No.

BASIC DESIGN STUDY REPORT
ON
THE PROJECT
FOR THE UPGRADING AND EXTENSION OF
ELECTRICITY SUPPLY FACILITIES IN PHNOM PENH
IN
THE KINGDOM OF CAMBODIA

SEPTEMBER 2004

JAPAN INTERNATIONAL COOPERATION AGENCY

YACHIYO ENGINEERING CO., LTD.

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PREFACE

In response to a request from the Government of the Kingdom of Cambodia, the Government of Japan decided to conduct a basic design study on the Project for the Upgrading and Extension of Electricity Supply Facilities in Phnom Penh in the Kingdom of Cambodia and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Cambodia a study team from March 7 to April 10, 2004.

The team held discussions with the officials concerned of the Government of Cambodia, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Cambodia in order to discuss a draft basic design, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Cambodia for their close cooperation extended to the teams.

September, 2004

Kazuhisa Matsuoka
Vice-President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

September, 2004

We are pleased to submit to you the basic design study report on the Project for the Upgrading and Extension of Electricity Supply Facilities in Phnom Penh in the Kingdom of Cambodia.

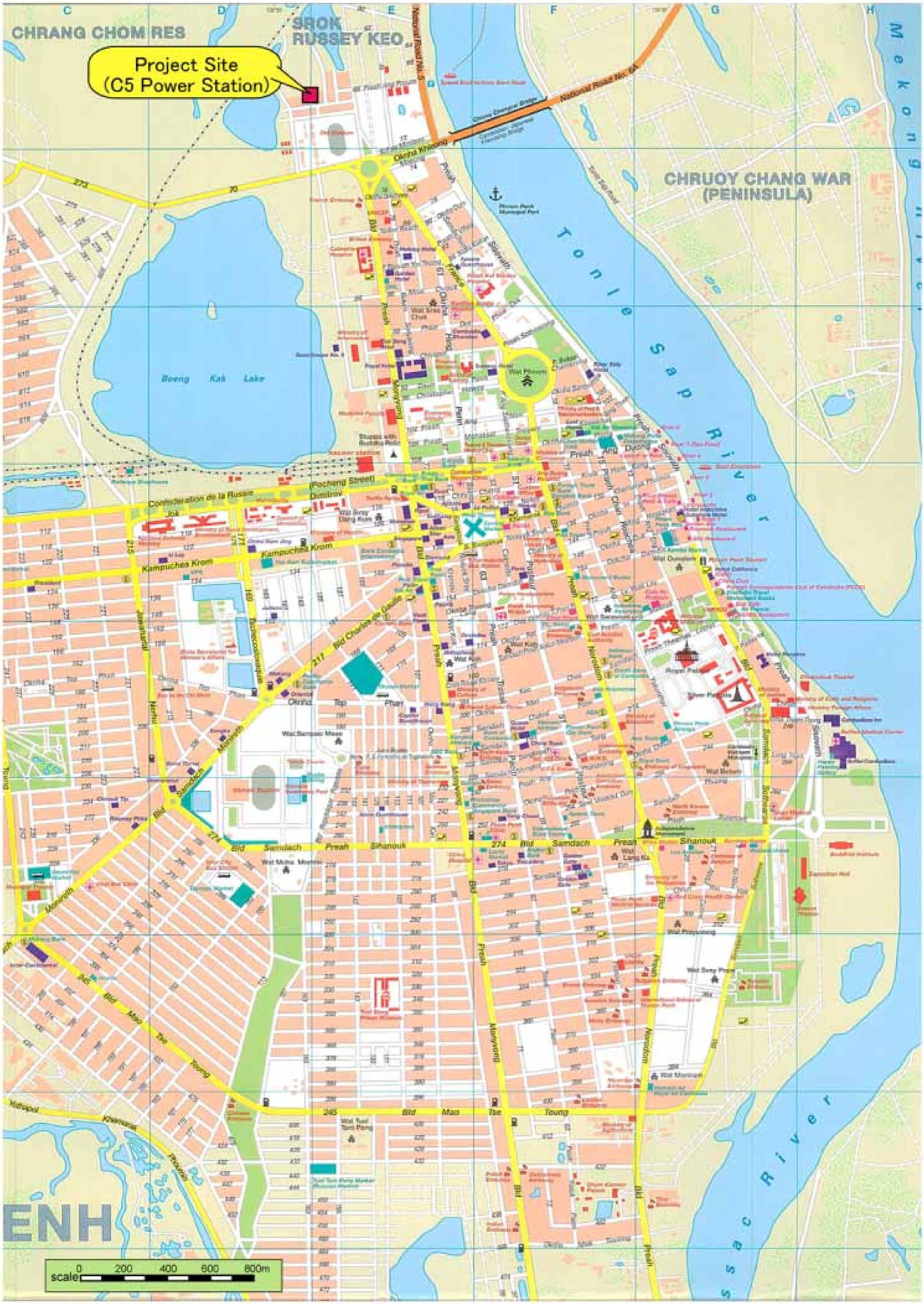
This study was conducted by Yachiyo Engineering Co., Ltd., under a contract to JICA, during the period from March, 2004 to September, 2004. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Cambodia and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

Noritsune Chiba
Project Manager,
Basic design study team on the Project for
the Upgrading and Extension of Electricity
Supply Facilities in Phnom Penh
in the Kingdom of Cambodia
Yachiyo Engineering Co., Ltd.

Location Map of the Kingdom of Cambodia



Location Map of the Project Site

LIST OF FIGURES AND TABLES

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
AFD	Agence Francaise de Development
AIJ	Architectural Institute in Japan
CESS	Cambodia Energy Sector Strategy
CPSS	Cambodia Power Sector Strategy
DEG	Diesel Engine Generator
EAC	Electricity Authority of Cambodia
EDC	Electricité du Cambodge
EDF	Electricité du France
EIA	Environmental Impact Assessment
IEIA	Initial Environmental Impact Assessment
E/N	Exchange of Notes
GDP	Gross Domestic Product
GNP	Gross National Product
IEC	International Electrotechnical Commission
IPP	Independent Power Producer
ISO	International Organization for Standardization
JEAC	Japan Electric Association Code
JEC	Japanese Electrotechnical Committee
JEM	Standards of Japan Electrical Manufacturer's Association
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
MD	Minutes of Discussion
MEF	Ministry of Economy and Finance
MIME	Ministry of Industry, Mines and Energy
MOE	Ministry of Environment
ODA	Official Development Assistance
OJT	On the Job Training
O&M	Operation and Maintenance
PRSP	Poverty Reduction Strategy Paper
SEDP	Socio Economic Development Plan
UNTAC	United Nations Transmission Authority in Cambodia
WB	World Bank

SUMMARY

SUMMARY

The Kingdom of Cambodia (hereinafter referred to as "Cambodia") is located on the southern Indochina Peninsula between 13º north latitude and 105º east longitude and faces Laos to the north, Vietnam to the east, Thailand to the west and the Gulf of Thailand to the south. The population of Cambodia is approximately 13.8 million (FY2002). Its land area is approximately 181,000km^2 and GDP per capita is US$291 (FY2002).

A civil war ended with the conclusion of the Paris Peace Treaty in October 1991 and Cambodia has moved toward political stability through the general election held under the supervision of the Untied Nations Transitional Authority in Cambodia (UNTAC) in May 1993. During the same period, the economic system has also been shifted from a state-planned economy to a free economy. Accordingly, the Constitution of the Kingdom of Cambodia enacted in September 1993 specifies that a free economy is to be promoted.

The Cambodian electric power supply system is operated by the state-run *Electricite du Cambodge* (EDC) owned by the Cambodian Ministry of Industry, Mines and Energy (MIME) and the Ministry of Economy and Finance (MEF), and EDC is responsible for power services in seven (7) regions, including Phnom Penh. Since most of the Cambodian electric power network was destroyed during the long-pending civil war, domestically electric power is supplied to only 13% of total households and annual power consumption is 35kWh per person which is the lowest level in Southeast Asia.

Due to political and financial restrictions in Cambodia, a centralized power supply system based on large-scale hydraulic power and thermal power facilities cannot be planned and constructed. Instead, in order to support vital economic growth and reconstruction after civil war, small scale expensive-to-run diesel engine generator facilities have been constructed. The total generating capacity in Cambodia was 157MW (FY2002), approximately 90% (138MW) of the facilities were installed in the capital, Phnom Penh. Among them, the generating facilities of independent power producers (IPPs) counted for approximately 52% (72MW) of the city's total generating capacity, which is high. Utilization of such small-scale power facilities, the high fuel cost for diesel engines and high cost of electric power from IPPs (7.7 to 14.2 ¥/kWh) has forced the unit price of electricity in Cambodia to the highest level in Asia, which seems to be one of the factors to hinder the economic growth Cambodia.

On the other hand, in line with Phnom Penh's rapid economic growth, an annual increase in power demand of 12% is anticipated. As of April 2004, due to a shortage of generating power capacity there have been planned scheduled power outages on a scale of about 10MW per day

in areas around Phnom Penh. Although the Cambodia Energy Sector Strategy (CESS) made by MIME in 1999 formulated a plan to develop hydraulic power plants or combined cycle thermal power plants, those plans were substantially or actually suspended after the F/S survey, therefore, there has been an urgent need for power sources to cover current power demands. Consequently, a plan to construct diesel engine generating stations in Phnom Penh in very near future has been acknowledged in the 2004 Revision of CESS as an emergency measure.

Although the Government of Cambodia deems the recovery of the above-mentioned shortage of generating facilities and a reduction of generation cost to be an urgent task, due to a lack of ability, experience and funding, it would be difficult to construct such facilities by their own efforts. As an assistance for emergency measures in the power generation plans demonstrated in the CESS, they have requested a grant aid from the Government of Japan for "New Installation of 10MW Heavy Oil Diesel Engine Generators (5MW × 2 units) at the C5 Power Station" and "Fuel System Conversion to cheaper Heavy Oil for Existing Generating Equipment at the C5 Power Station".

In response to this request, the Government of Japan decided to conduct the Basic Design Study and the Japan International Cooperation Agency (JICA) sent the Basic Design Study Team to Cambodia from March 7th to April 10th 2004 to confirm and discuss the contents of the request with Cambodian government officials, to carry out a project site survey and gather relevant information and data.

After their return to Japan, the Study Team examined the necessity, socio-economic effects and viability of the Project and compiled a basic design and optimal implementation plan in a draft final report. Based on these results, the JICA sent the Study Team to Cambodia again from July 11th to July 20th 2004 to explain the draft final report of the Basic Design.

As the result of the study, the scope of the requested Japanese assistance is determined to cover all contents of the requested items, including procurement and installation of materials and equipment related to "New Installation of 10MW Heavy Oil Diesel Engine Generators (5MW × 2 units) at the C5 Power Station" and "Fuel System Conversion to cheaper Heavy Oil for Existing Generating Equipment at the C5 Power Station", as well as technical transfer (soft component) of the operation and maintenance of heavy oil fired diesel engine generators.

The following is the summary of the compiled Basic Design based on the field survey and results of discussions made with the Cambodia side.

Basic Design Overview

Plan Classification	Fuel Conversion of Existing Units (Ph-1)	New Installation (Ph-2)
Target	Existing C5 power station (existing No. 1 & No. 2 units)	Existing C5 power station (New No. 3 & No. 4 units)
Procurement of Generating Facilities and Installation Work	1. Procurement of equipment related to diesel engine generating units (output 5 MW × 2 units) for fuel conversion of existing equipment and installation work 2. Procurement of mechanical auxiliary equipment necessary for relevant facilities and installation work (1) Remodeling of two existing diesel oil storage tanks into those for heavy oil storage (2) Newly installation of diesel oil storage tanks (3) Newly installation of heavy oil handling & transfer facility (4) Newly installation of heavy oil heaters & heat installation system (5) Remolding of air exhaust system (6) Renewal of sludge treatment system (7) Remodeling of bearing temperature measuring instrument (8) Remolding of piping system 3. Procurement of electrical auxiliary equipment necessary for relevant facilities and installation work (1) Newly installation of common alarm panel (2) Newly installation of station service common power board (3) Upgrading of 400 low- voltage power equipment (4) Upgrading of remote supervisory control panels (5) Upgrading of existing 400V low-voltage power panel (6) Wiring and grounding materials (7) House building facilities 4. Remodeling of electrical room and procurement of auxiliary equipment 5. Extension of exhaust gas stack (H 12m→16m) 6. Procurement of spare parts for generating facilities and auxiliary facilities 7. Procurement of operation and maintenance manuals (including teaching materials for OJT) of generating facilities and implementation of soft component	1. Procurement of diesel engine generating facilities (output of 5MW × 2 units) and installation work 2. Procurement of mechanical auxiliary equipment necessary for relevant facilities and installation work (1) Fuel oil system (2) Lubricating oil system (3) Cooling water system (4) Compressed air system (5) Air intake & exhaust gas system (6) Piping system 3. Procurement of electrical auxiliary equipment necessary for the relevant facilities (1) 22 kV high-voltage distribution panel (2) 6.3/22kVstep-up transformer (3) 22/0.4kV station service transformer (4) 400 V low-voltage power system (5) Remote supervisory, control & relay panel (6) Wiring & grounding materials (7) Additional installation of lighting equipment and remodeling of fire alarm system 4. Procurement of 22kV wiring equipment and materials and installation (1) Cable laying between C5 & C6 power stations （Approx. 300 m × 1 circuit） (2) Cable remodeling between C6 and GS-1 （Approx. 60 m × 2 circuits） 5. Procurement of spare parts and maintenance tools for generating facilities and auxiliary facilities 6. Procurement of operation and maintenance manuals (including teaching materials for OJT) of generating facilities and implementation of soft component

Should the Project be implemented under the grant aid scheme of the Government of Japan, the total project cost is estimated to be approximately ¥1,740 million (Japanese portion: approximately ¥1,734 million and Cambodian portion: approximately ¥6 million). Of those, the Cambodian side will be responsible for cleaning and arrangements at power stations necessary for fuel conversion work and additional installation of generators including the inside cleaning of diesel oil tanks and securing of access roads. The total project implementation period are estimated to be fifteen and half (15.5 months) for fuel conversion work and nineteen (19) months for new installation work (5MW × 2 units) respectively.

Following the completion of the Project, the EDC will conduct the operation and maintenance of the facilities and equipment. Although the EDC has basic knowledge on diesel oil fired diesel engine generators, they are considered to be unfamiliar with technologies related to operation and maintenance using heavy oil. If technologies necessary for operation and maintenance associated with fuel conversion under the Project are transferred through the soft component and OJT, appropriate equipment maintenance can be implemented after the completion of the Project.

Meanwhile, approximately 1.1 million residents of Phnom Penh will benefit from the Project. By implementing the Project, the total generating capacity will become 116MW against a peak power load of 114.6MW (estimated), thus, it will become possible to ensure 1.4MW reserve margin in the target year (2007). In addition, by utilizing cheap heavy oil as fuel for both existing units and new units in the C5 power station, generation cost will be reduced by ¥3.3/kWh (in the case of 50% of the utilization factor). As a consequence, a more stable electric power supply can be achieved, contributing to Cambodia's economic recovery and improving living standards. It is also expected to have a substantial effect in stabilizing operations at social, welfare and public facilities. Accordingly, the implementation of the Japan's grand aid for this Project is considered to be appropriate. No problems in terms of human resources and funding on the Cambodian side for operation and maintenance of the facilities and equipment in this Project are anticipated.

For the effective manifestation and continuity of the Project, the Cambodian side should ensure the development of new electricity sources and electricity purchases from Vietnam to meet the increase in power demand after 2008. An operation plan for new generators should be formulated to ensure that an operation rate of 50% or higher is achieved for equipment constructed under the Project. Moreover, profits obtained through the Project should be redirected to the poor through reduced electricity tariff and expansion of the distribution network to poverty stricken areas.

CONTENTS

[Appendices]

CHAPTER 1

BACKGROUND OF THE PROJECT

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Since the 1991 Paris Peace Accord, Cambodia has been striving to improve its power supply facilities with the support of international donor organizations such as WB, ADB and Japan.

In 1993, Japan introduced the "Master Plan Study on Rehabilitation and Reconstruction of Electricity Supply in Phnom Penh and Siem Reap, Cambodia". Based on the study results, the 10MW (5MW×2 units) diesel engine generators at C5 power station in Phnom Penh were installed under "The Project for the Rehabilitation and Upgrading of Electricity Supply Facilities in Phnom Penh" (1993 to 1994) through a Japan's grant aid scheme.

Other power station improvements have also been made through the contributions of other donor organizations, for example, improvement of the C1 power station by France in 1993, construction of the C6 power station by the Asian Development Bank (ADB) in 1995, and improvement of the C3 power station by the World Bank (WB) between 1995 and 1997. In addition, power supply capacity has gradually increased due to the construction of two power stations to supply electric power to Phnom Penh by IPP (independent power producers) in the late 1990s.

On the other hand, due to economic growth following reconstruction, power demand in Phnom Penh increased rapidly by 12% annually. Therefore, the *Electricite du Cambodge* (EDC) is implementing load shedding when needed due to shortages in power supply capacity (decrease in reserve margin). There is also a concern that the existing generating capacity will be unable to meet electric power demand by the end of 2004.

Furthermore, since most of the existing generators owned by EDC use expensive diesel oil, and the unit price of power from IPP is high, the average electricity tariff is 0.16US$/kWh (2001) which is too high for many of the poor, and one of the factors hindering economic growth.

The Government of Cambodia is treating the above-mentioned shortage in power supply capacity and reduction in unit price for electric power generation with the utmost importance. However, due to a shortage in financial resources as well as human resources and experience, it is having difficulty upgrading such facilities through its own efforts. As support for urgent power supply measures of the power development plan stated in the Cambodia Energy Sector Strategy (CESS), it has requested an "installation of 10MW (5MW x 2 units) heavy fuel oil (HFO) diesel generators at the C5 power station" and "fuel conversion from diesel oil to less-expensive heavy fuel oil for the existing generators at C5 power station" under the Japan's Grant Aid.

CHAPTER 2

CONTENTS OF THE PROJECT

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2-1 Basic Concept of the Project

2-1-1 Priority Goals and Project Purpose

With the assistance of the World Bank (WB) and the International Monetary Fund (IMF), the Government of Cambodia prepared the Poverty Reduction Strategy Paper (PRSP in 2002) for the purpose of creating "opportunities to escape from poverty (increase incomes through economic growth, utilization of land and infrastructure)", "expand employment", "improve social welfare" and "overcome vulnerability". The promotion of electrification, reduction in electricity charges and improvement in power supply reliability are listed up as measures to realize the "employment expansion". In this regard, power development to meet demand and the development of a transmission network between Phnom Penh and rural areas are regarded as the tasks to be solved.

Based on the above-mentioned policy, the aim of the Project is to construct generating facilities and reduce power generation cost in order to improve living standards and promote economic reconstruction in Phnom Penh as a part of the socioeconomic infrastructure essential to the improvement of people's lives, the stable operation of social and public facilities, and the revitalization of industries.

2-1-2 Outline of the Project

The Project aims at improving supply capacity and reducing electric power cost by installing two (2) additional generators (5MW/unit output capacity) at the existing C5 power station, and by converting the primary fuel of two generator units (5MW/unit output capacity) installed through the previous project from diesel oil to heavy fuel oil. By doing this, the power supply situation for Phnom Penh will improve and create a reduction in electricity charge borne by poor residents.

2-2 Basic Design of the Requested Japanese Assistance

2-2-1 Design Policy

2-2-1-1 Basic Concept

The basic concept of the Project such as the scope of cooperation, site selection and scale of equipment, etc. are described as follows.

(1) Scope of Cooperation

The scope of cooperation under the Project will include installation of two 5MW-output generator units at the C5 power station and procurement and installation of equipment, materials and facilities required to convert fuel of the existing generating facilities and construct fuel tanks in order to "improve the power supply situation in Phnom Penh" and "reduce in power generation cost".

(2) Site Selection

For efficient use of available sites at the existing C5 power station, adjoining C6 power station and land owned by the EDC, additional generators will be installed inside the power house in the existing C5 power station. Equipment and facilities required to convert fuel of the existing generating units will also be installed inside the power house at the existing power station or on the outskirts.

(3) Equipment Capacity

Capacity of new diesel engine generators will be decided so as to meet power supply and demand balance (for forecasted maximum demand of 115MW, total available supply capacity is 106MW) of the Phnom Penh power system in the completion year of the Project (scheduled for the beginning of 2007, the same year is regarded the target year of the Project), as well as to meet the space limit in the existing C5 power station and to conform to Japanese Grant Aid scheme.

