(2) An operating pressure at D-2 shall be decreased to a certain pressure less than 17 kg/cm^2G. By doing so, the gas can be cooled to 16°C at D-2 because a larger cooling capacity can be taken due to a larger differential pressure obtained at the pressure regulating valve.

On the other hand, when the feed gas temperature is lower than 27°C, it is necessary to increase the operating pressure of D-2 in order to keep the temperature of D-2 above the hydrate formation temperature (approximately 11°C).
In the event that there seems to be a possibility of the hydrate formation due to the following operating condition:

(a) At a natural gas operating temperature less than 11°C
(b) At an abnormal high pressure condition encountered

A methanol injection shall be made into the stream ahead of E-1.

By doing so, methanol absorbs the condensed free water and thus prevents the hydrate formation as well as it breaks the hydrate formed.

7-2-4 Process Flow (with material and heat balance)

A process flow with material and heat balance for the natural gas pretreating facility is shown in Chapter 8.

7-2-5 Equipment List

Equipment list for this natural gas pretreating facility is attached on the following page(s).

EQUIPMENT LIST

Item No.	Service	No.	Description
VESSELS			
D-2	Low Temperature Separator	1	600ϕ m/m x 1,800L m/m Material: Carbon Steel with Demister & Boot Design Temperature: 70°C Design Pressure: 38 kg/cm^2G
D-5	Product Gas Mist Separator	1	500ϕ m/m x 1,500H m/m Material: Carbon Steel with Demister Design Temperature: 70°C Design Pressure: 38 kg/cm^2G
HEAT EXCHANGER			
E-1	Feed/Product Gas Heat Exchanger	1	Type: Shell & Tube Surface Area: 8 m^2 Duty: 0.01 MMkcal/hr Material: Shell C.S, Tube 304SS Design temperature: Shell 70°C, Tube 70°C Design pressure: Shell 38 kg/cm^2G, Tube 38 kg/cm^2G
PUMP			
P-2	Low Temperature Separator Draw off Pump	1+1S	Type: Reciprocating/Diaphragm Capacity: 50 l/hr x 21 kg/cm^2
AUXILIARY			
Z-1	Methanol Injection Unit	1 set	Consisting of: Mathanol Storage Drum Methanol Injection Pump

8. CONCEPTUAL DESIGN OF LPG RECOVERY PLANT

In this Chapter, the conceptual design of LPG Recovery Plant is described, in which LPG for household and industrial use is recovered from condensate separated at the High Pressure Separator of Gas Oil Separation Plant (GOSP) of the natural gas production facilities, and filled into cylinders for sale.

8-1 Prerequisites

8-1-1 Raw Material

Natural gas produced in the Sengeti gas field is gathered to GOSP. The gathered gas is separated into gas, hydrocarbon condensate and water. Due to the reason stated in Section 6-2-2, the LPG Recovery Plant uses a High Pressure Separator condensate as its main feed material. A small amount of condensate separated at the pretreating facility is mixed with the HP Separator condensate before it is fed to the LPG Recovery Plant.

If un-separated water is sent to the LPG Recovery Plant, corrosion of equipment and a decrease of distillation efficiency may occur. Therefore, water in the condensate should be removed as much as possible before the condensate is introduced to the LPG Recovery Plant. Therefore, the High Pressure Separator will be installed with a boot for collection and removal of water. Also a boot will be installed at the Low Temperature Separator newly provided in the pretreating facility, for the same purpose.

Since the production volume of natural gas produced in the gas field is regulated in proportion to the required amount of the fuel gas for power generation and of the gas for utilities, the amount of condensates fed from both facilities is the amount that is produced by processing the natural gas proportional to the required gas. The properties of the condensate is shown in Table 8-1.

Table 8-1 Properties of Feedstock for LPG Recovery Plant

Component	mol.%
C_1	9.2
C_2	10.6
C_3	27.3
iC_4	10.8
nC_4	19.7
iC_5	11.1
nC_5	8.1
C_6+	0.9
CO_2	2.2
H_2O	0.1
Condition	
M.W.	50.16
Flow Rate	Max. 21.1 kg-mol/h
	Nor. 17.6 kg-mol/h

8-1-2 Specification of LPG Product

The LPG produced in this plant should meet the specification of PERTAMINA who is the sole producer of LPG in Indonesia.
PERTAMINA produces 3 kinds of LPG: propane, butane and mixed LPG under the specification they set for each product. Mixed LPG produced in this plant is a fuel in great demand by households and industry. Specifications of the mixed LPG product is shown in Table 8-2.

Table 8-2 Product Specifications of Mixed LPG

Specific Gravity at 60°/60°F	to be reported
Reid vapor pressure at 100°F, psig	max. 120
Total sulfur, grains / 100 Ft^3	max. 15
Water content	no free water
Composition	
C_1, wt%	Nil
C_2, wt%	max. 0.2
C_3 + C_4, wt%	min. 97.5
C_5 +, wt%	max. 2.5
Ethyl or Buthyl mercaptan added	50 ml/1,000 US gal.

8-1-3 Cooling Method

Distillation plants utilize the water cooling method and the air cooling method as cooling methods. The air cooling method is more economical in small plants because it does not require a water treating facility. Therefore, the air cooling method is adopted for this plant.
The average maximum temperature in Jambi district is 32°C; this shall be used as the ambient temperature required for designing of cooler units.

8-1-4 Applied Codes and Standards

In planning and designing this plant, American codes and standards are applied.

8-2 LPG Recovery Plant

8-2-1 Main Facilities of LPG Recovery Plant

As explained in Section 6-2-2, the LPG Recovery Plant in this project is a facility to distill and separate the LPG fraction contained in the condensate.

As shown in Table 8-1, there are light components and heavy components, besides LPG consisting of propane and butane, in the raw material condensates. Therefore, in order to recover LPG, it is required to separate these three fractions from the condensates. In distilling these three products, usually two columns are needed.

In this project for example, light components is separated from the top of the first column (deethanizer) and the liquid effluent out of the bottom is sent to the second column. In the second column (debutanizer) the product LPG is obtained from the top and the heavy components (natural gasoline) from the bottom. An additional distillation column is required to recover LPG for export purposes in order to separate propane from butane, but it is not required for this project.

In the LPG Recovery Plant, besides the distillation facility, auxiliary facilities such as LPG filling facility, power generating facility for use on the premises, instrument air facility, hot oil facility, fuel oil facility, fire fighting facility, waste water treating facility, waste gas burning facility (flare stack), communication facility, instrument and control room, office, and warehouse are required.

8-2-2 Summary of Design of Distillation Column

Distillation is a separation operation which uses the difference of volatility of components in the mixture. Figure 8-1 shows an outline diagram of distillation. Trays in multiple stages are installed in inside of the distillation column. Vapor rising from the lower tray comes into contact with liquid falling down from the upper tray and then the high volatile light components in the liquid vaporize, at the same time the heavy components in vapor condense. This phenomenon is repeated at each stage of trays in which the light components are concentrated at the top of the distillation column and the heavy components at the bottom of the column.

Vapor from the top tray is condensed in the condenser where it is cooled and a portion is drawn off as the top product while the balance is returned to the column as reflux. The ratio of the top product and the reflux is called the reflux ratio, an important factor for determining the accuracy of distillation.

On the other hand, a portion of liquid coming from the bottom tray is drawn off as the bottom product and the balance is returned to the column after being heated and vaporized at reboiler. Governing factors determining the accuracy of distillation are the number of trays and reflux ratio. A number of trays and reflux ratio to satisfy the required accuracy of distillation are in inverse proportion as shown in Figure 8-2. Therefore, since there exists the most economical combination of the number of trays and reflux ratio, the importance in the design of distillation lies in selecting the optimum combination. There are many cases in which the optimum combination is obtained empirically and distillation calculation is not required.

Another important element is to select an operating pressure of the distillation column. Since condensing temperature of vapor from the top of the column and vaporizing temperature of the bottom liquid are very closely related to the operating pressure of the column, the operating pressure is to be determined so as to condense the top vapor by coolant to be used and to vaporize the bottom liquid by a heating medium.

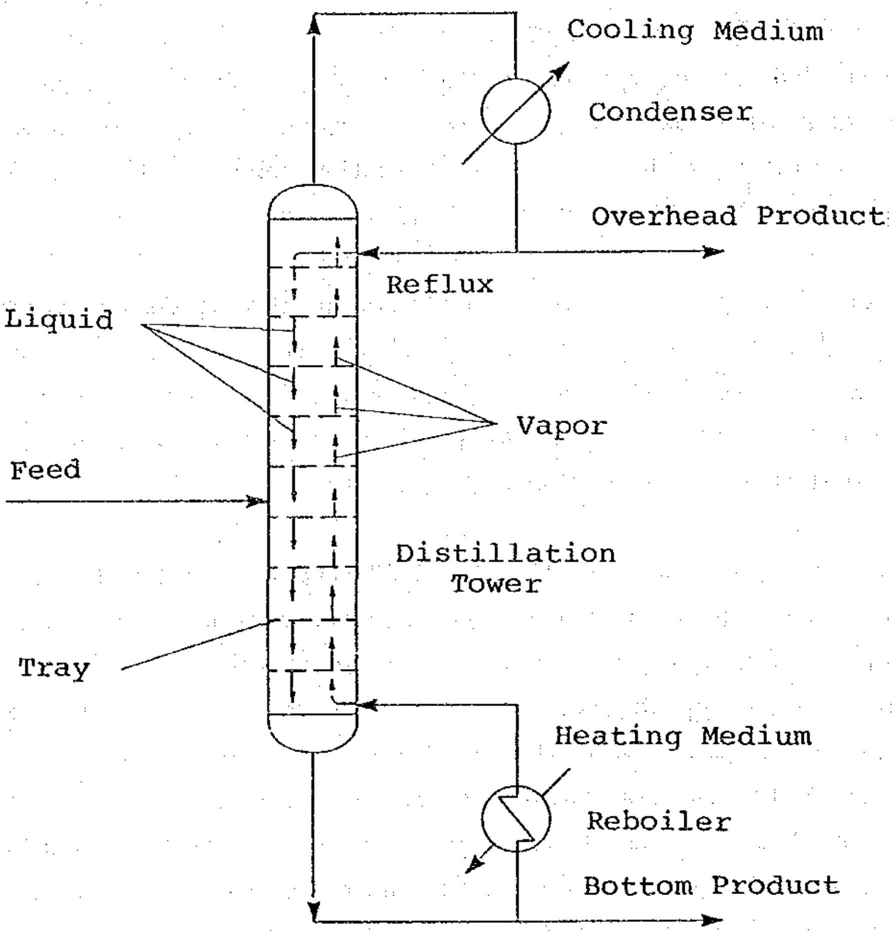


Figure 8-1 Schematic Flow Diagram of Distillation Process

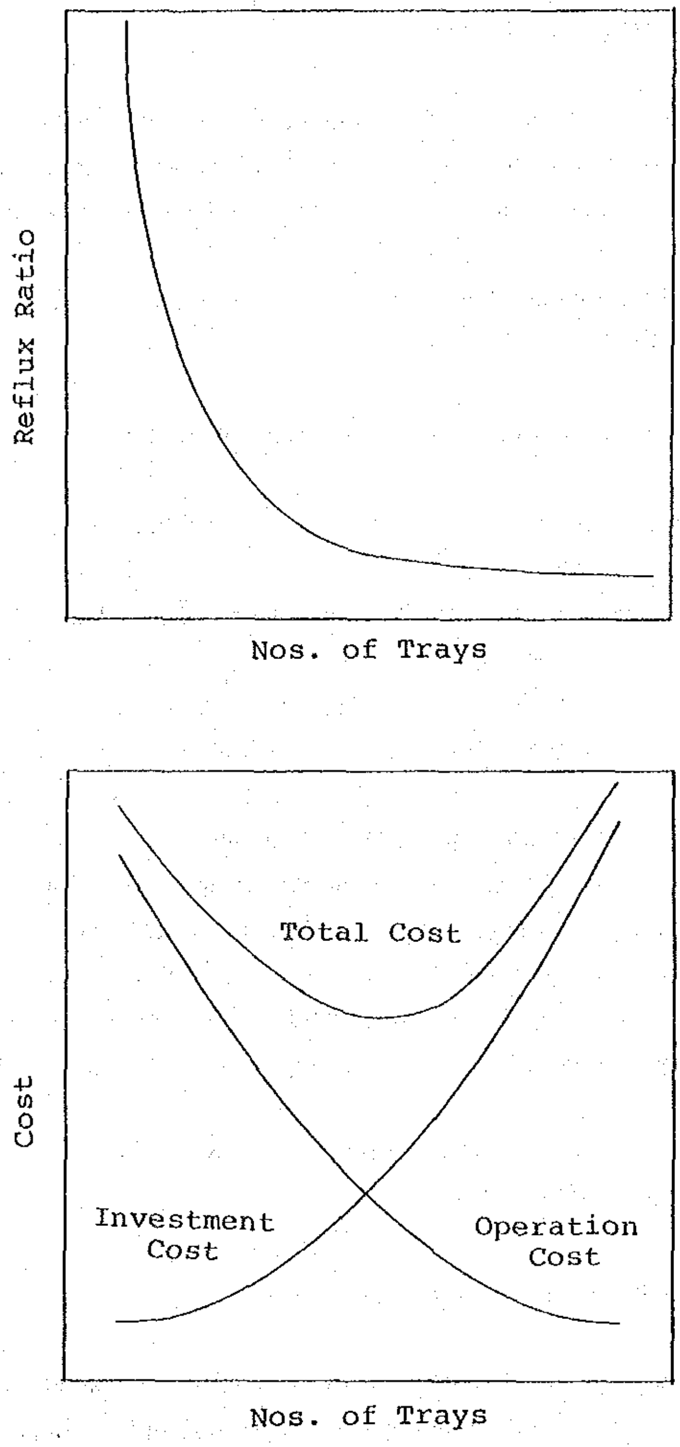


Figure 8-2 **Interrelation between No. of Trays, Reflux Ratio and Total Cost of Distillation**

8-2-3 Design of Deethanizer Column

The deethanizer column is for separating methane, ethane and a part of propane from the top of column, in order to satisfy the specifications on reid vapor pressure and ethane content for the LPG products.

Note: Reid vapor pressure is a vapor pressure of low viscosity oil at 100°F.

The following are explanations for major defined items.

(1) Determination of number of trays and reflux ratio

The concept of number of theoretical plates by which a certain mixture of vapor and liquid at each tray is in an equilibrium condition is used in distillation calculation.
Practical numbers of trays are 20% to 50% more than the numbers of theoretical plates respect to tray efficiency, i.e., deviation from the equibilium condition.
In the case of the deethanizer column for this project, the prominent operating factor is the draw off rate of light components gas from the top of column. On the other hand, the number of theoretical plates and reflux ratio are less important so they are decided based on empirical findings as follows:

Number of theoretical plates = 20 plates
Reflux ratio = 2.0

(2) Determination of operating pressure

Light components contained in feed stock is taken off from the condenser without condensation and is sent to gas pipeline by its own pressure. Therefore, the outlet pressure of the condenser should be kept above the inlet pressure of pipeline, i.e., the outlet pressure of the pretreating facility. On the other

hand, as described in Chapter 6, operating pressure of the High Pressure Separator of GOSP and of the pretreating facility are desired to have flexibility in view of possible variations of the supply conditions of natural gas.
From the results of gas reservoir analysis in Chapter 5, the maximum operation pressure of High Pressure Separator is set at approximately 40 kg/cm^2G. In this case, the outlet pressure of the condenser is to be 34 kg/cm^2G in order for the gas to inject into the pipeline by its own pressure. Effects on operating conditions and product property by the above defined pressure are analyzed, and the results are explained below.

(a) Draw off Rate of C_3

In the case that air cooled heat exchanger is used for the condenser, the most economical outlet temperature of the condenser is 46°C. In order to keep the pressure and temperature at the outlet of the condenser at 34 kg/cm^2G and 46°C, 64.5% of C_3 portion in the feed condensates should be drawn off as light gas.
The amount of LPG production in this case will be 9 to 10 tons per day which will suffice for the demand of the region.

(b) Property of LPG Product

The quality of LPG product satisfies specifications of LPG as shown below.

Reid vapor pressure: 75.6 psig
(LPG specification: below 120 psig)
C_2 content: 0.15 wt%
(LPG specification: less than 0.2 wt%)

(c) Temperature of Bottom of Deethanizer Column

If the outlet pressure of the condenser is set at 34 kg/cm^2G, the pressure of bottom of the deethanizer column becomes 34.4 kg/cm^2G and its temperature becomes 148°C. If diesel oil, readily available locally, is used as the hot oil medium, the feed temperature of the hot oil will become 210°C. Therefore, the temperature of the liquid from the bottom of the column is an appropriate temperature judging from the feed temperature of the hot oil.
The operating pressure of the deethanizer is set at 34 kg/cm^2G at the outlet of the condenser.

(3) *Selection of Type of Column*

There are two types of distillation columns, namely, a trayed column which has a number of trays as internals and a packed column which has a certain height of packings in order to provide better contact between vapor and liquid.
If a trayed column is selected for the deethanizer of this project, the diameter of a column would be about 500 milimeters, posing difficulty to installation of tray, and a specially designed, costly distillation column will be required.
Therefore, an inexpensive packed column is selected for this project. As packings, cascade mini rings made by Dodwell is selected because of their wide range of operations and high contact efficiency. As explained in Section 6-6-2, in order to cope with variations of compositions of feed natural gas, the LPG Recovery Plant should have a wide range of operation conditions. Therefore, considering the efficiency of packings of cascade mini ring and the control range of control valves, the operating range of the distillation column is designed at 130% of the design capacity as its upper level and at 30% as its lower level.
If the amount of processing corresponding to 20 MW power generation is set as the design capacity, diameters of the column will

be 250 mm at the top of the column and 400 mm at the bottom of the column. The height equivalent to a theoretical plate (H.E.T.P.) determined empirically is 500 mm, thus the height of the distillation column becomes 13,400 mm.

8-2-4 Design of Debutanizer Column

The purpose of debutanizer column is to remove C_5 and heavier components from the liquid effluent fed from the deethanizer, in order to satisfy the limitation of heavy components as specified for the LPG product. Major determining items are explained as follows:

(1) Operating Pressure

If all of C_3 and C_4 contained in the bottom liquid of the deethanizer is taken from the top of debutanizer, the composition of top product will be;

C_3	24.6 mol%
iC_4	26.1 mol%
nC_4	49.3 mol%

Since pressure at which the vapor of this composition totally condenses at 46°C is about 8.0 kg/cm^{2}G, the outlet pressure of the condenser is set at 8.0 kg/cm^{2}G. In this case, the pressure and temperature of the debutanizer bottom are 8.4 kg/cm^{2}G and 114°C, respectively.

(2) Determination of Number of Tray and Reflux Ratio

The separation conditions at the debutanizer are set as follows, according to empirical data and LPG specifications.

- Content of C_5 plus in the top product: 1.5 wt% (1% allowance is considered above LPG specification)

- Content of C_4 in the bottom product: 5 mol% (normal design practice)

Then the number of theoretical plates and reflux ratio satisfying the above conditions is calculated. The results are shown in Figure 8-3. As it is clear from the figure, if reflux ratio is set at 2.0, an almost infinitive number of trays are required. This reflux ratio is called as the minimum reflux ratio and the most economical reflux ratio is usually 1.2 to 1.3 times of the minimum reflux ratio. If the number of theoretical plates is calculated by using 2.4 to 2.6 reflux ratio, the number of trays will become 16 to 18 in accordance with this figure.
It is thus determined that the number of theoretical plates is 18 and the reflux ratio is 2.4.

