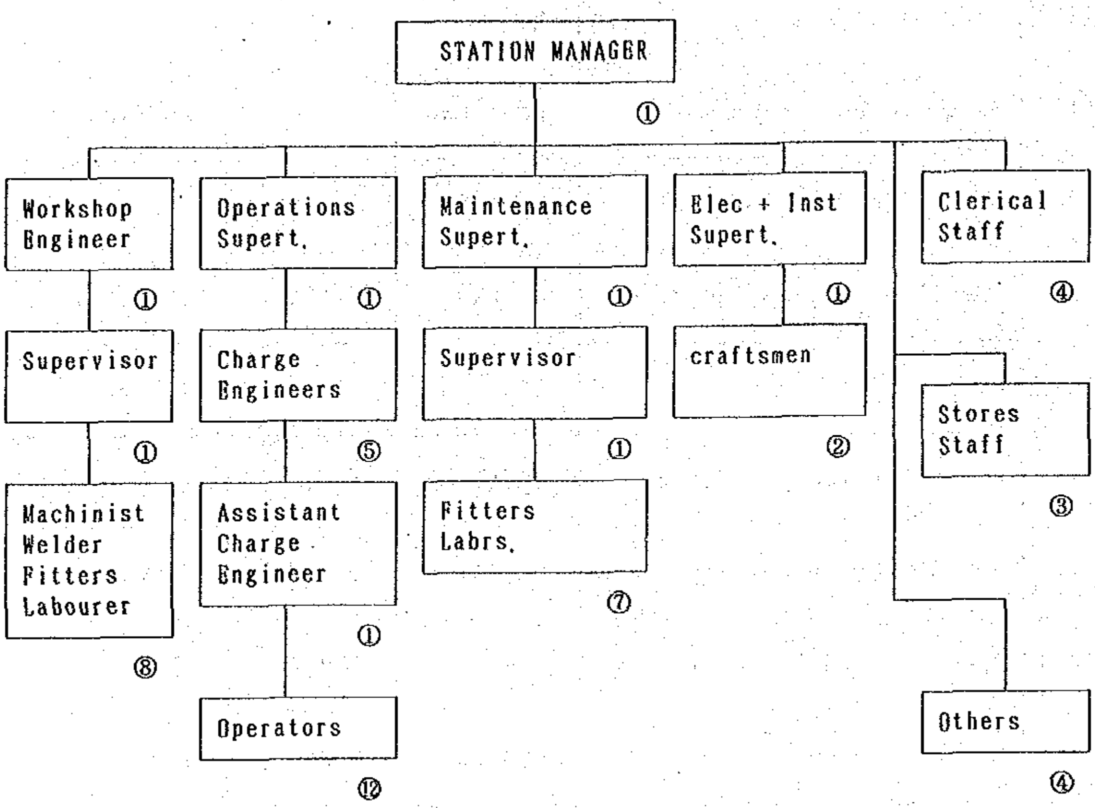
| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 1013.6 | 1013.3 | 1014.5 | 1013.2 | 1014.4 | 1014.8 | 1015.1 | 1014.2 | 1013.5 | 1012.8 | 1012.7 | 1013.3 |
| 1969 | 1012.0 | 1012.0 | 1013.5 | 1012.8 | 1013.3 | 1013.5 | 1014.8 | 1013.2 | 1012.5 | 1011.8 | 1011.7 | 1012.2 |
| 1970 | 1013.7 | 1013.2 | 1013.4 | 1013.9 | 1013.4 | 1014.0 | 1014.8 | 1011.0 | 1013.2 | 1011.8 | 1011.1 | 1012.1 |
| 1971 | 1012.7 | 1013.0 | 1013.2 | 1013.6 | 1013.8 | 1014.1 | 1013.8 | 1013.7 | 1013.4 | 1013.1 | 1012.4 | 1012.6 |
| 1972 | 1012.7 | 1013.7 | 1012.9 | 1013.4 | 1013.2 | 1014.1 | 1014.2 | 1013.6 | 1013.5 | 1012.5 | 1012.6 | 1013.5 |
| 1973 | 1015.0 | 1014.3 | 1014.4 | 1014.2 | 1014.5 | 1013.9 | 1014.3 | 1013.9 | 1014.3 | 1012.1 | 1012.8 | 1013.3 |
| 1974 | 1013.6 | 1013.1 | 1013.7 | 1014.6 | 1014.9 | 1014.2 | 1015.3 | 1014.2 | 1013.7 | 1013.3 | 1012.4 | 1013.3 |
| 1975 | 1014.0 | 1014.5 | 1014.8 | 1014.1 | 1014.0 | 1014.7 | 1014.6 | 1014.3 | 1013.9 | 1013.1 | 1012.9 | 1012.6 |
| 1976 | 1013.9 | 1014.5 | 1014.0 | 1014.1 | 1014.9 | 1014.7 | 1015.3 | 1014.4 | 1014.0 | 1012.1 | 1012.4 | 1013.3 |
| 1977 | 1014.5 | 1015.5 | 1015.2 | 1014.7 | 1014.5 | 1014.7 | 1014.8 | 1014.3 | 1014.5 | 1013.7 | 1013.3 | 1014.6 |
| 1978 | 1015.4 | 1014.9 | 1015.2 | 1013.9 | 1014.2 | 1015.1 | 1014.6 | 1014.9 | 1013.8 | 1012.9 | 1012.5 | 1013.9 |
| 1979 | 1013.9 | 1015.2 | 1014.2 | 1013.8 | 1013.9 | 1014.4 | 1015.4 | 1013.5 | 1013.4 | 1012.8 | 1011.6 | 1013.1 |
| 1980 | 1014.5 | 1014.8 | 1014.5 | 1014.1 | 1014.0 | 1014.6 | 1014.4 | 1014.2 | 1013.5 | 1013.5 | 1013.0 | 1013.2 |
| 1981 | 1013.9 | 1013.3 | 1014.3 | 1012.3 | 1013.0 | 1014.2 | 1014.7 | 1013.4 | 1013.3 | 1012.5 | 1011.1 | 1012.6 |
| 1982 | 1013.6 | 1013.7 | 1013.5 | 1013.8 | 1013.4 | 1013.9 | 1014.2 | 1014.1 | 1013.2 | 1012.6 | 1012.0 | 1012.5 |
| 1983 | 1013.9 | 1014.1 | – | 1012.5 | 1011.9 | 1013.6 | 1013.8 | 1014.7 | 1013.7 | 1012.8 | 1013.9 | 1013.9 |
| 1984 | 1013.3 | 1013.5 | 1013.8 | 1014.3 | 1013.2 | 1013.7 | 1013.6 | 1013.8 | 1013.0 | 1012.3 | 1012.2 | 1012.1 |
| 1985 | 1013.9 | 1015.1 | 1013.4 | 1014.1 | 1013.7 | 1015.1 | 1014.5 | 1014.1 | 1012.5 | 1012.1 | 1012.0 | 1013.5 |
| 1986 | 1014.3 | 1014.0 | 1014.3 | 1013.5 | 1013.4 | 1014.3 | 1016.1 | 1013.5 | 1013.6 | 1013.2 | 1012.1 | 1014.1 |
| 1987 | – | 1014.1 | 1012.8 | 1013.2 | 1012.3 | 1014.3 | 1012.7 | 1013.0 | 1013.1 | 1012.0 | 1012.1 | 1013.1 |
| 1988 | 1013.9 | 1012.7 | 1014.8 | 1013.3 | 1013.9 | 1013.8 | 1014.6 | | | | | |