In the following year (2008) of the above-mentioned Project target year, an interconnection of transmission line with Vietnam is scheduled. For the time being, Phnom Penh Power System will depend on power import from Vietnam up to around 40% of supply source in the system. However, the share of the power import will be gradually reduced as an analysis and report recommends that the share of single power supply source be kept within 15% of the Cambodian system demand (to prevent any

adverse effects from an accident in the Vietnam system). Furthermore, considering the political and economic situation in Vietnam and the possibility of power disruptions due to natural disasters, even after the interconnection with Vietnam is completed, the generating facilities to be supplied under the Project should be positioned as key generating facilities for the Phnom Penh power system.

(4) Expansion and Fuel Conversion Work

The basic plan of the Project involves the efficient use of the existing facilities. During the implementation period of the Project, temporary outage of the existing generating units to allow for conversion of fuel, and expansion of generating facilities will be necessary. As the existing facilities are the key generation stations in Phnom Penh, outage will have direct impact on social and economic activity. Minimization of the impact will be given highest priority during the Project's implementation period. In addition, an economically and technically appropriate expansion and remodeling plan should be formulated.

(5) Operations

The Project sites for the Project are categorized as "mixed areas of commerce, industry and residence" based on the Cambodian environmental criteria. According to the criteria, the maximum allowable noise level at night (10 p.m. to 6 a.m. the following morning) should be 50dB (A) or less. Therefore, operation of generating facilities will be restricted to 6 a.m. to 10 p.m. in principle.

2-2-1-2 Natural Conditions

(1) Temperature and Humidity

Cambodia has a tropical monsoon climate with each year being roughly divided into a rainy season and dry season. The rainy season runs from late May to late October, most of the rain falling between September and October. The dry season runs from the beginning of November to mid May. Although temperature exceeds 30℃ during the daytime, it is relatively cool from the beginning of November to late January. In the later period between the beginning of February and mid May, the daytime temperature reaches nearly 35 to 40℃. The average temperatures over the past fifty three (53) years are as follows:

Average lowest temperature : 18.3℃
Average highest temperature : 36.8℃

Average temperature : 27.5℃

Since the generating equipment to be procured under the Project will be installed inside a building in principle, no special measures will be required for ambient temperature and humidity. In addition, no special temperature-related measures will be required for the facilities installed outdoors such as radiators, since the difference in maximum and minimum ambient temperatures is relatively small. However, since the designated humidity is high (maximum 94%, minimum 60% and average 75%), during the formulation of the equipment and system specifications, measures to prevent condensation should be taken, considering that the maximum relative humidity is 94%. Moreover, due to the strong sunshine, the use of light-resistant paint and introduction of sun shading will be considered.

(2) Wind and Rainfall

While the recorded maximum wind velocity is 20m/sec in the designated area, the mean annual wind velocity is 4 to 8m/sec. Since the Mekong River Commission regards the maximum wind velocity to be 25m/sec, the Project will adopt their maximum wind velocity. The mean rainfall is 1,400mm/year but can reach 1,082mm/year to 1,773mm/year over a twenty-year (20) period. With respect to rainfall intensity utilized for a drainage plan, etc., given that rainfall occurs only a few hours a day, assuming that hourly rainfall is 50% of the daily total, 50mm/hr will be adopted. The record maximum number of thunderstorms is 38 a year for Phnom Penh and the surrounding area. Consequently, a lightning rod will be installed on the necessary facilities (such as fuel oil tanks) to avoid lightning damage to the facilities.

(3) Earthquakes

No earthquakes have been recorded for the Project site. Earthquakes were not taken into account even in the previous assistance project. Therefore, no special consideration will be given to seismic activity in the Project.

2-2-1-3 Socioeconomic Conditions

The majority of Cambodians are Buddhist and public agencies observe a 2-day per week holiday system (Saturdays and Sundays). Although there are 25 national holidays in a year, there are no customs or practices that greatly affect the construction period. When carrying out fuel conversion work, power outage time should be kept as short as possible so that blackouts in the metropolitan area will be limited to minimize the impact on local residents and social activities. A plan to ensure safety will also be formulated as paramount importance.

2-2-1-4 Procurement of Equipment and Materials

(1) Equipment and Materials for Facility Construction work

The main condition for the foundation work for engines and fuel tanks, etc. will be the procurement of local materials as much as possible. While construction materials such as gravel and timber are available locally, main materials such as cement, reinforcement bars, plywood, interior and exterior finishing materials will be imported. In the case of formulating a construction schedule, stocking of these materials in the market should be grasped and transportation routes and procurement period should be taken into account, including transporting from neighboring countries, if necessary.

It is possible to lease construction machinery to be utilized for facility construction under the Project at the local site (available maximum truck crane size to be 45 tons), and two private concrete plants in Phnom Penh are operating without particular problems in quality.

(2) Equipment and Materials for Generating Facilities

All equipment and materials for generators and distribution facilities in Cambodia are imported. Products from various country are introduced (differs depending on importing conditions of donor country). Accordingly, all equipment and materials required for expansion and fuel conversion work to be implemented under the Project will be imported products. The Cambodian side strongly hopes to utilize Japanese products which are high in quality and performance and for which a favorable system of after service can be secured, in addition to the needs of parallel operation with the existing Japanese generating facilities.

When importing equipment and materials into Cambodia for the Project, a master list which indicates items and the total quantity of equipment and materials to be imported shall be customarily presented to the Council for Development of Cambodia (CDC) approximately one month prior to the first import (one month after the contract). After approval for tax exemptions, etc. is obtained, the quantity of equipment and materials imported each item is deducted from the quantity described in the master list at customs.

2-2-1-5 Effective Use of Local Companies (Construction Firms)

(1) Effective Use of Local Companies (Facility Construction)

Local Cambodian companies to be involved in facility construction are relatively large (1,000 person labor force is possible). In the case of foundation work for engines and fuel tanks under the Project, implementation of construction work is possible by local firms under the supervision and guidance of engineers dispatched from Japanese construction firms. However, since some local firms lack the capital, the Japanese contractor as the main contractor should directly procure the equipment and materials or construction machinery.

(2) Effective Use of Local Companies (Equipment Installation Work)

Skilled technologies are required for fuel conversion or installation work including testing operations and adjustment of generating facilities, technical supervision to sub-contractors to be employed locally should be carried out by Japanese engineers dispatched to the Project site for the purpose of quality and schedule control.

2-2-1-6 Operation and Maintenance Capability of Project Implementation Body

The EDC has been implementing inspections and maintenance work for the existing two generating units (5MW each) installed under the previous assistance project and used spare parts are ordered each year generally based on manufacturers' manuals. Consequently, they are evaluated to have the basic technical capability to operate and maintain generating units to be procured under the Project. However, to cope with a problem which is not described in the O & M manual such as accident of the existing No.1 unit, the acquiring of necessary preventive maintenance technology and operation and maintenance technology for heavy oil fired diesel generating units is highly required.

As for the heavy fuel oil heat treatment for the fuel supply system which is to be applied in line with the fuel conversion work, whenever possible an electric heating system similar to the one used at the C6 power station or Siem Reap power station will be adopted for the Project which is familiar to maintenance personnel.

OJT (On the Job Training) and soft component during installation and the adjustment period for test operations of generating units will be implemented by Japanese engineers under the Project so that operation and maintenance of heavy oil fired diesel engine generating facilities will be conducted by EDC smoothly.

The scope of OJT and soft component will include the No.1 and No.2 units installed by the previous assistance project and necessary teaching materials will be procured under the Project.

2-2-1-7 Scope and Grade of Equipment, etc.

Considering the various above-mentioned conditions, the following basic principles will be adopted for the procurement of equipment / materials, facility construction and technical level under the Project.

(1) Scope of Facilities and Equipment

A facility configuration, types and number of equipment and materials which are necessary but minimum will be selected in order to achieve the Project objectives such as securing a power balance in Phnom Penh in 2007, contributing to the reduction of electric charges and providing a stable electric power to local residents and social and public facilities through the installation of generating facilities and procuring spare parts.

To achieve an economical and technically appropriate design, standard products are adopted to meet the specifications of equipment and materials which conform to international standards as much as possible. The facility configuration and specifications will be selected after considering the compatibility and future expansion of devices and parts, etc. If possible, existing facilities should be used to the utmost.

(2) Technical Level (Grades)

The specifications of equipment of the planned generating facilities should be the same as those of existing equipment familiar to EDC as much as possible so that equipment does not exceed the technical capability of EDC engineers and technicians.

Under the Project, OJT associated with the operation and maintenance by manufacturer's engineers during installation and testing and during adjustment periods and technical transfer through the soft component are scheduled. The aim of OJT and technical transfers through the soft component is to raise the technical competency of EDC personnel to a level where they can analyze data sets for operation and fault records of planned generating units for the purpose of preparing and implementing an appropriate response, to carry out optimal operation, appropriate periodic inspections and preventive maintenance after understanding the specific characteristics of heavy oil (HO) fired diesel generating units, on top of the basic knowledge of operation and maintenance technology possessed by EDC.

2-2-1-8 Construction and Procurement Methods and Schedule

As the Project will be implemented in accordance with Japan's grant aid scheme, it must be completed within a single fiscal year. However, due to the large scale of the Project, installation work of new generating facilities and fuel conversion work of the existing generating facilities will be carried out through the separated following phases:

Phase 1: Fuel conversion work (including construction of diesel oil storage tanks)
Phase 2: Installation of two 5MW generating units (including connection of 22kV cables to GS-1)

In the case of fuel conversion work, since the C5 power station is the key power station in Phnom Penh, the duration of outage will be kept to a minimum; a construction schedule should be formulated to reduce the impact on residents as much as possible.

2-2-2 Basic Plan (Equipment and Facility Plan)

2-2-2-1 Overall Plan

(1) Design Conditions

When formulating the scale and specifications of the equipment for the Project, the following design values will be established based on the result of the various above-mentioned conditions.

1) Climate and Site Conditions

	Item	Unit	Design values
①	Outside air temperature		
	Maximum	℃	36.8
	Average	℃	28
	Minimum	℃	13
②	Temperature in engine room	℃	40
③	Humidity		
	Maximum	%	94
	Average	%	75
④	Rainfall		
	Annual average	mm/year	1,400
	Maximum per hour	mm/hour	50

⑤	Wind velocity		
	Average	m/sec.	5
	Maximum	m/sec.	25
⑥	Wind direction		
	Dry season (Nov. to May)	---	Southwest → Northeast
	Rainy season (May to Oct.)	---	Northeast → Southwest
⑦	Annual number of days with thunderstorms	day	38 (approx.)
⑧	Lateral seismic factor	gal	Not considered
⑨	Site conditions		
	Elevation (above mean sea level)	m	10
	Soil bearing capacity	ton/m^2	20
	Ground water level	m	GL-3.0
⑩	Other		
	Dust	---	Considered
	Salt damage	---	None
	Flood	---	None

2) Applicable Codes/Standards and Units

In designing the Project, the present EDC design conditions and conformity with the existing facilities were taken into consideration. At the same time, international standards such as IEC and ISO, and Japanese standards will be applied to major equipment functions. Since local regulations have not yet been established, Japanese standards will be also applied for electrical installation work. The International System of Units (SI) will be used for the design of the Project.

	Standard Name		Applied for
①	International Organization for Standards (ISO)	:	Industrial products in general
②	International Electrotechnical Commission (IEC)	:	Electrical products in general
③	Japan Industrial Standards (JIS)	:	Industrial products in general
④	Standard of the Japanese Electrotechnical Committee (JEC)	:	Electrical products in general
⑤	Standards of Japan Electrical Manufacturers Association Code (JEM)	:	Electrical products in general
⑥	Technical Standards for Electrical Facilities in Japan	:	Design of electrical equipment in general

⑦ Japan Electric Association Code (JEAC) : Design of power equipment in general

⑧ Japanese Electrical Wire and Cable Makers Association Standards (JCS) : Electrical wires and cables in general

⑨ Architectural Institute of Japan (AIJ) : Building work in general

3) Power Demand Forecast

The EDC has predicted the future demand forecast by successively connecting the current Phnom Penh power system to isolated provincial and rural power systems. However, the examination was based on the following conditions by separating the current Phnom Penh power system from isolated power systems to be linked in the future.

① Demand Forecast for the Phnom Penh Power System

The EDC estimates that, if isolated power systems are not connected to the Phnom Penh power system, the average annual increase rate of peak demand will reach 2% from 2004, almost matching the city's population growth rate. This value will be also adopted in the Project.

② Demand Forecast Considering Interconnection

EDC's plan for interconnection with Vietnam and other countries, and demand forecast of districts managed by MIME other than areas presently maintained and operated by EDC, will be adopted.

③ Other

- Generating facilities to be additionally installed under the Project will begin commercial operation from the beginning of 2007.
- The lifespan of the existing generating facilities will be estimated based on the EDC forecast and current operating conditions.
- The power purchase plan from IPP will be examined based on the EDC plan.

[Results of the Demand Forecast]

When forecasting the power balance based on the above-mentioned conditions, decisive power crisis in 2007 can be avoided by means of implementing the Project because supply capacity exceeds the maximum peak demand, still reserve margin is not sufficient. However, if any one of generators owned by EDC are stopped due to

a sudden accident, a load shedding will be unavoidable in some areas. The power balance for the Phnom Penh power system is shown in Appendix 7-(2).

4) Environmental Considerations

The following values show the design impact on the environment associated with the remodeling and procurement of generating facilities under the Project based on relevant standards in Cambodia supplemented with related Japanese laws, ordinances and standards.

① NOx : not more than 950 ppm (when residual oxygen concentration is 13%)

② SOx : not more than 500 ppm (when sulfur content of fuel oil is 2%)

③ Oily water : not more than 30 ppm

④ Dust : not more than 100 mg/Nm^3

⑤ Noise : at the power station boundary when all generating units are in operation
- 6:00 a.m. to 6:00 p.m.: 75 dB (A)
- 6:00 p.m. to 10:00 p.m.: 70 dB (A)
- 10:00 p.m. to 6:00 a.m.: 50 dB (A)

⑥ Vibration : not more than 55 dB at the power station boundary

For the implementation of the Project, an Initial Environmental Impact Assessment (IEIA) on the Project must be approved by the Ministry of Environment.

5) Facility Layout Plan

The layout will be planned after considering the following conditions so that existing generating facilities can be utilized effectively:

① To minimize the impact of noise and vibration on neighboring residents;

② To make the layout for easy operation and maintenance of equipment;

③ To layout a new diesel oil storage tanks for easy maintenance;

④ To secure access routes for fuel tracks;

⑤ To lay 22kV high voltage transmission cables near the boundary for easy maintenance.

The general layout taking into consideration the above-mentioned matters will be shown in G-01.

(2) Comparative Examination of Fuel Heat Trace System (Steam and Electric)

One of the impacts on the facility configuration due to differences in the physical nature of diesel oil and heavy oil is “viscosity”. Diesel oil can be transferred and burned at normal temperature; whereas, heavy oil must be heated before it can be transferred or burned due to its high viscosity at normal temperature. Two types of heat sources will be used to heat the fuel, an electrical heater (electrical heat trace method) and steam heater (steam heat trace method). In the latter method, steam is obtained by recovering waste heat from diesel engines. In implementing the Project, a comparative examination will be made based on the following operational and economical aspects.

1) Examination of Operation Characteristics

The electrical heat trace method involves the installation of an electrical heater in equipment subjected for heating. Operation of the equipment is relatively simple. On the other hand, the steam heat trace method is slightly more difficult because various devices including a waste heat recovery boiler to collect heat from exhausted gas, a boiler feed water unit to provide water for steam, and a water treatment unit to prevent boiler corrosion should be operated and maintained. A comparison of operation characteristics is shown in Table 2-2-1.

Table 2-2-1 Operation Characteristics of Heat Trace System

	Electrical trace method	Steam trace method
Equipment to be operated	• Electric Heaters installed for; Fuel oil tanks, fuel oil supply pipes, fuel oil drainage pipes, fuel base pipes in diesel engine, etc.	• Waste heat recovery boiler • Water treatment unit • Boiler water supply unit (water supply tanks, pumps) • Steam trace pipes installed for; Fuel oil tanks, fuel oil supply pipes, fuel oil drainage pipes, fuel base pipes in diesel engine, etc.
Daily operations and inspection items	• Electric heater	• Quality control of boiler water • Chemical injection to the water treatment unit • Steam heater
Difficulty of operation	Easy	Slightly difficult

2) Examination of generation Cost

Although the electrical trace method requires less initial investment, approximately 800kW (in the case of two 5MW units) of electric power is necessary for heating. The actual transmitted power is approximately 90% (9MW level for two 5MW units) of the rated output. On the other hand, the steam trace method requires quite a large initial investment. The power required to operate the fuel heating unit is approximately 30kW (in the case of two 5MW units) which is less because waste heat can be effectively used. Consequently, the steam trace method can transmit approximately 97% (9.7MW for two 5MW units) of the rated output so that the capacity of the generating facilities can be fully utilized. If this is compared with generating unit cost when the service life of the facilities is deemed to be 15 years, as shown in Tables 2-2-2 and 2-2-3, the steam trace method (¥10.9/kWh) will reduce ¥0.7/kWh (approximately US ¢ 0.6/kWh) the generating unit cost compared with the electrical trace method (¥11.6/kWh).

Table 2-2-2 Preconditions of Comparing the Fuel Heating Methods

	Electrical trace method	Steam trace method
Construction cost	・Diesel generators and auxiliaries (¥125,000/kW)	Same as left
Facilities necessary for fuel heating	・Heaters for; Fuel oil tanks, fuel oil supply pipes, fuel oil drainage pipes, fuel base pipes in diesel engine, etc. ・Station transformer (large capacity) ・Construction cost for heating facilities is estimated to be ¥ 90 million.	・Waste heat recover boiler ・Water processing unit ・Boiler water supply unit (water supply tanks, pumps) ・Steam trace pipes for; Fuel oil tanks, fuel oil supply pipes, fuel oil drainage pipes, fuel base pipes in diesel engine, etc. ・Station transformer (smaller capacity) ・Construction cost for heating facilities is estimated to be ¥ 170 million.
Operation cost	・Generator maintenance cost (¥2/kWh)	・Generator maintenance cost (¥2/ kWh) ・Maintenance cost for fuel heating steam unit (¥ 1 million/year estimated) ・Chemical cost for water treatment (¥0.2/kWh estimated)
Consumables cost	・Lubricating oil cost: ¥174 /ℓ	Same as left
Fuel cost	・Heavy oil: US$260/ton ・Fuel consumption: 233g/kWh (heavy oil)	Same as left
Station power consumption	・Auxiliary unit power: Approx. 300kW ・Power for electric heating: Approx. 800kW	・Auxiliary unit power: Approx. 300kW ・Power for steam heating: Approx. 30kW
Remarks	1. Two units of 5MW generating units will be newly installed. 2. Operation conditions of generating units Output rate: 90%, the number of operation days: 300 days/year 3. The service life of generating units is 15 years, equal depreciation and terminal value is 10%. 4. 1US$ = ¥110	

Table 2-2-3 Comparison of Generating Cost by Fuel Heating Methods

Item			Electrical trace	Steam trace
Annual expenses (fixed cost)	Depreciation	① Generators & auxiliary units	¥75.0 million/year	¥75.0 million/year
		② Fuel heaters	¥6.0 million/year	¥11.4 million/year
		③ Total (①+②)	¥81.0 million/year	¥86.4 million/year
Annual cost (variable cost)	Operation and maintenance cost	④ Generator maintenance cost	¥129.6 million/year	¥129.6 million/year
		⑤ Steam unit maintenance cost	—	¥1.0 million/year
		⑥ Total (④+⑤)	¥129.6 million/year	¥130.6 million/year
	Consumables cost	⑦ Lubricating oil cost	¥18.0 million/year	¥18.0 million/year
		⑧ Pharmaceuticals cost for boiler water processing	—	¥13.0 million/year
		⑨ Total (⑦+⑧)	¥18.0 million/year	¥31.0 million/year
	⑩ Fuel cost		¥431.9 million/year	¥431.9 million/year
⑪ Total annual expenses (③+⑥+⑨+⑩)			¥660.5 million/year	¥679.9 million/year
⑫ Station service power			1,100kW	330kW
⑬ Annual transmission of electric power			56.9GWh/year	62.4GWh/year
⑭ Generating unit price (⑪÷⑬)			¥11.6 /kWh	¥10.9 /kWh

Remarks: 1US$ = ¥110

3) Comprehensive Evaluation

Based on a field survey conducted on the existing C5 and C6 diesel power stations and existing C2 power station which is the existing steam turbine power station and discussions with the EDC, the following policy will be adopted.