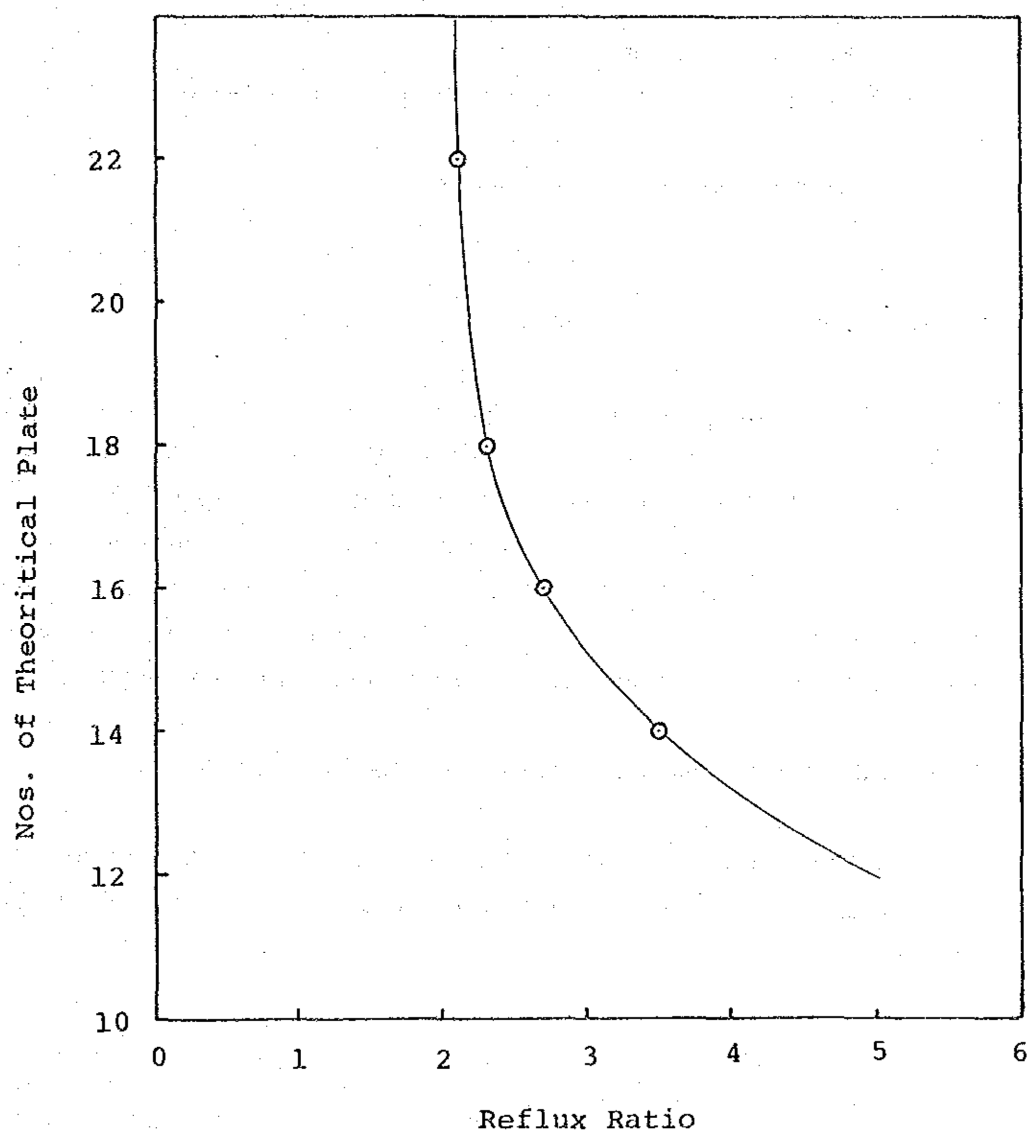


Figure 8-3 The Relationship between the Number of Theoretical Plates and Reflux Ratio in the Debutanizer

(3) Determination of Diameter and Height of the Column

Packed type tower is selected for the same reason it was selected for the deethanizer. Specifications are as follows:

- Diameter of column: 450 mm
- Packing : Cascade mini-ring of Dodwell
  H.E.T.P. = 500 mm
- Height of column : 11,900 mm

8-2-5 Process Flow and Material Balance

Figure 8-4 shows the overall process flow of total natural gas treating system including LPG Recovery plant. As described previously, the total flow rate of the system is determined by the required gas flow rate of the power plant, however natural gas is also used as the fuel for a generator in LPG Recovery Plant and for a hot oil heater. Material balance of total system is calculated taking the required gas for these two purposes into consideration.

The results for the material balance are shown in Table 8-3.

The maximum flow rate corresponds to generation of 20 MW by the generating facility and the normal flow rate corresponds to 17 MW generation.

Figure 8-4 Process Flow Diagram

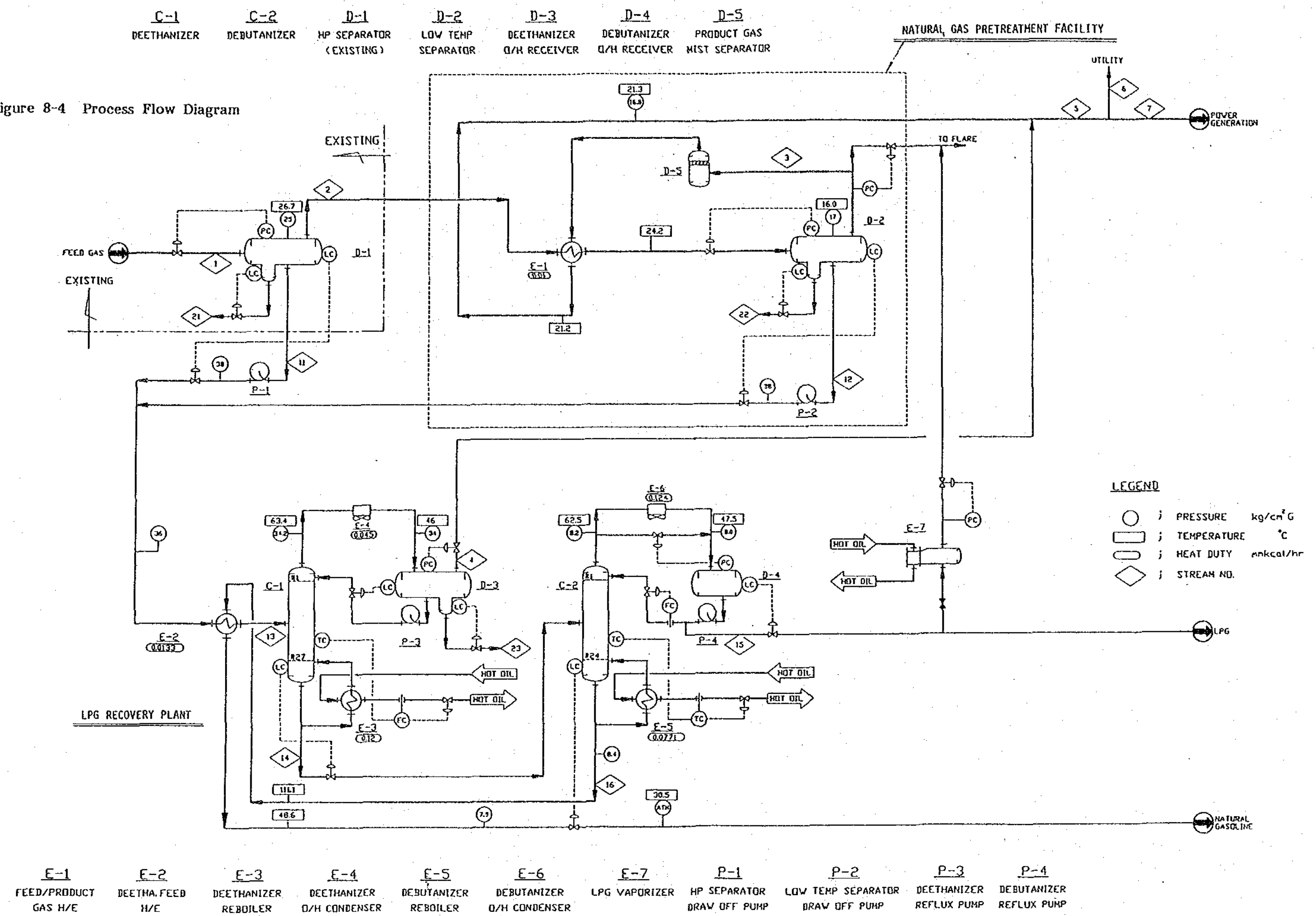


Table 8-3 Material Balance

(1/3)

STREAM ID		1	2	3	4	5	6	7
NAME		FEED	D-1 VAPOR	D-2 VAPOR	C-1 OVHD	PRODUCT GAS	UTILITY GAS	FUEL GAS
PHASE		MIXED	VAPOR	VAPOR	VAPOR	VAPOR	VAPOR	VAPOR
COMPOSITION	(mol%)							
H_2O		1.45	0.19	0.10	0.17	0.11	0.11	0.11
CO_2		6.06	6.67	6.70	5.35	6.62	6.62	6.62
C_1		50.82	57.15	57.37	22.87	55.55	55.55	55.55
C_2		14.61	15.35	15.39	26.04	15.95	15.95	15.95
C_3		14.93	13.48	13.45	43.62	15.05	15.05	15.05
IC_4		3.43	2.49	2.46	1.36	2.40	2.40	2.40
NC_4		5.20	3.33	3.27	0.60	3.13	3.13	3.13
IC_5		2.03	0.85	0.80	0.00	0.76	0.76	0.76
NC_5		1.36	0.49	0.45	0.00	0.43	0.43	0.43
C_6+		0.11	0.01	0.00	0.00	0.00	0.00	0.00
TOTAL		100.00	100.00	100.00	100.00	100.00	100.00	100.00
MAX. FLOW RATE	(kg-mol/h)	176.24	153.38	152.72	8.53	161.25	2.40	158.85
	(kg/h)	5222.0	4148.9	4118.8	292.2	4411.0	65.5	4345.5
	(MMSCFD)	3.54	3.08	3.07	0.17	3.24	0.05	3.19
NOR. FLOW RATE	(kg-mol/h)	146.92	127.87	127.32	7.11	134.42	2.04	132.38
	(kg/h)	4353.2	3458.8	3433.8	243.6	3677.2	55.9	3621.4
	(MMSCFD)	2.95	2.57	2.56	0.14	2.70	0.04	2.66
PRESSURE	(kg/cm^2G)	25.0	25.0	16.9	16.8	16.8	16.8	16.8
TEMPERATURE	(°C)	26.7	26.7	16.0	46.0	21.3	21.3	21.3

STREAM ID		11	12	13	14	15	16
NAME		D-1 LIQUID	D-2 LIQUID	C-1 FEED	C-1 BTMS	LPG PRODUCT	NATURAL GASOLINE
PHASE		LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID
COMPOSITION	(mol%)						
H_2O		0.07	0.03	0.07	0.00	0.00	0.00
CO_2		2.17	1.71	2.16	0.00	0.00	0.00
C_1		9.29	6.66	9.23	0.00	0.00	0.00
C_2		10.66	9.13	10.62	0.18	0.28	0.00
C_3		27.33	26.54	27.31	16.27	24.87	0.00
IC_4		10.83	11.39	10.84	17.26	26.23	0.29
NC_4		19.70	21.44	19.74	32.69	47.48	4.71
IC_5		11.07	12.82	11.11	18.63	0.98	52.01
NC_5		8.02	9.44	8.05	13.50	0.16	38.76
C_6+		0.87	0.84	0.87	1.46	0.00	4.23
TOTAL		100.00	100.00	100.00	100.00	100.00	100.00
MAX. FLOW RATE	(kg-mol/h)	20.61	0.53	21.14	12.61	8.25	4.36
	(kg/h)	1032.6	27.6	1060.2	768.0	451.3	316.7
	(m^3/h)	1.92	0.05	1.97	1.31	0.81	0.51
NOR. FLOW RATE	(kg-mol/h)	17.18	0.44	17.62	10.51	6.88	3.63
	(kg/h)	860.8	23.0	883.7	640.3	376.2	264.0
	(m^3/h)	1.60	0.04	1.61	1.09	0.67	0.42
PRESSURE	(kg/cm^2G)	25.0	16.9	35.5	34.4	10.0	8.4
TEMPERATURE	(°C)	26.7	16.0	47.6	148.5	47.5	114.3

STREAM ID		21	22	23
NAME		D-1 WATER	D-2 WATER	D-3 WATER
PHASE		LIQUID	LIQUID	LIQUID
COMPOSITION	(mol%)			
H_2O		99.99	100.00	100.00
CO_2		0.01	0.00	0.00
C_1		0.00	0.00	0.00
C_2		0.00	0.00	0.00
C_3		0.00	0.00	0.00
IC_4		0.00	0.00	0.00
NC_4		0.00	0.00	0.00
IC_5		0.00	0.00	0.00
NC_5		0.00	0.00	0.00
C_6+		0.00	0.00	0.00
TOTAL		100.00	100.00	100.00
MAX. FLOW RATE	(kg-mol/h)	2.25	0.14	0.0
	(kg/h)	40.4	2.5	0.0
	(m^3/h)	0.04	0.002	0.0
NOR. FLOW RATE	(kg-mol/h)	1.87	0.11	0.0
	(kg/h)	33.7	2.0	0.0
	(m^3/h)	0.03	0.002	0.0
PRESSURE	(kg/cm^2G)	25.0	16.9	16.8
TEMPERATURE	(°C)	26.7	16.0	46.0

8-2-6 Equipment List

Specifications for equipment for LPG Recovery Plant based on the material balance are shown in Table 8-4.

Specifications of each equipment shown in the equipment list are the design capacities corresponding to 20 MW generation and the operation range for the selection of equipment is to be 30 to 130% of the design capacity.

8-2-7 Plot Plan

A tentative plot plan of natural gas pretreating facilities, LPG Recovery Plant and their auxiliary facilities to be constructed in Sengeti area is shown in Figure 8-5.

All of these facilities should be constructed adjacent to the existing GOSP as explained in Chapter 6. It is also desirable to construct the pretreating facility and LPG Recovery Plant on a skid mounted basis for possible re-installation in other locations and a layout of skid mounted plant is shown in Figure 8-6.

Table 8-4 Equipment List of LPG Recovery Plant

(1/3)

Item No.	Service	No.	Design Condition Pressure (kg/cm^2G)	Design Condition Temperature (°C)	Material	Specification
C-1	Deethanizer	1	38	170	C.S	Dimension : 250ϕ/400ϕmm x $13,400^H$mm Packing : Cascade Mini Ring 4 beds
C-2	Debutanizer	1	9.5	135	C.S	Dimension : 450ϕmm x $11,900^H$mm Packing : Cascade Mini Ring 4 beds
D-3	Deethanizer Overhead Receiver	1	38	70	C.S	Dimension : 600ϕmm x $1,800^L$mm with Demister & Boot
D-4	Debutanizer Overhead Receiver	1	9.5	70	C.S	Dimension : 600ϕmm x $1,800^L$mm
D-5	Product Gas Mist Separator	1	38	70	C.S	Dimension : 500ϕmm x $1,500^H$mm with Demister
E-2	Deethanizer Feed Heat Exchanger	1	Shell: 9.5 Tube : 38	Shell: 135 Tube : 135	Shell: C.S Tube : C.S	Type : Shell & Tube Surface Area: 1.5 m^2 Heat Duty : 0.0133 MMkcal/h
E-3	Deethanizer Reboier	1	Shell: 7 Tube : 38	Shell: 230 Tube : 170	Shell: C.S Tube : C.S	Type : Shell & Tube Surface Area: 18 m^2 Heat Duty : 0.12 MMkcal/h

Item No.	Service	No.	Design Condition		Material	Specification
			Pressure (kg/cm^2G)	Temperature (°C)		
E-4	Deethanizer Overhead Condenser	1	38	85	Tube : C.S Fin: Alum.	Type : Air Fin Cooler Surface Area: Bared 9.0 m^2 Finned 174 m^2 Fan : 7.5 kW x 1 Heat Duty : 0.0445 MMkcal/h
E-5	Debutanizer Reboiler	1	Shell: 7 Tube : 9.5	Shell: 230 Tube : 135	Shell: C.S Tube : C.S	Type : Shell & Tube Surface Area: 5 m^2 Design Duty : 0.0771 MMkcal/h
E-6	Debutanizer Overhead Condenser	1	9.5	70	Tube : C.S Fin: Alum.	Type : Air Fin Cooler Surface Area: Bared 18 m^2 Finned 350 m^2 Fan : 11 kW x 1 Heat Duty : 0.124 MMkcal/h
E-7	LPG Vaporizer	1	Shell: 14 Tube : 7	Shell: 65 Tube : 230	Shell: C.S Tube : C.S	Type : Shell & Tube (Kettle) Surface Area: 2 m^2 Design Duty : 0.034 MMkcal/h

Item No.	Service	No.	Design Condition Pressure (kg/cm^2G)	Design Condition Temperature (°C)	Material	Specification
P-1	H.P. Separator Draw Off Pump	2			Casing: C.S Impeller : C.S	Type : Centri. Capacity : 2 m^3/h x 13 kg/cm^2 Motor : 3 kW (BHP)
P-3	Deethanizer Reflux Pump	2			Casing: C.S Impeller : C.S	Type : Centri. Capacity : 2 m^3/h x 3 kg/cm^2 Motor : 1 kW (BHP)
P-4	Debutanizer Reflux Pump	2			Casing: C.S Impeller : C.S	Type : Centri. Capacity : 3 m^3/h x 3 kg/cm^2 Motor : 1 kW (BHP)