Table 7.4 Analysis data for economic evaluation

| | | | | |
|---|---|---|---|---|
| (1) | Unit installed capacity | kW | 5,700 | |
| (2) | Station power consumption | % | 3.0 | |
| (3) | Total delivered power | kW | 5,529 | (1) x (1-0.03) |
| (4) | Annual operating hours | hrs/Year | 6,132 | 24 x 365 x 0.7 |
| (5) | Annual delivered power | Gwh/Year | 33.9 | (3) x (4) |
| (6) | Total construction cost | Million US$ | 5.77 | |
| (7) | Construction cost per kW | US$ | 1,012 | (6)/(1) |
| (8) | Depreciation | US$/Year | 288,500 | (6)/20 |
| (9) | Number of operators | Person | 15 | |
| (10) | Salaries per head | US$/Year | 2,640 | 1G$=0.1US$<br>2200G$/monthx12x0.1 |
| (11) | Total salaries | US$ | 39,600 | (9) x (10) |
| (12) | Total fixed cost | US$ | 328,100 | (8) + (11) |
| (13) | Total fixed cost per kWh | US$/kWh | 0.00968 | (12)/(5) |
| (14) | Fuel price per liter | G$/liter | 1.33 | |
| (15) | Fuel price per liter | US$/liter | 0.133 | 1G$=0.1US$ |
| (16) | Specific gravity of fuel | | 0.860 | |
| (17) | Fuel price per kg | US$/kg | 0.155 | (15)/(16) |

| | | | | |
|---|---|---|---|---|
| (18) | Thermal efficiency | % | 43.0 | |
| (19) | Specific heat consumption | Kcal/kWh | 2,000 | 860/(18) |
| (20) | Calorific value of fuel | Kcal/kg | 10,300 | |
| (21) | Specific fuel consumption | kg/kWh | 0.194 | (19)/(20) |
| (22) | Fuel cost per kWh | US$/kWh | 0.03007 | (17) x (21) |
| (23) | Lub-oil price per liter | G$/liter | 18.4 | |
| (24) | Lub-oil price per liter | US$/liter | 1.84 | 1G$=0.1US$ |
| (25) | Specific gravity of lub-oil | | 0.9 | |
| (26) | Lub-oil price per kg | US$/kg | 2.044 | (24)/(25) |
| (27) | Specific lub-oil consumpiton per kWh | g/kWh | 1.25 | |
| (28) | Lub-oil cost per kWh | US$/kWh | 0.00256 | (26) x (27) x $10^{-3}$ |
| (29) | Variable maintenance cost | US$/kWh | 0.00385 | |
| (30) | Total operation cost per kWh | US$/kWh | 0.03648 | (22) + (28) + (29) |
| (31) | Unit cost per kWh | US$/kWh | 0.04616 | (13) + (30) |