Although the steam trace method is superior economically based on the studies above, considering the current technical level of EDC's staffs with regards to facility operations and the maintenance system, and its additional complicated operation, it can be said that the steam trace method is somewhat less efficient in operations and maintenance to ensure constantly keeping economical superiority. In addition, the future facility utilization factor of the C5 power station is estimated to be approximately 50%, with frequent starting and stopping of generators anticipated. Therefore, the electrical trace method is more advantageous due to easy operation and maintenance.

Both the C6 power station and other heavy oil fired diesel power stations such as Siem Reap power station adopt the electrical trace method. The EDC is familiar with operation of the electrical trace method and hopes it will also be adopted for the Project.

After considering the above-mentioned examination results, the electrical trace method for fuel heating system will be adopted for the Project.

(3) Initial Environment Impact Evaluation (IEIA)

The procedures and regulations of the Environmental Impact Assessment (EIA) in Cambodia were prescribed in the ministerial ordinance "Sub-Decree on Environmental Impact Assessment" on August 11, 1999. The said ministerial ordinance imposes a duty on the implementation of EIA or Initial Environmental Impact Assessment (IEIA) with respect to new generating facilities of over 5MW. In particular, the ordinance requests the full-scale implementation of IEA with respect to any project deemed to have a serious impact on natural resources, the ecosystem, public health and welfare. Since this Project involves the additional installation of generating facilities (5MW×2＝10MW) to the existing power station and fuel conversion of existing generating facilities, the IEIA should be implemented at first.

When conducting the IEIA, Cambodia's Air Pollution and Noise Prevention Act is considered to be the criteria, and the "JICA Environmental and Social Considerations Guidelines" (enforced on April 1, 2004) were also taken into account in the study techniques and evaluation methods, etc.

The maximum ground concentration of NOx, maximum ground concentration of SOx and noise forecast results are shown in Tables 2-2-4, 2-2-5 and 2-2-6 respectively. If the height of the smokestack of the existing No.1 and No.2 units is 12m, the maximum ground concentration of NOx will not satisfy Cambodian environmental standards. However, if the height of the smoke stack is renovated to 16m under the Project, and similarly, if the height of the smokestacks of the new No.3 and No.4 units are upgraded to 16m, the maximum ground concentration of NOx will be 1/3 to 1/2 the environmental standard value. Other items will lower the reference value of the Cambodian Air Pollution and Noise Prevention Act. A lower impact on the environment was confirmed.

As for the future procedures within Cambodia, the results of the Initial Environmental Impact Assessment (IEIA) at this time will be translated into Khmer and presented to the Cambodian Ministry of Environment (MOE) and their assessment will be obtained. The IEIA Report is shown in Appendix 6.

Table 2-2-4 Results of the Maximum Ground Concentration of NO_2

(mg/Nm^3)

	Cambodian Environmental Criteria	Predicted Value
average 1-hour value	0.3	0.1127
average 24-hour value	0.1	0.0434

Table 2-2-5 Results of the Maximum Ground Concentration of SO_2

(mg/Nm^3)

	Cambodian Environmental Criteria	Predicted Value
average 1-hour value	0.5	0.0824
average 24-hour value	0.3	0.0317
average 1-year value	0.1	0.0054

Table 2-2-6 Results of Noise Forecast at the Boundary

Predicted point	Noise level (dB (A))	Remarks
1	61	South side of the boundary
2	62	South side of the boundary
3	61	South side of the boundary
4	65	East side of the boundary
5	63	East side of the boundary
6	65	East side of the boundary
7	63	East side of the boundary
8	60	North side of the boundary
9	62	North side of the boundary
10	62	North side of the boundary

Table 2-2-7 Environmental Noise Level Criteria in Cambodia

District Classification	Time Zone		
	06:00～18:00	18:00～22:00	22:00～06:00
1. Quiet district	45dB(A)	40dB(A)	35dB(A)
Hospitals			
Libraries			
Schools			
Kindergartens			
2. Residential district	60dB(A)	50dB(A)	45dB(A)
Hotels			
Governmental office streets			
Residents			
3. Commercial district	70dB(A)	65dB(A)	50dB(A)
4. Small-scale factories scattered throughout residential district	75dB(A)	70dB(A)	50dB(A)

Source: Cambodian Air Pollution and Noise Prevention Act

The C5 power station (Project site) falls under the above-mentioned district classification of 4.

2-2-2-2 Outline of Basic Plan

The main components of the Project are outlined in Table 2-2-8 based on the basic design conditions.

Table 2-2-8 Outline of Basic Plan

Classification	Fuel conversion plan for existing generating units	Construction plan for new generating units
Target	Existing No.1 and No.2 units in the existing C5 power station and new common utility equipment	New No.3 and No.4 units in the existing C5 power station
Procurement and installation of generating facilities	• Procurement and installation of equipment and materials necessary for the fuel conversion works (output 5 MW × 2 units) • Procurement and installation of equipment and materials necessary for mechanical auxiliaries - Remodeling of two units of the existing diesel oil storage tanks into those for heavy oil storage - Newly installation of a new diesel oil storage tank - Newly installation of heavy oil cargo handling & transfer facility - Newly installation of heavy oil heaters & insulation - Remolding of exhaust gas system - Renewal of sludge treatment system - Remodeling of bearing temperature measuring instrument - Remolding of piping system • Procurement and installation of equipment and materials necessary for electrical auxiliaries - Newly installation of common alarm panel - Newly installation of common station MCC panel - Upgrading of remote supervisory and control panels - Upgrading of existing 400V low-voltage power panel - Wiring and grounding materials - Upgrading of building services • Remodeling of electrical room and procurement of auxiliary equipment • Remodeling of smokestack (height: 12m → 16m) • Procurement of spare parts for generating facilities and auxiliary facilities • Procurement of operation and maintenance manuals (including teaching materials for OJT) of generating facilities and implementation of soft component (Operation and maintenance manuals shall be translated in Khmer)	• Procurement and installation of diesel engine generating facilities (output of 5MW × 2 units) • Procurement and installation of mechanical auxiliaries - Fuel oil system - Lubricating oil system - Cooling water system - Compressed air system - Air intake and exhaust gas system - Piping system • Procurement and installation of electrical auxiliaries - 22 kV high-voltage feeder panels - 6.3/22kV step-up transformers - 22/0.4kV station transformers - 400 V low-voltage power system - DC power system with auxiliaries - Remote supervisory, control and relay panels - Wiring and grounding materials - Additional installation of lighting equipment and remodeling of fire alarm system • Procurement and installation of 22kV feeder cables - Cable laying between C5 and C6 power stations (300 m × 1 circuit) - Cable remodeling between C6 and GS-1 (60 m × 2 circuits) • Procurement of spare parts and maintenance tools for generating facilities and auxiliary facilities • Procurement of operation and maintenance manuals (including teaching materials for OJT) of generating facilities and implementation of soft component (Operation and maintenance manuals shall be translated in Khmer)

2-2-2-3 Equipment and Materials Plan

(1) Fuel Supply System Remodeling Plan

Under the Project, the contents of the fuel supply system remodeling plan for existing diesel engine generators at the C5 power station will be as follows.

1) Basic Requirements

① Outline of Fuel Supply System Remodeling

Fuel oil unloading, storage and transfer equipment and fuel combustion and control equipment will be modified under the Project in order to convert fuel oil utilized for existing diesel engine generators from diesel oil to C heavy oil. The general specifications of main equipment are shown in Table 2-2-13.

② Composition of Fuel

The composition of the diesel oil and C heavy oil available in Phnom Penh city are shown in Tables 2-2-9 and 2-2-10 respectively.

Table 2-2-9 Composition of Diesel Oil (DO)

Description	Unit	Value	Remarks
Specific gravity	kg/ℓ	＜0.86	15 ℃
Kinematics viscosity	Stokes (cSt)	＜5	50 ℃
Pour point	℃	< 10	
Flash point	℃	> 60	
Sulfur content	Wt %	< 0.9	
Water content	Vol.g	< 0.1	
Ash content	Wt.g	0.01	
Carbon residue	Wt %	< 0.01	
Sediment by extraction	Wt %	< 0.1	
Calorific value	kcal/kg	Min. 10,100	Gross
Cetane value		> 45	

Source: EDC：

Table 2-2-10 Composition of C Heavy Fuel Oil (HO)

Description	Unit	Value	Remarks
Specific gravity	kg/ℓ	＜0.965	15 ℃
Kinematics viscosity	Stokes (cSt)	＜180	50 ℃
Pour point	℃	< 21	
Flash point	℃	> 66	
Sulfur content	Wt %	< 3.0	
Vanadium	mg/kg	< 95	
Sodium	mg/kg	< 40	
Water content	Vol.g	< 0.5	
Ash content	Wt.g	< 0.1	
Carbon residue	Wt %	< 15.0	
Sediment by extraction	Wt %	< 0.1	
Calorific value	Btu/lb	Min. 18,500	Gross
Asphaltenes	Wt %	< 5.0	
Aluminum & silicon	Wt %	< 60.0	

Source: EDC

③ Composition of Lubricating Oil

Although the applied composition of lubricating oil may vary slightly from one engine manufacturer to another, to handle C heavy fuel oil, medium-alkaline SAE grade No.40 will be suitable. One example of the lubricating oil composition is shown in Table 2-2-11.

Table 2-2-11 Composition of Lubricating Oil (LO)

Description	Unit	Value	Remarks
Kinematics viscosity	Stokes (cSt)	12.2 to 16.5	100℃
		120 to 178	40℃
Viscosity index		85 or more	
Pour point	℃	－5 or less	
Total base number	mgKOH/g	26 to 30	2.0＜S（Wt %）＜2.5
		31~	2.5＜S（Wt %）

Source: Engine manufacturer's materials

④ Cooling water

City water is used primarily to cool down the engine at the existing C5 power station. River water is used for secondary cooling. In the remodeling of the cooling water system associated with the remodeling of the fuel oil supply system, the capacity of the engine lubricating oil cooler will be increased and a new turbocharged lubricating oil cooler will be installed. However, the supply sources and volume of the primary and secondary cooling water will be the same as the existing facilities. Presently, the cooling water system is being operated without any special problems, so that existing facilities will be used.

Composition of city water at existing facilities is shown in Table 2-2-12.

Table 2-2-12 Composition of City Water

Description	Unit	Value	Remarks
PH	---	7.85	
Conductivity	μ S/cm	239.96	(at 20 ℃)
Evaporation residue	mg/l	119.98	
Alkalinity	mg/l	66	
Carbon dioxide	mg/l	15.3	
Hardness calcium	mg/l	59	
Magnesium	mg/l	11	
Total hardness	mg/l	70	(CaCO3)
Chloride	mg/l	10.4	
Potassium	mg/l	0.894	
Sulfate	mg/l	15	
Zinc	mg/l	0.1	
Dissolved O_2 (D.O)	mg/l	3.29	

Source: EDC

2) Planning Concept

① Fuel Supply System Remodeling

Since a reduction of approximately 25% of the generating unit cost as shown in Table 2-4-5 is anticipated by converting the main fuel oil of existing diesel engine generators (5MW×2units), the economic effect will be substantial. As a result of a study on existing facilities, although replacement, modification and additions of equipment necessary for fuel conversion are technically possible,

due to limited space inside the existing power house, the special consideration should be given to the arrangement of the newly installed equipment.

② Mechanical System Plan

(a) Modification of Engine Parts

Associated with fuel conversion, fuel injection value, exhaust valve seats, and fuel injection pumps will be replaced to accommodate C heavy oil combustion. Since fuel injection nozzles will be replaced by a cooled type associated with the fuel conversion, fuel valve cooling pipe will be newly installed. The main fuel pipe, return pipe, high-pressure pipe and other fuel pipes will be covered by heat insulation material.

Due to the high viscosity of heavy oil, the bore diameter of fuel draining pipe will be widened for easy flow. Lubricating oil piping will be designed to separate the turbocharger lubricating oil system from the engine system.

In addition, due to the early deterioration of lubricating oil associated with fuel conversion to C heavy oil, main bearing temperature sensors will be installed on the main bearing for easy detection of abnormal conditions.

(b) Fuel Supply System

C Heavy Oil Storage Tank

Two of the existing 1,000m^3 diesel oil storage tanks will be remodeled and used for heavy oil storage. In order to ensure the viscosity required for transfer of heavy oil, a heat trace system on fuel pipes, and fuel unloading and transfer systems will be installed.

[Examination of Heavy Oil Storage Tank Capacity]

Generator output: 5,000（kW/unit）
Heavy oil consumption rate of generator: 233 (g/kWh)
Specific gravity of heavy oil: 0.9(kg/ℓ)
Fuel consumption per day/unit ＝ 5,000×0.233/0.9×24 = 31,066（ℓ）
Total member and capacity of generating units (Existing and new installation) 5MW×4 units ＝ 20MW
Consumption of heavy oil per day ＝ 31.07×4 ＝ 124.3m^3
Heavy oil storage tank capacity: 1,000 m^3×2 ＝ 2,000 m^3

Number of days for storage provision of tank: 2,000/124.3 ＝ 16.09（days）

The heavy oil storage tank is able to store fuel for 16 continuous days of rated operation and is therefore judged to have sufficient capacity.

Diesel Oil Storage Tank

Heavy oil diesel engine generators require diesel oil at startup and shutdown and during light-load operation. In addition, if some defect arises in the heavy oil system, the generators should be operated with diesel oil. Consequently, even in the case of fuel conversion, a diesel oil storage tank with a certain capacity should be installed. Under the Project, one diesel storage tank with a capacity of 300m^3 will be installed by totaling the portion of fuel conversion of existing generating facilities and additional generators. Floating suction will be installed inside the new tank to prevent water or foreign objects from remaining in the fuel oil so that transfer of fuel oil without impurities to the diesel engine can be carried out. The existing unloading and transfer systems will be effectively utilized.

[Examination of Diesel Oil Storage Tank Capacity]

Generator output: 5,000 (kW/unit)
Diesel oil consumption rate of generator: 210 (g/kWh)
Specific gravity of diesel oil: 0.85 (kg/ℓ)
Fuel consumption per day/unit ＝ 5,000×0.210/0.85×24 = 29,647（ℓ）

On the assumption of the rated operation of four diesel oil units during an emergency:

Diesel oil consumption per day ＝ 29.65×4 ＝ 118.6m^3
Diesel storage tank capacity: 300m^3
Number of feasible days use of diesel storage tank ＝ 300/118.6 ＝ 2.53（day）

Accordingly, the diesel oil storage tank can store fuel for approximately 2.5 days of continuous rated operation with four units running during an emergency, so it is judged to have sufficient capacity.

Heavy Oil Buffer Tank and Service Tank

When using heavy oil, a fuel oil purifier unit is necessary. A buffer tank and service tank will be installed on the upstream and downstream side of the purifier unit respectively. A fuel heater will be attached to these units to ensure the flowability of heavy oil. Two generating units after fuel conversion should have the capacity required for approximately 2 hours operation. In addition, the existing diesel oil buffer tank will be effectively utilized by converting it to a heavy oil buffer tank. A new heavy oil service tank will be installed.

Generator output: 5,000 (kW/unit)
Heavy oil consumption rate of generator: 233 (g/kWh)
Specific gravity of heavy oil: 0.9 (kg/ℓ)
Fuel consumption for 2 hours with 2 generators: 5,000×0.233/0.9×2 = 5,178 (ℓ)

Consequently, one modified buffer tank and one new service tank with capacity of $5m^3$ will be installed respectively. The heavy oil buffer tank and service tank will be shared by the No.1 and No.2 units.

Diesel Oil Service Tank

The existing tank ($5m^3$) will be effectively utilized as the diesel oil service tank for both units.

Heavy Oil Purifier Unit

Heavy oil once stored in the buffer tank is sent to the service tank after separating and purifying sludge and water through centrifugal separation. Sludge and water are collected in the waste oil tank and processed by a sludge treatment system (mentioned later).

Fuel Oil Change-over Device

Since heavy oil fired diesel generating units use diesel oil at startup and shutdown and during light-load operation, a device to convert heavy oil into diesel oil (and vice versa) during operation is necessary. Fuel will be converted through a fuel change-over valve and a fuel heater will be provided to adjust the temperature to a viscosity suitable for combustion. In order to prevent the fuel flowing into the engine from suddenly

changing during the conversion of fuel oil, the change-over should be done only after sufficient mixing of heavy oil and diesel oil in the mixing tank has been done. Foreign objects mixed in the fuel oil should be thoroughly removed by the fuel oil filter.

Heavy Oil Supply Pipe

An electrical heat trace (heating unit provided on pipe) and heat insulation materials will be installed on the heavy oil supply lines from fuel storage tank to the flow meter installed beside the engine. The electrical line heater with heat insulation cover will be provided on the line from the flow meter to the engine inlet in order keep the required temperature of the fuel.

(c) Lubricating Oil System

The lubricating oil system for the turbocharger which requires constant lubrication due to its high revolution speed will be separated from the lubricating oil system of the engine which is more likely deteriorated by heavy oil burning sludge. Consequently, a new lubricating oil cooler for the turbocharger system, lubricating oil tank, lubricating pump, cooling water system will be installed.

In addition, since engine lubricating condition will become severe when heavy oil is used, the lubricating oil viscosity should be higher and oil film in lubricating areas should be thicker. In order to lower the lubricating oil temperature by approximately 10℃ from the present temperature applied for the existing generating units, the capacity of the engine lubricating cooler should be made larger and the cooling water system also be modified. The properties of lubricating oil suitable for heavy oil fired diesel engine should be selected.

(d) Cooling Water System

The primary cooling water pipe system will be partially modified in line with the modifications of the engine lubricating cooler and separation of the turbocharger lubricating oil cooler. Although EDC personnel responsible for operation and maintenance do not fully understand the secondary cooling water system, the system will not be modified under the Project, because OJT will be conducted again for this secondary cooling system during installation.

(e) Sludge Treatment System

In the current sludge treatment system, the tank which stores waste oil and sludge discharge does not function well due to sludge blockage in the transfer pipe. The pipe is also blocked by sludge from the collecting tank to sludge separating tank, so that the sludge separating tank and oil water separator unit also do not function.

Resulting from fuel conversion, sludge volume discharged from the heavy oil purifier unit will increase. Therefore, the capacity of the sludge separating tank and oily water separation unit will be modified to larger size by expanding the bore diameter (aperture) of sludge pipe and by applying heat trace and thermal insulation.

(f) Exhaust stack

The height of the existing exhaust stacks will be increased from 12m to 16m in order to lower the ground concentration of NOx exhaust gas. By effectively utilizing the existing exhaust silencer, only the main exhaust stack body installed with a flange on the top of the silencer will be replaced.

3) Summary of the Specifications of Main Equipment

An overview of specifications of the main fuel conversion equipment to be implemented under the Project is shown in Table 2-2-13.