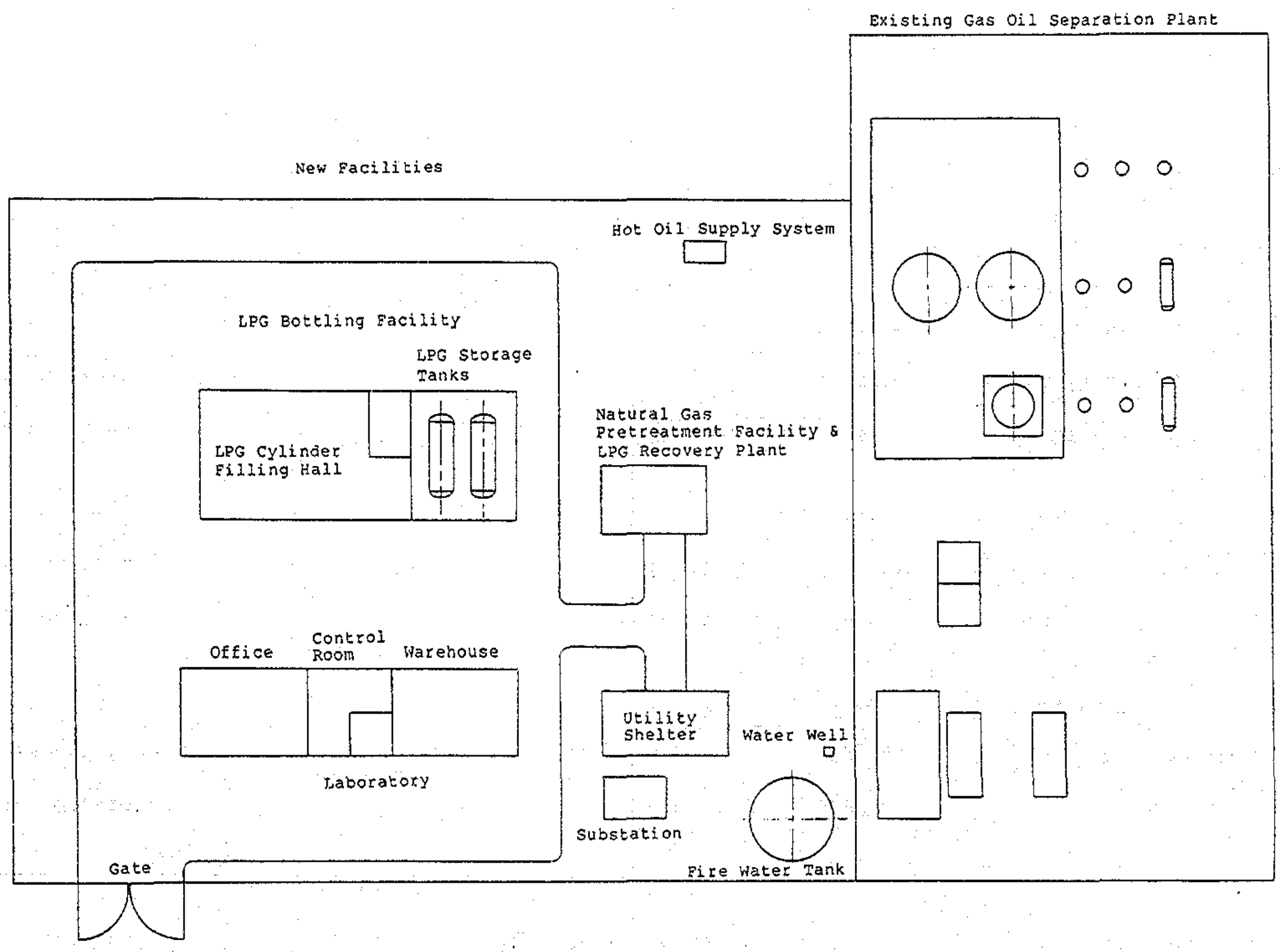


Figure 8-5 Plot Plan of Natural Gas Treating Facilities

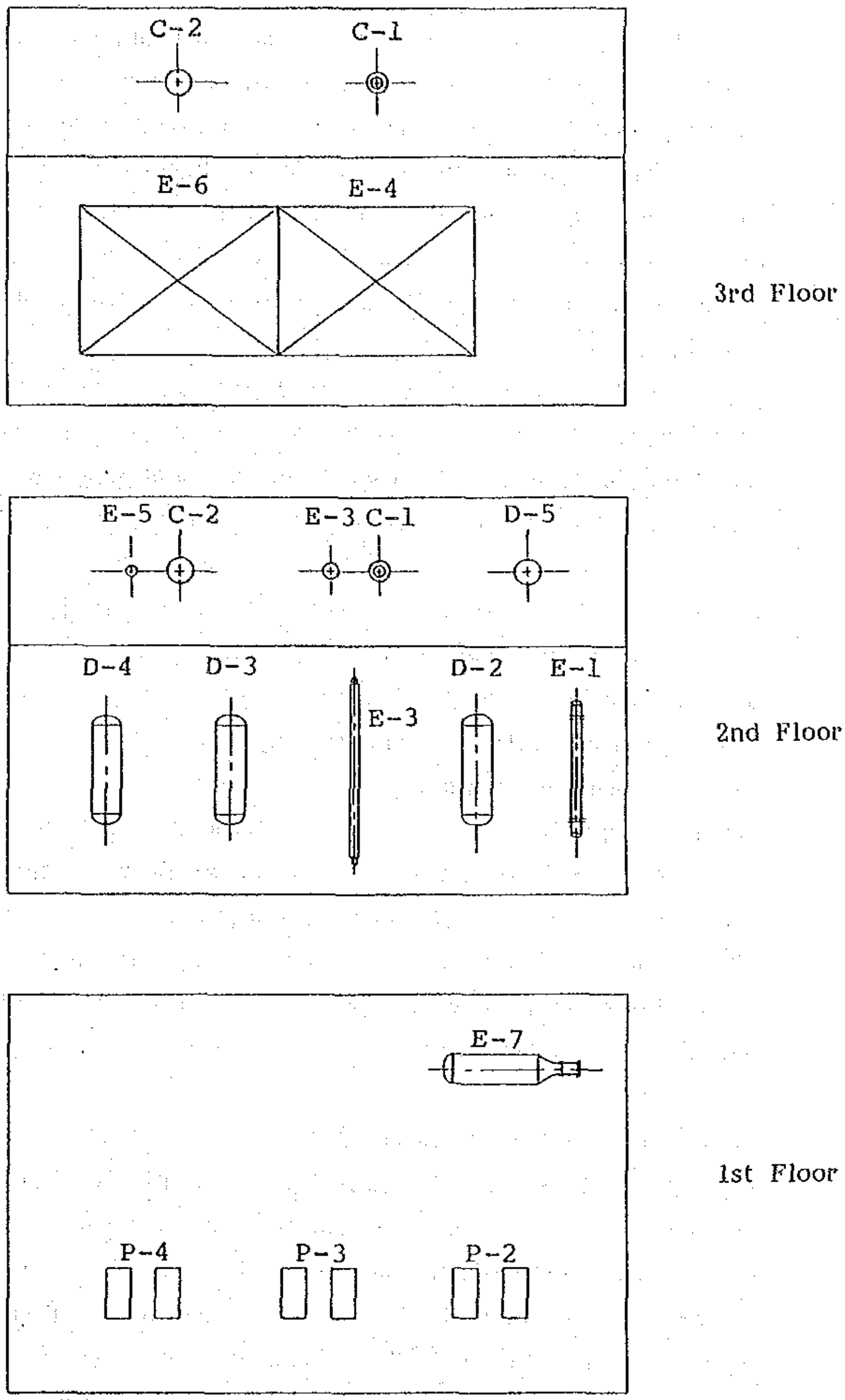


Figure 8-6 Layout of Skid Mounted Plant

8-2-8 Process Description (refer to Figure 8-4)

This LPG Recovery Plant uses, as raw material, condensates separated from High Pressure Separator of GOSP and from the natural gas pre-treating facility. The raw material is heated at E-2 (Deethanizer Feed Heat Exchanger) by heat exchange of high temperature natural gasoline from C-2 (Debutanizer), after being pressurized by P-1 (High Pressure Separator Draw-out Pump) and P-2 (Low Temperature Separator Draw-off Pump) and is then sent to C-1 (Deethanizer).

Vapor coming from the top of C-1 is cooled down to 46°C by E-4 (Deethanizer Overhead Condenser) and is sent to D-3 (Deethanizer Overhead Receiver). At that time, C_3 and heavier components and water contained in overhead vapor are condensed. At D-3, fluid from E-4 is separated into non-condensed gas, hydrocarbon condensate and water and the non-condensed gas is injected into fuel gas pipeline by its own pressure. The hydrocarbon condensate is returned to the top of C-1 as reflux through P-3 (Deethanizer Reflux Pump).

The separated water is sent to oily water treatment facility by its own pressure for treatment.

From the bottom of C-1, C_3 and heavier components are taken out and a part of it is naturally recirculated between the bottom of C-1 and E-3 (Deethanizer Reboiler) by heated and vaporized at E-3.

The balance is fed to C-2 (Deethanizer) by its own pressure.

Vapor taken from the top of C-2 is totally condensed at E-6 (Debutanizer Overhead Condenser) and sent to D-4 (Debutanizer Overhead Receiver).

Liquid from D-4 is pressurized by P-4 (Debutanizer Reflux Pump) and a part of it is sent to LPG filling facility as LPG product. The balance is returned to the top of C-2 as reflux. The heavy components is taken from the bottom of C-2 and a part of it recirculated between the bottom of C-2 via E-5 (Debutanizer Reboiler). And the balance is sent to TK-1 (Test Tank) of the existing GOSP by its own pressure as natural gasoline product. This natural gasoline is sent through the existing crude oil pipeline, eventually to the refinery in Palembang for processing. Transfer line of LPG product has a branch line, so if the product does not meet specifications, the off-specification LPG is evaporated at E-7 (LPG Evaporator) provided in the branch line and sent to the waste gas burning facility for flaring.

8-3 Auxiliary Facilities

Table 8-5 is the equipment list for the auxiliary facilities required in LPG Recovery Plant. The following are brief explanations.

8-3-1 LPG Filling Facility

LPG produced in LPG Recovery Plant is filled into 11 kg cylinders for household use and into 45 kg cylinders for industrial use at LPG filling station and are handed to LPG dealers.

Figure 8-7 shows schematic flow diagram of LPG filling facility. LPG from LPG Recovery Plant is once stored in LPG storage tanks and sent to a filling machine through a filling pump.

Table 8-5 Equipment List of Auxiliary Facilities for LPG Recovery Plant

(1/5)

Service	No.	Design Condition Pressure (kg/cm^2G)	Design Condition Temperature (°C)	Material	Specification
<LPG Bottling Facility>					
. LPG Storage Tank	2	14	55	C.S	Dimension: 2,600φmm x 8,000^{L}mm
. Automatic Rotary Filler (for 11kg cylinders)	1 set				Filling Machine : 6 units Filling Head Type : Self Decoupling Composed Equipment: Auto Introduction Unit, Auto Ejection Unit Motor : 0.75 kW (BHP)
. Fixed Filler (for 45kg cylinders)	1				Filling Head Type : Self Decouplng
. Leakage Detector	4				Portable Detector with Compact Valve
. Roller Conveyor	4				Type: Movable Length: 3 m each
. Evacuation Device	1 set				Consisting of: 2 Tanks, Cylinder Rack & 1 Compressor (Motor: 5.5 kW)
. Check Scale	2				1 Check Scale for 11 kg Cylinder 1 Check Scale for 45 kg Cylinder

Service	No.	Design Condition Pressure (kg/cm^2G)	Design Condition Temperature (°C)	Material	Specification
. Odorant System	1 set				Consisting of Odorant Drum & Odorant Pump Injection Rate : 50 ml/1,000 US. gal.
. Filling Pump	2			Casing: C.S Impeller : C.S	Type: Centri. Capacity: 10 m^3/h x 5 kg/cm^2 Motor: 4 kW (BHP)
<Electricity Generation Facility>					
. Power Generator	2				Type: Gas Engine Driven (main) Diesel Engine Driven (stand-by) Battery Start Rated Capacity: 140 kW
<Instrument Air Facility>					
. Instrument Air Compressor	2				Type: Motor Driven (main) Diesel Engine Driven (stand-by) Capacity: 60 Nm^3/h x 7 kg/cm^2 Driver: 8 kW (BHP)

Service	No.	Design Condition Pressure (kg/cm^2G)	Design Condition Temperature (°C)	Material	Specification
. Instrument Air Dryer	1 set				Type: Pressure Swing Type with Filter Capacity: 60 Nm^3/h Air Dew Point: 0°C at 7 kg/cm^2G
. Instrument Air Drum	1	9	60	C.S	Dimension: 1,200ϕmm x $3,000^H$mm
<Hot Oil Facility>					
. Direct Fired Heater	1				Type: Package Type
. Hot Oil Expansion Drum	1				Heat Duty: 0.25 MMkcal/h
. Hot Oil Circulation Pump	2				Hot Oil Circulation Rate: 2.5 m^3/h Motor: 2 kW (BHP)
<Fuel Oil Facility>					
. Fuel Oil Storage Tank	1	Full Water	60°C	C.S	Dimension: 1,500ϕmm x $4,500^L$mm
. Fuel Oil Receiving & Supply Pump				Casing: C.S Impeller : C.S	Type: Centri. Capacity: 2.5 m^3/h x 2 kg/cm^2 Motor: 0.5 kW (BHP)

Service	No.	Design Condition		Material	Specification
		Pressure (kg/cm^2G)	Temperature (°C)		
. Fuel Oil Day Drum for Power Generator	1	Full Water	60°C	C.S	Dimension: 600ømm x $1,500^H$mm
. Fuel Oil Day Drum for Instrument Air Comp. Engine	1	Full Water	60°C	C.S	Dimension: 400ømm x $1,000^H$mm
. Fuel Oil Day Drum for Fire Water Pump Engine	1	Full Water	60°C	C.S	Dimension: 400ømm x $1,000^H$mm
<Fire Fighting Facility>					
. Fire Water Tank	1	Full Water	60°C	C.S (Internal Coating)	Type: Cone Roof Tank Capacity: 660 m^3
. Fire Water Pump Pump	1				Type: Centri. Diesel Engine Driven Capacity: 328 m^3/h x 7 kg/cm^2
. Water Hydrants					in accordance with NFPA Code
. Water Spray System					
. Fire Extinguisher					
<Waste Water Treatment Facility> (. Oily Water Treating Facility)					Common use of existing facility
. Sanitary Sewer Treating Facility					Type: Package type

Service	No.	Design Condition Pressure (kg/cm^{2}G)	Design Condition Temperature (°C)	Material	Specification
<Flare Blow Down System>					
(. Flare Stack) (. Gas Scrubber)					common use of existing facility
<Communication Facility>					
. Paging System	1 set				for Plant Site Communication
. Radio Communication System	1 set				for Telecommunication between Sengeti and Payo Celincah
<Buildings>					
. Control Room					Floor Area: 10 m x 10 m with Air Conditioning
. Laboratory					Floor Area: 5 m x 5 m included in the control room
. Office					Floor Area: 10 m x 15 m
. Substation					Floor Area: 5 m x 8 m with Air Conditioning
. Warehouse					Floor Area: 10 m x 15 m
. Utility Shelter					Roof Area : 8 m x 15 m without walls
. LPG Bottle Filling Hall					Roof Area : 15 m x 25 m without walls

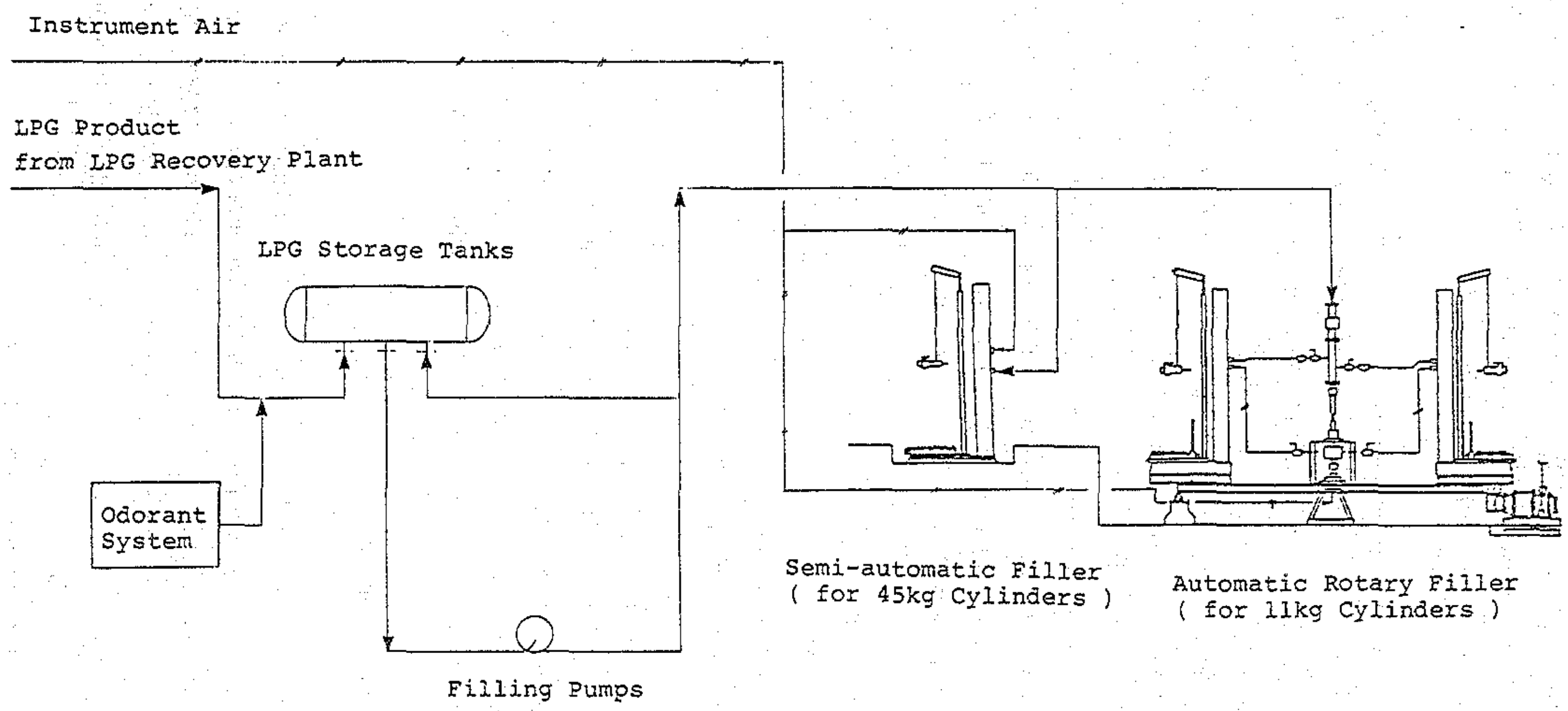


Figure 8-7 Schematic Flow Diagram of LPG Filling Facility

A rotary filling station to fill LPG into 11 kg cylinders having high demand and a stational filling station to fill 45 kg cylinders are established in the LPG filling station.

Six (6) filling machines are installed on one rotating disc station. Cylinders are set automatically in the automatic rotary filler once cylinders are placed on designated place by operators. The operators connect an injection mouth on a cylinder, and LPG filling is started by pressing a start-button, then stopped when the designated weight of LPG is filled in the cylinder and the injection mouth is automatically disconnected. When the rotating disc-stand rotates to a set position, the cylinder is automatically discharged. This operation will be completed in series while the automatic filler rotates one revolution (360°). At a stational filler, operators set a cylinder on the filler, connect a injection mouth onto the cylinder, and press a start-button to start LPG filling. Filling will be stopped when the cylinder weighs a designated weight, and the injection mouth is automatically disconnected. Then the operators remove the cylinder from the stational filler. This filling facility will have an LPG filling capacity of 300 tons per month by an 8-hour working day rate.

Among equipment shown in the equipment list, a leak detector is an instrument to detect LPG leakage from the nozzle on the top of cylinders after filling and an evacuation device is a device to evacuate and recover LPG in cylinder when leakage is detected and to return the recovered LPG to the LPG storage tanks.

8-3-2 Power Generator Facility

The purpose of this facility to supply electricity required in the natural gas pretreating facility and LPG Recovery Plant.
There are two generating systems; one is driven by gas engine and used during normal operation, the other is driven by diesel engine and used during start-up and when the normal running generator is out of service.
Table 8-6 shows electricity consumption.