Fig 7.1 Organization of Garden of Eden Pwer Station




Not : Numerals shows the

Number of personnel

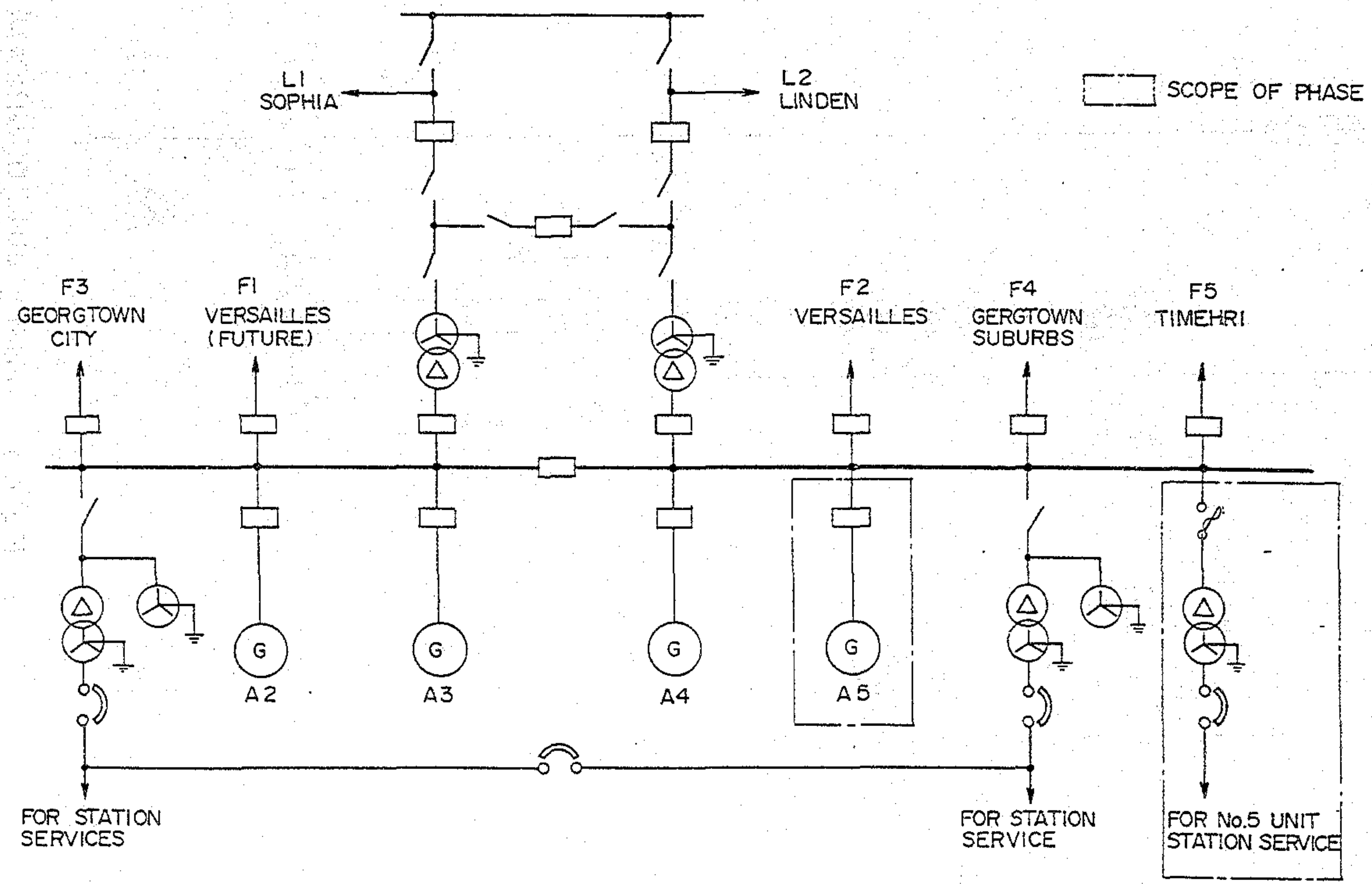



Fig. 7.2 MAIN ONE LINE DIAGRAM OF GARDEN OF EDEN

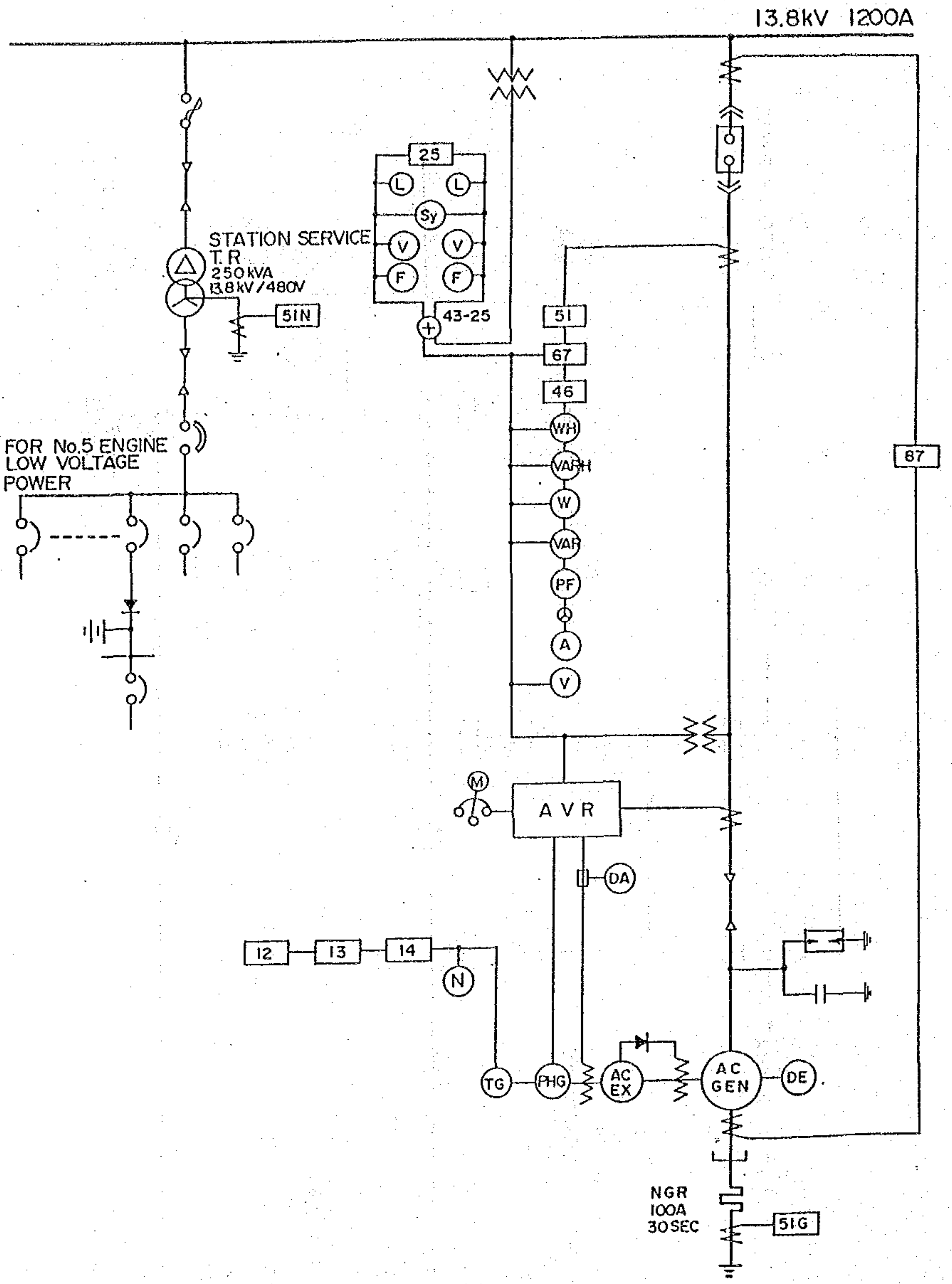



Fig. 7. 3 SINGLE LINE DIAGRAM OF GARDEN OF EDEN POWER STATION, No. 5 UNIT