Table 2-2-13 Outline of Main Equipment (Fuel Conversion)

Equipment Name	Quantity	Specifications
1) Mechanical system Diesel engine (existing)	2 units	Replace fuel injection valves Replace exhaust valve seat Replace fuel injection pump Install main bearing temperature sensors Modification of other related pipes
2) Mechanical systems		
① Systems to be newly procured		
a) Diesel oil storage tank	1 unit	a) Capacity: 300 m^3, vertical type, outdoor
b) Heavy oil unloading and transfer unit	1 set	b) Outdoor use with shed, unloading pump and filter
c) Heavy oil service system		c) Heavy oil purifier unit, service tank ($5m^3$), piping
② Existing systems to be modified	1 set	system with heat trace and insulation
a) Heavy oil storage tank	2 units	a) Capacity: 1,000 m^3, vertical type, outdoor, with heater (additional)
b) Heavy oil buffer tank	1 set	b) Outdoor ($5m^3$), with heater (additional)
c) Fuel supply pipe	1 set	c) Electrical line heaters and filters installed
d) Lubricating oil cooler	2 sets	d) Lubricating oil coolers for diesel engines replaced, lubricating oil coolers for turbo chargers installed
e) Sludge treatment system	1 set	e) Sludge separator installed, oily water separator replaced
f) Smokestack	2 sets	f) Increased to 16m height
3) Electrical equipment		
① Equipment to be newly procured		
a) Station common panel	1 set	a) Self standing type, indoor
b) Fuel handling panel	1 set	b) Self standing type, outdoor
c) Sludge treatment panel	1 set	c) Self standing type, indoor
d) Common alarm panel	1 set	d) Self standing type, indoor
② Existing equipment to be remodeled		
a) Generator control panel	2 sets	a) Self standing type
b) Synchronized & alarm panel	1 set	b) Self standing type
c) No.1 low-voltage power panel(MCC)	1 set	c) Self standing type
d) No.2 low-voltage power panel(MCC)	1 set	d) Self standing type
4) Spare parts for generating facilities For normal operation (consumables)	for 16,000 hours	Oil filter elements, lubricating oil filter elements, O-rings, fuel injection nozzles, ion exchange resins for water softening

4) Remodeling Plan for Existing Facilities Foundation

Associated with the remodeling plan for fuel service system, a new diesel oil storage tank ($300m^3 \times 1$ unit) will be constructed at the place adjoining the existing fuel tank yard. In addition, the ground floor slab in the existing waste oil treatment facility will be modified and a place will be provided to install a new sludge treatment system.

① Foundation

Although the foundations of the existing 1,000m^3 fuel tanks were constructed by direct foundation method in 1996, any defects such as differential settlement or cracks have not yet occurred up to the present. Furthermore, the results of the boring test and soil bearing tests show that the ground conditions at the planned site where a new diesel oil storage tank will be constructed have sufficient bearing capacity. Therefore, a direct foundation will be adopted.

(2) Plan on Construction of New Generating Equipment

1) Basic Requirements

The available space for the Project is limited due to the constraint of installing within the existing C5 power station. Therefore, sufficient consideration should be taken not to hinder operation and maintenance of the existing generating units in establishing general layout and specifications of major equipment supplied under the Project including cabling and piping routes. At the same time, easy operation and maintenance as well as economical installation and operation should be considered. Although most of the main equipment and systems will be installed within the existing generating power house, some auxiliary equipment such as radiators will be installed outdoors. In such case, the site conditions such as wind, rain and dust should be taken into account.

In the case of laying 22kV transmission cables, the existing units should be stopped when connecting new cables to the existing C6 power station and cables between the said power station and Grid Substation 1 (GS-1). Therefore, a work plan to minimize the impact on residents should be formulated.

The contents of equipment and materials to be procured under the Project will be based on the following basic requirements and planning concept. The general arrangement and generating facility arrangement are shown in the Basic Design Drawings G-01 and G-02. Electrical and mechanical key flow diagrams are shown in M-01 to M-07.

① Generating Method

The diesel engine generating method will be adopted in consideration of the generating method of existing power station, the request of the Cambodian side, as well as easy operation and maintenance.

② Control Method

In a manner similar to the existing generating system, both remote and manual operation methods will be adopted. Although remote operation will be carried out by the existing supervisory and control room, manual operation will also be adopted after considering safety during startup and shutdown of the diesel engine.

③ Fuel

The existing generating facilities owned by EDC use both diesel oil and C heavy oil. The price of heavy oil is approximately 60% that of diesel oil, and it can be easily obtained in Phnom Penh. C heavy oil will be used as the main fuel under the Project because EDC regards the reduction in generating unit price to be an issue. Moreover, power stations recently constructed by EDC also use heavy oil.

In the case of using C heavy oil as the main fuel, since the fuel combustion efficiency worsens under lower loads, the lowest feasible output with C heavy oil will be approximately 50% of the rated output, and approximately 2.5MW in the case of the 5MW unit. As the existing generating units at the C5 power station are generally operated at the rated output, there is no hindrance in operation. However, diesel oil will be used on the occasion of ① 30 minutes from an engine start up, ② 30 minutes before an engine shutdown and ③ when some troubles happen on heavy oil supply system. Therefore, a diesel oil supply facility should also be provided. The fuel exchange will be carried out automatically or manually depending on load conditions.

④ Lubricating Oil

If available lubricating oil at the existing facilities can be used for the newly installed units, compatibility with existing facilities and efficient utilization of storage space should be promoted. However, after the tender, lubricating oil for the new units will be decided on the manufacturer's recommendation.

⑤ Cooling Water

Under the Project, the city water will be used for cooling system; its composition is shown in Table 2-2-12.

2) Planning Concept

The power demand forecast in Phnom Penh Power System as of the end of March 2004 is shown in Appendix 7-(2). The planning concept for the Project based on the forecast is as follows.

① Generator Output and Unit Capacity

As shown in Appendix 7-(2), from 2005 the Phnom Penh Power System will begin to experience shortages (shortage in supply capacity). If the Project is not implemented, a shortage of approximately 9MW is expected in 2007. To satisfy the maximum power demand and secure a slight emergency supply, a 10MW or greater capacity of generating unit should be provided in the relevant year. As the basic principle of the Project is to provide necessary but minimal equipment and materials needed to avoid a power crisis in Phnom Penh, the output of new generating units in the Project will be 10MW. From this point of view, the generating units (10MW) requested by Cambodia are judged to be appropriate. With respect to unit capacity, the same generating units as the existing 5MW units will be selected since EDC is familiar with their operation and maintenance.

② Engine Revolution Speed

In general, a medium-speed unit of 750 rpm or lower speed will be selected for diesel engine generating units of 2MW or greater unit capacity used for continuous operation. Most of existing medium-scale diesel engine units in Cambodia have an engine speed of 750 rpm. Therefore, the engine speed under the Project will be 750 rpm or lower.

③ Mechanical Auxiliary Systems

Whenever possible, a common equipment system will be adopted for auxiliary mechanical equipment and systems in order to ensure easy operation, maintenance and energy conservation including equipment procurement cost, and to harmonize with the existing facilities. These systems are outlined as follows.

(a) Fuel Supply System

A fuel supply system for new generating units will branch off from fuel pipelines near the C heavy oil transfer pump to be installed at the time of fuel conversion and the existing diesel oil transfer pump under the Project.

New fuel service units will be installed after the branching points. The fuel oil system diagram is shown in Basic Design Drawing M-02.

(b) Lubricating Oil System

A lubricating oil tank for engine and generator, which is generally installed in the common bed, will be installed at outside of the common bed for easy maintenance. To remove foreign objects mixed in the lubricating oil, a filter-type oil cleaner will be installed in the lubricating oil system. For making up purposes, lubricating oil for engine and generator will be directly supplied to the tank from the drum using an electric pump inside the power house while handy pump will be used for turbocharger lubricating oil system. The lubricating oil system diagram is shown in Basic Design Drawing M-03.

(c) Cooling Water System

A closed circulation system using a radiator will be adopted for the new generating units to reduce cooling water consumption and to ensure easy maintenance. Cooling water will be supplied to high-temperature /low-temperature service tanks via a circulation pump from the existing feed water buffer tank. The cooling water system diagram is shown in Basic Design Drawing M-04.

(d) Start-up System

The start-up system for the diesel engine will be a pneumatic start-up system using compressed air similar to that of existing systems due to the advantage of its large startup torque. A motor driven air compressor will be adopted. Ten years have already elapsed since the existing air compressor system was installed, so its reliability is questionable. Consequently, a new air compressor system will be installed as a generating startup unit under the Project. At the same time, the existing facilities will be connected to the new air compressing system for improving the reliability of the system. The system has a sufficient capacity to start one engine three times. The compressed air system diagram is shown in M-05.

(e) Intake Air and Exhaust Gas System

This system for the supply of combustion air for the engines will be installed outside of the power house. Exhaust air from the engine will be discharged outside via an outdoor silencer. The system capacity will be sufficient enough to allow the rated operation of two new generating units. The air intake and exhaust gas system flow diagram is shown in Basic Design Drawing M-06.

(f) Sludge Treatment System

Under the Project, waste oil discharged from the engine and auxiliary equipment will be connected to the existing sludge collection tank. The sludge treatment (disposal) system diagram is shown in M-07.

(g) Piping

Under the Project, piping includes piping for compressed air, cooling water, fuel oil and draining. The pipes will be laid in trenches or with supports inside the power house for easy maintenance. Each pipe will be color coded for easy maintenance and to avoid miss operation.

④ Electrical Facility Plan

The single line diagrams for the relevant generating facilities are shown in Basic Design Drawings E-01 to E-03.

(a) Electrical System

The electrical system for the new equipment will be the same as the existing system described below.

a) Nominal voltage: 22 and 6.3 kV, three phase, three wires
400-230 V, three phase four wires (three phase + neutral line)
DC 110 V, two wires

b) Frequency: 50 Hz

c) Interrupting capacity: 22 kV system: 25 kA (1 sec. sym)
6.3 kV system: 20 kA (1 sec. sym)

d) Grounding system: Direct grounding

e) Basic insulation level (BIL): 22 kV system: BIL 125 kV, AC50 kV
6.3 kV system: BIL 60 kV, AC 20 kV

f) Cree page distance: 20 mm/kV

g) DC control voltage: DC 110 V

h) Allowable voltage fluctuation: 22 kV system: + 5 to - 5 %
6.3 kV system: + 5 to - 5 %
400-230 V system: + 5 to - 5 %
DC 110 V system: + 5 to - 10 %

(b) Electrical Equipment

The following conditions will apply to electrical equipment in due consideration of existing systems and climatic conditions.

a) Phase identification: IEC standards (red, yellow, blue and black)

b) Insulator: Ceramic material, white (indoor)

c) Contamination level: IEC standards (medium pollution area)

d) Distribution panel protection grade and thickness:

Application	Panel thickness	Protection grade
Outdoor	not less than 2.3 mm	IP53 or higher
Indoor	not less than 1.6 mm	IP20 or higher

(c) Generator

New 3-phase, 3-wire, synchronous generator will have a horizontal shaft, air cooling system and salient or cylindrical pole type with removable perforated sheet metal for cooling air, same output as the existing generators and need for easy maintenance. The generator voltage will also be 6.3kV, same as the existing generators. The main specifications are as follows.

a) Rating: Continuous

b) Capacity: Not less than 6,250 kVA

c) Voltage: 6.3 kV

d) Frequency: 50 Hz

e)	Power factor	0.8 (lagging)
f)	Revolution speed:	Same as diesel engine (directly connected to engine)
g)	Excitation:	Brushless thyrister type
h)	Neutral point grounding:	Transformer installed (high impedance grounding)

(d) 22kV High Voltage System

In similar manner as the C6 power station, the generating voltage (6.3kV) will be stepped up to 22kV which is the distribution voltage in Phnom Penh in order to promote energy conservation at the facility. At the same time, synchronization with the existing generators will be conducted through this 22kV high voltage panels. Although the said panels are planned to be installed in the existing high voltage panel room, space for the said panel is inadequate. Therefore, some of 15kV panels which are not presently being utilized will be removed in order to ensure the space for the new panels. Its operation will be controlled both locally and from the supervisory and control room for easy operation and maintenance.

The circuit breaker used for this high voltage panel will be a vacuum-type breaker not containing PCBs or Freon. The 22kV high voltage panel will comprise of the following five panels.

- Generator CB panel (2 panels)
- Bus interconnection panel (2 panels)
- Station transformer feed panel (1 panel)

On the other hand, the main step up transformers will be installed outdoors, like the existing transformers, next to the existing transformers for easy maintenance. Station transformers will also be installed outdoors and all transformers will be surrounded by a protective fencing for safety.

A transformer for excitation and 6.3kV panels for the neutral point transformer will be installed inside the fence.

(e) Low Voltage Power Panel

So that the power supply to all related auxiliary equipment can be controlled, 400V and 230V low voltage power panels will be installed. In due consideration of supply stoppages from a power supply accident, a plan should be formulated to supply emergency power from the low voltage power panel of the existing No.1 and No.2 units. The low voltage power panels are as follows.

- Low voltage station service power panel (1 panel)
- Low voltage power panel for No.3 and No.4 units (total 2 panels)
- Common low voltage power panel for No.3 and No.4 units (1 panel)
- DC system panel (1 panel)

Although the existing low voltage power panels are installed in the supervisory and control room, there is inadequate space to install the above-mentioned panels to be procured under the Project. No space is also available to lay new cables even in the existing cable pit. Consequently, under the Project the above-mentioned low voltage power panel will be installed by modifying the existing warehouse to an new electrical room. This will contribute to the easy connection of cables for related auxiliary equipment and be economically advantageous in promoting energy conservation.

(f) Local Control Panel

A local control panel will be provided near the engine to monitor the status of engine operation, startup and shutdown.

(g) DC Power Supply System

The capacity of the existing DC power supply system is insufficient as power source for operation and monitoring of the new system. Under the Project, a new 110V DC power supply system will be installed as the power source for the control panel and circuit breaker, etc.

(h) Grounding System

The required grounding system under the Project will consist of the following.

• Grounding to protect grounding faults
• Grounding to prevent electric shock from metal surfaces or electrical equipment
• Grounding for the fuel oil tank (independent grounding)

(i) Cable Installation

The same cable installation method used in a previous project will be used for the Project. The cables inside the power house will be placed inside a cable trench, tray or conduit while the cables outside the power house will be either placed inside a conduit or buried directly underground. Those cables placed inside a cable trench or conduit will not be armored, while those buried directly underground will have armor protection. Copper conductor cables will be used because of their flexibility and general-purpose cross-linked polyethylene will be used for insulation.

(j) Instruments

Given the fact that the instruments to be used for various types of equipment will be used for a public power supply, a special class of JIS 1.0 will be adopted for integrated instruments such as watt-hour meters because they are directly associated with the performance and economic operation of the equipment; while an accuracy 1.5 or higher will be adopted for indicators such as ammeters, voltmeters and pressure gauges, etc. since their primary purpose is checking of operating conditions. However, an accuracy of 1.0 will be adopted for watt-hour meters for station low voltage power.

3) Outline of Main Equipment

The outline of specifications for the main equipment of generating facilities to be constructed under the Project is shown in Table 2-2-14.

Table 2-2-14 Outline of Main Equipment (Additional Installation)

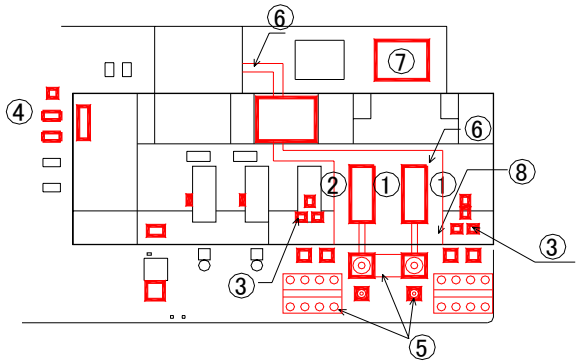
Equipment name	Q'ty	Approximate specifications
Additional installation plan (all newly established)		
1) Diesel engine generating system		
(a) Diesel engine	2 units	Duty: Continuous operation Output: 5 MW Revolution speed: No more than 750 rpm Type: Four cycle Cooling system: Radiator cooling Fuel: Heavy oil with service tank with common bed and anti-vibration system
(b) Generator	2 units	Duty: Continuous operation Rated output: 6.25 MVA Number of phases: Three phase three wire Rated voltage: 6,300 V Revolution speed: Not more than 750 rpm Power factor: 0.8 (lagging) Frequency: 50 Hz Coil connection: Y (connected to neutral point of the transformer) Exciter: Brushless thyrister type
2) Main transformer	2 units	Duty : Continuous operation, outdoor installation Capacity: 6.3 MVA Number of phases: Three phase three wire Rated voltage: High voltage: 22kV ±2 x 2.5% Low voltage: 6,300 V Tap changer: Off load
3) Station transformer	1 unit	Duty: Continuous operation Capacity: 1.6 MVA Number of phases: Three phase three wire Rated voltage: High voltage: 22kV ±2 x 2.5% Low voltage: 400-230V (three phase four wire)
4) Electrical equipment		
a) Control panel	2 panels	a) Self-standing type, monitoring and control of generators and auxiliary equipment
b) Protection relay panel	2 panels	b) Self-standing type
c) High voltage monitoring and relay panel	1 panel	c) Self-standing type, for 22 and 6.3 kV
d) 22 kV high voltage panel	2 panels	d) Self-standing type, vacuum circuit breaker, indoor installation,
e) 6.3 kV high voltage panel	1 panel	e) Self-standing type, indoor installation
f) 400 V low voltage panel	1 panel	f) Self-standing type, ACB and MCCB, indoor installation
g) DC power panel	1 panel	g) Self-standing type, indoor installation
h) Wiring materials	1 panel	h) Cables, pipes for cables, trays, etc.
5) Mechanical equipment		
a) Heavy oil supply system	1 set	a) Heavy oil purifier units, a buffer tank ($5m^3$) and a service tank ($5m^3$)
b) Diesel oil supply system	1 set	b) A diesel oil service tank ($5m^3$)
c) Fuel supply pipe	1 set	c) Electrical line heaters, pumps and filters
d) Lubricating oil system	1 set	d) Lubricating oil coolers, purifiers and sump tanks ($7m^3$/tank)
e) Cooling water system	1 set	e) Radiators, cooling water tanks and pumps
f) Compressed air system	1 set	f) Air compressors and air receivers
g) Sludge treatment system	1 set	g) A sludge collecting tank ($2m^3$)
6) Spare parts for generating facilities Normal operation (Consumables)	16,000 hours	Oil filter elements, lubricating oil filter elements, o-rings, fuel injection nozzles and ion exchange resin for water softener, etc.

4) Generating Facilities Foundation Plan

New construction and remodeling foundations for equipment associated with the Project are shown in Table 2-2-15.

Table 2-2-15 Foundations for Equipment

Foundations		Work description
①	Foundation for new generating facilities	Newly constructed for 2 units (existing foundation was removed for both 2 units)
②	Foundation for existing generating facilities	Removed foundation for existing unit (site will be used for new generator units)
③	Foundation for indoor auxiliary equipment	Newly constructed
④	Foundation for transformer	Newly constructed
⑤	Foundation for outdoor auxiliary equipment	Newly constructed (existing foundation was removed)
⑥	Cable pit	Newly constructed
⑦	Blower room	Newly constructed
⑧	Auxiliary equipment pit	Remodeling of existing pit



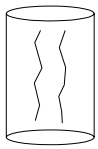
Equipment Layout Diagram

① Remodeling Plan for Generator Foundation

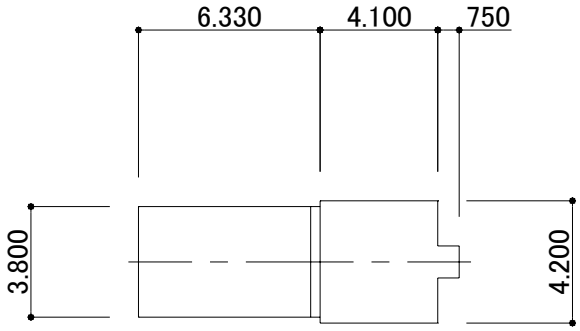
Although there are foundations for the existing three generator units built by the former Soviet Union, it does not conform to the new generators' specifications for length, width, thickness and location. As shown in Table 2-2-16, for the purpose of studying the strength of the concrete of the existing foundation, a compression test through core sampling in four different spots was carried out. However, the result of the test showed that the density was low (2.26 to 2.31 t/m^3), and cracks occurred instead of shearing, so the concrete appears to be fragile. In addition, the test sample revealed that the foundation was not constructed of 100% concrete; sand was also used. Based on the test results shown above, the strength of existing foundations was judged to be insufficient enough to support the weight of the new generating facilities (80 to 100 tons) and the vibration from equipment. Under the Project, new more suitable

foundations will be constructed after removal of the existing foundations. The direct foundation method will be adopted since, based on plate bearing and boring tests, the ground at the Project site is sufficient enough to support the generator foundations and auxiliary equipment. In addition, a basic foundation design able to handle a weight distribution percentage 1.5 to 2.0 times that of the generators should be formulated taking their vibration characteristics into consideration.