Table 8-6 Electricity Consumption

Item No.	Service	Electricity Consumption (BHP-kW)
E-4	Deethanizer Overhead Condenser	7.5
E-6	Debutanizer Overhead Condenser	11.0
P-1	High Pressure Separator Draw Off Pump	3.0
P-2	Low Temperature Separator Draw Off Pump	0.5
P-3	Deethanizer Reflux Pump	1.0
P-4	Debutanizer Reflux Pump	1.0
	<LPG FILLING FACILITY>	
	. Filling Pump	4.0
	. Automatic Rotary Filler	0.75
	. Evacuation Device (Compressor)	5.5
	<Instrument Air System>	
	. Instrument Air Compressor	8.0
	<Hot Oil System>	
	. Hot Oil Circulation Pump	2.0
	<Fuel Oil Facility>	
	. Fuel Oil Receiving & Supply Pump	0.5
	<Fire Water Facility>	
	. Well Water Pump	1.2
	<Lighting>	15
	<Air Conditioning>	25
	<Instrumentation>	8
	Total	94

8-3-3 Instrument Air System

This facility is for supplying instrument air required in the natural gas pretreating facility and LPG Recovery Plant. The facility consists of two sets of compressors, a dehydrator and an instrument air tank. The main compressor is driven by an electric motor and used during normal operation. The dehydrator is a device to remove water contained in the compressed air by adsorption. Regeneration of the adsorbent is performed by a depressuring method called the pressure swing method.

8-3-4 Hot Oil Facility

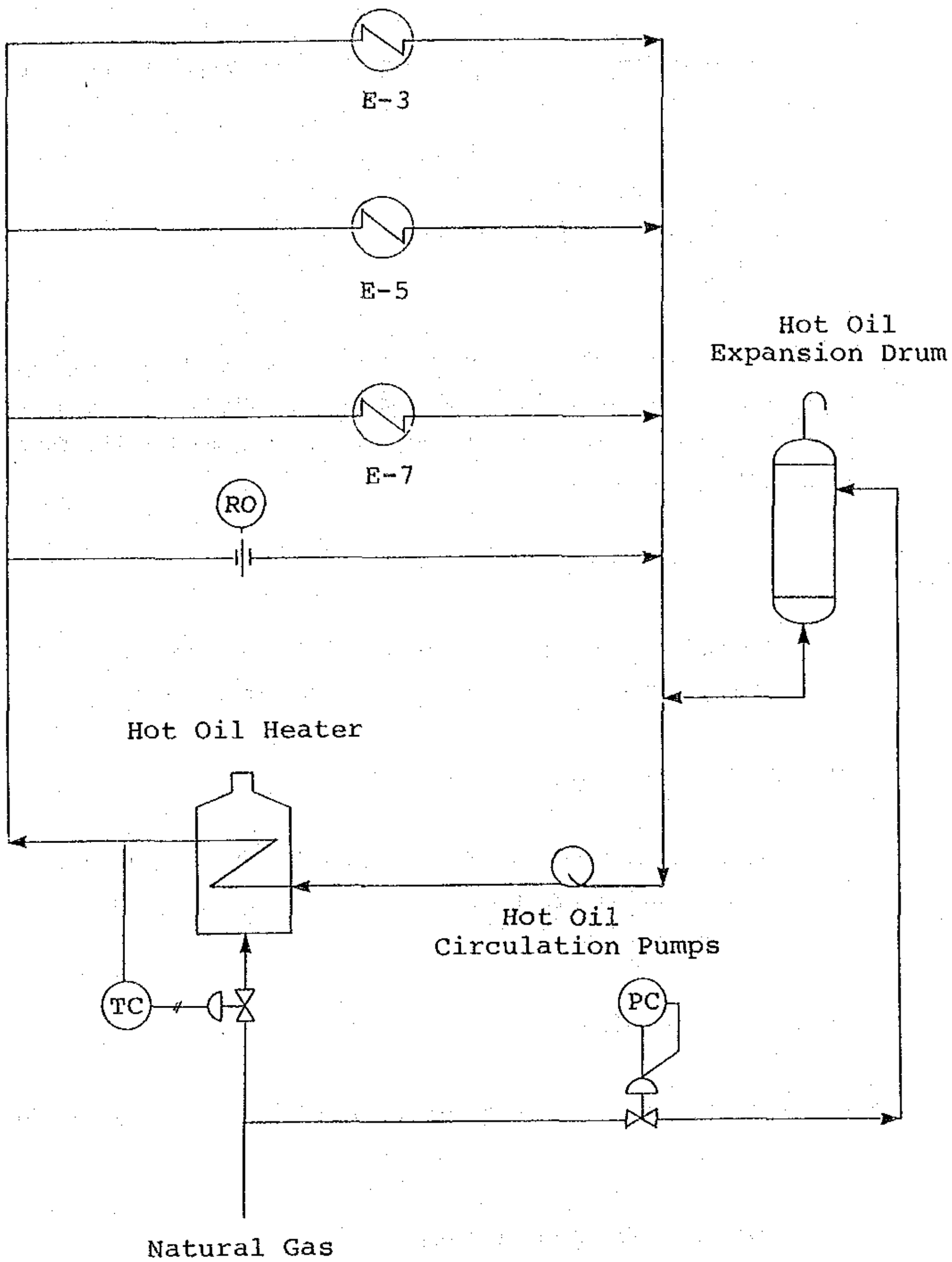
The purpose of this facility is to supply hot oil which is a heat source for the following units in LPG Recovery Plant.

E-3 Deethanizer reboiler
E-5 Debutanizer reboiler
E-7 LPG revaporator

The facility is of the package type and consists of a hot oil heater which uses gas as fuel, hot oil circulation pumps and a hot oil expansion drum.

As shown in Figure 8-8, the hot oil is pressurized by a hot oil circulation pump and heated to a certain temperature by the hot oil heater before being fed to individual process equipment.

The hot oil which is cooled by heat exchange with process fluid is returned to the hot oil circulation pump. The hot oil expansion drum is provided to absorb the expansion of volume of hot oil due to temperature rise and is sealed by continuous feeding of small amounts of natural gas into the drum, in order to prevent degradation of oil by air contact.



Note:RO=Restriction Orifice

Figure 8-8 Schematic Flow Diagram of Hot Oil System

8-3-5 Fuel Oil Facility

The following three (3) diesel engines are used in the auxiliary facility of LPG Recovery Plant.

- Engine for generator
- Engine for instrument air compressor
- Engine for fire fighting pump

In the hot oil facility, diesel oil is also used as a hot oil. Therefore, a facility is necessary to receive, store and supply diesel oil to be used in the various pieces of the equipment. The following equipment are provided.

(1) Fuel Oil Storage Tank

The tank is for receiving diesel oil from a tank truck. Storage capacity is set at 8 m^3 because a tank truck capacity is 7 m^3.

(2) Fuel Oil Feed Pump

The pump is used to transfer diesel oil from a tank truck to the fuel oil storage tank or from the storage tank to day tanks for each machine.

(3) Fuel Oil Day Tank

The following day tanks are provided for each piece of equipment.

- Day tank for generator engine
  : For capacity of 12 hours-operation
- Day tank for instrument air compressor
  : For capacity of 2 days-operation
- Day tank for fire fighting pump
  : For capacity of 3 hours-operation

8-3-6 Fire Fighting Facility

The following equipment are provided in accordance with guidelines of the National Fire Protection Association (NFPA) of the U.S.A.

(1) Fire Fighting Pump

Pump is driven by a diesel engine and to supply water to hydrants and a deluge system. Capacity of the pumps are:

(a)	Discharge amount to hydrants	:	227 m^3/h
(b)	Amount to the deluge system in LPG filling station	:	101 m^3/h
		Total :	328 m^3/h

(2) Fire Fighting Water Storage Tank

The tank has storage capacity of 660 m^3, capable of supplying the above-mentioned amount of water for a duration of two hours.

(3) Well Water Pump

The pump is pumping out well water for the purpose of fire fighting and supplying it to fire fighting water storage tank.

(4) Hydrants

Hydrants will be provided in appropriate locations in the LPG Plant.

(5) Deluge System

In order to spray water over 50% space of LPG filling station with focus on fillers, the appropriate spray nozzles and fire fighting pipework will be provided.

(6) Extinguisher

Portable powder-type fire fighting extinguishers will be provided.

8-3-7 Waste Water Treating Facility

There are two types of waste water coming out from the GOSP, the natural gas pretreating facility and the LPG Recovery Plant. One is free water separated from

- D-1 High Pressure Separator
- D-2 Low Temperature Separator
- D-3 Deethanizer Overhead Receiver

and the other is sanitary water from human activities.
Since free water contains oil, the water is discharged to the Batang Hari river after oil is separated. An oily water separation facility installed in the existing GOSP is used for this purpose.
A septic tank is newly installed for treating sanitary water due to human activities of employees in the plant.

8-3-8 Waste Gas Burning Facility

In order to keep operating pressure of the natural gas treatment system below the design pressures of each equipment, safety valves and gas discharge pipe for pressure regulation are provided. For the purpose of discharging the gas safely in case of emergency, the discharged gas should be burnt. The flare blow down system in the existing GOSP is used.

8-3-9 Communication Facility

A paging system is provided in the plant. A wireless communication system is provided for communication between the natural gas processing plant in Sengeti and the proposed power plant in Jambi City.

8-3-10 Buildings

The following buildings are to be newly constructed for the natural gas pretreating facility and the LPG Recovery Plant.

Buildings	Floor Area
Control room (air conditioned)	10 m x 10 m
Laboratory (a part of Control room)	5 m x 5 m
Office	10 m x 15 m
Substation (air conditioned)	5 m x 8 m
Warehouse	10 m x 15 m

The following facilities are covered by roofs without enclosures.

Facilities	*Roof Area*
LPG filling station	15 m x 25 m
Utility supply facilities	8 m x 15 m

9. CONCEPTUAL DESIGN OF NATURAL GAS PIPELINE

In this chapter, described are basic idea and design conditions of the pipeline transporting natural gas, which is produced from Sengeti gas reservoirs, to the proposed power plant in Jambi City. It is necessary to carry out the detailed design based on the site survey including survey for pipeline route prior to the construction of the pipeline.

9-1 Preconditions

Field survey for this project was made in February 1988. During the survey, field reconnaissances were made for several areas through which the natural gas pipeline may be laid. Basic design conditions were also discussed during the survey with BPPT of Indonesian counterpart, relating authorities and possible project executive organizations such as PERTAMINA and PLN. Therefore, the proposed natural gas pipeline is planned/designed based on the result of above-mentioned field survey, the discussions made with BPPT and data obtained during the survey.

9-1-1 Properties of Natural Gas

The natural gas consumed as fuel for dual-fuel engines in the proposed power plant is the gas which is produced from Sengeti gas field, and is transported and supplied by means of pipeline.

The natural gas as fuel for the engines shall meet requirements of calorific value and high concentration of methane. Additionally, ethane and heavier components which cause knocking problem of the engines shall be removed from the gas to the extent that remained components will not present any practical difficulty in operation. Moreover, it is very important that the gas shall not form hydrate nor deposit free water during the transportation through pipeline.

(1) Characteristics of Recovered Natural Gas

The natural gas separated and recovered at the high pressure separator in GOSP is to be utilized as fuel gas for the proposed power plant. The characteristics of the recovered gas is shown in Table 9-1. The gas characteristics in the table satisfies requirements of fuel gas for power generating dual-fuel engines and it is not required to make any precaution for further adjustment of compositions for the fuel gas. However, adjustment of gas composition, which is so-called dew point control of the gas, is required for pipeline transportation to prevent hydrate formation and free water deposit in the pipeline.

Table 9-1 Properties of Gas
(at outlet of gas/oil separator)

Components	Mol %
C_1	57.1
C_2	15.4
C_3	13.5
iC_4	2.5
nC_4	3.3
iC_5	0.8
nC_5	0.5
C_6^+	trace
H_2O	0.2
CO_2	6.7

(2) Adjustment of Gas Composition by Gas Pretreating Facility

The gas recovered by the high pressure separator is saturated with water and hydrocarbons at its operating conditions (pressure and temperature). The water and hydrocarbons in the gas will condense when the temperature and pressure of the gas are decreased during transportation through pipeline. These condensates not only remain at the lower parts of pipeline and decrease transportation efficiency, but may cause internal corrosion of the pipeline. Especially, in the case of this project, carbon dioxide contained in the gas at higher level might corrode pipeline easily in the presence of freewater and will cause leakage in the pipeline.

Therefore, the dew point of the gas transferred by pipeline shall be controlled by the gas pretreating facilities prior to feeding the gas into the pipeline. Table 9-2 shows the characteristics of the gas to be transported by the pipeline as fuel for the power plant, i.e. the mixture of the gas treated to control dew point by the gas pretreating facility and the lighter hydrocarbons separated in the LPG recovery plant.

Table 9-2 Properties of Gas
(at inlet of gas pipeline)

Components	Mol %
C_1	55.6
C_2	16.0
C_3	15.0
iC_4	2.4
nC_4	3.1
iC_5	0.8
nC_5	0.4
C_6+	trace
H_2O	0.1
CO_2	6.6

Low Heating Value = 12,580 kcal/Nm^3

9-1-2 Gas Flow Rate

The pipeline shall have a capacity of transporting required amount of gas for continuous operation of the power plant. The maximum flow rate of the pipeline shall satisfy the maximum gas demand of the power plant corresponding to the gas consumption rate at the maximum load. The maximum capacity of the pipeline is the function of pipe size, pipeline length, operating pressure (pipeline inlet and outlet pressure), operating temperature and so on. Accordingly, the pipe size shall be determined taking the all factors concerned as mentioned above into consideration.

(1) Design Flow Rate

The design flow rate of the pipeline shall be the consumption rate of the power generating dual-fuel engines (4 x 5 MW) of the power plant operating at their maximum load equal to 20 MW. The design flow rate of the pipeline is calculated by the following formula. In the formula, thermal efficiency of 36% for the dual-fuel engine (low heating value base), efficiency of 96% for the generator and gas/diesel oil ratio of 9:1 in fuel are taken.

$$\frac{20{,}000(\text{kW}) \times 24(\text{h/d}) \times 860(\text{kcal/kWh}) \times 0.9}{0.36 \times 12{,}580\ (\text{kcal/Nm}^3) \times 0.96} = 85{,}453(\text{Nm}^3/\text{d}) = 3.2\ \text{MMSCFD}$$

(2) Future Demand

As the gas volume in Sengeti reservoirs is limited, future demand increase by appearance of large consumers such as city gas and new power plant (inclusive of expansion of the proposed power plant) is not considered basically in the design of this pipeline. However, as described in 9-2-1, the selected pipe size can afford transporting 160% of the designed gas flow rate.

9-1-3 Design Pressure of Pipeline

Design pressure of the pipeline system composed of pipes, valves, fittings, and so on is determined in view of anticipated maximum operating pressure. Especially, pipeline inlet pressure has the most dominant factor to determine the operating pressure, necessity of pressurizing equipment such as compressors, pipe size, mechanical design pressure of facilities and so on.

(1) Pipeline Inlet Pressure

Pipeline inlet pressure is a dominant factor of the design of pipeline system. In the case of this project, the pipeline inlet pressure shall be the outlet pressure of the gas pretreating facility without pressurizing equipment such as compressors by the following reasons.

a. the operating pressure of the high pressure separator is relatively high pressure of 25 kg/cm^2G.

b. the pressure drop through the gas pretreating facility is small.

c. the minimum outlet pressure of the gas pretreating facility is 16 kg/cm^2G.

d. consequently, a small size pipeline of 6 or 8 inch can transport gas of the design flow rate from Sengeti field to the proposed power plant without compressors at the conditions mentioned in a - c above.

(2) Design Pressure

In pipeline system, the cost of line pipes occupies the largest part of the total construction cost. In the case of this project, design pressure does not affect the selection of pipe wall thickness because the size of the line pipe is small (refer to 9-2-2), and higher operating pressure of the high pressure separator produces higher quality of the fuel gas, therefore, the same design pressure rating of ANSI class 300 for the pipeline system as that of the gas/oil separation plant is taken to enhance operational flexibility. The design pressure of equipment such as pig facilities is decided at 38 kg/cm^2G based on the maximum operating pressure of the high pressure separator.

9-1-4 Pipeline Route

(1) Route Plan

The proposed pipeline route is shown in Figure 9-1. The total length of the pipeline is approximately 20 km. As field surveys along the whole length of the route has not been made, the final route shall be selected after detailed field surveys satisfying the following conditions as practical as possible.

- the route shall be the shortest one
- coarse density of residential buildings in the areas along the route and minimum effect on environments
- easy acquisition of the Right of Way (R.O.W.)
- easy access to the route both in construction period and maintenance stage

(a) Sengeti - Crossing Point of the Batang Hari river

Areas along the route from Sengeti to the crossing point of the northern bank of the Batang Hari river are marshy low land areas and houses are coarsely scattered. The pipeline route through these areas shall be selected to connect straightly between adjacent crossing points with existing roads as much as possible resulting in convenience of construction and minimization of preparation of temporal access roads for construction.

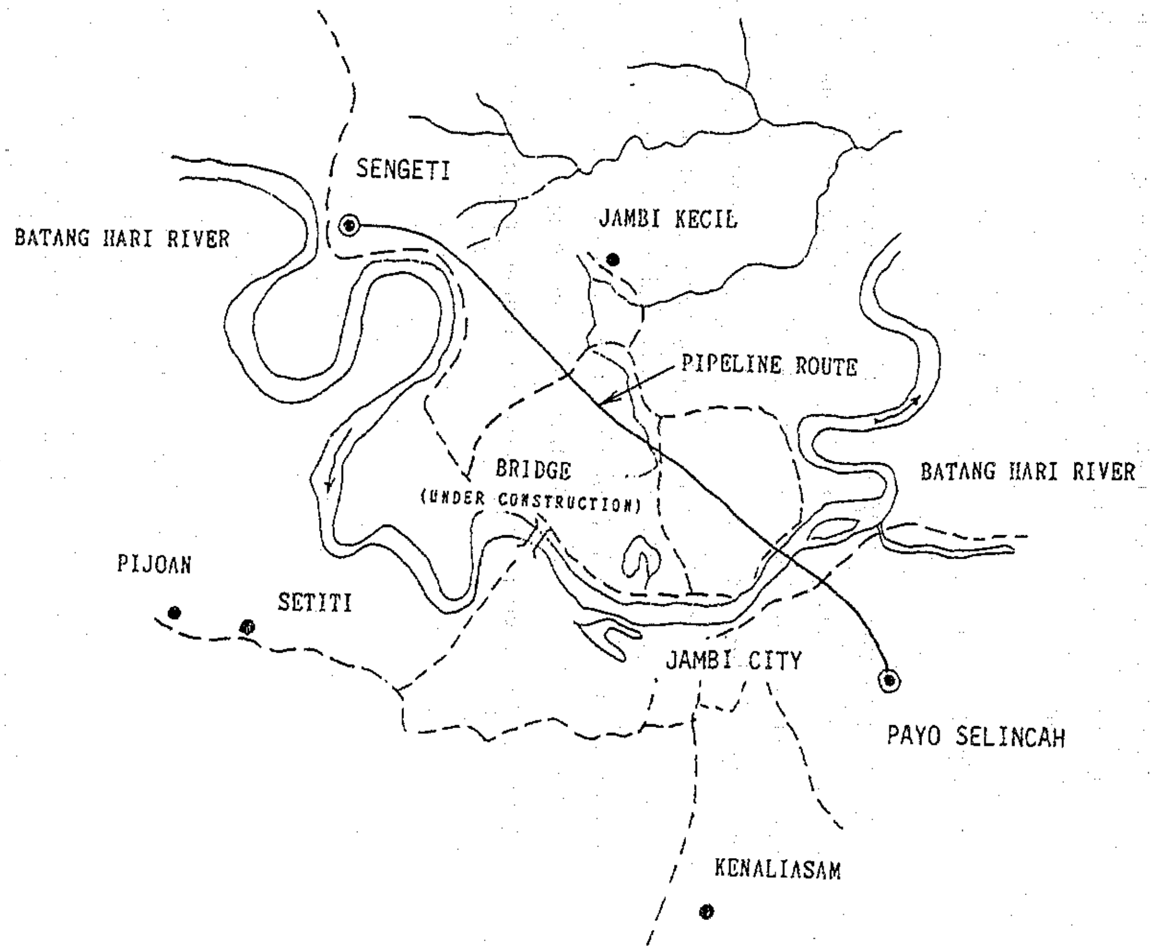


Figure 9-1 Gas Pipeline Route (Sengeti - Payo Selincah)

(b) Crossing Point of the Batang Hari river - the proposed power plant

Area from the crossing point of the southern bank of the Batang Hari river to the proposed power station are urban or semi-urban areas and many buildings are densely built. Therefore, in these areas, a route detouring living areas is normally recommendable from both safety and economical viewpoints.