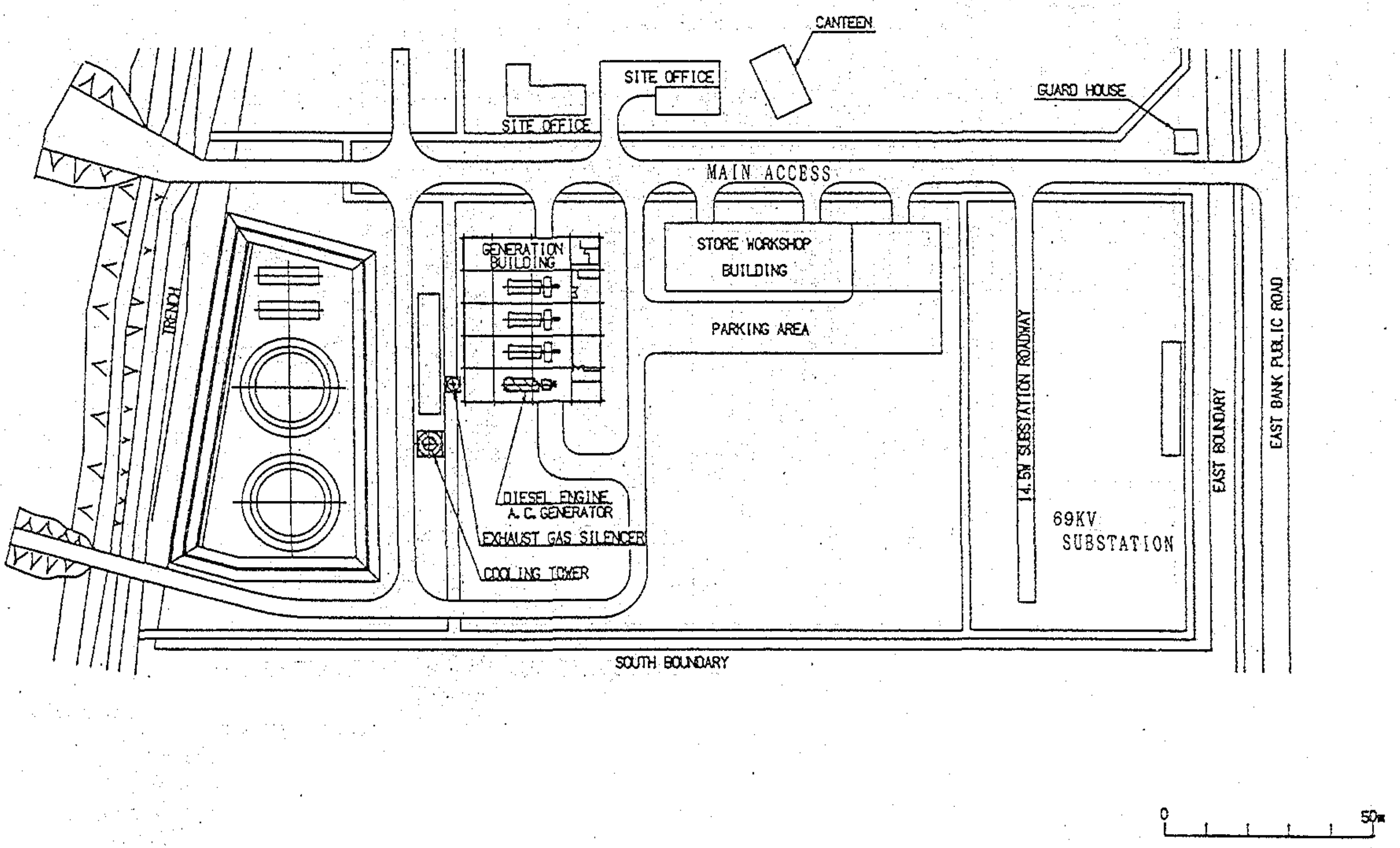



Fig 7.4 GENERAL LAYOUT(PLAN) GARDEN OF EDEN POWER STATION

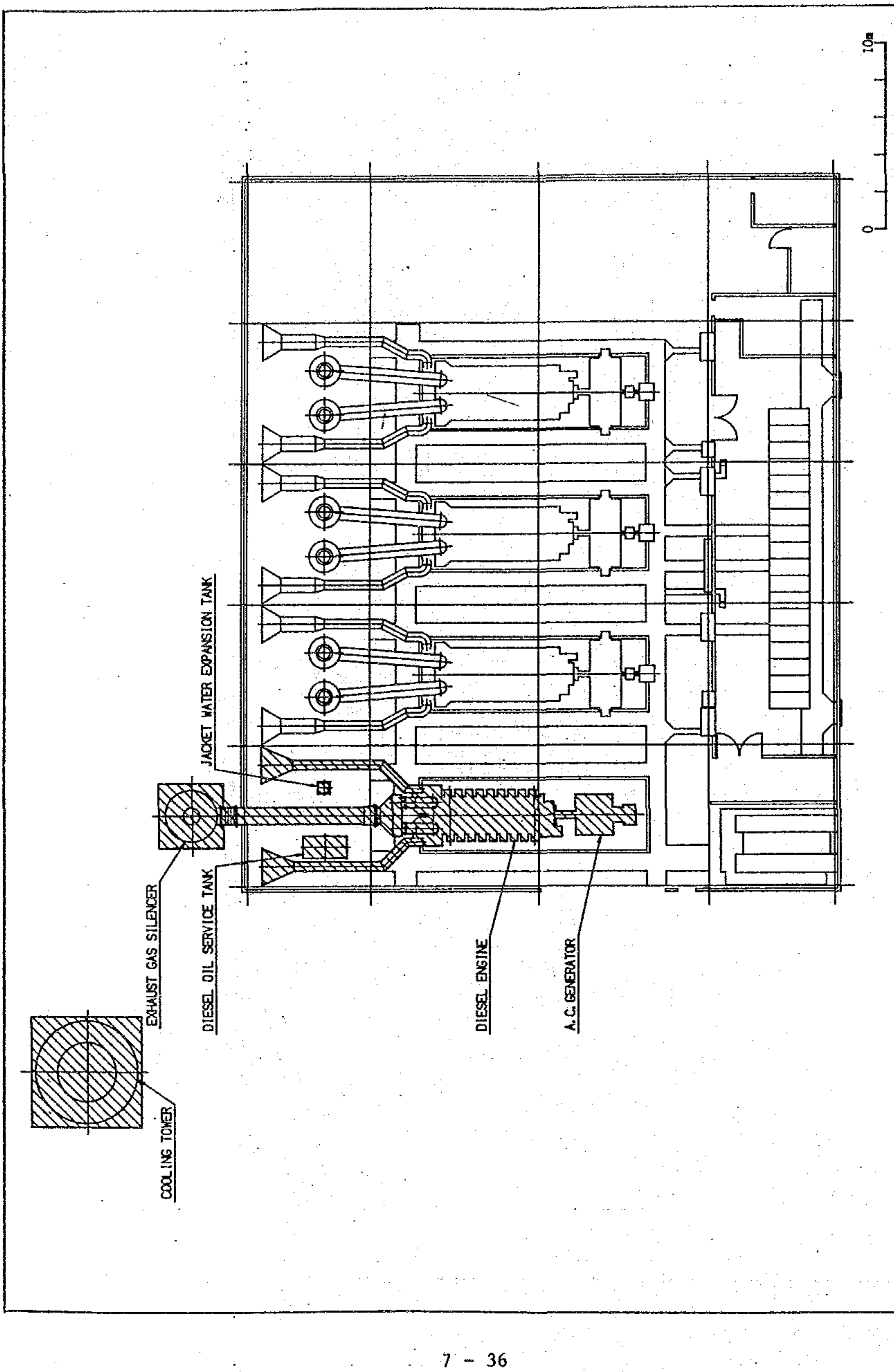



Fig 7.5 POWER HOUSE LAYOUT(PLAN) GARDEN OF EDEN POWER STATION

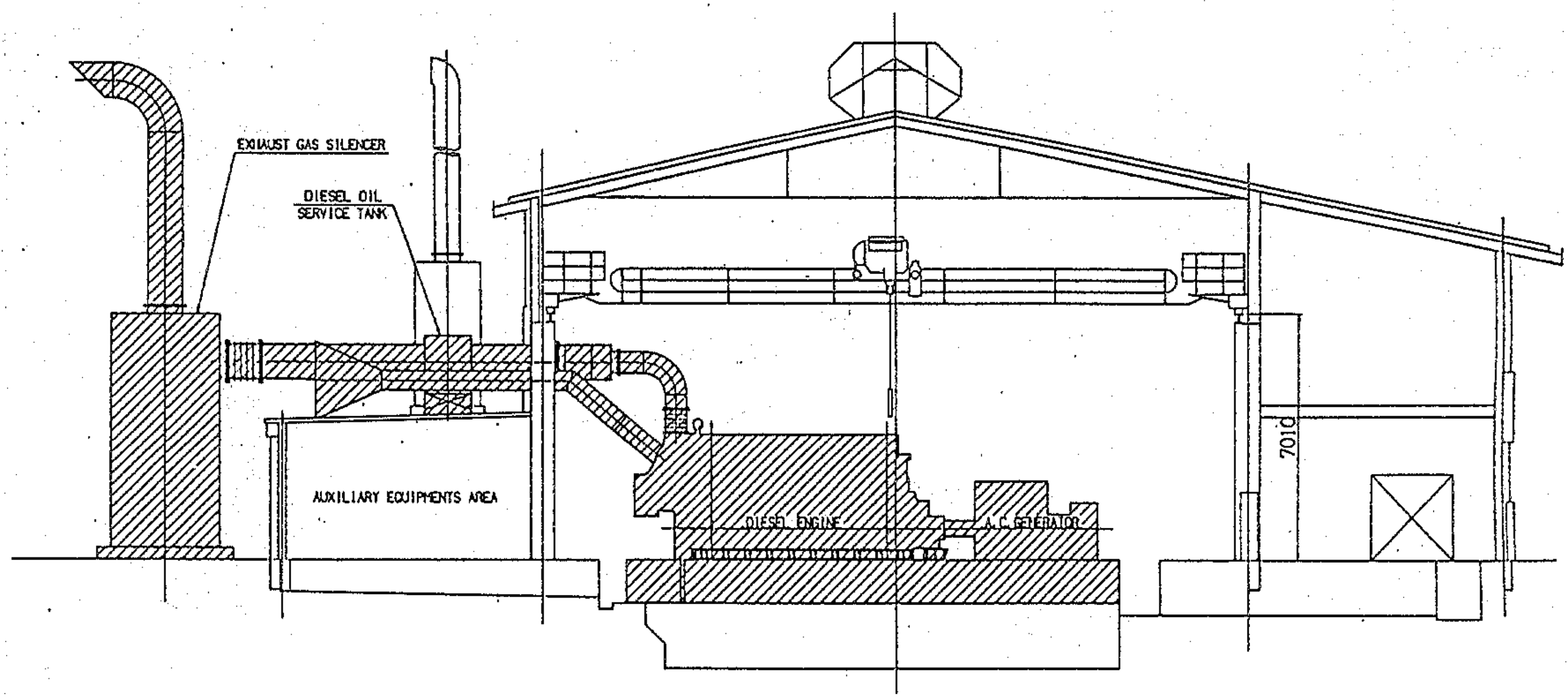



Fig 7.6 POWER HOUSE LAYOUT(SECTION)
GARDEN OF EDEN POWER STATION