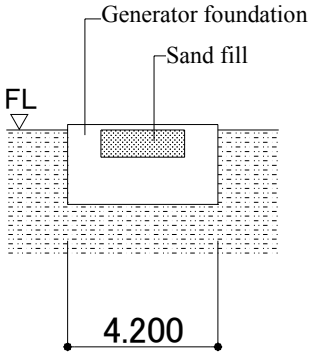
Table 2-2-16 Results of the Concrete Compression Test

Date of test	April 2, 2004						
Specimen locations	Foundation of the existing generators						
Specimen No.	Specimen size (cm)		Cross section (cm^2)	Density (t/m^3)	Break load (kgf)	Compressive strength (MPa)	Break shape
	Length	Diameter					
No.1	17.45	10	78.54	2.31	208.0	27.00	 Crack
No.2	Breaking						
No.3	19.60	10	78.54	2.30	232.0	30.12	
No.4	19.85	10	78.54	2.26	182.0	23.62	

1MP=10kg/cm^2



Plane size of existing generator foundation



Cross section of the existing generator foundation

2-2-3 Basic Design Drawings

The following basic design drawings have been prepared and shown in Appendix 5.

G-01	Site Plan	M-02	Fuel Oil System Key Flow Diagram
G-02	C5 Power House Equipment Layout	M-03	Lubricating Oil System Key Flow Diagram
E-01	Key Single Line Diagram	M-04	Cooling Water System Key Flow Diagram
E-02	22/6.3 kV Single Line Diagram	M-05	Compressed Air System Key Flow Diagram
E-03	Low Voltage Single line Diagram	M-06	Air Intake & Exhaust Gas System Key Flow
M-01	Symbol List	M-07	Sludge System Key Flow Diagram

2-2-4 Implementation Plan

2-2-4-1 Implementation Policy

The Project will be implemented in accordance with the framework of Japan's grant aid scheme. Accordingly, the Project will only be implemented after its approval by the Government of Japan and the formal Exchange of Notes (E/N) between the Government of Japan and the Government of Cambodia. The basic issues and special points of consideration for the implementation of the Project are described below.

(1) Project Implementation Body

The organization responsible for the implementation of the Project on the Cambodian side is the Ministry of Industry, Mines and Energy while the *Electricite du Cambodge* (EDC) will be in charge of the actual implementation of the Project. The EDC is responsible for all aspects of power supply services in Cambodia, ranging from studies and planning for construction, operation and maintenance. The Cambodian side should appoint a person from the EDC to be responsible for the Project through close communication and consultation with the Japanese Consultant and the Contactor to ensure the smooth implementation of the Project.

The selected person will be required to explain the contents of the Project to staff of power stations and related government officials in Cambodia. He/she will also fully explain the contents of the Project to local residents who live around the Project site to obtain their understanding and will provide guidance for local people in view of their safety during the construction period and their cooperation with the Project to ensure its smooth implementation.

(2) Consultant

In order to construct the necessary facilities and to procure and install the necessary equipment for the Project, the Japanese Consultant will conclude a consultant services agreement with the Government of Cambodia and will conduct the detailed design and supervision of the site work for the Project. The Consultant will also prepare the tender documents and will assist the prequalification and tender to be implemented by EDC which will be the project implementation body.

(3) Contractor

The Contractor, which will be (a) Japanese company(ies) selected by the Government of Cambodia by means of open tender in accordance with Japan's grand aid scheme, will carry out the construction of the planned facilities and the procurement and installation of the equipment and materials of the Project.

As it is necessary for the Contractor to provide after-care in terms of the supply of spare parts and repair of breakdowns in the equipment supplied under the Project, the Contractor should establish a post-Project liaison system.

(4) Necessity to Dispatch Japanese Engineers

The planned new generating facilities installation work including the fuel conversion work are a combination of the equipment foundation work and the equipment installation work, both of which will be conducted simultaneously. This complexity will make it necessary to dispatch a site manager from Japan to provide consistent management and guidance on schedule control, quality control and work safety.

Moreover, the planned installation of the generating equipment will demand wide-ranging knowledge and expertise in regard to the equipment functions and configuration. Accordingly, the manufacturers of generating equipment will be required to dispatch experts at appropriate times to supervise the installation, test operation and adjustment of the relevant main equipment.

In general, the possibility of system fault can be illustrated by the bathtub curve which is classified into three periods, the initial fault period, accidental fault period and aged breakdown period. A proper response to necessary repairs in the initial breakdown period during which the number of breakdowns is comparatively high is very important to ensure long life of the equipment. Accordingly, dispatching of instructors (lecturers) will be considered within the period of the E/N to provide technical guidance (OJT) to assist engineers and technicians to learn the skills required to deal with initial breakdowns.

2-2-4-2 Implementation Conditions

(1) Condition of the Construction Industry in Cambodia

1) While it is possible to employ Cambodian laborers for construction work, there are not many skilled workers or engineers with special knowledge and technical expertise in scheduling, and quality and safety control, etc. Therefore, it will be

necessary for the Japanese contractor to dispatch engineers and/or skilled workers to Cambodia when deemed appropriate.

2) As it will be difficult to recruit local engineers with experience in installing and tuning the medium size generating units to be provided under the Project, dispatching of Japanese engineers is planned to supervise such work and for schedule control referred to in 2-2-4-1 (4).

3) As the minimum construction equipment and other machinery required for site construction work and inland transportation and installation of equipment under the Project are available in Cambodia, such equipment will be utilized locally.

(2) Special Considerations in Construction Planning

1) The rainy season at the Project site lasts from May to October. Appropriate measures including the planning of shelters for rain and rainwater drainage should be included for the outside foundation or excavation work and termination of 22kV high voltage cables during this period.

2) The fuel conversion work and generating equipment installation should be implemented simultaneously with the foundation work and building services work in order to keep the work period as short as possible to minimize any adverse effects on residents due to power cut off during construction period.

3) Outdoor excavation work for fuel pipes or power cables should be carefully conducted to avoid any damage to the existing underground power cable, water supply, sewers and telephone line. The schedule should be planned so that it does not hinder the fuel oil supply to C6 power station.

4) In the case of the new generating facility installation work, generating equipment installation and the building services work will be conducted simultaneously so that the contracted completion date can be strictly met. Therefore special attention should be given to work safety since due to the likelihood of simultaneous implementation of construction and installation work workers will be working above others at different levels.

5) In the case of any additional work, such as the necessary cutting of existing trees, the scope of the required work and its timing, etc. should be agreed upon by EDC in advance. In addition, such work should be approved by the relevant ministry or

agency and be fully understood by local residents to avoid any environmental damage or dispute with local residents.

2-2-4-3 Scope of Work

The respective scope of the procurement and installation work for the Japanese and Cambodian sides under the Project is shown in Table 2-2-17.

Table 2-2-17 Work Share between Japanese and Cambodian Sides

Work Item	Procurement (to bear)		Installation (to implement)		Remarks
	Japan	Cambodia	Japan	Cambodia	
1. Common work					
(1) Cleaning of existing 2 diesel oil storage tanks including removal of sludge	-	○	-	○	To be completed before commencement of the Project
(2) Construction of diesel oil storage tanks necessary for C6 power station	-	○	-	○	Same as above
(3) Repair work for existing No.1 engine and damage newly discovered during the repair work	-	○	-	○	Completed in June, 2004
(4) Cleaning of access roads to the construction site and removal of obstacles	-	○	-	○	To be completed before commencement of the Project
(5) PR activities to consumers on load shedding associated with the implementation of the work	-	○	-	○	If necessary
(6) Obtaining approval on IEIA from the Ministry of Environment	-	○	-	○	Obtained in June, 2004
(7) Providing temporary storage yard for equipment and materials to be procured under the Project	-	○	-	○	To be completed before commencement of the Project
(8) Construction of a site office and temporary warehouse, etc.	○	-	○	-	Necessary area(s) should be provided by Cambodian side.
(9) Preparation of connection points for electricity, water supply and drainage, etc.	-	○	-	○	To be completed before commencement of the Project
(10) Electricity charges during the work and test operation periods	-	○	-	○	
(11) Water charges during the work and test operation periods	○	-	○	-	
(12) Lubricating oil expenses during the work and test operation period	○	-	○	-	
2. Fuel conversion work for existing generating facilities					
(1) Procurement of Equipment and materials necessary for the works	○	-	-	-	
(2) Installation work for above-mentioned equipment and materials	-	-	○	-	
(3) Modification of existing diesel oil storage tank to heavy oil tank with heating system	○	-	○	-	
(4) Modification work associated with fuel conversion for existing engines (2 units) and related auxiliary equipment	○	-	○	-	
(5) Modification work for existing electrical equipment	○	-	○	-	
(6) Implementation of civil engineering construction for fuel conversion work	○	-	○	-	If applicable
(7) Preparation of installation and maintenance manuals	○	-	○	-	

Work Item	Procurement (to bear)		Installation (to implement)		Remarks
	Japan	Cambodia	Japan	Cambodia	
(8) Testing instruments and tools	○	-	-	-	During the construction period, a construction company uses.
(9) Field (in-place) test	○	-	○	-	
(10) Technical transfer (OJT and soft component)	○	-	○	-	Classroom training (off-the-job training) will be conducted at the EDC training center.
(11) Provision of spare parts	○	-	○	-	For 2-year operation
3. Construction of new No.3 and No.4 generating units					
(1) Procurement of Equipment and materials necessary for the works	○	-	-	-	
(2) Installation of above-mentioned equipment and materials	-	-	○	-	
(3) Procurement of electrical equipment such as step up transformers, station transformers, 22kV circuit breakers, MCCBs, Battery equipment, etc.	○	-	-	-	
(4) Installation of the above-mentioned electrical equipment / materials	-	-	○	-	
(5) Procurement and installation of 22kV cables to GS-1 sub-station via C6 power station	○	-	○	-	Including replacement of cables from C6 to GS-1
(6) Civil engineering work including building services (such as lights and fire alarms)	○	-	○	-	Demolishing of existing engine foundations
(7) Preparation of installation and maintenance manuals	○	-	-	-	
(8) Testing instruments and tools	○	-	-	-	During the construction period, a construction company uses.
(9) Field (in-place) test	○	-	-	-	
(10) Technical transfer (OJT and soft component)	○	-	○	-	Classroom training (off-the-job training) will be conducted at the EDC training center.
(11) Provision of spare parts	○	-	-	-	For 2-year operation

Remark: "○" indicates side responsible for work/procurement concerned.

2-2-4-4 Consultant Supervision

The Consultant will organize a project team in accordance with Japan's grant aid scheme and the concept and principles of the basic design in order to smoothly proceed with the implementation of the Project. The Consultant will also appoint at least one full-time onsite engineer to supervise the schedule control, quality control and safety control and will dispatch other relevant expert engineers in accordance with the progress of the installation, test operation and adjustment and acceptance test, etc. to supervise the work assigned to the Contractor.

Furthermore, the Consultant will arrange Japanese experts to attend, when necessary, the inspection of equipment manufactured in Japan or a third country at the manufacturing and/or pre-shipment stages if necessary to prevent any equipment problems after delivery to Cambodia.

(1) Supervision Principles

The Consultant will supervise the work progress to ensure punctual completion within the planned period and will supervise and guide the Contractor in order to achieve the work quality and to observe the delivery schedules for the equipment, etc. indicated in the contract without accidents or other problems at the site.

The main points to be noted for the supervisory work are described as below.

1) Schedule Control

The Consultant will make weekly and monthly comparisons between the actual work progress and the contract schedule submitted by the Contractor at the time of signing the contract on the following items. If the Consultant foresees any delay of the work, he/she will issue a warning to the Contractor, to request the Contractor to submit remedial plans to ensure the completion of the construction work and equipment delivery within the planned work period.

① Confirmation of the working progress (including the volume of manufactured equipment by the manufacturers)

② Confirmation of the date of shipment of the equipment

③ Confirmation of the temporary work and preparations for the construction machinery

④ Quantity of the equipment and materials delivered (for generation equipment and construction facilities)

⑤ Work efficiency and actual record of engineers, technicians and workers at site

2) Safety Control

The Consultant will discuss and cooperate with the representative of the Contractor with a view to supervising the onsite construction and installation work to prevent any accidents to workers with due attention paid to the following safety control principles.

The points to be noted concerning safety control at site are described as below.

① Establishment of safety control rules and appointment of a person responsible for industrial safety

② Enforcement of safety control rules and regular checks

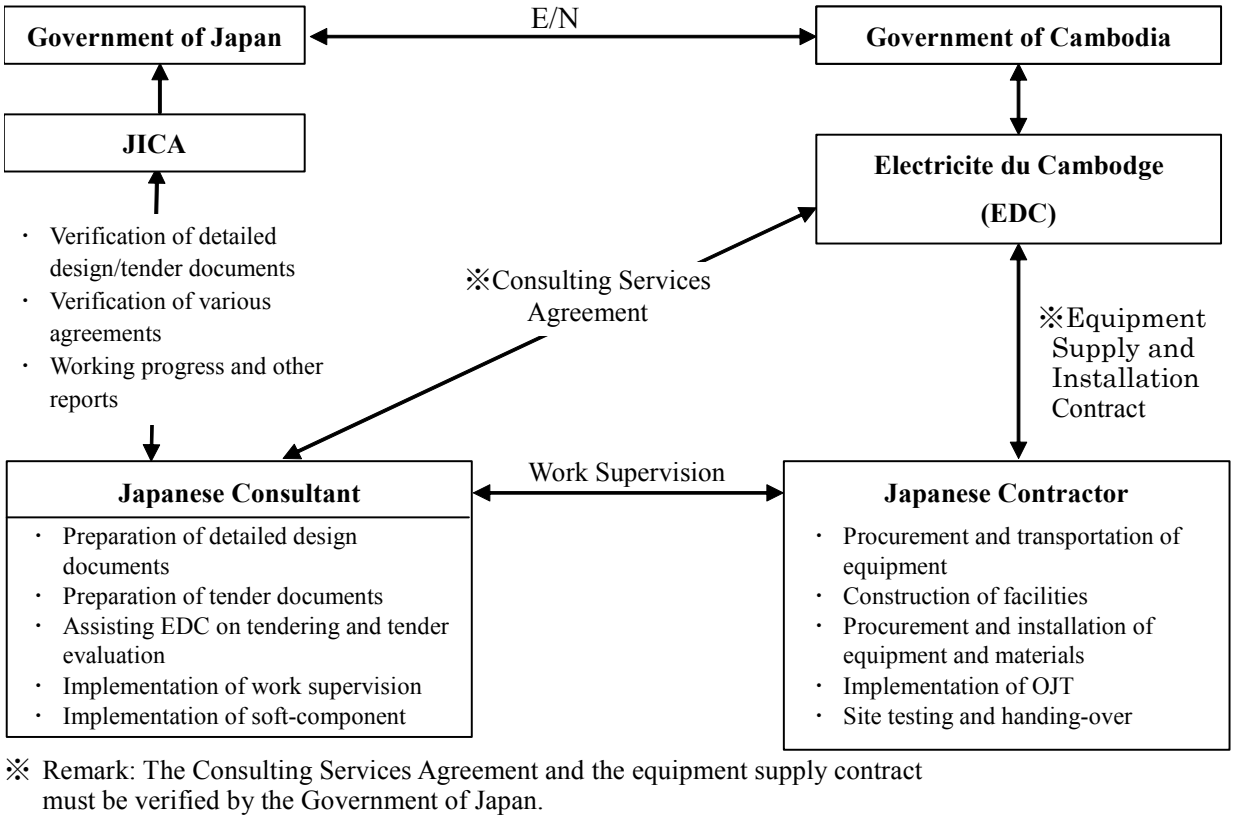
③ Prevention of accidents to workers by means of regular inspection of construction machinery

④ Determination of travel routes for work vehicles and construction machinery, etc. and thorough enforcement of slow driving at the site

⑤ Enforcement of welfare measures and days-off for workers

3) Project Implementation Regime

The project implementation regime, i.e. relationship between the parties involved in the implementation of the Project, including at the work supervision stage, is shown in Figure 2-2-1.



※ Remark: The Consulting Services Agreement and the equipment supply contract must be verified by the Government of Japan.

Figure 2-2-1 Project Implementation Regime

(3) Work Supervisors

The Contractor must have sufficient experience to make proper judgment on all aspects of the work and must be capable of providing appropriate technical guidance in view of the smooth implementation of the construction work and equipment procurement and installation work as described in the detailed design documents within the planned work period. It is desirable, therefore, that the Contractor dispatches a site supervisor to the Project site with previous experience of similar projects to ensure the high quality of the work to be conducted.

Given the size and contents of the Project, the appointment of the following full-time onsite supervisor by the Contractor is deemed essential.

☆ Site Manager (1): General management of onsite work (civil engineering, construction, mechanical and electrical work)

In addition to the above, further dispatching of engineers will be required in accordance with the work progress. The subject areas for expert supervision will include equipment installation and test operation/adjustment. The following personnel are estimated to be main specialists.

☆ Electrical engineer - 1 Installation of generators
☆ Electrical engineer - 2 Generator testing
☆ Electrical engineer - 3 22kV and 6.3kV high voltage systems
☆ Electrical engineer - 4 22kV and 6.3kV cable handling
☆ Electrical engineer - 5 Panel installation and wiring work
☆ Electrical engineer - 6 Comprehensive OJT of electrical work
☆ Electrical engineer - 7 Transformer installation adjustment and testing
☆ Mechanical engineer - 1 Installation of Engine
☆ Mechanical engineer - 2 Testing of Engine
☆ Mechanical engineer - 3 Auxiliary equipment assembly, installation and testing
☆ Mechanical engineer - 4 Comprehensive OJT of mechanical work
☆ Mechanical engineer - 5 Welding work
☆ Building services - 1
☆ Civil engineering foundation - 1

2-2-4-5 Procurement Plan

Most of the construction materials to be used and equipment to be procured under the Project are not manufactured in Cambodia. Although some construction materials (such as aggregate, cement and forms) are available locally, it will be difficult to guarantee the punctual delivery or quality of other items which will, therefore, be procured in Japan and/or a third country.

All equipment and materials for generating facilities procured in the previous assistance project are Japanese products which operation and maintenance personnel of EDC are accustomed to handle. The generating systems to be procured under the Project can be installed next to the existing Japanese generating equipment and operated in parallel. In addition, the after-services of Japanese manufacturers are highly organized. Accordingly, EDC strongly requests the Japanese equipment and materials to be procured under this Project. On the other hand, products such as low voltage cables and piping materials made in ASEAN countries (Thailand, Singapore, etc.) are lately available in the local market. Therefore, the procurement of these types of equipment and materials from third countries (ASEAN) will be considered.

The planned equipment and material supply sources for the Project are shown in Table 2-2-18 based on a comparative analysis of possible sources from the viewpoint of (i) reliability in terms of standards, specifications, quality, production and supply, (ii) ease of operation and maintenance, and (iii) availability of spare parts, after-sales service in case of defects, etc.

Table 2-2-18 Equipment and Materials Supply Sources

Equipment/Materials	Supply Source		
	Cambodia	Japan	Third Country
Fuel oil, cooling water	○	-	-
Lubricating oil	○	○	-
(Construction equipment and materials)			
Sand, gravel	○	-	-
Cement	○	-	-
Ready-mixed concrete	○	-	-
Reinforcing bar	-	○	○
Structural steel	-	○	○
Building equipment, fishing materials	-	○	○
(Equipment and materials for diesel engine generating facilities)			
Diesel engine, generator (generator panel and remote control panel, etc.)	-	○	-
Auxiliary equipment for the above (fuel supply system, cooling water system and compressed air system, etc.)	-	○	-
Piping materials and accessories for the above	-	○	○
Electrical system (transformer, 22kV-CBpanel, power control panel and DC power system, etc.)	-	○	-
Electrical equipment materials (22kV and 6.3kV cables and accessories, etc.)	-	○	-
Electrical equipment materials (low voltage cables, electric wire, conduit pipe, cable, racks and accessories, etc.)	-	○	○
Diesel oil storage tank	-	○	○
Spare parts for diesel engine generating facilities	-	○	-
Maintenance tools for diesel engine generating facilities	-	○	-
(Construction machinery/vehicles for transportation)			
Construction machinery (up to 45-ton truck crane)	○	-	-
Over 45-ton truck crane	-	-	○
Low floor trailer (for engine transportation)	-	-	○

2-2-4-6 Quality Control Plan

The Consultant will supervise the Contractor with regards to the following items so as to ensure the quality of the facilities and equipment described in the contract documents by the Consultant (technical specifications and detailed design drawing, etc.) If the Consultant believes that the quality does not meet the requirements, he/she will request that the Contractor correct, change or modify the situation.