(2) Pipe Laying Location

Existing pipelines in Jambi district, for example, the crude oil pipeline from Sengeti to Kanari Asam, are laid aboveground except river crossing portion. However, in the case of this project, as the gas pipeline is the high pressure main, underground pipeline is basically applied from safety point of view at operation stage. The aboveground pipeline is acceptable when a land owner allows and where open space of at least 15 meters on both sides of the pipeline can be maintained as well as minimum clearance of 30 meters between an adjacent building and the pipeline.

9-2 Specification of Line Pipe

9-2-1 Pipe Size

The optimum pipe size of a pipeline is determined by the relation between construction cost and transportation cost in operation (including installation cost of pressurizing equipment, if necessary and its operation cost). In this project, future demand increase is not considered in the design, however, it is preferable that the selected pipe size gives the pipeline some extra capacity over the design flowrate without laying an additional pipeline when gas demand is increased to some extent in the future.

(1) Capacity of Pipeline vs Pipe Size

In Table 9-3, throughput of pipelines with various diameter, 4", 6" and 8", are shown.
The calculation in the table is made based on the pipeline length of 20 km as well as the pipeline outlet pressure of 10 kg/cm^2G. In the table, the pipeline inlet pressure of 16 kg/cm^2G corresponds to the outlet pressure of the gas pretreating facility and the throughput of 3.2 MMSCFD corresponds to the maximum fuel demand of the power plant. Case 1, 3 and 5 indicate required pipeline inlet pressure to transport the design flow rate of gas, and case 2 and 4 indicate the maximum capacity of pipeline when the minimum pipeline inlet pressure of 16 kg/cm^2G is applied, which is equivalent to the minimum outlet pressure of the gas pretreating facility.

Table 9-3 Pipe Size vs Throughput

Case	Nominal Diameter	Inlet Pressure (kg/cm^2G)	Throughput (MMSCFD)
1	8	11	3.2
2	8	16	10.8
3	6	13	3.2
4	6	16	5.2
5	4	27	3.2

(2) Selection of the Pipe Size

As it is clear from Table 9-3, the line pipe size of 6" and 8" can transport gas of the design flow rate by using the outlet pressure of the gas pretreating facility without adding any compressors. In case of 4" pipe, a compressor is required to increase the inlet pressure of the pipeline in order to transport gas required by the power plant.

Comparing 6" pipe with 8" pipe, allowance of capacity to the design rate is of course smaller but the required tonnage of pipes is about 290 tons less (in case of schedule 40 pipes) resulting in a considerable saving of total investment cost. Moreover, 6" pipeline can transfer gas of 5.2 MMSCFD corresponding to power output of 32.5 MW (160% of the rated capacity of the power plant). Therefore, 6" (outside diameter=168.3 mm) pipe is selected for this project.

9-2-2 Pipe Material and Wall Thickness

(1) Pipe Material

The API Spec. 5L Grade B seamless pipe is selected for the pipeline pipes considering its good weldability. High strength pipes normally used for large diameter pipelines to reduce pipe thickness aiming at total cost reduction are not applicable to this project. Because in the case of small diameter pipeline like this project, the reduction of the wall thickness by using high strength pipes is not significant.

(2) Pipe Wall Thickness

The pipe wall thickness shall be determined not only to endure the internal pressure of fluid transported but to be strong enough for external forces anticipated during transportation and construction works. In the case of this project, the wall thickness of 7.1 mm equivalent to the schedule 40 is applied (the weight of the pipe = 28.22 kg/m).
And the strength to the internal pressure of the selected pipe is 104 kg/cm^2G taking the safety factor of 2 to the specified yield strength of the pipe material.

(3) Countermeasure for pipe floating

As pipes in water are subject to floating power (bouyancy), a countermeasure for pipe floating is required in the area where pipes are submerged in water. The normal method of anti-bouyancy of pipes is to increase unit weight of pipe by applying concrete coating on pipes in order to control pipe weight in water. In the case of this pipeline, as the specific gravity of pipe to the fresh water is 1.27, the weight increase of pipe is not required except for pipes laid under rivers or where disturbance of soil surrounding pipes is anticipated. The pipe having the wall thickness of 7.9 mm (the weight of the pipe =

31.25 kg/m, specific gravity = 1.40) is applied to increase the pipe unit weight in the area such as river crossings and where disturbance of soil surrounding the pipe is anticipated.

9-3 System Description

The schematic flow of the pipeline system is shown in Figure 9-2.

9-3-1 Pressure Control Device

As the pressure rating of the pipeline equals to the pressure rating of GOSP on upstream side, no pressure control device is required on the inlet side of the pipeline. On the contrary, a pressure reducing valve is required on the outlet side of the pipeline to protect the piping system and equipment in the power plant from destruction, the rating of which is lower than that of the pipeline.

9-3-2 Flow Measuring Device

A flow measuring device shall be installed to measure the supplied gas volume to the proposed power plant at the matching point between the pipeline and the power plant. The device shall be of orifice type removable under operation and measure not only a flow rate but an integrated flow(volume) equipped with automatic pressure and temperature calibrators.

9-3-3 Block Valves

(1) Type of Block Valves

The type of block valves shall be full bored ball type as specified in API 6D to allow smooth passage of pigs.

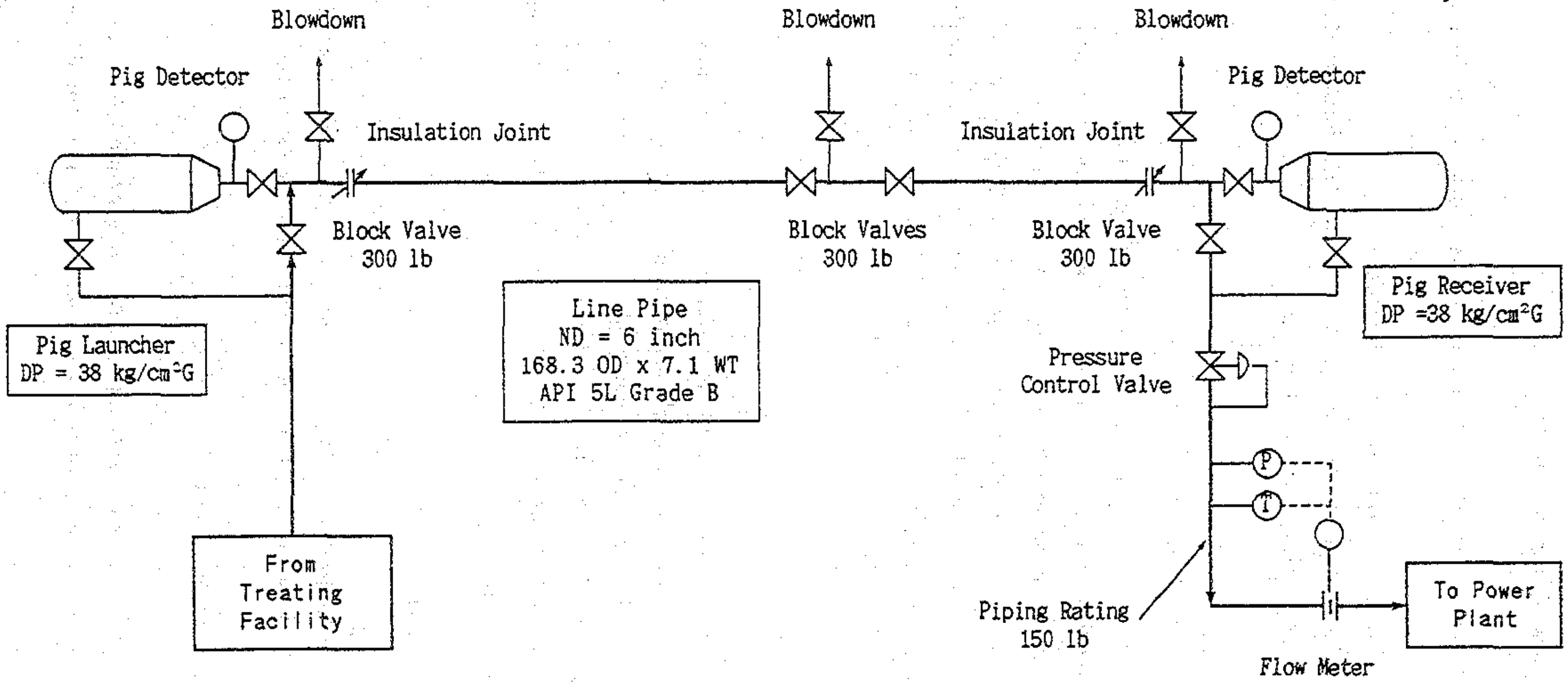


Figure 9-2 Pipeline Flow Diagram

(2) Location of Block Valves

Block valves shall be installed at the following locations.

- the inlet point of the pipeline
- both sides of the crossing point of the Batang Hari river
- the outlet point of the pipeline

(3) Blowdown

Each section of the pipeline isolated by block valves shall have a blowdown valve of 3" to allow the pipeline to be blown down as rapidly as practical in the case of an emergency. A mouth of blowdown pipe to atmosphere shall be located away from neibouring houses and safety measures such as a high elevation of the mouth and/or providing fencing around blowdown pipe shall be taken as required.

9-3-4 Pig Facilities

A pig trap shall be installed at each end of the pipeline for pigging operation for maintenance such as internal cleaning. A closure of the pig trap shall be of quick opening hinged type with the safety device to release the internal pressure before opening. A pig detector is installed on each inlet or outlet line of the pig trap to confirm the passage of a pig.

9-4 Corrosion Control

To keep the pipeline as sound conditions, corrosion control of both external and internal surfaces of the pipeline is essential.

9-4-1 External Corrosion Control

To protect the external surface of the underground pipeline from corrosion, both an external protective coating and a cathodic protection system are required and shall be installed. And external surfaces of above ground pipes shall be painted.

(1) Protective Coating

External surface of the buried pipeline shall be coated with protective polyethylene tapes to protect the surface from corrosion caused by soil and water. Single wrapping with minimum overlap of 25 mm using the tape of 150 mm wide and of 0.5 mm thick shall be applied. Double wrapping by overlapping half width of the tape shall be required for the portion of pipes to be laid under rivers and roads.

(2) Cathodic Protection

Cathodic protection using an impressed current system shall be applied to assure external corrosion control performed by protective coating. It seems preferable for a rectifier and anodes to be installed in or near the proposed power plant where continuous electric supply source for the system is easily obtainable and steadily available, however, the optimum locations shall be selected considering the free access by personnel of the pipeline operating organization, space for buring anodes and influence on other structures.

(3) Electrical Isolation

The buried portion of the pipeline cathodically protected shall be electrically isolated from the above ground pipeline and other metal structures in order to protect the pipeline effectively from corrosion. For this purpose, an insulating joint shall be installed at the point of riser piping from underground, and at the same time, the buried pipeline shall be laid at least 30 cm apart from other underground metal structures.

(4) Corrosion Monitoring

Test stations for measurement of protective potential shall be installed to determine the adequency of cathodic protection periodically. The test stations are to be located at the points of river and road crossings and at least 5 km intervals along the pipeline.

9-4-2 Internal Corrosion Control

Though the gas transported by the pipeline contains high level of CO_2 gas, internal corrosion caused by CO_2 gas is not anticipated because the dew point of the gas is adjusted by the gas pretreating facility to a degree of avoiding water condensation during transportation. Therefore, in the case of this pipeline, it is not required to inject corrosion inhibitor nor to install corrosion coupons for corrosion monitoring.

9-5 Installation

9-5-1 Cover and Dimension of Trench

The minimum requirements for trench and backfill for the buried pipeline is shown in Figure 9-3. The minimum soil coverage of 0.9 meter shall be kept for the general pipeline section and the minimum cover of 1.2 meters is required for the pipeline section installed within the urban area of Jambi City and at road crossings. Additionally, casing pipes to protect the pipeline main are required at road crossings. At the Batang Hari river, the pipeline crosses at downstream of Jambi port, the minimum cover of 2.0 m shall be provided to protect pipe from the damage by anchors of vessels.

9-5-2 Clearance between buried Structure

A minimum clearance of 30 cm shall be kept between the pipeline and other buried structure for safety reason.

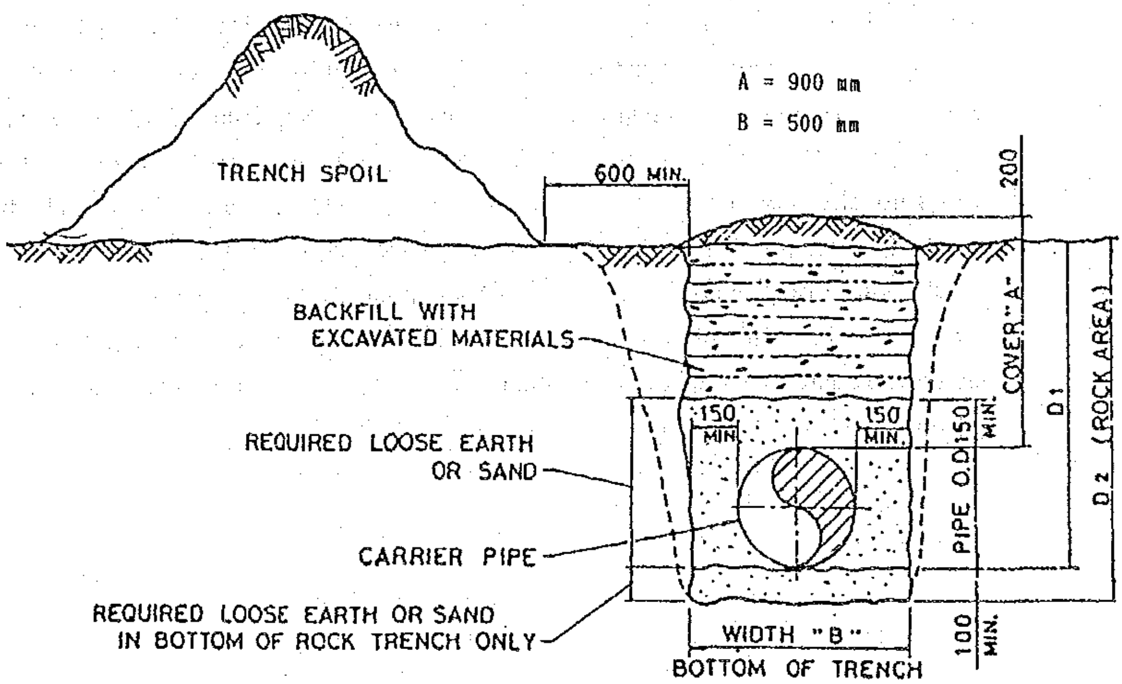


Figure 9-3 Trench and Backfill Requirements

9-5-3 Minimum Radius of Bend

As a general rule, changes of the direction and elevation of the pipeline is performed by using field applied cold bends. The minimum radius of a cold bend shall be 18 times of the outside diameter of the pipeline.

9-6 Strength and Tightness Test

After completion of construction, the whole length of the pipeline shall be tested for its strength and tightness at the pressure of 53 kg/cm^2G for the duration of 24 hours. Additional strength test for 2 hours at the time of installation shall be performed for the pipeline section crossing the Batang Hari river. The test fluid shall be water injected with corrosion inhibitor. After the test, test water in the pipeline shall be drained off and drying operation shall follow immediately to dry the inside of the pipeline to a degree that the dew point in the pipeline becomes 5°C lower than surrounding earth temperature. The pipeline thoroughly dried shall be filled with nitrogen gas or dried natural gas to prevent corrosion until it is put into the operation.

10. CONCEPTUAL DESIGN OF POWER PLANT

This Chapter describes the conceptual design of a 20 MW power plant, the capacity of which is determined in Chapter 6 PROJECT SCHEME.

10-1 Design Conditions

In order to carry out the conceptual design of the power plant, the following premises are used as the design conditions.

(1) Proposed Site

The site for the proposed power plant will be an area adjacent to the existing Payo Selincah Power Plant, which is located in the east district of Jambi City.

(2) Design Conditions for Power Generator

In this project, dual-fuel engine generator, with 20 MW rated capacity which will continuously generate 17 MW electricity as normal output at bus bar, will be installed.
The unit rate of the generator will be 5 MW with 50 cycle per second frequency and there will be total number of four units and a spare unit will not be provided.

Since river water is not easily obtainable, the engine will be cooled by an air cooled radiator. The design temperature for engines and radiators will be 32°C, which is the average maximum temperature in this area.

(3) Design Conditions for Buildings

(a) Soil Condition

Soil structure of the proposed site area is considered the same as that of the existing Payo Selincah Power Plant because of their proximity. Therefore, the foundation work will be carried out by the same construction method as applied for the existing power plant.

(b) Seismic Condition

Since Jambi is located far distant from the volcanic zone, earthquakes will be very rare and a horizontal seismic coefficient of Kh=0.1 is adopted as a design condition for structural buildings.

(c) Other Conditions

In designing buildings, special attention will be paid to better ventilation, taking the high temperature and high humidity of this tropical region into consideration.

10-2 Fuel Oil and Lubricating Oil

Natural gas produced in Sengetti gas field will be used as main fuel and diesel oil (HSD; High Speed Diesel) will be used as pilot oil for the dual-fuel engine. Amount of diesel oil required as pilot oil is approximately 10% of the required heating value at the maximum rated output based on a low calorific value. The compositions and characteristics of the natural gas as fuel and those for the diesel oil (HSD) are shown in Table 10-1 and Table 10-2, respectively.

Fuel gas shown in Table 10-1 contains hydrocarbons of higher carbon numbers than methane such as ethane, propane, butane and pentane.