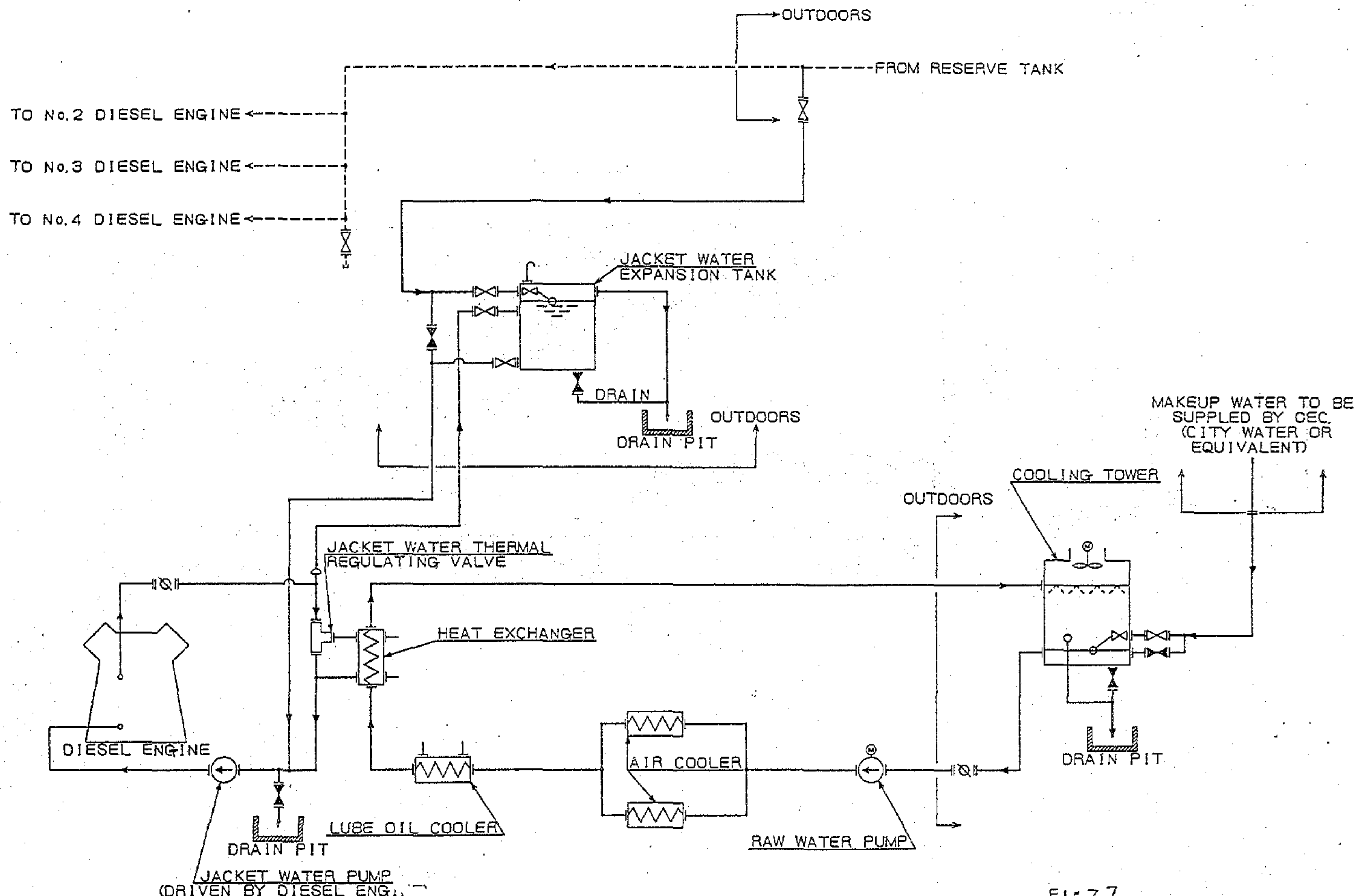



Fig.7.7
SCHEMATIC PIPING DIAGRAM
COOLING WATER SYSTEM
FOR No.5 UNIT OF
GARDEN OF EDEN POWER STATION

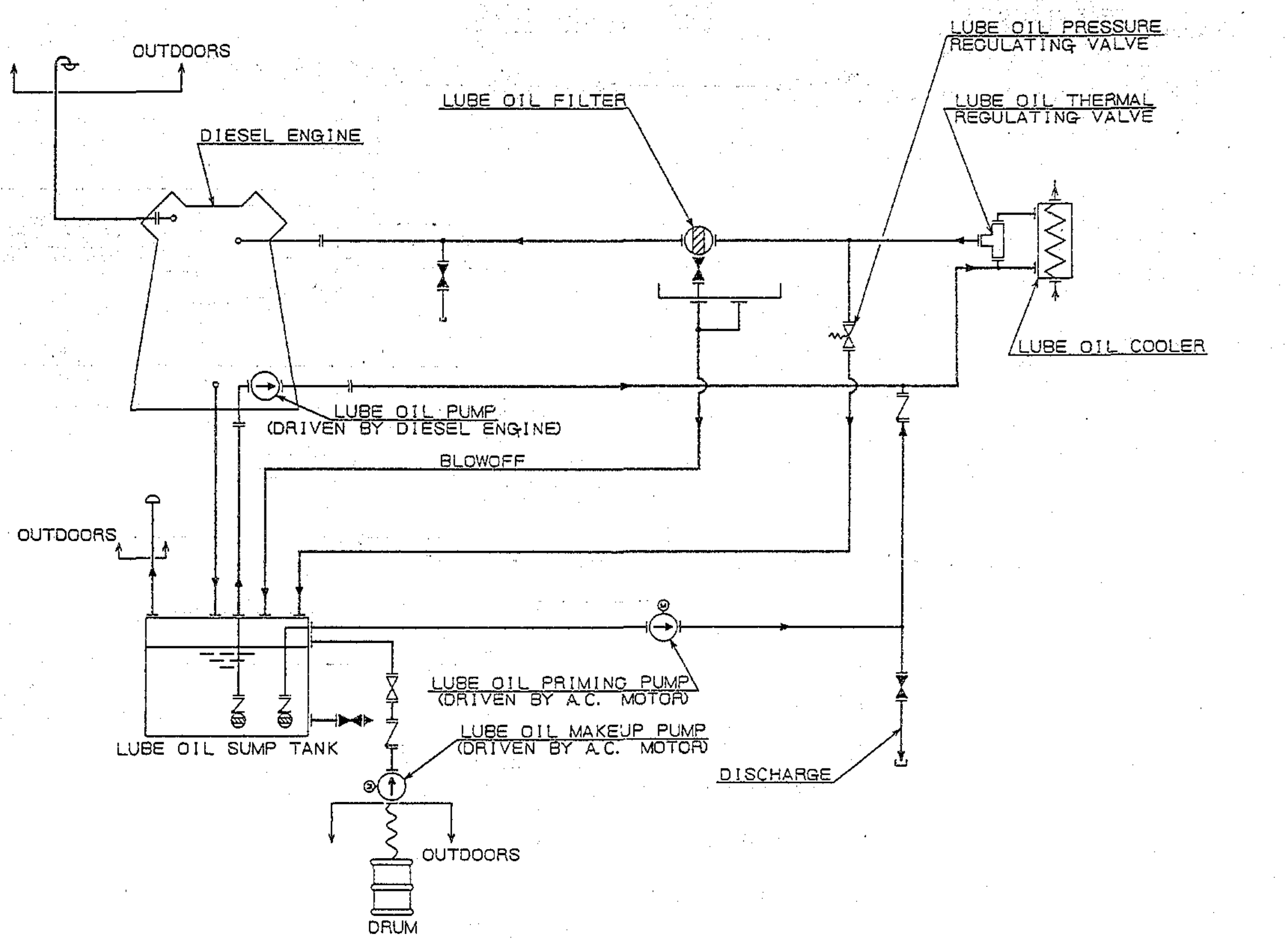



FIG. 7.8
SCHEMATIC PIPING DIAGRAM
LUBE OIL SYSTEM
FOR No.5 UNIT OF
GARDEN OF EDEN POWER STATION

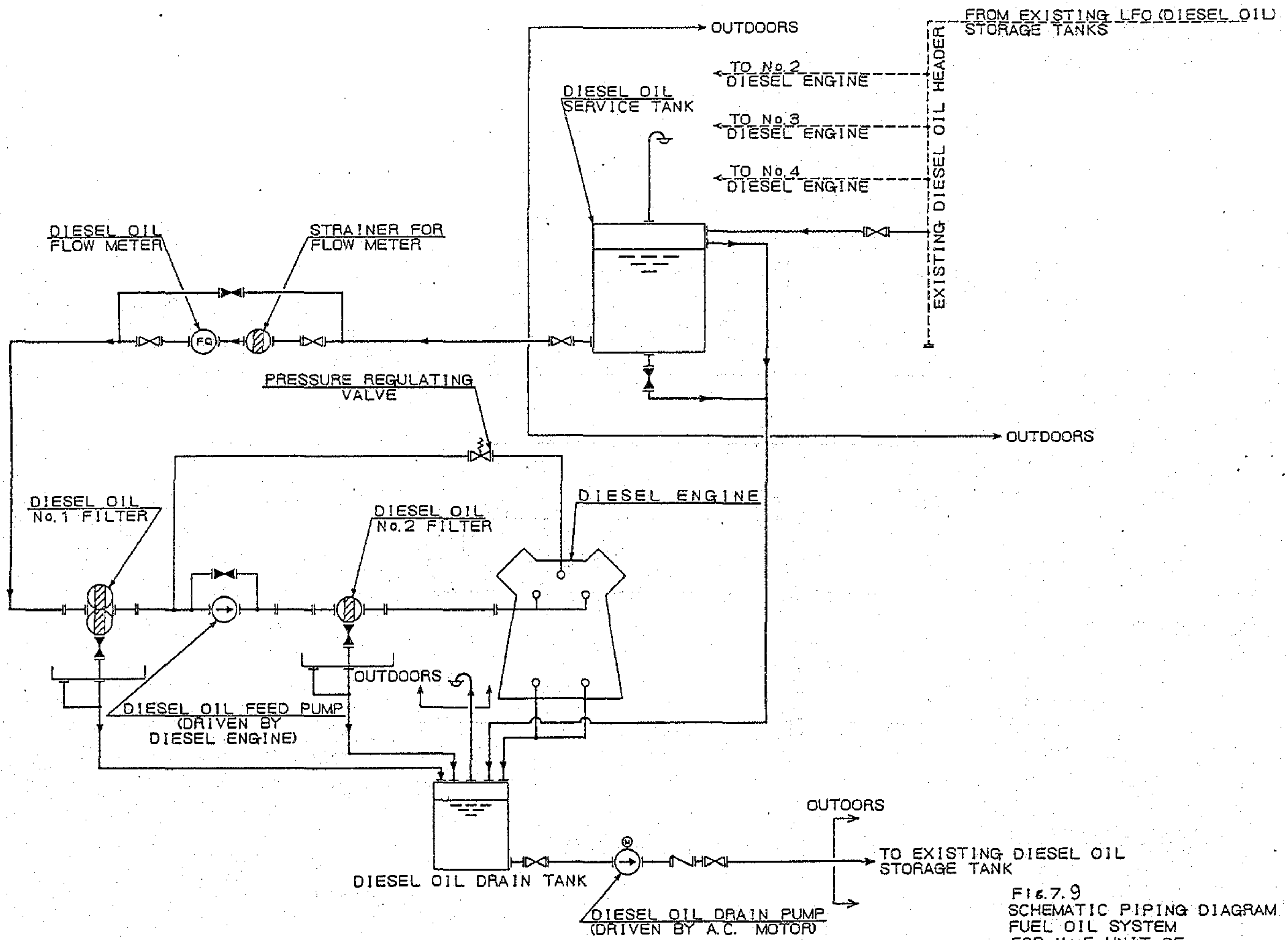