(1) Checking of the shop drawings and specifications for equipment

(2) Checking of the factory inspection results for equipment or attendance at the shop inspection

(3) Checking of the packaging, transportation and temporary onsite storage methods

(4) Checking of installation drawings and installation manuals for the equipment and materials

(5) Checking of test operations, adjustment and inspection manuals for equipment at the manufacture's factories and onsite

(6) Supervision of site installation of equipment and materials, and attendance at test operations, adjustment and inspection

(7) Comparing of construction drawings and finished work

(8) Checking of as-built (Completion) drawings

2-2-4-7 Implementation Schedule

The Project will be implemented as follows in accordance with the Japanese grant aid scheme.

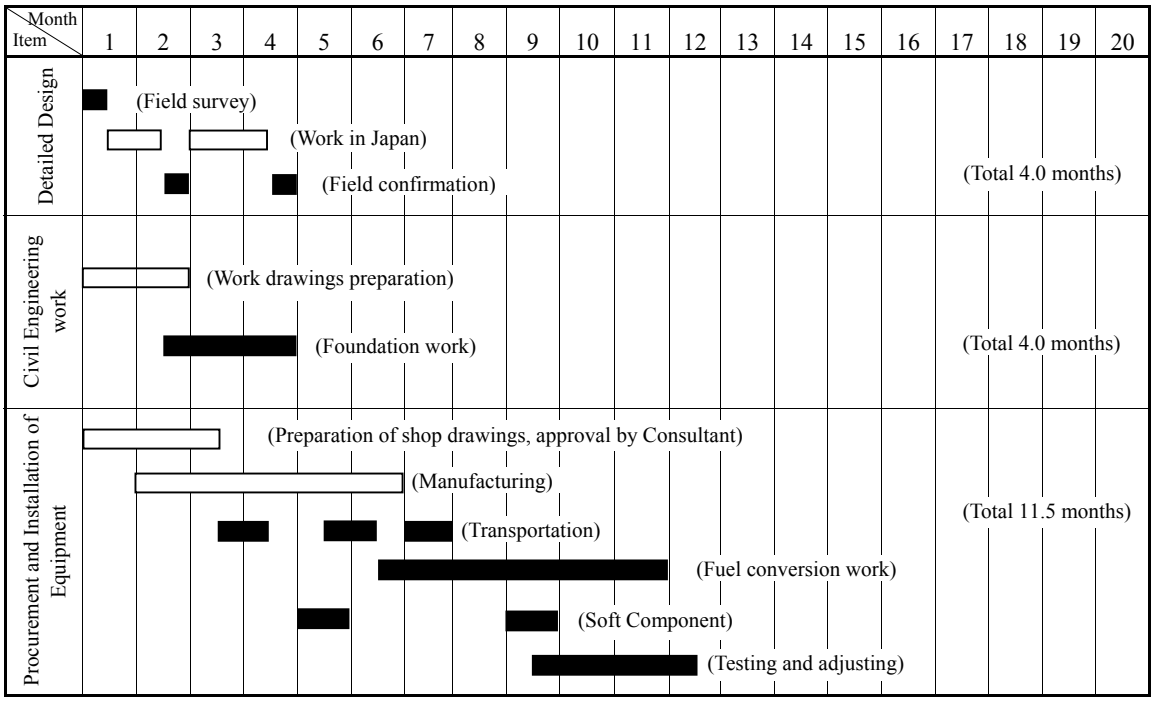


Figure 2-2-2 Project Implementation Schedule (Phase 1: Fuel Conversion Work)

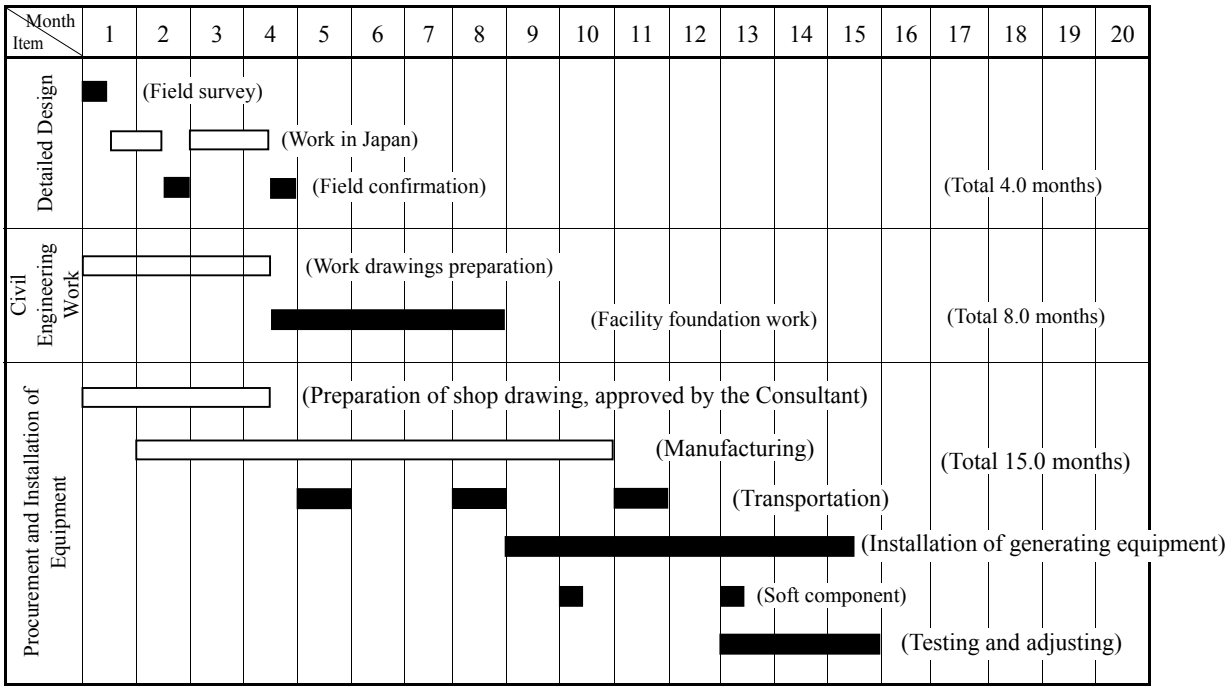


Figure 2-2-3 Project Implementation Schedule (Phase 2: Expansion Work)

2-3 Obligations of Recipient Country

In the course of the implementation of the Project, the Government of Cambodia will be responsible for the following work and providing the following items in addition to the scope of work by the Cambodian side as described in "2-2-4-3/ Scope of Work".

(1) To provide necessary data and information for the Project.

(2) To clear and arrange the Project site and access road necessary for fuel conversion work and new generating facilities / equipment construction work prior to the commencement of the work by the Japanese side.

(3) To ensure prompt unloading, customs clearance and tax exemption of equipment and materials for the Project at port and/or airport of disembarkation in Cambodia.

(4) To accord Japanese nationals whose services may be required with regards to the supply of products and services under verified contracts for their entry into Cambodia and stay therein in the performance of their work.

(5) To exempt Japanese nationals from customs duties, internal taxes and other fiscal levies that may be imposed in Cambodia with respect to the supply of products and services under the verified contracts.

(6) To bear commissions to a Japanese bank when opening a bank account based on banking arrangements.

(7) To bear all expenses other than those borne under the grant aid scheme necessary for the implementation of the Project.

(8) To attend delivery inspections for equipment and materials at the Project site, and to select engineers and/or technicians as counterparts in order to transfer operation and maintenance skills.

(9) To make plans and take necessary procedures for power cut off during the construction/installation period.

(10) To use and maintain properly and effectively all equipment and materials provided under Japan's grant aid scheme.

(11) To obtain approval for Initial Environmental Impact Assessment (IEIA) from the Ministry of Environment by the end of May 2004.

(12) To provide proper disposal sites for excavated soil, waste water and waste oil discharged during the construction period and also for removed equipment and materials.

(13) To tap diesel oil from the existing two (2) diesel oil tanks, remove the sludge and to clean up the bottom of the tanks before the commencement of the fuel conversion work.

2-4 Project Operation Plan

2-4-1 Basic Policy

Among the equipment to be provided under the Project, the generating unit is the most crucial equipment in terms of proper maintenance. The appropriate operation and maintenance of the unit and the preservation of the surrounding environment will be essential to enable a stable power supply which responds to daily demand fluctuations. In order to maintain the proper performance and functions of the planned generating units to ensure a stable supply of power, the establishment of a maintenance system enabling appropriate preventive maintenance designed to improve the reliability, safety and efficiency of the generation facilities is highly required. EDC should establish an organization to formulate an operation plan for the C5 power station in conformity with load characteristics of the Phnom Penh power system in order to operate the power system economically.

Figure 2-4-1 demonstrates the basic concept of maintenance for the generating facilities.

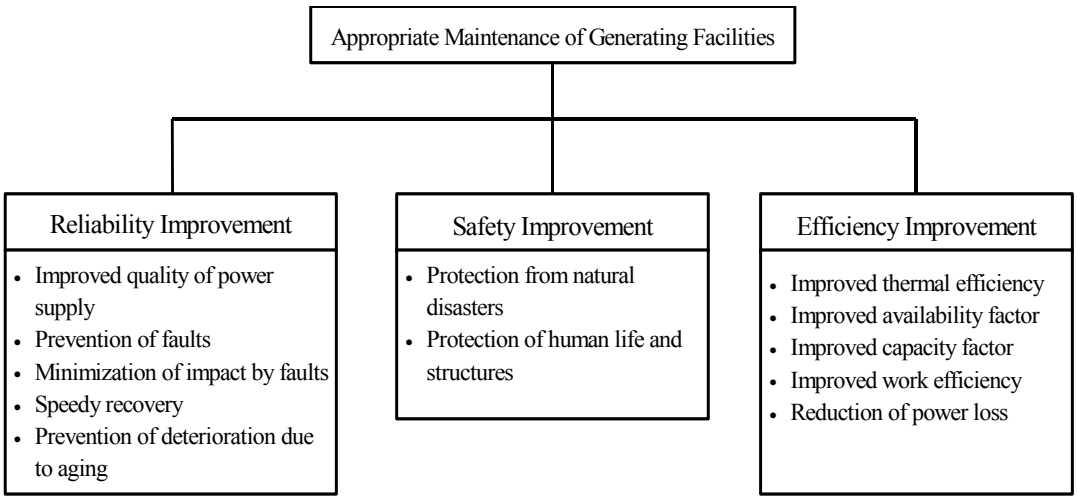


Figure 2-4-1 Basic Concept on Maintenance of Generating Facilities

For the successful outcome of the Project, it will be necessary for EDC to conduct adequate operation and maintenance of all equipment using the O & M techniques transferred to the Cambodian side through the Soft Component (technical transfer) by the Consultant and OJT to be provided by the engineers dispatched by the Contractor during the installation work and the test operation and adjustment period and also in accordance with the O & M manuals provided by the Contractor including the concept of preventive maintenance. The subject

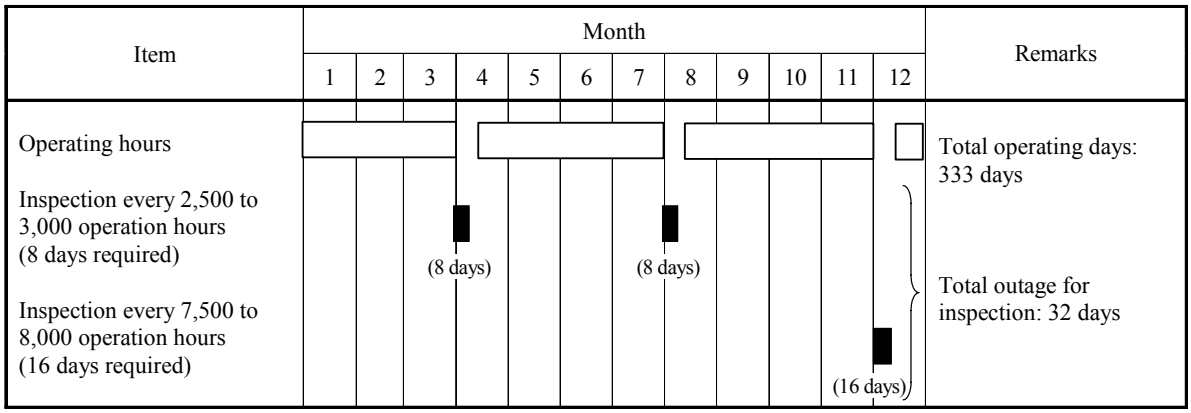
persons of the technical transfer will be engineers and technicians. A total of 22 persons in mechanical and electrical areas are planned to receive the technical transfer.

2-4-2 Operating Plan for Generating Facilities

The planned generating facility under the Project will provide for middle load operation between 6:00 a.m. and 10:00 p.m. as described in 2-2-2 and the adoption of the following operating conditions is deemed appropriate in view of its purpose and specifications.

Annual availability factor: 60% or higher (approx. 5,000 hours)
Annual utilization factor: No less than 50%

Table 2-4-1 shows the periodical inspection items required for the proper operation of the concerned generating facility while Figure 2-4-2 shows the annual operation program for the same facility for the first year based on the operating conditions mentioned above, taking the periodical inspection items into consideration. It is expected that the operation of the concened generating facility will be stopped for approximately 32 days/year as shown in Figure 2-4-2.



Note: Based on an annual availability factor of 90%.

Figure 2-4-2 Annual Operation Program for Generating Facility

2-4-3 Periodic Inspection Items

(1) Generating Facility

The standard items for the periodical inspection of the planned generating facility are shown in Table 2-4-1. The Cambodian side will be required to prepare an operation and maintenance plan for the planned generating unit in accordance with the O & M manuals

to be submitted by the manufacturers with a view to establishing an economical operation program for the unit in line with the actual power demand.

Table 2-4-1 Standard Periodical Inspection Items of Generating Facility

	Type of Inspection	Main Inspection Item/Work
Diesel Engine	Daily inspection	- Checking of fuel oil level of fuel oil tank and lubricating oil level of sump tank - Checking of jacket cooling water level - Checking of starting-up air receiver pressure - Visual checking of various sections
	1,000 hour inspection	- Checking of proper tightening of bolts and nuts - Cleaning of fuel and lubricating oil filters
	2,500 to 3,000 hour inspection	- Checking of proper working of and oil leakage from intake and exhaust valves, starting valve, fuel valve, fuel pump, piston and liner, etc. - Analysis of lubricating oil quality in sump tank
	7,500 to 8,000 hour inspection	- Checking of proper working of and oil leakage from fuel oil pump, piston, cylinder liner and replacement of gasket - Replacement of piston ring, O-ring, etc. - Overhauling of cylinder head and replacement of gasket and O-ring - Inspection of intake and exhaust valves and replacement of exhaust valve O-ring - Inspection of fuel injection valve and replacement of nozzle - Inspection of crank pin bearings and replacement if necessary - Overhauling and inspection of turbo charger and replacement of bearings, etc. - Analysis of lubricating oil of sump tank and oil replacement if necessary
	16,000 hour inspection	- The above-mentioned items under 7,500 to 8,000 hours inspection - Inspection and replacement of main bearings if necessary - Inspection and replacement of exhaust valve rotor if necessary - Overhauling, inspection and replacement of lubricating oil pump attached to engine if necessary
Generator	Daily inspection (during operation)	- Visual inspection of all sections and checking of abnormal sounds and temperature
	Monthly inspection	- Checking of abnormal vibration - Checking of lubricating oil flow and oil leakage from bearings - Necessary cleaning of components
	Annual inspection	- Measurement of insulation resistance and inspection of lead wires and terminals - Visual inspection of accessories, including space heater - Visual inspection of bearings and cleaning if necessary

The following number of days will be required to complete the standard inspections listed in the table.

- 2,500 to 3,000 hour inspection: 7 to 8 days/inspection
- 7,500 to 8,000 hour inspection: 15 to 18 days/inspection
- 16,000 hour inspection: 20 to 25 days/inspection

(2) Electrical System

The standard periodical inspection items for the station auxiliary power supply system to be procured and installed under the Project are shown in Table 2-4-2.

As the table shows, the inspection of the electrical system is classified into the following three categories.

1) "Patrol inspection" which is conducted daily using human senses to check any abnormal heating and sound, etc. of the equipment.
2) "Standard inspection" to check energized sections beyond the daily patrol inspection, including the tightness of bolts, etc. for equipment and cleanliness of or damage to the surface of insulated items, etc.
3) "Detailed inspection" to check the proper functioning of the interlocking mechanism between equipment and the accuracy of instruments, etc.

Standard inspections are conducted once every one year or two years on and detailed inspections are conducted once every four years. Replacement of parts is preferred based on confirmation of the characteristics and frequency of use of such parts. These include the fuses, measuring instruments and relays, etc. installed inside the distribution panels and others which are subject to performance deterioration, including the insulation performance, abrasion of contact points and change in characteristics.

Table 2-4-2 Standard Periodical Inspection Items for Electrical System

Subject	Inspection Item (Method)	Patrol Inspection	Standard Inspection	Detailed Inspection
Equipment Outlook	Condition of indicators and indication lamps	○	○	
	Abnormal sound or odor	○	○	
	Thermal discoloration of terminals	○	○	
	Cracks, damage or contamination of bushing and insulator	○	○	
	Rust on casings and frames	○	○	
	Abnormal temperature (thermometer)	○	○	
	Fastening of bushing terminals (mechanical check)	○	○	
Operating Apparatus and Control Panels	Correct indication by various instruments	○	○	○
	Reading of operation counters		○	○
	Condensation, rust and damage inside console and panels		○	○
	Status of oil supply and cleaning		○	○
	Fastening of cable terminals	○	○	○
	Status of open-close indications		○	○
	Air leakage and oil leakage		○	○
	Pressure before and after operation (air pressure, etc.)		○	○
	Working of instruments		○	○
	Rust, deformation and/or damage to springs (maintenance)	○	○	○
	Abnormality of fastening pins		○	○
	Auxiliary contactors and relays (maintenance)		○	○
	Checking of DC control power source	○		
Measurement/ Testing	Measurement of insulation resistance		○	○
	Measurement of contact resistance			○
	Breaking of heater cable		○	○
	Operation check of protection relays		○	○

2-4-4 Fuel Oil Procurement Plan

Fuel oil required for operating No.1 to No.4 units at the C5 power station procured under the Project will be heavy oil as main fuel and diesel oil for operation at startup, shutdown or at emergency time. Necessary daily volume is shown below.

Heavy oil: Approximately 84 m^3 (during rated operation of 4 units)
Diesel oil: Approximately 5 m^3 (during rated operation of 4 units)

So not to hinder stable operation of the concerned generating equipment, EDC should formulate a fuel oil procurement plan. In addition, tank trucks for fuel supply for the C6

power station will pass through the C5 power station site, so special consideration for this is required.

2-4-5 Spare Parts Procurement Plan

Spare parts for the generating and electrical facilities include those to replace aged parts (consumables) and emergency spare parts, which are required during a breakdown, etc. Accordingly, the Cambodian side should procure and prepare these spare parts in advance in line with the periodical inspection cycle. (Refer to Table 2-4-1.)

A two-year supply of spare parts to cover 16,000 hours' operation of newly supplied equipment, during which a periodical inspection cycle will be implemented, is planned under the Project. The main procurement items based on the periodical inspection items are shown in Table 2-4-3.

In order to ensure continuous operation of the generating unit and electrical system to be installed under the Project, the Cambodian side will be responsible for appropriating the necessary budget to cover the procurement cost of consumables, spare parts (total approximately 6% of the cost of generating unit for two years) required for the operation and periodical maintenance of the said unit and also the cost of emergency spare parts within two years of the commissioning of the new generating unit.