Table 10-1 Composition and Characteristics of Fuel Gas

Composition	Mol%
Methane (CH_4)	55.7
Ethane (C_2H_6)	15.9
Propane (C_3H_8)	15.0
i-Butane (i-C_4H_{10})	2.4
n-Butane (n-C_4H_{10})	3.1
i-Pentane (i-C_5H_{12})	0.8
n-Pentane (n-C_5H_{12})	0.4
Hexane (C_6H_{14} and heavier components)	Nil
Carbon Dioxide (CO_2)	6.6
Water (H_2O)	0.1
Low calorific value	12,580 kcal/Nm^3
	(1.337 x 10^{-3} MMBTU/SCF)
Methane Number	Approx. 65

Table 10-2 Characteristics of Fuel Oil (HSD)

Characteristics:	
Specific gravity at 15.6°C (60°F)	0.8440
Kinematic viscosity at 37.8°C (100°F)	3.862 cSt
Pour point	1.67°C (35°F)
Cetane index	57.5
Ash content	0.002 wt%
Sulfur content	0.442 wt%
Low calorific value	10,423 kcal/kg (18,781 BTU/lb)

Should the gas with those compositions be used as fuel for dual-fuel engines, knocking phenomenon is likely to occur compared with the case of using methane rich gas as fuel. Therefore, the engine compression ratio should be kept slightly low compared with that for pure methane dual-fuel engine.

In order to avoid deterioration of lube oil (decrease of alkaline number, TBN: Total Base Number), sulfur content of fuel oil should be kept below 1% and good compression ignitability or cetane index of 45 or higher is required.

Lube oil for the dual-fuel engine should have low sulfur ash content (low TBN) compared with that for ordinary diesel engines.

The advantage in using this kind of lube oil is that interruption of combustion, due to accumulated sulfur ash within combustion chamber, will not often occur, and damage of mechanical components will be kept to a minimum. On the other hand, a lube oil having low sulfur content tend to degrade when encountered with sulfur contained in fuel, resulting in corrosion of equipment. Therefore, continuous diesel operation of duel-fuel engines for prolonged periods is not recommendable, since diesel oil used as the sole fuel during diesel operation contains more sulfur than fuel gas.

Characteristics of the lube oil for dual-fuel engine are shown in Table 10-3.

Table 10-3 Characteristics of Lube Oil

Characteristics:	
Specific gravity at 15/4°C	0.85 - 0.95
Flash point	240 - 260°C
Viscosity (at 40°C) (at 100°C)	90 - 105 cSt 11 - 12 cSt
Viscosity index	95 - 105
Total acid number (mg KOH/g)	0.7 - 1.5
Total base number (mg KOH/g) (Hydrochloric acid method)	4 - 7
Ash content	0.5 - 0.9 wt%
Residual carbon	0.7 - 0.8 wt%
API grade	C D

Remarks:

1) Lubricating oil should have stability for nitration and oxidation.
2) Deposit in the combustion chamber will be small.
3) CD: Standard of lubricating oil which will be suitable for high-temperature dual-fuel engine.

10-3 Power Generating Facility

10-3-1 Description of Dual-Fuel Engine

The dual-fuel engine is a compression ignition type internal combustion engine designed to use gas as its main fuel and also uses liquid fuel for pilot oil since compression ignition can not be achieved only by gas. Moreover, since this engine is a compression ignition engine, it also can be operated using liquid fuel only, like a diesel engine, which is referred to "diesel operation mode".

The dual-fuel engine is started by using only liquid fuel, and when the engine load has come 30% or more of the rated output, it becomes possible to switch from diesel operation mode to operation using gas fuel and liquid fuel, referred to as "gas operation mode".

The dual-fuel engines have different control systems for fuel flow rate in both operation modes. In the case of diesel operation mode, an appropriate amount of liquid fuel corresponding to the power load is injected into the cylinders. On the other hand, the amount of pilot oil is kept constant, and the load is controlled by the amount of gas fuel in the gas operation mode. This situation is shown in Figure 10-1.

In the dual-fuel engine, mixture of air and gas fuel is compressed into which liquid fuel is injected for ignition. For this reason, detonation (abnormal combustion which is a cause of diesel knocking) may occur more frequently than in the case of a diesel engine which only compresses air and injects liquid fuel, and the compression ratio needs to be adjusted lower. This lowers the mean effective pressure (Pme), which reduces the output generated by the cylinder. Therefore, in order to obtain the same output, an engine larger than a diesel engine is required for dual-fuel engine.

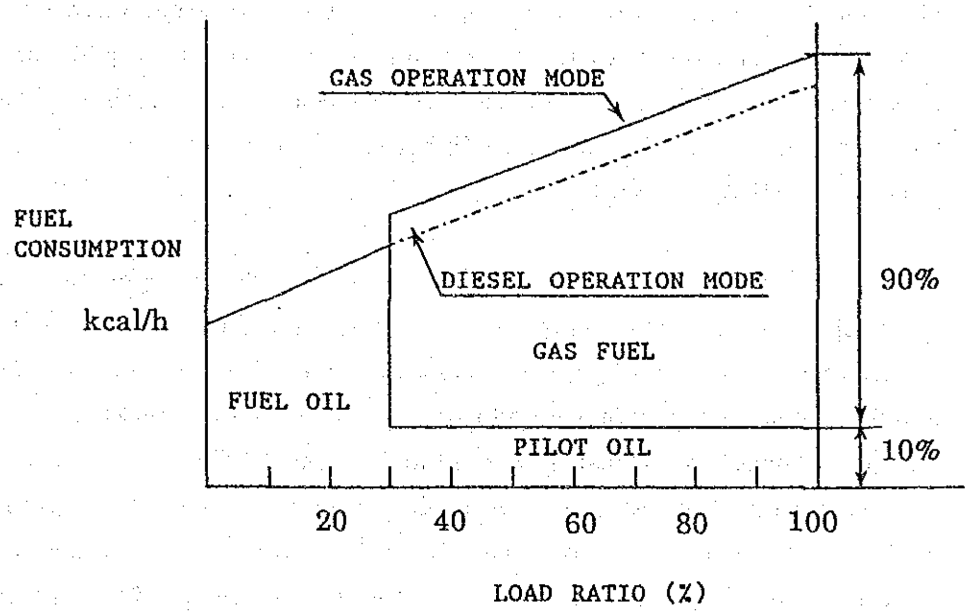


Figure 10-1 Fuel Consumption - Load Ratio

Detonation occurs depending upon the composition of gas used. Natural gas with a composition close to that of pure methane yields better performance than gas which contains components with higher carbon numbers such as ethane, butane, etc. Moreover, mixing non-combustible gas such as carbon dioxide is also effective for suppressing detonation. Therefore, the composition of fuel gas affects the compression ratio to be applied, which is one factor determining the size of an engine.

Gas and air are fed in through a gas flow regulator and an air flow regulator respectively, in accordance with the load fluctuation. They are mixed, and fed into the cylinders. These regulators have slightly larger time constants than the system controlling the liquid fuel of diesel engines. Therefore, the response to large load fluctuation tends to be slightly dull. However, sufficiently stable responses are secured from the dual-fuel engine for practical use.

The dual-fuel engine always goes through the diesel operation mode when starting and when stopping. Further, the diesel operation mode is switched to the gas operation mode manually so that the gas supply condition and other safety conditions can always be checked, and the unit is interlocked against any abnormal states in the gas system. On the other hand, the gas operation mode switches to the diesel operation mode automatically at low load operation, and also switches automatically for abnormal conditions in the gas system. This switching stops feeding of gas and fuel oil continues to be supplied to maintain the load. After the transition, continuous normal operation is maintained under diesel operation mode, and the output is kept constant.

10-3-2 Engine and Generator

Since the required power generation capacity of the power plant is 17 MW at the power transmission end, four engines with a rated output of 5 MW are used. Further, this engine can sustain an overload operation of 110% for one hour in a 12 hour operation.

Since a device to follow fluctuation of the demand is not provided at the supply side of gas fuel, the load of the dual-fuel engine must be kept constant. Consequently, in principle, the power plant is used for base load, and the additional power at peak load is produced by the existing diesel power plants in Kasang and Payo Selincah.

For design of the generator, the power factor is established as 0.8. The engine couples the generator directly and the engine speed will be 500 rpm to correspond with a 50 Hz system frequency.

Since the composition of gas fuel is not close to that of pure methane, the compression ratio must be lower than the standard diesel engine to prevent knocking, and the mean effective pressure also must be lower. Therefore, the result is a duel-fuel engine with a larger number of cylinders than a standard engine with the same output.

The intake pressure and temperature are within the same range of values employed by retail available standard engine.

Main items and performance of the engine and the generator are shown in Table 10-4. Further, their drawings are shown in Figure 10-2.

Table 10-4 Principal Particulars of 5 MW Dual-Fuel Engine Generator

Engine:	
Type	Turbo-charged, 4 cycle, compression ignition type dual-fuel engine
No. of cylinders	16
Cylinder arrangement	Vee-form
Cylinder bore	400 mm
Stroke	460 mm
Rated output	7,050 PS for 5 MW generator terminal
Engine speed	500 rpm
Brake mean effective pressure	13.72 kg/cm^2G
Fuel oil injection	Direct injection
Fuel gas control	By gas regulating valve
Fuel consumption at normal output	(at 85% load)
Natural gas	*0.18 Nm^3/kWh
Fuel oil (HSD)	*23.8 g/kWh
Lube oil consumption at normal output (at 85% load)	*1.8 g/kWh
Generator:	
Type	Open protected self ventilating, brushless type with damper
Capacity	6,250 kVA (5,000 kW)
Power factor	0.8 lagging
Phase	Three phase and three wires
Frequency	50 Hz
No. of poles	12
Rated current	573A
Insulation class	Class F (temp. rise: Class F)
Lubrication	Forced lubrication
Total weight (including generator)	Approx. 123 tons/unit

Remarks: The figures with * are based on the generator terminal.

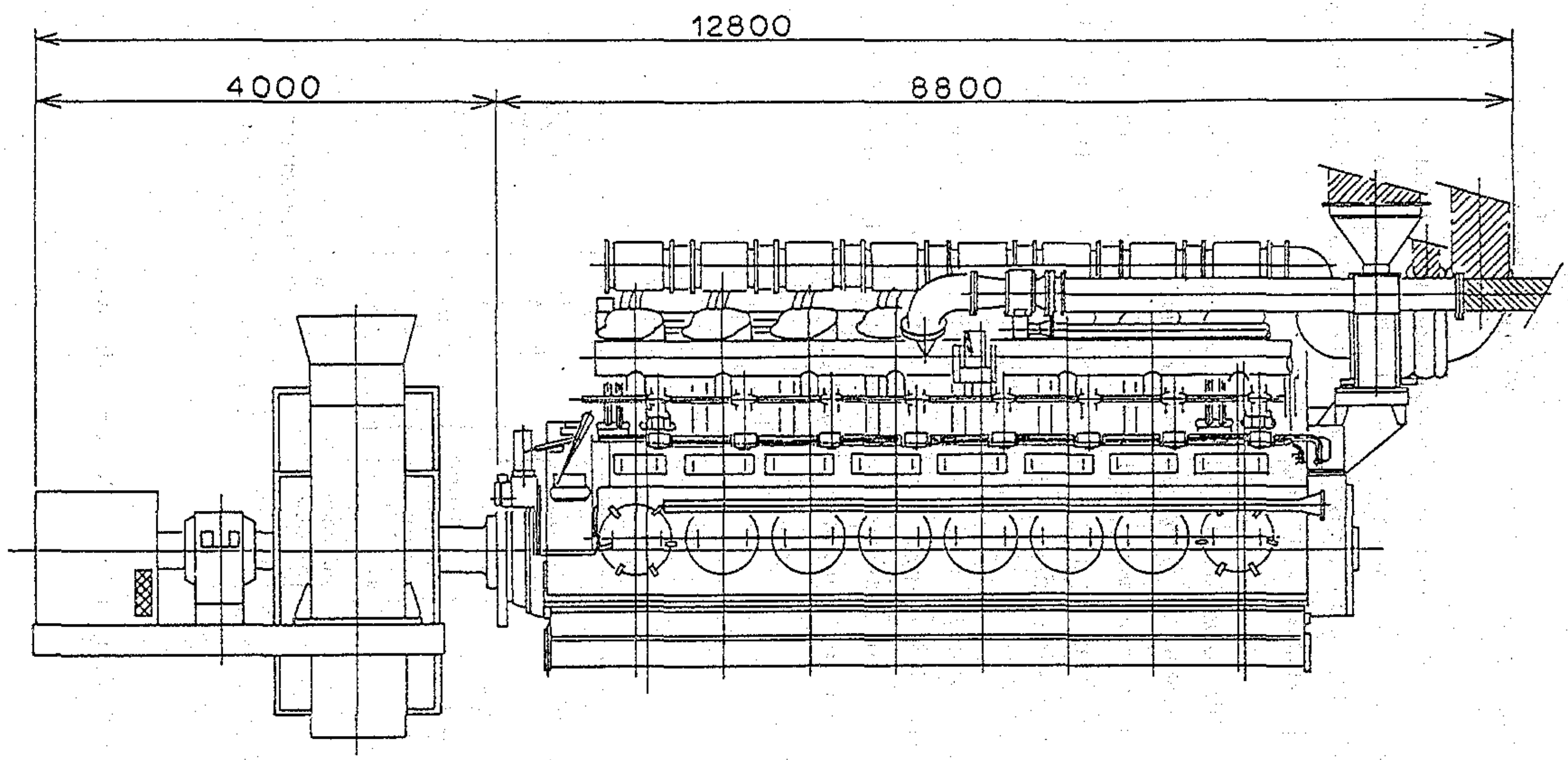


Figure 10-2 Dual-Fuel Engine Generator Set

10-3-3 Auxiliary Equipment for Engine

(1) Starting Air System (Refer to Figure 10-3)

The engine is started by compressed air. Therefore, an air compressor is provided to store air with a pressure of 18 to 30 kg/cm^2G in an air receiver, which is directly fed into the cylinder of the engine at starting.

One air receiver is provided for each engine. However, it shall be possible to start any engine from any air receiver by providing connections among these air receivers. The air receiver has a capacity of air for a minimum of 3 starting operations without recharging.

Two motor-driven air compressors will be provided. This air compressor is controlled by a pressure switch installed at the air receiver for automatic start and stop so that the pressure in an air receiver is maintained in a constant range.

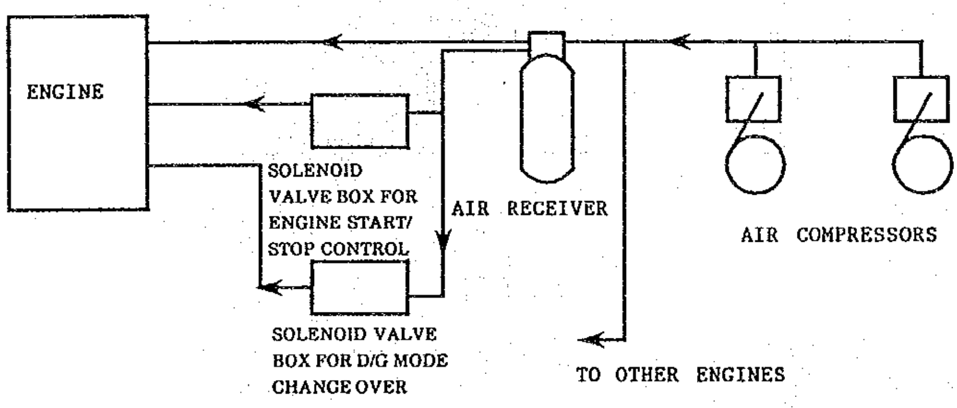


Figure 10-3 Starting Air System

(2) Lubricating Oil System (Refer to Figure 10-4)

Lubricating oil supplied to the engine is collected and stored in a lubricating oil sump tank. From here lubricating oil is delivered to an oil cooler by a motor driven lubricating oil pump, cooled to an appropriate oil feed temperature (60°C), and then sent to the engine. The oil cooler is of an air cooled type (radiator), and the temperature is controlled by a bypass control valve attached to the radiator outlet.

One lubricating oil pump and one radiator shall be installed for each engine. A mist blower is connected to the crank case to ventilate leaked gas and gas misted by lubricating oil out of the crank case. Since the amount of the gas is not large, it is discharged out of the building by a duct.

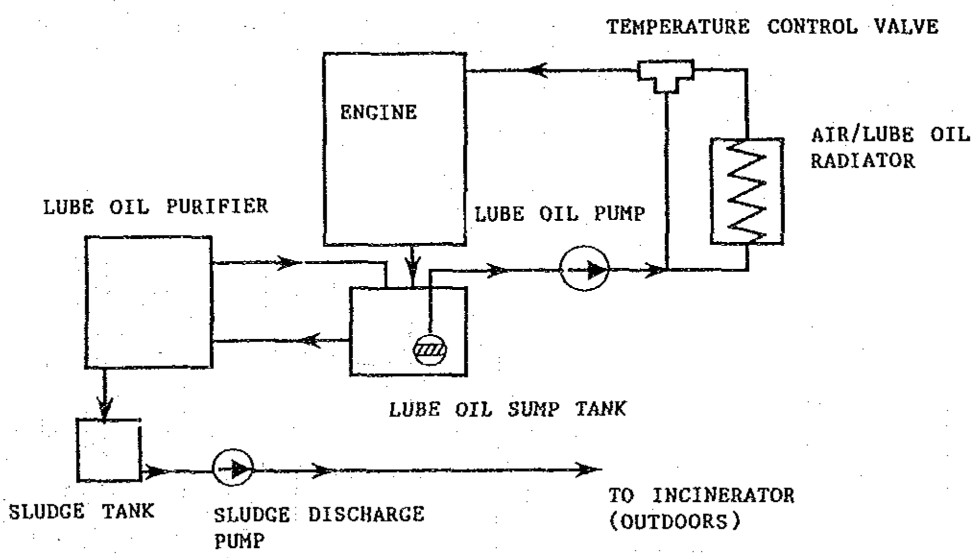


Figure 10-4 Lube Oil System

Lubricating oil should be replaced at appropriate intervals since it deteriorates with the accumulation of sludge and foreign materials. A centrifugal-type oil purifier is also provided for removing sludge and foreign materials from oil in the sump tank.

(3) Fuel System (Refer to Figure 10-5 and 10-6)

Fuel oil (HSD) is used in the diesel operation mode at start, stop and low load, and it is also used as pilot oil in the gas operation mode.
Fuel oil is transported by tank truck and stored once in an outdoor oil storage tank, then sent to a service tank by a transfer pump. Fuel oil is fed by a fuel oil feed pump from the service tank to the fuel injection pumps of an engine and is then injected by high pressure into the cylinders through fuel injection valves. The amount of injection is controlled by injection pump racks, and excessive oil is returned to the service tank after being collected in a drain tank.
The fuel feed pump will be of a motor-driven type, and one spare pump will be provided.

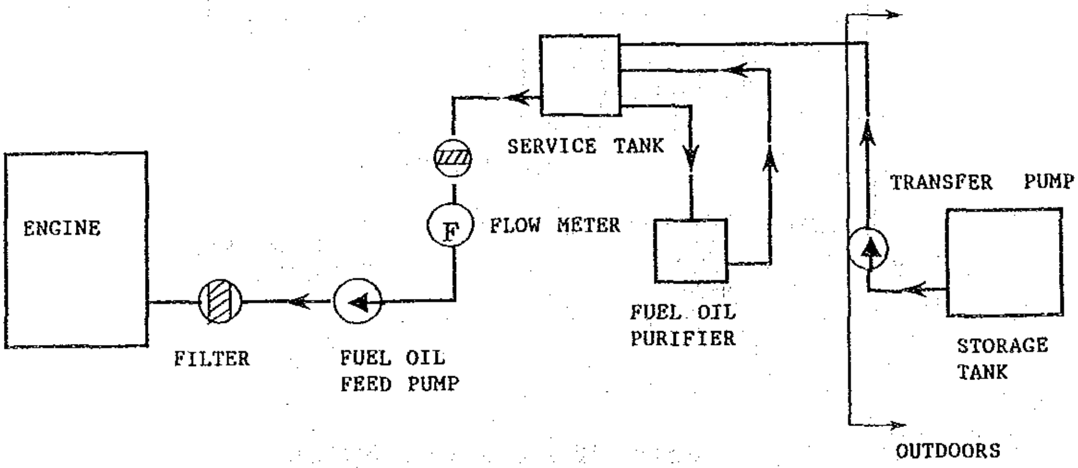


Figure 10-5 Fuel Oil (HSD) System

Gas fuel is delivered from the natural gas production facility by a pipeline and fed to the engine through the surge tank and gas pressure regulating valve.
At the inlet of the engine, gas shut-off valves are provided in double for safety, and a spark arrester is provided ahead of them to prevent backfiring from the engine to the gas supply system.
Gas is mixed with combustion air at the cylinder inlet and fed into the engine cylinder. The gas flow is controlled by a gas pressure regulating valve before mixing.