Fig.7.9
SCHEMATIC PIPING DIAGRAM
FUEL OIL SYSTEM
FOR No.5 UNIT OF
GARDEN OF EDE[illegible] POWER STATION

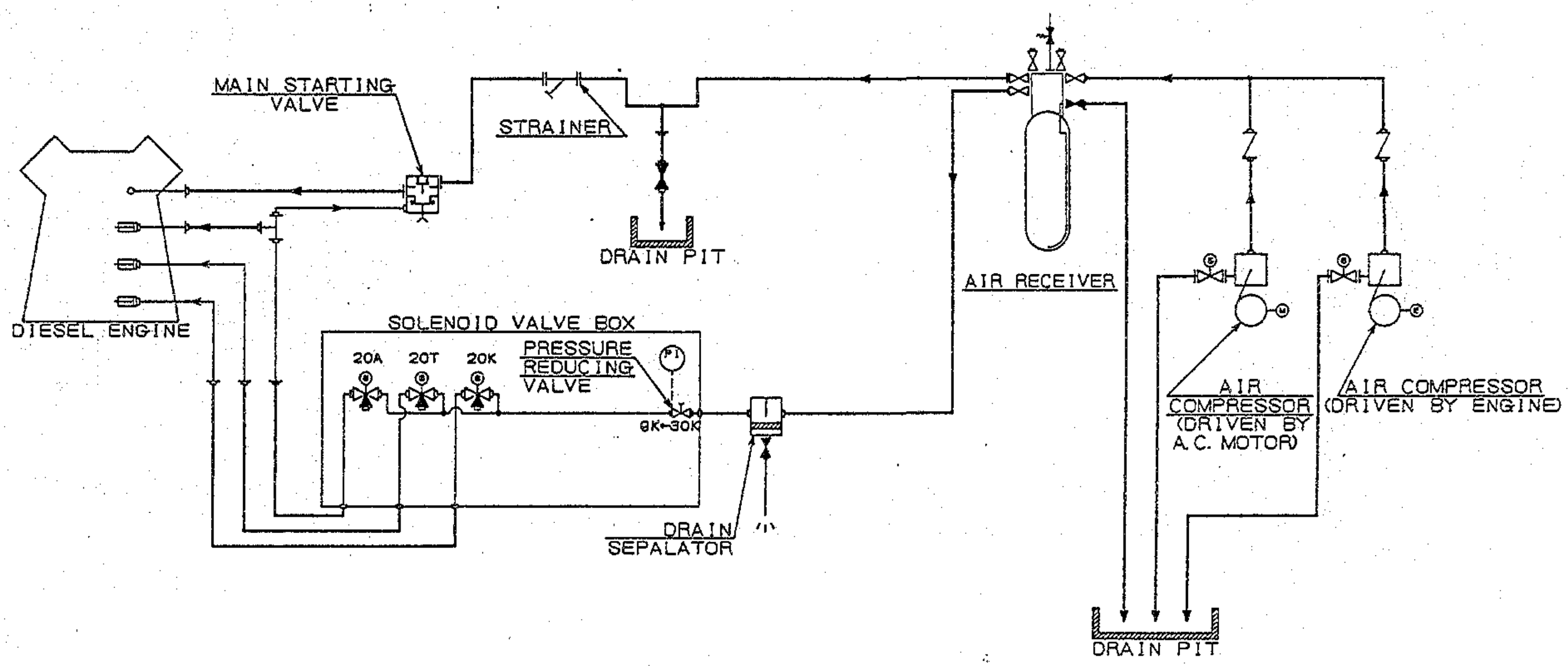



Fig.7.10
SCHEMATIC PIPING DIAGRAM
STARTING AIR SYSTEM
FOR No.5 UNIT OF
GARDEN OF EDEN POWER STATION

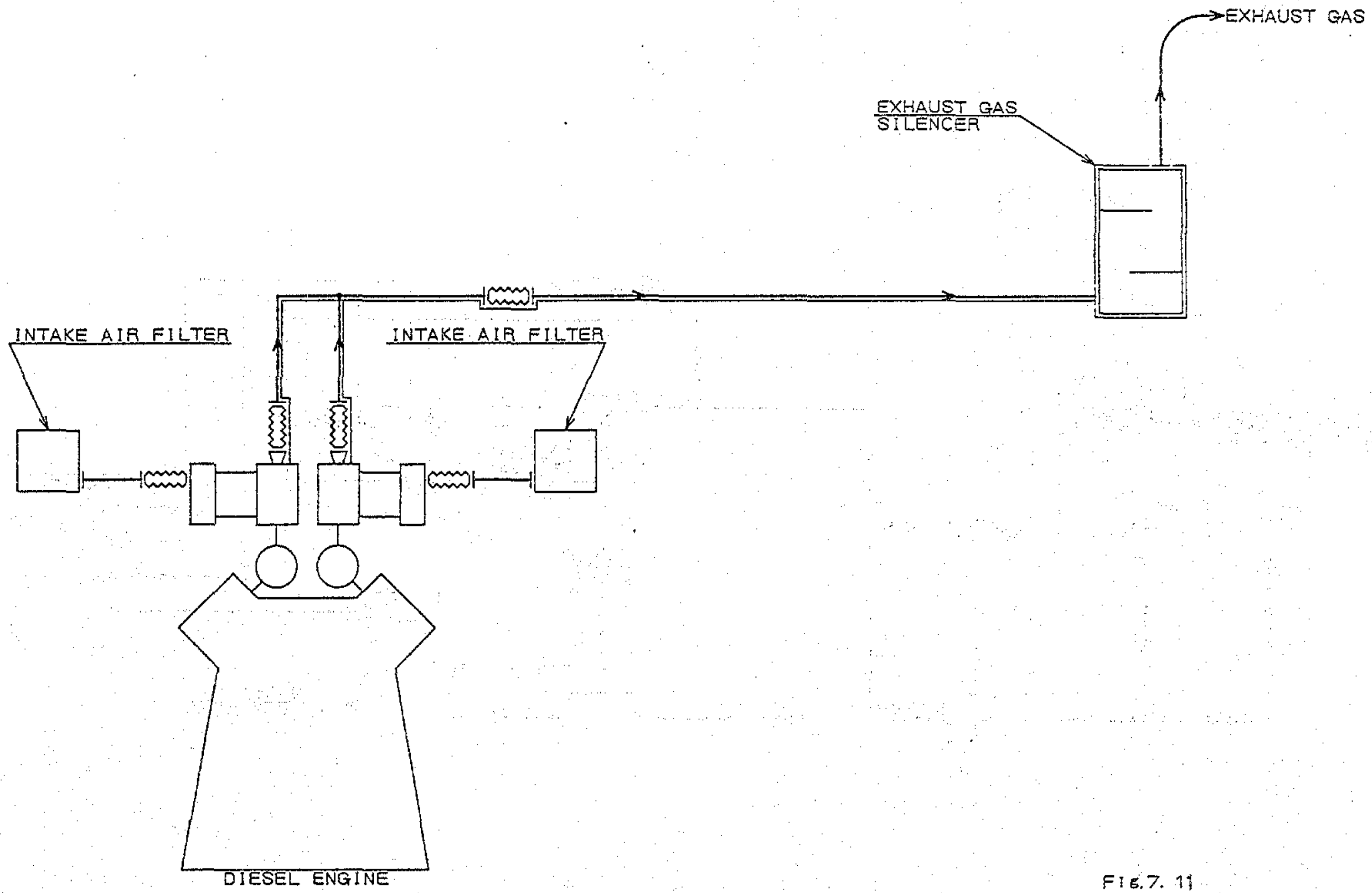



Fig.7. 11