Table 2-4-3 Spare Parts to be Procured Under the Project (Fuel Conversion)

I-1. Spare Parts for Generating Facility

Item	Quantity
1. Diesel Engine and Auxiliary Equipment	
(1) Normal operation (consumables)	
1) Gasket kit for heavy oil purifier	2 sets
2) Seal kit for heavy oil purifier	1 set
(2) Emergency spare parts	
1) Fuel oil injection nozzle complete	1 set
2) Fuel oil injection pump and valve	1 set
3) Lubricating oil filter for turbo charger	1 set
4) Pre-filter for turbo charger	1 set
5) Spare parts for auxiliary pump	100 %

Table 2-4-4 Spare Parts and Maintenance Tools to be Procured Under the Project (Expansion)

I-1. Spare Parts for Generating Facility

Item	Quantity
1. Diesel Engine and Auxiliary Equipment	
(1) Normal operation (consumables)	
1) Fuel oil filter element	1 set
2) Lubricating oil filter element	1 set
3) Cylinder cover packing (all cylinders)	2 sets
4) Air cooler packing	2 sets
5) Exhaust gas valve complete (all cylinders)	1 set
6) Intake air valve complete (all cylinders)	1 set
7) Turbo charger bearing	2 sets
8) Piston ring (all cylinders)	2 sets
9) Fuel oil injection pump sleeve, deflector (all cylinders)	2 sets
10) Fuel oil injection nozzle tip (all cylinders)	1 set
11) Packing, O-ring, etc.	1 set
12) Blower filter ($1m^2$)	1 set
13) Water softener filter, ion exchange resin	1 set
(2) Emergency spare parts	
1) Fuel oil injection block complete	2 sets
2) Cylinder cover complete	1 set
3) Fuel oil injection nozzle complete	1 set
4) Fuel oil injection pump and valve	1 set
5) Jacket cooling water pump	1 set
6) Lubricating oil filter for turbo charger	1 set
7) Lubricating oil bypass filter element	1 set
8) Pre-filter for turbo charger	1 set
9) Suction and exhaust valve complete	1 set
10) Starting valve complete	1 set
11) Spare parts for auxiliary pump	100 %
12) Instruments (pressure gauge and thermometer, etc.)	One of each type
2. Electrical Equipment and Auxiliary Equipment	
(1) Consumable spare parts for normal operation	
1) Fuse elements for control circuits	200% for each type
2) Lamps or bulbs for indicators (excluding LEDs)	200% for each type
3) On-off indicator covers	100% for each type
4) Fluorescent lamps for inside panels	200% for each type
(2) Emergency spare parts	
1) Printed circuit board for AVR (for exciter)	1 set
2) High voltage circuit breaker (VCB)	1 unit
3) Auxiliary relay and timer	1 unit for each type
4) Various MCCBs and ELBs	1 unit for each type
5) Electro-magnetic contactors	1 unit for each type
6) Electrical meter for panels (voltage and ampere, etc.)	1 unit for each type
7) Thermal relay	1 unit for each type
8) Fuse for voltage transformer	1 unit for each type
9) Fuse for high voltage transformer	1 unit for each type
10) Tripping and closing coil for circuit breaker	1 set for each type

I-2. Spare Parts for Electrical System

Item	Quantity
(1) For normal operation	
1) Fuse elements for control circuit	200% for each type
2) Lamps or bulbs for indicators (excluding LEDs)	200% for each type
3) On-off indicator covers	100% for each type
4) Auxiliary relays, timers and MCCBs	1 unit for each type
5) Fluorescent lamps for panels	200 % for

II. Maintenance Tools and Instruments

Item	Quantity
1. For Diesel Engine	
(1) Tool set for mechanical equipment	1 set
(2) Remover for cylinder liner	1 set
(3) Ladder	1 set
(4) Ear protectors	10 pieces
(5) Simplified intake/exhaust valve and seat grinder	1 set
(6) Measuring device	1 set
2. For Distribution Equipment	
(1) 5 ton cable drum jack	2 sets
(2) 3 ton cable drum jack	2 sets
3. Common Use for Generator and Distribution System	
(1) Circuit tester (analog meter)	2 units
(2) Tool set for electrical maintenance	2 sets
(3) Insulation tester by dry cell (500 V, 1000 M-ohm)	2 pieces
(4) Insulation tester by dry cell (2500 V, 100 G-ohm)	2 pieces
(5) Portable earth resistance tester (0 to 100 ohm, 0 to 30 V)	2 units
(6) Phase rotation meter for low voltage circuit	2 units
(7) Voltage detector for low voltage circuit	2 pieces
(8) Voltage detector for 22 kV circuit	1 units
(9) Digital multi-meter	2 units
(10) AC/DC clamp meter	2 units
(11) Grounding tool for maintenance work (3 phase)	1 set
(12) VCB checker	1 set

2-4-6 Electricity Tariff Plan

As of April 2004 there are ninety three (93) electric power suppliers in Cambodia licensed by the Electricity Authority of Cambodia (EAC). With regards to electricity rates applied by each suppliers, EAC allows the addition of profit above expenses related to power generation and distribution. Table 2-4-5 demonstrates the Cambodian electricity tariff system (EDC supply areas). EAC is preparing an ordinance pertaining to the establishment of electricity tariff (Enforcement Order of the Electric Power Act) with the assistance of ADB.

Generally speaking, the Phnom Penh electricity tariff system is favorable to socially deprived consumers. In the case of monthly electricity consumption for 0 to 50kWh the unit cost is 8.79 ¢ /kWh, while, the average generating cost of EDC power stations is 12.3 ¢ /kWh, so a rate substantially lower than the generating cost is being applied. Approximately 60% of EDC sales volume of electricity is for general residences. Therefore, the application of a rate lower than the generating unit cost reduces EDC's revenue. Since the current tariff system does not reflect fuel prices or fluctuations in foreign exchange rates, a tariff mechanism to reflect such fluctuations in short term through ministerial ordinance has been in preparation by EDC.

Independent networks other than the Phnom Penh system (such as Sihannoukville, Takeo and Kampong Cham) have established a tariff that reflects local conditions, for example, increases in the supply cost for small-scale power generation and distribution or increases in the fuel oil cost for remote transportation. Accordingly, the electricity tariff is 20 cents per kWh which is higher than the standard rate in Phnom Penh or its neighboring countries. Cambodia plans to connect independent systems such as Takeo, Campong Cham and Sihannoukville with Phon Penh through the interconnection of transmission lines. Furthermore, importation of electricity from Vietnam will provide cheap electricity to local cities.

Table 2-4-5 Cambodian Electricity Tariff System (EDC Supply Areas)

Classification	Electricity Tariff		Remarks
	(Riel/kWh)	(US ¢ /kWh)	
Phnom Penh (revised August 2000)			
Residential:			Local NGOs, Schools, local governments, religious facilities, public facilities, small-scale commercial facilities
0 to 50 kWh	350	8.79	
51 to 100 kWh	550	13.82	
＞100 kWh	650	16.33	
Commerce and services			Commercial facilities such as markets, shops, amusement stores, services industry and banks (regardless of nationality)
＜45,000 kWh	650	16.33	
45,000 to 80,000 kWh	600	15.08	
80,000 to 130,000 kWh	600	15.08	
＞130,000 kWh	500	12.56	
Medium voltage（22kV）	480	12.06	
Hotels and guest houses:			
＜45,000 kWh	650	16.33	
45,000 to 80,000 kWh	600	15.08	
80,000 to 130,000 kWh	600	15.08	
＞130,000 kWh	500	12.56	
Medium voltage（22kV）	480	12.06	
Governmental agencies	700	17.59	All public facilities financed through public funds
Embassy, foreigners' houses and other	800	20.10	NGO
Industry and manufacturing:			All manufacturing and industries (regardless of nationality)
＜45,000 kWh	600	15.08	
45,000 to 80,000 kWh	550	13.82	
80,000 to 130,000 kWh	550	13.82	
＞130,000 kWh	500	12.56	
Medium voltage (22kV)	480	12.06	
Siem Reap (All sectors)			Revised July 1999
＜20,000 kWh	850	21.36	
20,000 to 50,000 kWh	757	19.02	
50,000 to 110,000 kWh	690	17.34	
＞110,000 kWh	635	15.95	
Takeo (Flat rate)	900	22.61	Revised in 1999
Kampong Cham (Flat rate)	850	21.36	Revised in 1999

Source: EDC 1US$ = 3,980 Riels. (2003)

The generating cost of the existing No.1 and 2 units at the C5 power station will be lowered by ¥3.3/kWh (in case of 50% of utilization factor) through fuel conversion under the Project for an annual reduction of approximately ¥140 million. A comparison of generating cost associated with the fuel conversion is shown in Table 2-4-6.

Table 2-4-6 Comparison of Profitability of Existing No.1 and No.2 Units Associated with Fuel Conversion

Item			Diesel Oil	Heavy Oil	Remarks
Annual expenses (Fixed cost)	Depreciation	①Generating facility (10MW)	¥141.5 million/annual	¥141.5 million/annual	C5 actual expense
		②Heavy-oil firing equipment	—	¥22 million/annual	Assumed equipment cost to be ¥200 million
	Salaries	③Salaries for staff	¥7 million/annual	¥7 million/annual	C5 actual expense
	Other	④Outsourcing cost	¥2.8 million/annual	¥2.8 million/annual	C5 actual expense
Annual expenses (Variable cost)	O & M cost	⑤Maintenance cost	¥24.1 million/annual	¥24.1 million/annual	C5,C6 actual expenses: 0.5 ¢ /kWh
	Consumables cost	⑥Lubricating oil cost	¥48.1 million/annual	¥48.1 million/annual	C5 actual expense: 1 ¢ /kWh
	⑦ Fuel cost		¥463.9 million/annual (base)	¥292.7 million/annual (0.63 times)	Diesel oil: US$459/t Heavy oil: US$261/t
⑧ Total annuel expenses (Total ① to ⑦)			¥687.3 million/annual (base)	¥538.2 million/annual (0.78 time)	
⑨ House consumption rate （%）			2.9	4.8	C5,C6 actual rates
⑩ Annual power sent out			42.5 GWh/annual	41.6 GWh/annual	Utilization factor: 50%
⑪ Generating unit cost (⑧÷⑩)			¥16.2/kWh (base)	¥12.9 /kWh (0.75times)	Heavy-oil fired generating cost is cheaper at ¥3.3 /kWh than that of diesel oil.

Note: 1US$ = ¥110

The generating cost in the case of installing an additional two 5MW diesel engine generators at the C5 power station, assuming 50% utilization factor, is ¥12.2/kWh, ¥2.1/kWh cheaper than IPP (Jupiter). Due to the additional installation at the C5 power station, if the purchase volume of electricity from IPP can be reduced, approximately ¥90 million can be reduced annually.

The total cost reduction from the above-mentioned fuel conversion and additional installation of generating units will be approximately ¥230 million. However, in EDC power generation plan, the power generated in C5 is only approximately 12% of all power stations including IPPs in 2007, so it appears that contribution to the reduction in electricity tariff is relatively low. EDC plans to use funds saved under the Project to expand the power network to the poor residing near Phnom Penh EDC. It is hoped that the Project outcome can be returned to Cambodian people.

Table 2-4-7 Generating Cost for New Generating Equipment (No.3 and No.4)

Item			Newly installed 5MW×2	Remarks
Annual expenses (Fixed cost)	Depreciation	①Generators (10MW)	¥137.5 million/annual	Assumed equipment cost to be ¥12.5/kW
	Salaries	②Salaries for staff	¥3.5 million/annual	C5 actual expense×0.5 (for 2 in 4 units)
	Other	③Outsourcing	¥2.8 million/annual	C5 actual expense
Annual expenses (Variable cost)	O&M cost	④Maintenance cost	¥24.1 million/annual	C5,C6 actual expenses: 0.5 ¢ /kWh
	Consumables cost	⑤Lubricating oil cost	¥48.1 million/annual	C5 actual expense: 1 ¢ /kWh
	⑥Fuel cost		¥292.7 million/annual	Heavy oil: US$261/t
⑦Total annual expenses (Total ① to ⑥)			¥508.6 million/annual	
⑧House consumption rate（%）			4.8	C5,C6 actual expenses
⑨Annual power sent out			41.6 GWh/annual	Utilization factor: 50%
⑩Generating cost (⑦÷⑨)			¥12.2/kWh	¥2.1/kWh cheaper than IPP (Jupiter: ¥14.3/kWh)

Note: 1US$ = ¥110

2-5 Estimated Project Cost

2-5-1 Estimated Project Cost

This cost estimation is provisional and would be further examined by the Government of Japan for the approval of the Grant. In the case of the Project's implementation under the Japan's grant aid scheme, the total project cost is estimated to be approximately ¥ 1,740 million. The financial undertaking by each side is estimated below based on the work share described earlier and estimation conditions shown as follows.

(1) Cost to be borne by Japanese side

Cost Item		Estimated Project Cost	
Equipment	Fuel conversion for existing unit No. 1 & No.2	¥ 293 million	¥ 1,588 million
	New installation of No. 3 & No. 4 generators	¥ 1,295 million	
Consultant Fee		¥ 146 million	
Total		¥ 1,734 million	

However, it should be noted that the estimated project cost does not limit the amount of E/N if formally exchanged between both governments.

(2) Cost to be borne by the Cambodian side

US$ 51,000 (Approximately ¥ 5.5 million)
The main cost items to be borne by the Cambodian side are shown in Appendix 8.

(3) Estimated Conditions

1) Date of estimation : April 2004

2) Foreign exchange : 1US$ = ¥108.75 (average TTS from Nov. 2003 to Apr. 2004)

3) Work period : The Work for The Project may be divided into two (2) phases (Fuel conversion work of the existing generating units and the construction of new generating units); detailed design, construction and equipment procurement period are shown in the Implementation Schedule (Fig. 2-2-3).

4) Others : The Project shall be implemented in accordance with the Japan's grant aid scheme.

2-5-2 Operation and Maintenance Cost

The average EDC electricity tariff in Phnom Penh is ¢ 13.8-/kWh (2003). Tables 2-5-1 and 2-5-2 show the assumed operating balance of C5 power station in the case of applying the said electricity rate at the generating units under the Project.

Table 2-5-1 Expected Operating Income and Expenditure for the Generating Facilities (No. 1 and No. 2 Units)

Item	Unit	Annual Utilization Factor (%)		
		45	46	50
1. Conditions				
(1) Installed capacity (5MW x 2)	MW	10	10	10
(2) Annual operating hours	hr	3,942	4,030	4,380
(3) Electric energy generated	MWh	39,420	40,296	43,800
(4) House consumption	MWh	1,892	1,934	2,102
(5) Distribution loss	MWh	4,593	4,695	5,104
(6) Electric energy sold	MWh	32,934	33,666	36,594
2. Income				
(1) Income from power sales	US$	4,550,940	4,652,072	5,056,600
3. Expenditure				
(1) Fuel oil cost	US$	2,397,248	2,450,521	2,663,609
(2) Lubricating oil cost	US$	394,200	402,960	438,000
(3) Personnel cost	US$	63,865	63,865	63,865
(4) Spar parts procurement cost	US$	197,100	201,480	219,000
(5) Outsourcing cost	US$	25,339	25,339	25,339
(6) Depreciation cost (Main body of generator)	US$	1,286,423	1,286,423	1,286,423
(Fuel conversion equipment)	US$	200,000	200,000	200,000
Total expenditure	US$	4,564,176	4,630,589	4,896,237
4. Operating balance	US$	-13,237	21,483	160,362

Preconditions:

1) The house consumption and distribution loss are assumed to be 4.8% based on the actual results at C6 power station and 12.24% based on the 2002 results respectively.
2) The unit power sales price is assumed to be ¢ 13.8-/kWh based on EDC 2003 results.
3) The unit cost of the fuel oil used and the fuel consumption are assumed to be US$261/t and 233g/kWh based on 2003 results respectively.
4) The actual value of ¢ 1-/kWh at the C5 power station is adopted for lubricating oil cost.
5) The actual value of expenses at the C5 power station is applied to personnel cost.
6) The actual value of ¢ 0.5-/kWh at the C5 and C6 power stations is applied to spare parts procurement cost.
7) The actual value of expenses at the C5 power station is applied to outsourcing cost.
8) In accordance with EDC regulations, the depreciation cost is calculated using the straight line method with an expected equipment life of nine (9) years.
9) The depreciation cost for No. 1 and No. 2 units is calculated by assuming 2003 results for the main body of each unit and ¥ 200 million for fuel conversion equipment.
10) Foreign exchange rate used is 1US$ = ¥ 110

Table 2-5-2 Expected Operating Income and Expenditure for the Generating Facilities (No. 3 and No. 4 Units)

Item	Unit	Annual Utilization Factor (%)		
		37	38	50
1. Conditions				
(1) Installed capacity (5MW x 2)	MW	10	10	10
(2) Annual operating hours	hr	3,241	3,329	4,380
(3) Electric energy generated	MWh	32,412	33,288	43,800
(4) House consumption	MWh	1,556	1,598	2,102
(5) Distribution loss	MWh	3,777	3,879	5,104
(6) Electric energy sold	MWh	27,079	27,811	36,594
2. Income				
(1) Income from power sales	US$	3,741,884	3,843,016	5,056,600
3. Expenditure				
(1) Fuel oil cost	US$	1,971,071	2,024,343	2,660,569
(2) Lubricating oil cost	US$	324,120	332,880	437,500
(3) Personnel cost	US$	31,933	31,933	31,933
(4) Spare parts procurement cost	US$	162	166,440	218,750
(5) Outsourcing cost	US$	25,339	25,339	25,339
(6) Depreciation cost (Main body of generator)	US$	1,250,000	1,250,000	1,250,000
Total expenditure	US$	3,764,523	3,830,935	4,624,091
4. Operating balance	US$	-22,639	12,081	432,509

Preconditions:

1) The house consumption and distribution loss are assumed to be 4.8% based on actual results at the C6 power station and 12.24% based on the 2002 results respectively.
2) The unit power sales price is assumed to be ¢ 13.8-/kWh based on the EDC 2003 results.
3) The unit cost of fuel oil used and fuel consumption is assumed to be US$261/t and 233g/kWh based on the 2003 results respectively.
4) The actual value of ¢ 1-/kWh at the C5 power station is adopted for lubricating oil cost.
5) The actual value of expenses at the C5 power station is applied to personnel cost.
6) The actual value of ¢ 0.5-/kWh at the C5 and C6 power stations is applied to spare parts procurement cost.
7) The actual value of expenses at the C5 power station is applied to outsourcing cost.
8) In accordance with EDC regulations, the depreciation cost is calculated using the straight line method with an expected equipment life of nine (9) years.
9) The depreciation cost for No. 3 and No. 4 units is calculated by assuming the equipment cost to be ¥ 125,000/kW.
10) Foreign exchange rate used is 1US$ = ¥ 110.

As shown in Tables 2-5-1 and 2-5-2, if the generating units are operated by an annual utilization factor (50%) of the present planning, it is possible to purchase spare parts and consumables, etc. for the relevant generating equipment, and independent operation is possible. However, if the utilization factor becomes less than 45% and 37% for No. 1 and No.2 units and No. 3 and No. 4 units respectively, the operating balance is anticipated to be

minus. Accordingly, the Cambodian side should formulate the optimum operation plan for the generating facilities and implement it in order to ensure the economic capacity factor.

2-6 Soft Component (Technical Transfer) Plan

(1) Background

In Phase 1 of the Project, fuel conversion from diesel oil to C heavy oil will be applied to the existing diesel engine generating facilities (5MW×2 units) at C5 power station and the new heavy-oil fired diesel engine generating facilities (5MW×2 units) will be installed in the Phase 2 under the Project.

The unit cost of heavy oil is approximately 60% that of diesel oil so that heavy oil contributes significantly to the reduction in generating cost. On the other hand, its viscosity is higher than diesel oil and contains more sludge, so combustion is difficult. In order to maintain stable operation of the diesel engine generating facilities, after conversion, it is necessary to conduct fuel combustion control, combustion system maintenance, fuel management, lubricating oil management, cooling water management and sludge disposal management carefully and continuously.

Personnel responsible for operation at C5 power station are experienced in operation of the existing diesel-oil fired diesel engine generators and have had classroom lessons (off-the-job training) in power generation and safety at the EDC Training Center. However, they have had no systematic technological guidance in heavy-oil fired diesel engine generators, so that they are inexperienced in the basic system control of heavy oil from fuel combustion to the composition of fuel oil necessary for heavy-oil fired operation, related oil lubricating, cooling water and sludge disposal.

Accordingly, in order to continuously provide appropriate maintenance for efficient operation of the existing diesel engine generators to be converted from diesel oil firing to heavy oil firing and new heavy-oil fired diesel engine generators, before the commencement of commercial operation of such facilities supplied under the Project, it is important for personnel at the C5 power station to ensure the necessary operational capacity by transferring the overall knowledge and skills in fuel combustion theory to the operation and maintenance of heavy-oil fired diesel engine generating units.

The Contractor will provide individual technical guidance on operation and maintenance of equipment to be procured to personnel at the C5 power station during the construction work period as OJT. Whereas, the Consultant will provide systematic technical guidance on the overall facilities and its function as a generating power plant, including heavy-oil fired diesel engine generator system operations, diesel combustion theory, combustion control, combustion system maintenance, fuel management, lubricating oil management,

cooling water management and sludge disposal through the Soft Component (technical transfer).