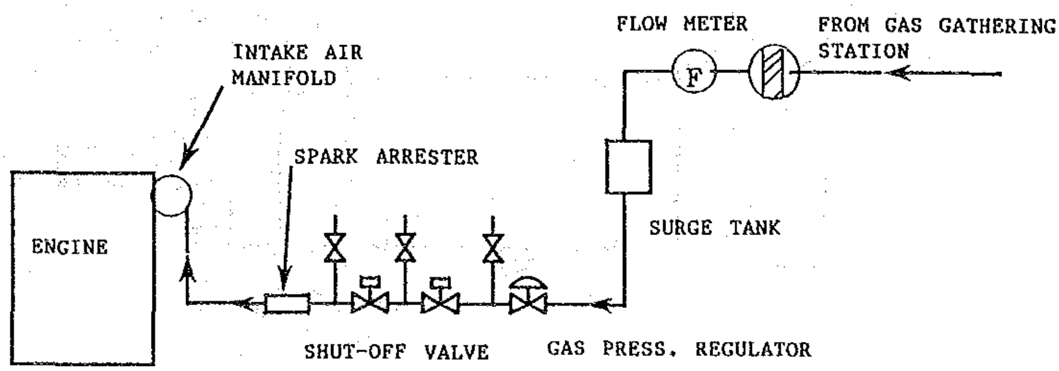


Figure 10-6 Fuel Gas System

(4) Engine Cooling System (Refer to Figure 10-7)

The jacket of the engine is cooled by water (fresh water), and this cooling water is delivered to the air-cooled cooler (radiator) by a closed circuit system.
A radiator and a cooling water circulation pump are provided for each engine.
Water used as an engine cooling medium should meet the standard properties shown in Table 10-5.

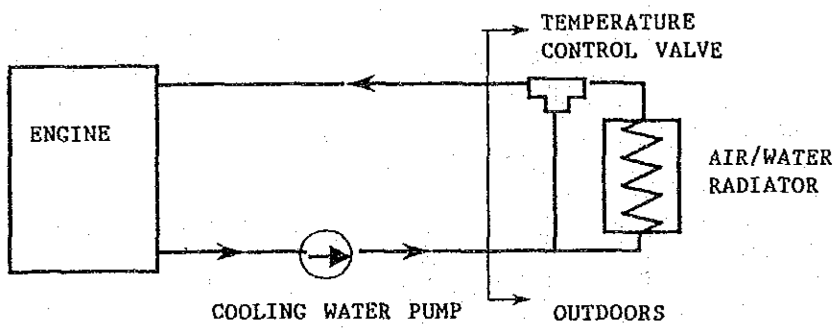


Figure 10-7 Cooling Water System

Table 10-5 Properties for Cooling Water

Composition: (Limitation for Supply Water)	
Turbidity	10 Degree
PH at 25°C	6 - 8.5
Conductance at 25°C	< 400 micro mho/cm
M-alkalinity as $CaCO_3$	< 150 ppm
Total hardness as $CaCO_3$	< 100 ppm
Chlorine ion (Cl^-)	< 100 ppm
Sulphate ion (SO_4^{++})	< 100 ppm
Ammonium ion (NH_4^+)	< 10 ppm
Hydrogen sulfide (H_2S)	< 10 ppm
Iron (Fe)	< 1 ppm
Silica	< 50 ppm
Total residue on evaporation (Total Solid)	< 400 ppm

(5) Intake and Exhaust System (Refer to Figure 10-8)

Air fed to the engine is sucked into the compressor of the supercharger from the intake duct though an oil-bath type air filter. Since compressed air is hot, it is sent to the intake system of the engine after being cooled through the radiator again.

Exhaust gas of the engine is fed into the turbine of the supercharger and drives the compressor that compresses intake air. The exhaust gas from the turbine is discharged into the atmosphere through a silencer (equipped with a spark arrester) to lower the exhaust noise.

An air intake and gas exhaust system is installed in each engine.

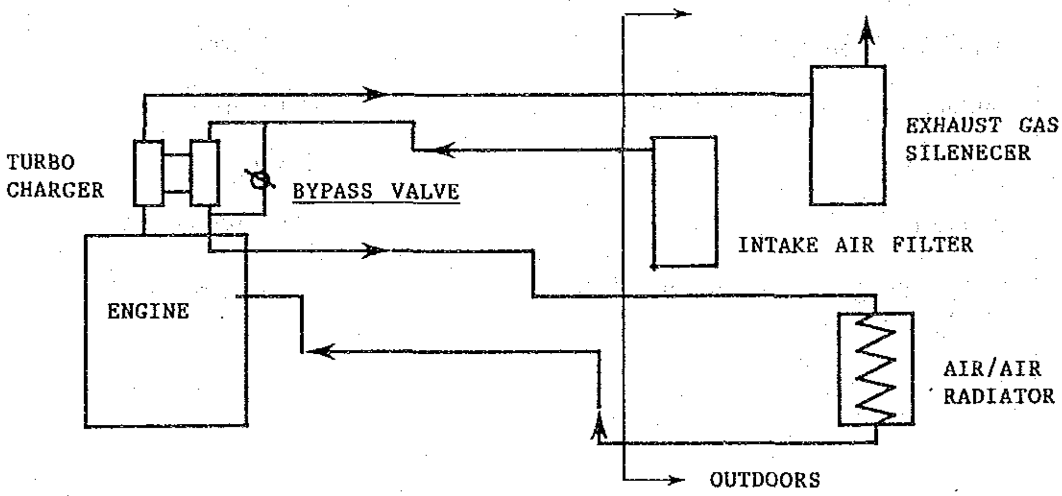


Figure 10-8 Intake and Gas Exhaust System

The main items of main auxiliary equipment are summarized in Table 10-6.

Table 10-6 Particulars of Auxiliaries

The following auxiliaries shall be installed in 4 sets of dual-fuel generators sets.

(1/3)

Starting Air System :		
Air compressor	Quantity:	2 sets
	Capacity:	60 m^3/h (standard condition)
	Pressure:	30 kg/cm^2
Prime mover for air compressor		2 set x 15 kW electric power
Air receiver	Quantity:	4 bottles
	Capacity:	1.0 m^3
Lube Oil System :		
Oil pump	Quantity:	4 sets
	Capacity:	140 m^3/h x 7 kg/cm^2
Oil cooler (radiator)	Quantity:	4 sets
	Heat transfer area:	Approx. 1,540 m^2
Mist blower	Quantity:	4 sets
	Capacity:	0.8 m^3/h x 40 mmAq
Oil purifier	Quantity:	4 sets
	Capacity:	1.8 m^3/h
Sump tank	Quantity:	4 sets
	Capacity:	7.5 m
Sludge discharge pump	Quantity:	4 sets
	Capacity:	1.0 m^3/h x 3 kg/cm^2
Fuel Oil System :		
Storage tank	Quantity:	1
	Capacity:	1,000 m^3

Transfer pump	Quantity: 2 sets
	Capacity: 17 m^3/h x 2 kg/cm^2
	Electric motor: 5.5 kW
Service tank	Quantity: 4 sets
	Capacity: 7.5 m^3
Fuel oil flow meter	Quantity: 4 sets
	Positive displacement type
Feed Pump	Quantity: 4 sets
	Capacity: 3 m^3/h x 3 kg/cm^2
	Electric motor: 1.5 kW
Fuel purifier	Quantity: 4 sets
	Capacity: 1.8 m^3/h
Fuel Gas System :	
Gas filter	Quantity: 4 sets
	Type: Wire mesh type
Gas flow meter	Quantity: 4 sets
	Type: Delta sensor type
Surge tank	Quantity: 4 sets
	Capacity: 1.0 m^3
Gas regulating valve	Quantity: 4 sets
	Type: Diaphragm type
Cooling Water System :	
Cooling water pump	Quantity: 4 sets
	Capacity: 185 m^3/h x 30 mAq
Cooling expansion tank	Quantity: 4 sets
	Capacity: 0.6 m^3

Water cooler (radiator)	Quantity: 4 sets
	Heat transfer area: Approx. 1,480 m^2
Intake Air and Exhaust Gas System :	
Intake air filter	Quantity: 8 sets
	Type : Oil bath type
Intake air duct	Quantity: 8 sets
	Size (approx.): 400 mm dia. x 20 m length
Intake air cooler (radiator)	Quantity: 8 sets
	Heat transfer area: Approx. 290 m^2
Exhaust gas silencer	Quantity: 8 sets
	Overall noise level of 100 dBA at 1 m distance from gas outlet
Exhaust gas duct	Quantity: 8 sets
	Size (approx.): 700 mm dia. x 18 m length

10-3-4 Electrical System

As shown in Figure 10-9 Single-line Diagram, the generator output is stepped up to 20 kV by a transformer and it is transmitted to the bus bar via a circuit breaker. Although the figure shows three outgoing feeders, the required number of feeders is finally determined on the basis of the PLN plan. In-plant service power is supplied after the voltage is reduced to 380 V, 3ϕ by a station service transformer.

The generator output will be connected with the existing power plants through tie lines. A synchronizing unit will be equipped so that parallel operation of the generators in this power plant and generators of other power plants is possible.

The main particulars of the transformer and each electrical panel are shown in Table 10-7.

One 20 kV step-up transformer is installed outdoors for each generator. The station service transformers are also installed outdoors. One will have the capacity of the plant service power, and one will be for stand-by.

All the electrical panels are installed in spaces provided in the same generator building so that operation and monitoring are possible at the same place.

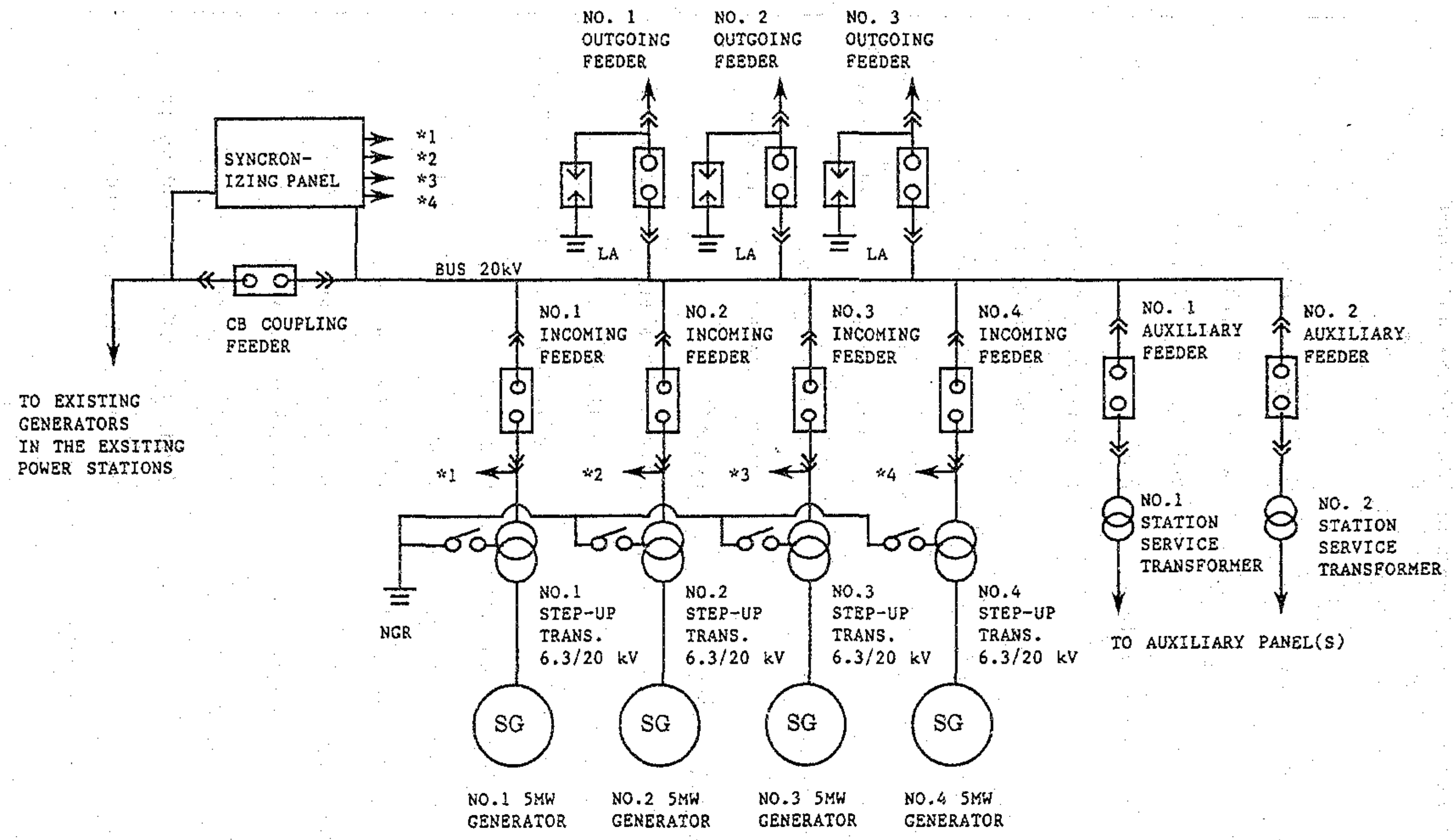


Figure 10-9 Single Line Diagram

Table 10-7 Particulars of Transformers and Panels

Transformer:		
	Step-up transformer	Quantity: 4 sets
		Capacity: 6,250 kVA
		Voltage : 6.3/20 kV
	Station service transformer	Quantity: 2 sets
		Capacity: 1,500 kVA
		Voltage : 20 kV/380 V
Panels:		
	Incoming feeder	Quantity: 4 sets
		Circuit breaker: 6.3 kV x 630 A
	Outgoing feeder	Quantity: 3 sets
		Circuit breaker: 6.3 kV x 630 A
	CB coupling feeder	Quantity: 1 set
		Circuit breaker: 6.3 kV x 630 A
	Auxiliary feeder	Quantity: 2 sets
		Circuit breaker: 6.3 kV x 630 A
	Disconnecting switch panel	Quantity: 1 set
	Neutral ground register	Quantity: 1 set
	Generator control panel	Quantity: 4 sets
	Synchronizing panel	Quantity: 1 set
	Motor control center	Quantity: 5 sets
	DC control panel	Quantity: 1 set
		Capacity: DC 110 V, 40 Ah/10 h
		Battery : Alkaline type

10-3-5 Operation and Control

(1) Start and Stop of Engine

The generator control panels of the generators are installed on the second floor of the same building, and engines are started and stopped from the local panel installed adjacent to the engines. The monitoring instruments related to the engines are also installed on this local panel, and monitoring is conducted by periodically patrolling the area.

The engines can be also started and stopped at the generator control panels by switching the control position selector switch provided on the local panels.
In case of an emergency, the engines can be stopped by fuel cut-off levers provided with the engines, or by switches on the local panels, or by switches on the generator control panels. Moreover, in an emergency, the circuit breaker on the incoming feeder is tripped from the common bus bar.

Starting operation is conducted using only fuel oil (HSD), i.e., by the "diesel operation mode".

(2) Parallel Operation

In the diesel operation mode, the engine speed is controlled by adjusting the feed amount of fuel oil by a governor. Synchronization between generators is conducted manually using instruments and a motor-drive speed control provided on the synchronizing panel, and parallel operation is performed by manually closing the circuit breaker. This can be modified to an automatic operation. However, manual operation was selected, because the generator capacity is not very large, and the operators are already skilled in manual operation.

(3) Operation Mode Change Over

After the engines are started up in the diesel operation mode, when load factor exceeds 30%, operation can be changed to gas operation mode.
When the load and gas pressure are confirmed at appropriate levels, the mode is switched by the mode-changing switch on the local panel. Mode-switching starts the feeding of gas; in this state, pilot oil is supplied in constant quantity and the gas supply amount is regulated in accordance with engine load. This state is called the "gas operation mode".
Switching from the diesel operation mode to the gas operation can be performed only when the conditions below are met. They must be met simultaneously, since they have been interlocked.

Cooling water temperature: 60°C or higher
Load factor: 30% or greater
Gas fuel pressure: within a range of 5 to 10 kg/cm^2

The gas operation mode automatically changes to the diesel operation mode when the gas fuel supply amount is reduced and the engine enters the state of not requiring gas supply. However the diesel operation mode does not switch to gas operation mode unless done so manually.
In the event that supply of gas fuel is stopped, operation automatically switches to the diesel operation mode. Since the diesel operation mode is capable of the rated output operation and 110% of over-load operation, electricity will be generated even when gas supply is stopped.
The control of the increase/decrease of the supply amount of gas fuel and discharging of excessive gas are controlled at the sending end of the gas production facility side and not at the power plant side. Therefore, a flare facility will not be provided at the power plant.

(4) Operation of Auxiliary Equipment

The cooling water pumps, radiator fans, lubricating oil pumps, and fuel oil feed pumps must be operated prior to the start of the engines. Start and stop switches are provided on the auxiliary control panel. Instruments for operation monitoring (pressure gauges, thermometers, etc.) are fitted locally to aid patrolling and monitoring.

Each purifier for fuel oil and lubricating oil is manually operated at the panel by the purifier. Sludge discharged from each purifier is collected in the sludge tank. The sludge discharge pump starts and stops automatically in accordance with the level monitored in the sludge tank to facilitate the transport of sludge to the incinerator tank.

The starting air compressor automatically starts and stops in accordance with monitored pressure of the air tank as mentioned previously. A motor starter is installed adjacent to the air compressor so it can be operated at the location manually.

The fuel oil transfer pump is automatically starts and stops in accordance with the monitored oil level in the fuel oil service tank. Further, it can be also manually operated by the starter adjacent to the pump.

10-3-6 Safety Device

When abnormal conditions occur in the engines, generators, and auxiliary equipment, alarms are sounded and the engines are stopped in case of serious danger. The conditions of sounded alarms and emergency engine stoppage are shown in Table 10-8.

When the engine is stopped during an emergency, the heavy fault indication lamp installed on the generator control panel is illuminated and the alarm bell is sounded. Further, in the case of gas operation mode, mixture of gas and air remaining in the intake manifold is purged to outside.

The alarm bell can be stopped manually, but illumination of the indication lamp and the engine stoppage are not released until the cause of the emergency is eliminated.
Moreover, when abnormal conditions described below occur during the gas operation mode, operation automatically switches to the diesel operation mode in order to protect the engine; and the operation mode indication lamp on the generator control panel is illuminated, and in addition, the fault indication lamp is illuminated and the alarm bell is sounded.