SCHEMATIC PIPING DIAGRAM
EXHAUST GAS
INTAKE & AIR SYSTEM
FOR No.5 UNIT OF
GARDEN OF EDEN POWER STATION

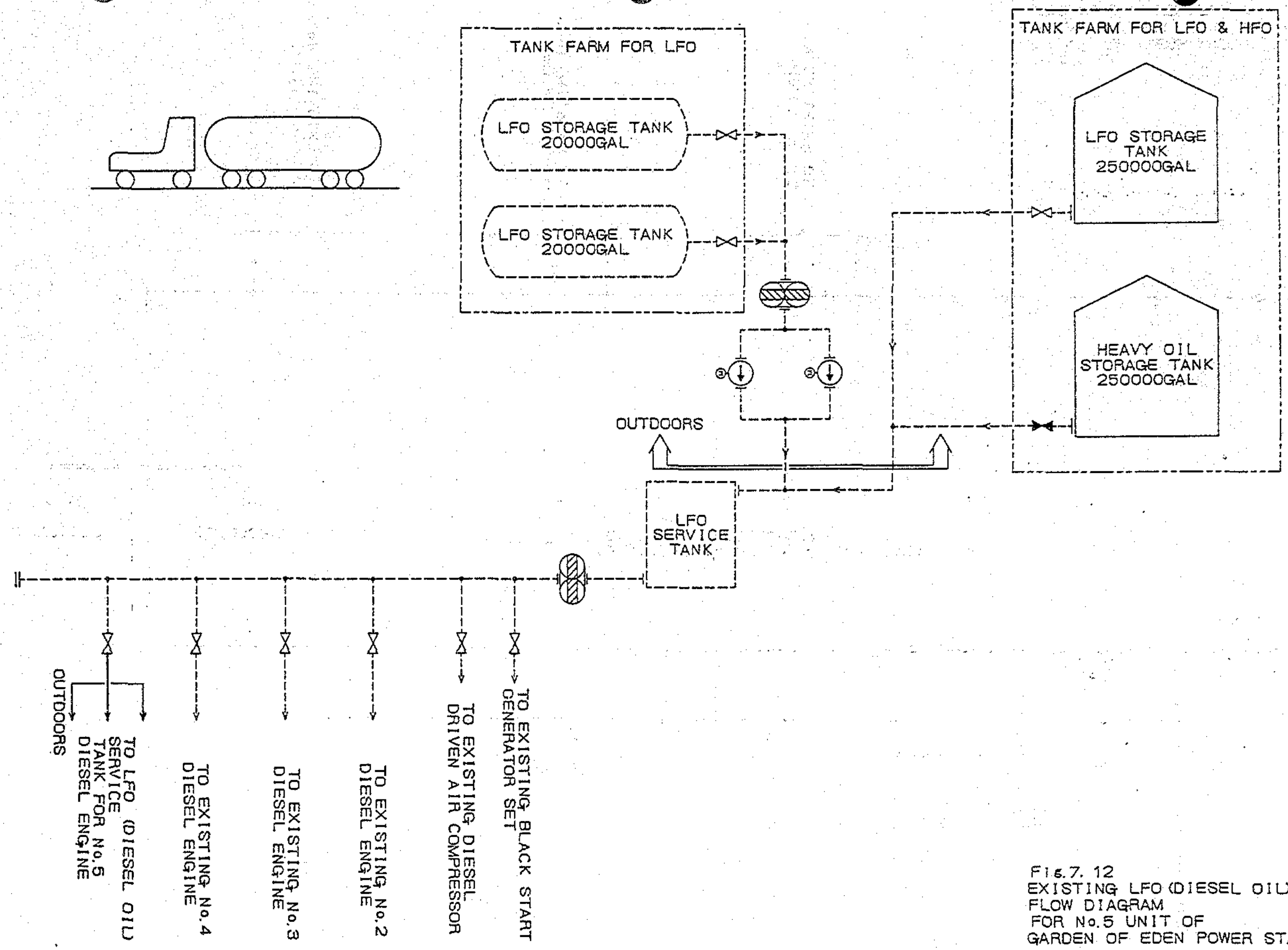



Fig.7. 12
EXISTING LFO (DIESEL OIL)
FLOW DIAGRAM
FOR No.5 UNIT OF
GARDEN OF EDEN POWER STATION

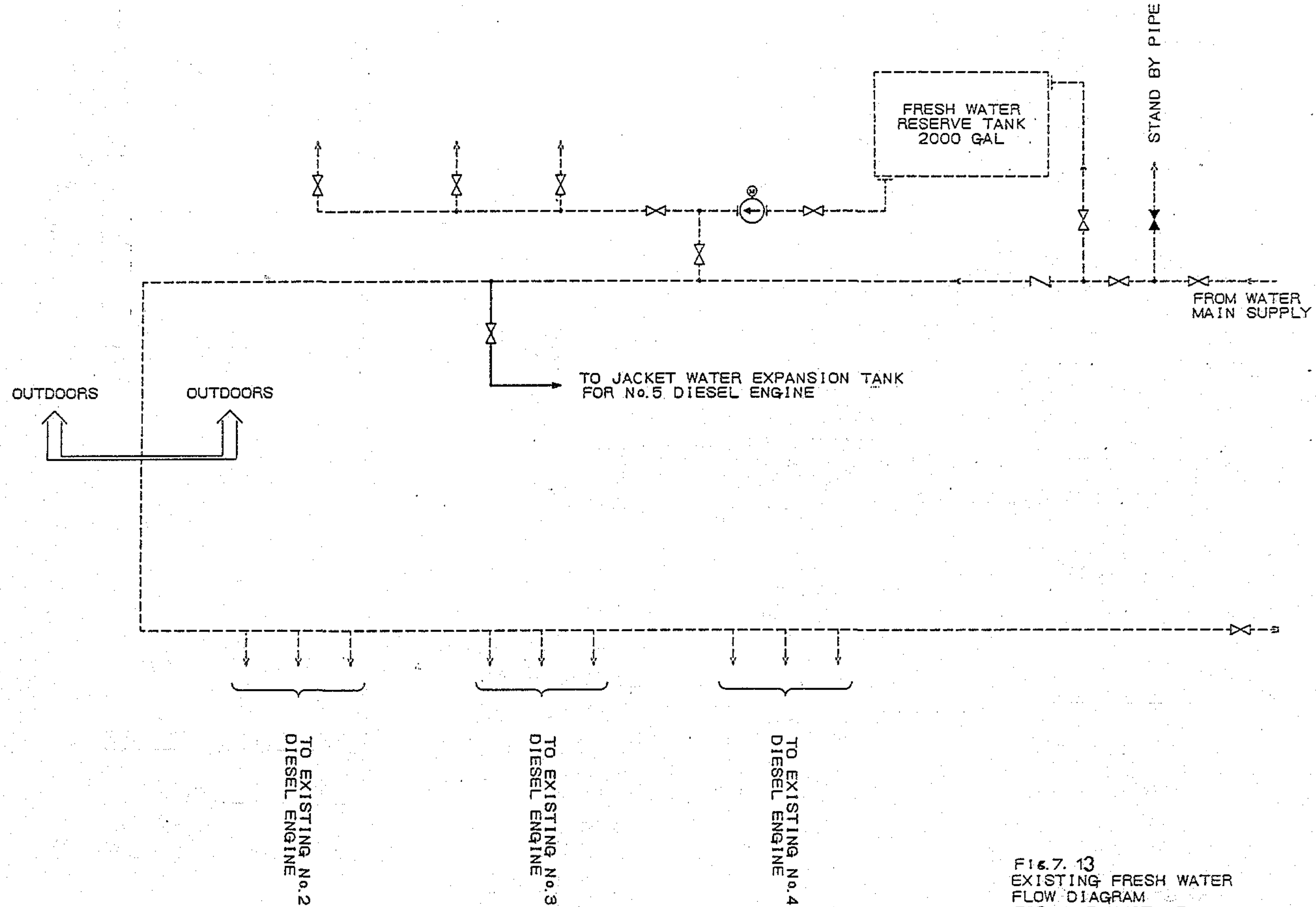
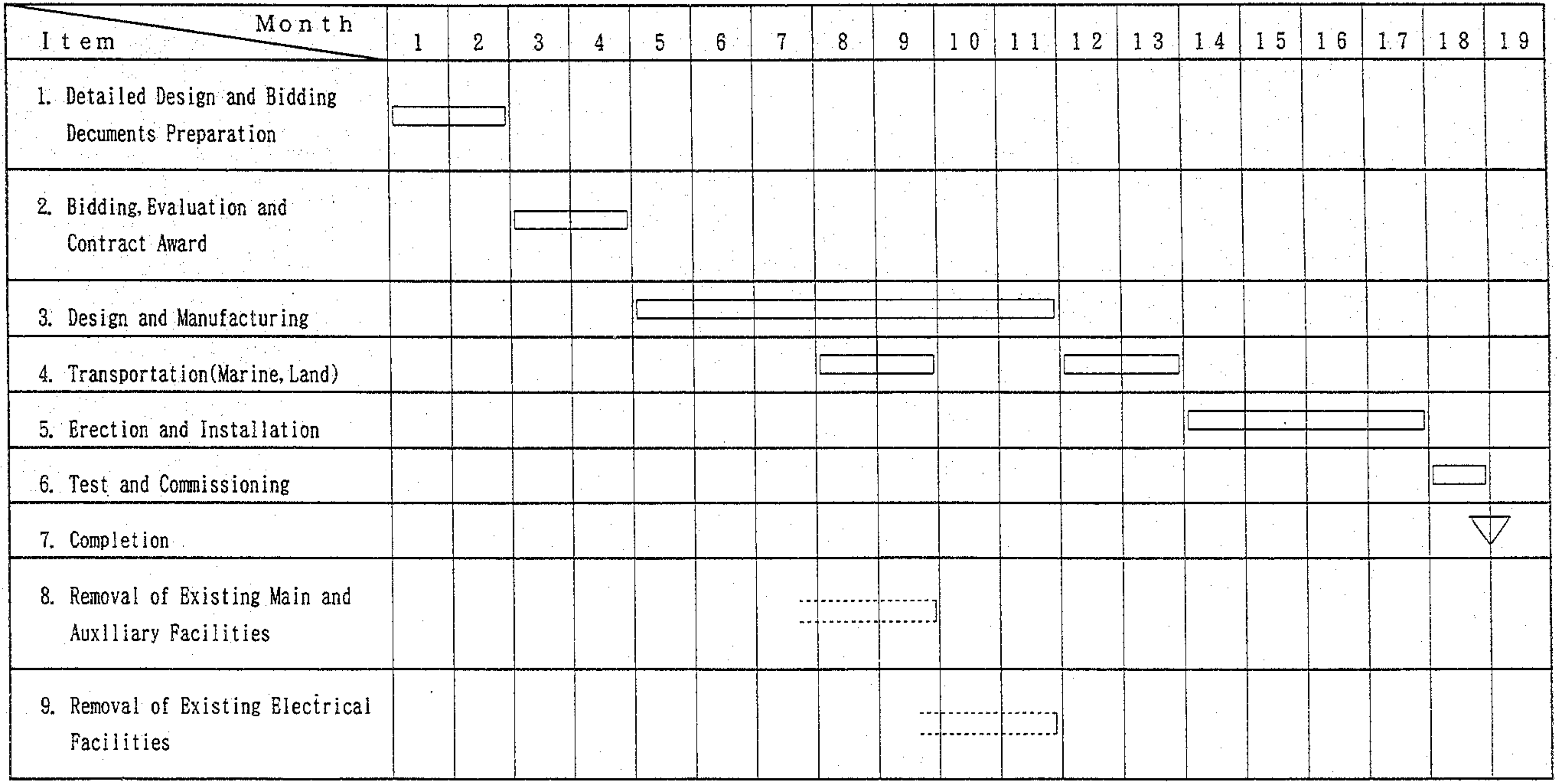