The Soft Component related to operation and maintenance technologies for diesel engine power stations was provided to approximately 30 personnel in charge of operation and maintenance at the Siem Reap office of the EDC through "The Project for Expansion of Electricity Supply Facilities in Siem Reap" (2003), the Japanese grand aid scheme. As a result, the technical level of EDC personnel who belong to the Siem Reap improved drastically and EDC personnel can now operate the new Siem Reap diesel engine power station by themselves. The outcome of the Soft Component was confirmed and was highly evaluated by EDC. However, the Siem Reap power system is separated geographically from Phnom Penh and transmission lines have not been connected. Since each power station is operated independently personnel systems are organized individually, and thus staff exchanges are rare. For the above reasons, the Cambodian side is strongly requesting a Soft Component under this Project for EDC personnel involved in operation and maintenance of the concerned power generating facilities in the Phnom Penh power system.

(2) Goal (Target)

The Soft Component is designed for the purpose of transferring technologies necessary for operation and maintenance of heavy-oil fired diesel engine generating facilities at the C5 power station to EDC who has the aim of increasing the amount of power supply to Phnom Penh city, a stable power supply and reduction in power generating cost.

(3) Outcome

Through the introduction of the Soft Component, the following outcome is anticipated.

1) Operation and maintenance technologies for heavy-oil fired diesel engine generators to be constructed under the Project will be established.
2) An operation and maintenance system for the heavy-oil fired diesel engine generators will be created under the Project and customer service will be improved.

(4) Activities

The activity policy of the Soft Component is outlined as follows.

1) Guidance on combustion control technology will be provided as a basic technology for the heavy-oil fired diesel generating facilities.

2) Technical guidance on plant operation control and general maintenance of the C5 power station with regards to heavy oil firing will be provided.

In the case of implementing the Soft Component, trainees should be engineers, technicians and operators who have already taken the "training course on power generation and safety" implemented by the EDC, who have acquired a certain technical level or have received similar or higher training abroad as a prerequisite. In addition, the EDC Training Center will be effectively utilized as a place for classroom training for the concerned Soft Component.

Personnel to receive the Soft Component is shown in the Table 2-6-3: "Personnel at C5 Power Station attending the Soft Component class".

The organization implementing the Soft Component and description of activities are as follows.

1) Technical Guidance related to Heavy-oil Fired Diesel Engine Generating Facilities (Phase-1)

   * Technical guidance required to establish an operation and maintenance practice for the heavy-oil fired diesel engine generating facilities of No.1 and No.2 where fuel conversion will be implemented in Phase 1 of the Project.
   * Japanese engineers experienced in diesel engine operation and maintenance technologies will be appointed.
   * Technical guidance will be given to senior technical staff and operators at C5 power station.
   * The Cambodian side should post one interpreter (English – Khmer) throughout the period of the Soft Component who is able to understand the technical terms.

   The implementation period of the concerned Soft Component will be 1.6 months in total within the period from singing of the contract for Phase 1 to handing over of the facilities.

   English technical materials (technical materials on fuel converted diesel engine generating system, technical materials on combustion control technology of C heavy oil, examination questions and answers) necessary for technical guidance will be prepared. The period for preparing the relevant manuals in Japan will be 0.4 months.

① Technical guidance for fuel conversion diesel engine power plants (Step 1)

- Confirmation of trainees' technical level and safety education
- Guidance on overview of C heavy-oil fired diesel engine generating facilities at C5 power station
- Guidance on construction and functions of C heavy-oil diesel engine generating plants

② Guidance on combustion control of C heavy oil and operation (Step 2)

- Technical guidance on combustion of C heavy oil
- Technical guidance on operation and maintenance technologies of C heavy-oil fried diesel engine generating plants
- Examination to confirm trainee's understanding

2) Guidance on operation and maintenance of overall generating plants at C5 power station (Phase 2)

* Technical guidance on comprehensive plant operation and maintenance at the C5 power station covering C heavy-oil fired generators (No.3 and No.4 units) to be newly installed during Phase 2 of the Project and diesel engine generating facilities (No.1 and No.2 units) after fuel conversion during Phase 1.

  (In addition, generating equipment manufacturers may differ between Phase 1 and Phase 2. Accordingly, the Soft Component will be provided for guidance on operation and maintenance technologies by integrating all No.1 to No.4 units)

* Technical guidance will be given to senior technical executives and operators at the C5 power station.

* Japanese engineers with expertise in diesel engine operation and maintenance technologies will be appointed.

The Cambodian side should post one interpreter (English – Khmer) who can understand the technical terms for the period of the Soft Component.

The local activity period for the concerned Soft Component will be 0.8 months in total within the period from signing the construction contract of Phase 2 to the handing over the facilities.

English technical materials (technical materials on overall heavy-oil fired diesel engine generating facilities at the C5 power station, technical materials on maintenance technology for overall C5 power station, examination questions and answers) necessary for technical guidance will be prepared. The period for preparing the relevant manuals in Japan will be 0.2 months.

① Guidance on a power generating system and a maintenance plan for the overall C5 power station (Step 3)

- Guidance on system for the new heavy-oil fired generating plant
- Guidance on maintenance plan
- Guidance on comprehensive operation and maintenance at the C5 power station by integrating new generators (No.3 and No.4 units) and generators after fuel conversion (No.1 and No.2 units)

② Comprehensive operation management and confirmation of comprehensive operating procedure at the C5 power station (Step 4)

- Confirmation of comprehensive operating procedure
- Comprehensive examination to confirm the training outcome

(5) Detailed Activity Plan

The Soft Component activities of the Project are shown in Table 2-6-1. A schedule plan for each activity is outlined in Table 2-6-2.

Table 2-6-1 Detailed Activity Plan

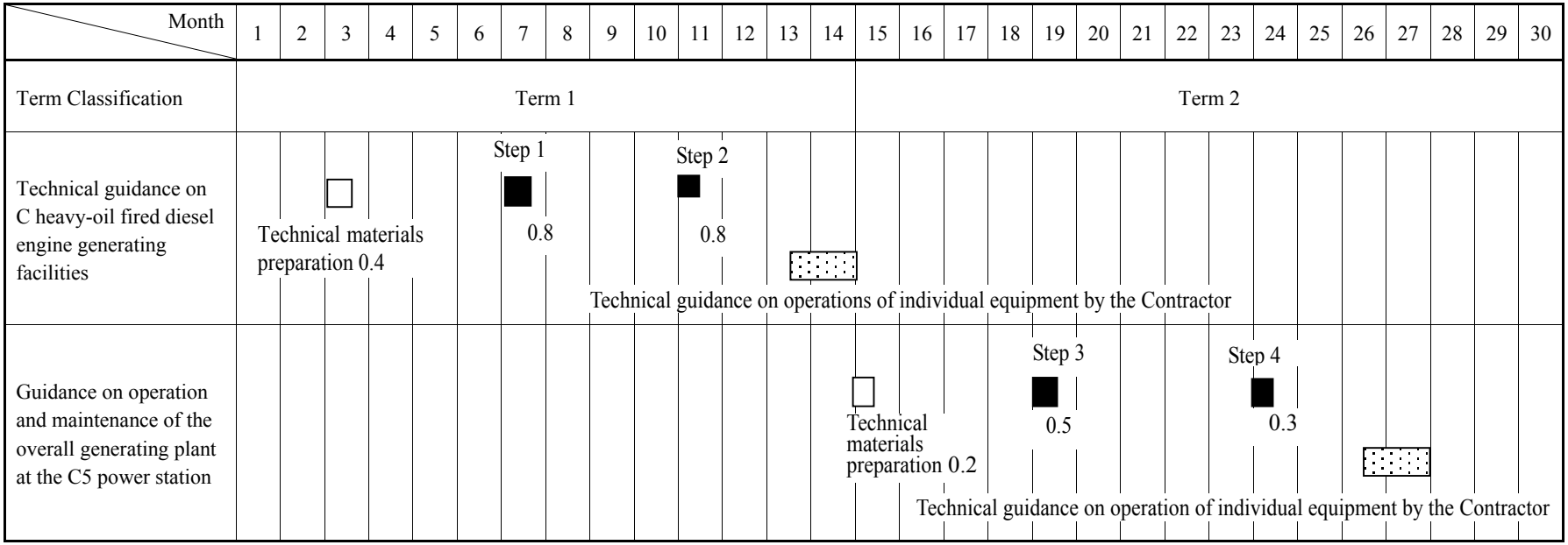
Step No.	Classification	Description of Activities	Guidance Manual, etc. (Visible Outcome)	Activity Method	Necessary Quantity Invested	Total Person Months
1	Technical guidance on C heavy-oil fired diesel engine generating facility (Part 1) "Technical guidance on fuel converted diesel engine generating plant"	(1) Confirmation of trainees' technical level ① Implementation of examination to confirm their technical level ② Explanation of examination contents and confirmation of trainees' understanding level	• Examination questions • Answer sheets • Report cards	① Trainee: Technical executives and O&M staffs at C5 power station ② Classroom training (EDC Training Center)	1 person × 0.1 months	Step 1 Total 0.8 months
		(2) Guidance on overview of C heavy-oil fried generating facility at C5 power station ① Confirmation of heavy oil fuel conversion system and equipment layout ② Comparison of equipment configuration and function between C5 power station (diesel-oil fired) and C6 power station (heavy-oil fired)	• Technical materials on fuel converted diesel engine generating facility	① Trainee : Technical executives and O&M staffs at C5 power station ② Classroom training (same as above) ③ The existing facilities will be used.	1 person × 0.1 months	
		(3) Technical guidance on fuel converted diesel engine generating plant ① Configuration and functions of main fuel system components ② Configuration and functions of main lubricating oil system components ③ Configuration and functions of main cooling water system components ④ Configuration and functions of main intake air and exhaust gas system components ⑤ Configuration and functions of main compressed air system components ⑥ Configuration and functions of main sludge treatment system components ⑦ Configuration and functions of main fuel heating system components	• Technical materials on fuel converted diesel engine generating facility	① Trainee : Technical executives and O&M staffs at C5 power station ② Classroom training (same as above)	1 person × 0.6 months	
2	Technical guidance on C heavy-oil fired diesel engine generating facility (Part 2) "Guidance on combustion control of heavy oil and operation"	(1) Technical guidance on C heavy oil combustion control technology ① Diesel engine combustion system ② Diesel engine fuel combustion theory ③ Heavy oil combustion control (characteristics, temperature and viscosity etc.) ④ Combustion control (fuel unloading, storage, transfer, purifying, filtering, heating and insulation, etc.)	• Technical materials on combustion control of C heavy oil	① Trainee: Technical executives and O&M staffs at C5 power station ② Classroom training (EDC Training Center is utilized)	1 person × 0.4 months	Step 2 Total 0.8 months

Step No.	Classification	Description of Activities	Guidance Manual, etc. (Visible Outcome)	Activity Method	Necessary Quantity Invested	Total Person Months
		(2) Technical guidance on operation management of C heavy-oil fired diesel generating plant ① Confirmation of operation manual of diesel engine generating plant ② System confirmation before starting operation ③ Practical training to confirm start-up with diesel fuel oil, operation, converting into heavy oil, converting into diesel oil and shut-down of engine ④ Practical training to confirm operations of heavy oil purifier, heater and insulation equipment ⑤ Practical training to confirm operations of sludge treatment and oily water separation system	• Technical materials on fuel converted diesel engine generating facilities	① Trainee: Technical executives and O&M staffs at C5 power station ② Classroom training (same as above) ③ Effective use of heavy-oil fired diesel engine generating facilities at C6 power station	1 person × 0.3 months	
		(3) Examination to confirm the understanding level ① Implementation of examination on operations of C heavy-oil fired diesel engine generating plant ② Confirmation of training outcome through examination results	• Examination questions • Answer sheets • Report cards	① Trainee: Technical executives and O&M staffs at C5 power station ② Classroom training (same as above	1 person × 0.1 months	
3	Guidance on operation and maintenance of overall generating plant at the C5 power station (Part 1) "Guidance on new diesel engine generating facilities and maintenance plan"	(1) Guidance on new C heavy-oil fired diesel engine generating facilities Confirmation of the difference in characteristics, functions and nature between the existing power generating system (No.1 and 2 units) after the fuel conversion and new power generating system (No.3 and 4) ① Grasping an overview of new heavy-oil fired generating facilities ② Configuration and functions of main fuel system components ③ Configuration and functions of main auxiliary equipment system components	• Technical materials on new heavy-oil fired diesel engine generating facilities	① Trainee: Technical executives and O&M staffs at C5 power station ② Classroom training (same as above)	1 person × 0.2 months	Step 3 Total 0.5 months
		(2) Guidance on a maintenance plan Confirmation of the difference in characteristics, functions and nature between the existing power generating system (No.1 and 2 units) after the fuel conversion and new power generating system (No.3 and 4) ① Spare parts, equipment and materials and tools management plan ② Maintenance and repair work plan, techniques to record maintenance and repair data	• Technical materials on a maintenance plan at the overall C5 power station	① Trainee: Technical executives and O&M staffs at C5 power station ③ Classroom training (same as above)	1 person × 0.1 months	

Step No.	Classification	Description of Activities	Guidance Manual, etc. (Visible Outcome)	Activity Method	Necessary Quantity Invested	Total Person Months
		(3) Guidance on comprehensive operation of the overall power generating plant at C5 ① Monitoring of operations of the overall plant ② Recording, sorting and storing of systems and equipment operation data ③ Analysis of systems and equipment operation data, grasping of performance, abnormal diagnosis ④ Analysis on characteristics and consumption of fuel oil, lubricating oil and cooling water ⑤ Analysis on volume and sludge characteristics	• Technical materials on heavy-oil fired diesel engine generating facilities at the overall C5 power station	① Trainee: Technical executives and O&M staffs at C5 power station ② Classroom training (same as above)	1 person × 0.2 months	
4	Guidance on operation and maintenance of overall generating plant at the C5 power station (Part 2) "Comprehensive control of diesel engine power plant and comprehensive confirmation of operations"	(1) Comprehensive confirmation of operations at the C5 power station ① Confirmation of new diesel engine generating plant operation manual ② System confirmation before starting operations ③ Confirmation of operations of main units and auxiliary equipment ④ Confirmation of plant start-up with diesel oil, operations by converting into heavy oil, converting into diesel oil and plant shut-down ⑤ Confirmation of operations of heavy oil purifier, heater and insulator ⑥ Confirmation of operations of sludge treatment and oily water separation systems	Same above	① Trainee: Technical executives and O&M staffs at C5 power station ② Training though systems at the C5 power station	1 person × 0.2 months	Step 4 Total 0.3 months
		(2) Comprehensive examination to confirm training outcome ① Implementation of comprehensive examination on overall operation control at the C5 power station ② Confirmation of training outcome through examination results	• Examination questions • Answer sheets • Report cards • Certificate of commendation	① Trainee: Technical executives and O&M staffs at the C5 power station ② Classroom training (same as above)	1 person × 0.1 months	

Note-1: A comprehensive 100-point examination on training results will be implemented and persons who achieve an excellent score will be officially commended.

Table 2-6-2 Technical Guidance Schedule



: Local technical guidance period

: Pre-preparation period

Table 2-6-3 Personnel at C5 Power Station Attending to the Soft Component class

Type	Job Classification	Number of personnel attending the Soft Component	Technical level, etc. of personnel attending the Soft Component class				
			Qualifications	Practical experience		English proficiency	Training experiences at the existing training center
				Facility	Number of years experience		
A	Manager	1	Engineer	Diesel engine power station	23	Reading, Writing and conversation	Yes (or same level or higher training)
	Assistant manager in maintenance dept.	1	Engineer	Diesel engine power station	21	Reading, Writing and conversation	Same as above
	Assistant manager in operation dept.	1	Engineer	Diesel engine power station	13	Reading, Writing and conversation	Same as above
B	Management section chief	1	Engineer	Diesel engine power station	25	—	Same as above
C	Operation section chief	1	Engineer	Diesel engine power station	13	—	Same as above
	Operation assistant chief	1	Engineer	Diesel engine power station	9	—	Same as above
	[C5 operation section]						
	Head	1	Technician	Diesel engine power station	14	—	Same as above
	Assistant head	1			10	—	Same as above
	Group chief	1			18	—	Same as above
	Workers	2			—	—	
	[Operation support team]						
	Head	1	Technician	Diesel engine power station	19	—	Same as above
	[Mechanical maintenance]						
	Staffs	1	Technician	Diesel engine power station	6	—	Same as above
	Workers	4			—	—	Same as above
	[Electrical maintenance]						
	Staffs	1	Technician	Diesel engine power station	14	—	Same as above
	Workers	3					
	[Safety dept.] Staffs	1	Technician	Diesel engine power station	18	—	Same as above
Total		22					

CHAPTER 3

PROJECT EVALUATION AND RECOMMENDATIONS

CHAPTER 3
PROJECT EVALUATION AND RECOMMENDATIONS

3-1 Project Effects

Implementation of the Project is expected to have the following effects.

(1) Direct Effects

Current Situation and Problems	Counter Measures under the Project (Grant Aid Portion)	Project Effects and Degree of Improvement
1. Load shedding is implemented every day in Phnom Penh because peak demand exceeds the total available power supply capacity.	Two 5MW diesel engine generators will be newly installed at the C5 power station owned by EDC in Phnom Penh.	By implementing the Project, the total available generating capacity in Phnom Penh will be 116MW to a peak demand of 114.6MW (estimated), so it is possible to ensure 1.4MW reserve capacity in the target year (2007).
2. Since the majority of EDC's generating facilities utilize expensive diesel oil as fuel, the generating cost is high.	Fuel utilized for the existing diesel engine generators (5MW×2 units) at the C5 power station will be converted to cheap heavy oil. In addition, fuel utilized for new diesel engine generators to be installed under the Project will be heavy oil.	By utilizing cheap heavy oil as fuel for the existing and new generating facilities at the C5 power station, the generating cost will be reduced by ¥3.3/kWh (in the case of 50% of the utilization factor).

(2) Indirect Effects

Current Situation and Problems		Counter Measures under the Project (Grant Aid Portion)	Project Effects and Degree of Improvement
1.	Since the power balance in Phnom Penh is strained, EDC operates aged generators of low generating efficiency and output at C2 and C3 power stations. As a result, EDC's generating cost is high.	Two new 5MW diesel engine generators will be installed at the C5 EDC's power station in Phnom Penh.	When new generators begin operation through the Project, it will be possible to demolish aged generators with low efficiency.
2.	Since the power balance strained in Phnom Penh city, it is difficult to conduct periodical inspection of the generating equipment and generators are operated in excess of an interval for standard periodical inspection (3,000 hours). As a result, more deterioration or troubles of the generating equipment is introduced.	Same as above	Although reserve capacity of -4.3% and -3.5% is anticipated in 2005 and 2006 respectively, if new generators begin operation through the Project, reserve capacity of +1.2% will be obtained in 2007.
3.	Since approximately 52% of the supply capacity in Phnom Penh depends on IPPs, the high power purchase cost from IPPs forces to raise EDC's power supply cost.	Same as above	If new generators begin operation through the Project, it will be possible to reduce the purchase volume of expensive electricity from IPP.

3-2 Recommendations

The Cambodian side should take measures to address the following issues in order to ensure the realization and continued effects of the Project.

(1) Although the 2007 supply capacity can be ensured through the implementation of the Project, necessary power development and power purchases from Vietnam are carried out to meet the growth in power demand after 2008.

(2) EDC has formulated an "Action Plan on Improvement of Financial Conditions" incorporating the set-off between electricity charge which have not yet been collected and EDC debt, a review of the electivity tariff and reduction in operating cost. Fuel conversion of the existing C5 generating facilities under the Project is regarded as one step for the Action Plan. EDC should return profits obtained through the Project to low income people by expanding the distribution network to poverty stricken areas.

(3) For the utilization factor of equipment granted under the Project to be 50% or higher, an operation plan for new generators should be formulated.

(4) Generators owned by EDC with low generating cost should be effectively utilized and the power purchase cost should be reduced by reviewing the purchase volume of power and purchase cost in power purchase agreements with IPPs.

(5) EDC must convey the outcome of the Soft Component to operators and maintenance personnel and endeavor to maintain and improve operation and maintenance technology.

(6) EDC must implement the environmental management plan described in the Initial Environmental Impact Assessment (IEIA) and take into consideration the environmental impact of the Project so as not to exceed the values in IEIA report.