Fig.7. 13
EXISTING FRESH WATER
FLOW DIAGRAM
FOR No.5 UNIT OF
GARDEN OF EDE POWER STATION

Fig 7.14 IMPLEMENTATION SCHEDULE



# CHAPTER 8

# NEW THERMAL POWER STATION DEVELOPMENT PROGRAM

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## 8.1 OBJECTIVE

The objective of this New Thermal Power Plant Development Program is to construct new thermal power station, to add new generating units to existing thermal power stations, and replace decommissioned units in thermal power stations of GEC, according to the Power Supply Enhancement Plan of Chapter 6, so that the supply shortage is eliminated, adequate reserve capacity is maintained, and new power demands are met, thereby realizing stable supply of electric power which is essential to stabilizing people's living standard and vitalizing industry.

## 8.2 OUTLINE OF PROGRAM

The general plan for construction of a new power plant, addition of generating units to existing power plants, and replacement of generating units to be decommissioned, consists of specific programs described below. The request for grant aid has already been submitted by the Government of Guyana to the Government of Japan for replacement of one generating unit out of two 5.7 MW units in Garden of Eden Power Station as described in Chapter 7, Replacement program Garden of Eden Power Station.

(1) Addition to Onverwagt Power Station under contingency measures for reinforce power supply

An additional capacity of 7.8 MW (consisting of 2.6 MW unit x 3) will be installed at Onverwagt Power Station with the objective of urgently reinforcing power supply capacity to overcome current supply shortage. To install these new generating units, the existing generating equipment (1MW x 4) will be removed, and high speed (900 RPM) diesel generators of the largest capacity which can utilize the existing foundations will be installed.

(2) Construction of New Kingston Power Station as major thermal power supply

New Kingston Thermal Power Plant, with total output of 52 MW, will be constructed at the site of old Kingston "A" Power Station. This new power station will have the role of major power station in Demerara Power System to supply base load by replacing Kingston "B" Power Station to be decommissioned.

New Kingston Power Station will be equipped with low speed diesel engines operating on fuel oil only and 60 Hz rating generators. Two 13 MW units will be installed in 1993, and other two 13 MW units in 1995. As this power station will supply power to Georgetown District at 60 Hz, the commercial frequency in Georgetown must be unified to 60 Hz by the time this power station is completed.

(3) Replacement of generating units corresponding to decommissioning of units

The generating units in the existing power station will be decommissioned one by one as the equipment life expires, and will be replaced by generating units of same capacity, according to Chapter 6, Power Supply Enhancement Plan. According to this Plan, all generating units of power stations except Versailles and Onverwagt will be replaced.

## 8.3 ADDITION OF GENERATING UNIT TO ONVERWAGT POWER STATION

### 8.3.1 Objective of project

Generating units having a total capacity of 7.8 MW (2.6 MW x 3) will be installed at Onverwagt Power Station in 1991 in order to urgently solve the shortage of power supply in Berbice Power System. The existing units ( 1 MW x 4) will be dismantled, and high speed (900 RPM) diesel units, having the largest capacity that utilize the existing foundation, will be installed. The equipment in the existing 69 kV outdoor switch yard will be utilized in order to make the project economical.

### 8.8.2 Current status of Onverwagt Power Station

Onverwagt Power Station is a diesel power station in Berbice Power System, located approximately 80 km to the east of Georgetown. The existing generating facility consists of 5 diesel generator units, with a total plant capacity of 6.5 MW (1.0 MW x 4, 2.5 MW x 1). No. 1, No. 2 and No. 4 Units were commissioned in 1973, No. 3 Unit in 1980, and No. 5 Unit in 1981.

(1) Current condition of facilities

During the period from 1979 to 1986, all of No. 1, No. 2, No. 3 and No. 4 Units (each having 1.0 MW rating) have become inoperable by failure of crank shaft. In 1988, No. 5 Unit (2.5 MW rating) failed due to damage of turbo charger, leaving no operable unit in the power station. Of these units, only No. 5 Unit can be repaired by the Rehabilitation Plan.

Diesel Generator Specification (No. 5 Unit)

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|---|---|
| Manufacturer: | GM of USA |
| Type: | Single stroke, 2 cycle, water cooled, turbo-charged type with charged air cooler. |
| Output: | 3,600 HP (3,650 PS) |
| Speed: | 900 RPM |

Generator Specification

| | |
|---|---|
| Manufacturer: | GM of USA |
| Type: | 3-phase, AC synchronous generator |
| Capacity: | 3,250 kVA (output; 2,500 kW) |
| Frequency: | 60 Hz |
| Voltage: | 4.16 kV |

(2) Power station facilities

This power station has a land area of 8,200 $m^2$, where the following facilities are located.

1) Power plant building (approximately 685 $m^2$)

Five diesel generator units, a control room, a cubicle room, etc. are accommodated in this building.

2) Outdoor switch yard (approximately 3.670 $m^2$)

One main transformer (69/13.8 kV, 16.7 MVA) and 69 kV switchgears are linstalled.

3) Fuel storage tank

Three, 90 kl tanks and two, 20 kl tanks are installed (with total storage capacity of 310 kl according to BEI Report), which will be utilized in this project.