Gas fuel pressure high	:	10 kg/cm^2 or higher
Gas fuel pressure low	:	5.0 kg/cm^2 or lower
Exhaust gas temperature	:	600°C or higher

Table 10-8 Protection Device

(1/2)

Item	Alarm	Shut-down
Mechanical Fault:		
Lube oil pressure, low	4.2 kg/cm^2G	3.5 kg/cm^2G
Cooling water temperature, high	92°C	95°C
Lube oil temperature, high	65°C	70°C
Cooling water pressure, low	1.5 kg/cm^2G	1.0 kg/cm^2G
Turning device, engaged		o
Overspeed		115% of rated speed
Fuel oil pressure, low	1.5 kg/cm^2G	
Starting air pressure, high	32 kg/cm^2G	
Starting air pressure, low	18 kg/cm^2G	
Control air pressure, low	6.5 kg/cm^2G	
Rocker arm lube oil pressure, low	0.8 kg/cm^2G	
Fuel gas pressure, high	10 kg/cm^2G	
Fuel gas pressure, low	5 kg/cm^2G	
Intake air differential pressure, high	o	
Cooling water expansion tank level, low	30%	
Fuel oil service tank level, high	90%	
Fuel oil service tank level, low	40%	
Lube oil sump tank level, low	50%	
Sludge tank level, high	100%	
Fuel oil drain tank level, high	100%	
Rocker arm lube oil tank level, low	50%	
Fuel & lube oil purifier fault	o	

(2/2)

Item	Alarm	Shut-down
Electrical Fault:		
Incomplete starting		o
Emergency stop		o
Over-voltage		o
Under-voltage		o
Reverse power		o
Generator bearing temperature, high		o
Generator differential		o
Generator stator winding temp., high		o
Generator over-current		o
Generator earth fault		o
Loss of field		o
Step-up transformer differential		o
Incoming feeder over-current		o
CB coupling feeder over-current		o
CB coupling feeder earth fault		o
Disconnecting feeder over-current		o
20 kV earth fault		o
Station service transformer differential		o
Auxiliary power earth fault		o
Loss of DC power		o
Loss of auxiliary power		o
Auxiliary power under volateg	o	
Auxiliary motor fault	o	

10-3-7 Safety Measures for Gas Fuel Use

The following safety measures should be considered in using gas fuel.

(1) Basic Matters

(a) It is considered to select a type that is unlikely to cause gas leak for gas piping and auxiliary equipment.

(b) Ability to cut off gas supply quickly by a safety shut-off valve if a safety device, such as the emergency engine stop or fire detection device, is activated.

(c) Safe ventilation of areas near gas piping and where auxiliary equipment are installed.

(2) Electrical System

(a) Providing protection on relays and terminal boards and not exposing electrical terminals.

(3) Gas Piping

(a) Installation of two safety shut-off valves in series to increase reliability. In case of engine trouble and abnormal pressure of supply gas, these safety shut-off valves are actuated to protect all equipment and facility.

(b) Providing a strainer at the inlet of the power plant to protect the shut-off valves, gas pressure regulator and other equipment at the downstream.

(c) Providing a gas pressure regulator upstream of the safety shut-off valve.

10-4 Power Plant

10-4-1 Arrangement of Equipment

Based on the result of study in 10-3 Dual-Fuel Engine Power Plant, an arrangement of equipment is shown in Figure 10-10.
The four engines are arranged at the center of the building. A two-floor section separated by walls is provided at the side close to the road, where the control panels and feeder panels are arranged. Operators shall remain in this section for operating and monitoring. The transformer is installed outside of this section, with an underground cable leading to the pole for power transmission.
Auxiliary equipment such as pumps, air receivers, air compressors, purifier, etc., are installed in a building on the opposite side from the engines.
The equipment for intake air and exhaust gas are installed here outside, and radiators are arranged further away.

10-4-2 Building

One 15-ton overhead travelling crane is installed in the central section of building where the engines are installed, for use in the maintenance and inspection of the engines. Therefore, the ceiling height needs to be adequately high.
Since no large-sized equipment is installed both in the electrical panel section and the auxiliary equipment section, the ceilings are made low. These sections are installed with windows to aid ventilation.

Steel frames are used for the building, and the roof and wall consist of galvanized iron sheets. Because of the high level of the engine noise, noise-proof material is used for the walls between the electrical panel section and the engine section. Moreover, since natural gas is sent into the building, ventilators are provided on top of the roof to allow it to escape in case of an accidental leak. An explosion-proof type motor is installed in these ventilators for driving their fans.

In order to detect gas leakage, gas detectors are installed on the ceiling, in the electrical area, and in the control room of the building.

An outline of the building is shown in Figure 10-11, and main items, section areas, and structure of the buildings are shown in Table 10-9.

Figure 10-10 Arrangement of Power House

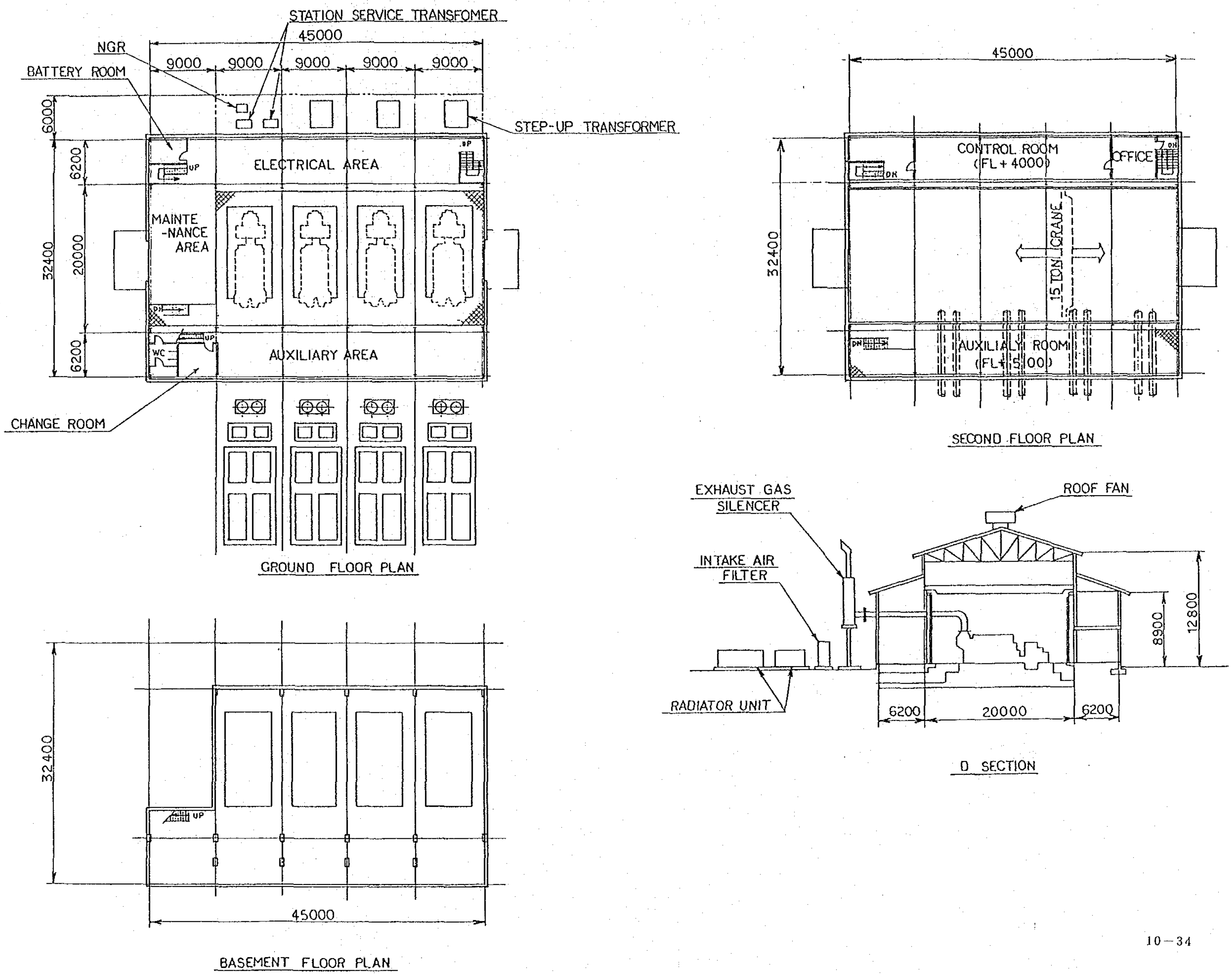
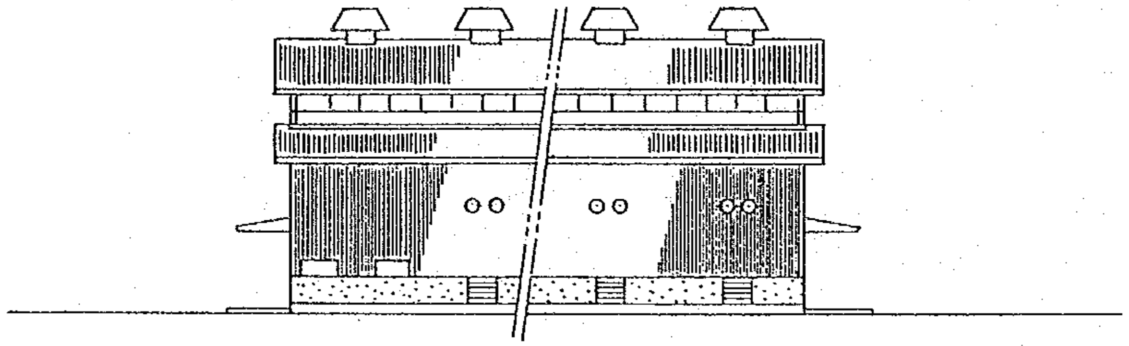
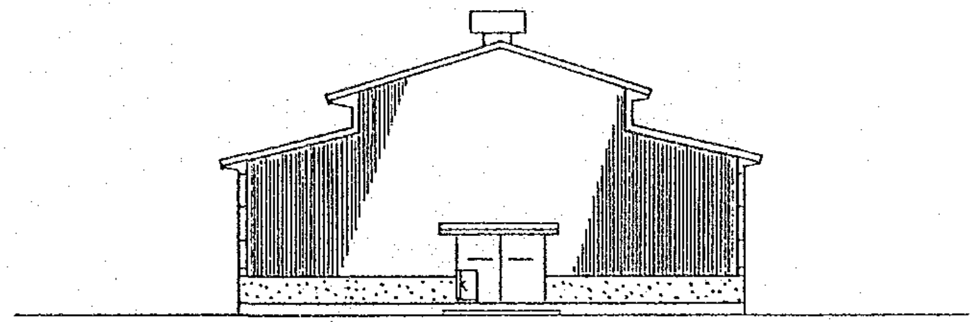


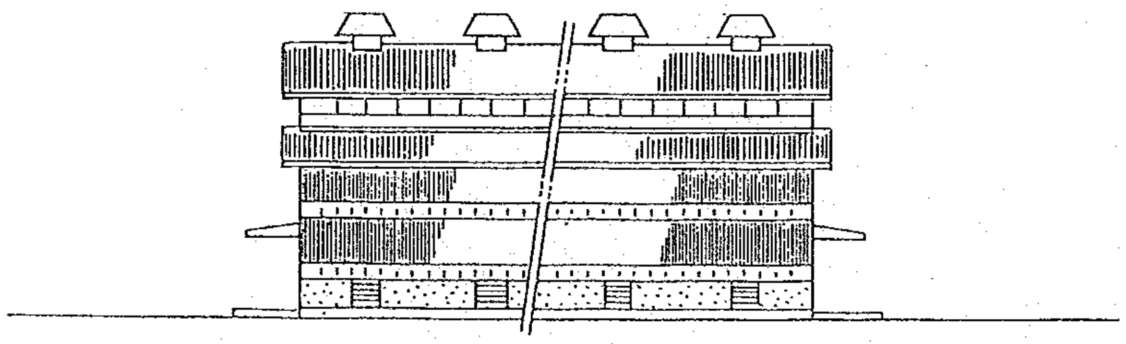
Figure 10-11 Building of Power House



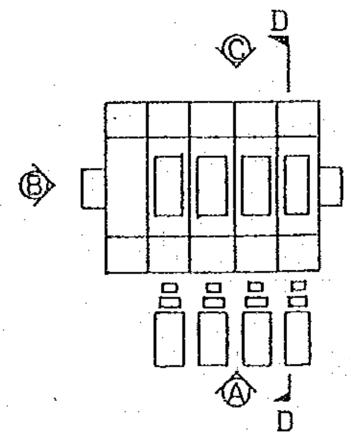
A ELEVATION



B ELEVATION



C ELEVATION



KEY PLAN

Table 10-9 Particulars of Power House

Size:	
Length	45 m
Width	31 m
Height	12 m
Total area	1,395 m^2
Section area:	
Engine and generator space	943 m^2
Maintenance space	144 m^2
Electrical area	188 m^2
Office	36 m^2
Control room (2nd floor)	162 m^2
Construction:	
Structure	Steel
Roof	Corrugated galvanized iron sheet
Wall	Galvanized iron sheet
Wainscot	Brick wall bed mortar trowelled
Floor (1st floor)	Concrete trowelled

10-4-3 Other Facilities

(1) Fuel Oil Storage Tank

Even if the supply of gas is interrupted, the power plant shall maintain operation using fuel oil. Therefore, a fuel oil storage tank is installed having a capacity of feeding fuel oil to four engines operated at 100% load in the diesel operation mode for one week.
This capacity is equivalent to the oil consumption rate for 10 weeks when the engine is operated in the gas mode operation.
Since the size of the storage tank depends on the fuel supply plan, it is necessary to finally determine the size after consulting with PERTAMINA, the supplier of fuel.
An oil dyke is provided around the fuel storage tank so that no oil will overflow, even if all of the tank's contents spills due to a leak.

(2) Workshop

A workshop is provided to perform simple repair and maintenance of the engines, generators, and auxiliary equipment, since there seems to be no shop which can perform repair work in the Jambi district. Since a power plant exists in Payo Selincah, the shop should be able to accommodate the repair and maintenance of equipment for both power plants.
A drilling machine, grinder, vice, gas cutter, arc welder, tool set, etc., are necessary for performing simple repair work.

(3) Sludge Incinerator

A small incinerator to burn sludge discharged from the purifiers of fuel oil and lubricating oil is installed.

(4) Fire Extinguisher

Two pumps, one small diesel engine-driven fire fighting pump and one motor-driven pump, are installed in the fire fighting pump station located outside of the main building, and 2 indoor hydrant boxes with foam solution are installed in the building. Moreover, 2 large type powder content fire extinguishers with wheels and 10 portable-type powder content fire extinguishers are installed preparing for oil fires or general fires.

(5) Warehouse

A warehouse is established for storing spare parts of the engines and auxiliary equipment.

(6) Water Supply System

A water supply system is provided for engine cooling water, fire fighting water, and miscellaneous water used in the power plant. Since the Payo Selincah district is on a hill and there is no river to take water from in the vicinity, a well will be drilled and water is pumped up for use.
The location of the well needs to be investigated. Since a well has to be dug outside of the site if there is no water vein within the site of the power plant, it is also necessary to search for water veins when selecting the site.
If the quality of water obtained from the well does not satisfy the requirements for engine cooling water mentioned previously, it is necessary to provide an appropriate water treatment facility.

The main items of miscellaneous equipment are shown in Table 10-10.

Table 10-10 Other Facilities

Fuel oil storage tank	Quantity: 1 Capacity: 1,000 m^3 Size: 14 m dia. x 7 m height
Incinerator	Quantity: 1 set Capacity: Approx. 70 m^3/h
Fire fighting pump	Quantity: 2 Capacity: 1,000 l/min x 6 kg/cm^2 Prime mover; - 1 x 30 kW electric motor - 1 x 44 PS diesel engine Type: indoor installation unit type
Warehouse	Space: 60 m^2
Water supply	Well pump: 2 x 3 m^3/h Water tank: 1 x 4 m^3

10-5 Environmental Protection

10-5-1 General

Since the Jambi district has few factories and automobiles are not used widely, there has been no specific regulations for exhaust gas. Moreover, few noise sources exist except for power plants. Since the only a power plants in operation are those relatively distant from houses, there has been no restrictions for noise level either.

10-5-2 Air Pollution

(1) Sulfur Oxides (SOx)

The sulfur content of the natural gas is negligible; the following is estimated for pilot oil, assuming it has a sulfur content of 0.442% wt:

Concentration in the exhaust gas: approximately 20 ppm

(2) Nitrogen Oxides (NOx)

Estimated emission of nitrogen oxides under normal operating conditions is as follows:

Concentration in the exhaust gas: approximately 600 ppm

(3) Dust

The estimated amount of dust under normal operating condtions is as follows:

Amount of dust: 100 mg/Nm^3 or below

10-5-3 Noise

The noise level at 1 meter away from the dual-fuel engine is approximately 105 dBA.
The noise at 1 meter from the outside wall of the building installed with four engines as described in Section 10-4-2 is estimated to be approximately 110 dBA. Therefore, considering that the strength of the sound is attenuated in inverse proportion to the square of the distance, in order to maintain a noise level of 45 dBA or lower at night, it is necessary to keep a distance of 300 m between the plant and the neighboring houses.

10-5-4 Others

(1) Vibration

The engine foundation is designed so that vibration of the surface of the engine foundation is limited to 0.03 mm or below at 8.33 Hz.
The vibration will not cause hazards at outside of the building.

(2) Treatment of Waste Oil and Sludge

Sludge discharged from purifiers is treated by an incinerator as described previously. The amount is approximately 0.8 t/d, and the influence on the environment is small.
Moreover, since the power plant will probably be polluted by oil, all water sewage will be collected in a small sump for separating oil content before being discharged. The separated oil is also treated by the incinerator.

11. CONCEPTUAL DESIGN OF TRANSMISSION AND DISTRIBUTION SYSTEMS

11-1 Input Variables

11-1-1 Transmission and Distribution Systems

It is assumed that the proposed power plant for this Project would be located in the Payo Selincah district of the eastern region of Jambi City in anticipation that the electricity demand will increase rapidly, particularly in the eastern industrial zone as mentioned in 6-3.

The existing distribution systems which are expected to be expanded according to the PLN plan have a configuration as explained in Appendix-3.

The exact location of the proposed power plant will be decided later, but, for the purposes of the current studies of transmission and distribution systems for this Project, the plant will be assumed to be sited at a point, as illustrated in Figure 11-1, some 300 meters away from the existing PLTD Payo Selincah.

The proposed power plant is to be linked with the existing PLTD Payo Selincah, so that they may be put into parallel operation or the produced energy may be interchanged between the two grids when required. It is further proposed that, in addition to the provisions of the PLN expansion program, a new distribution circuit be constructed and connected with the proposed power plant and two distribution circuits be newly added to the existing PLTD Payo Selincah, so that these may serve additional power requirements in the eastern industrial zone as needed. It is also proposed that a tie line be constructed between the proposed power plant and the existing switching station, ST Kantor, and that two additional distribution circuits be newly constructed and connected with ST Kantor. As a result, the network in and around Jambi City, for this Project, will be assumed to be of a configuration as shown in Figures 11-1 and 11-2.

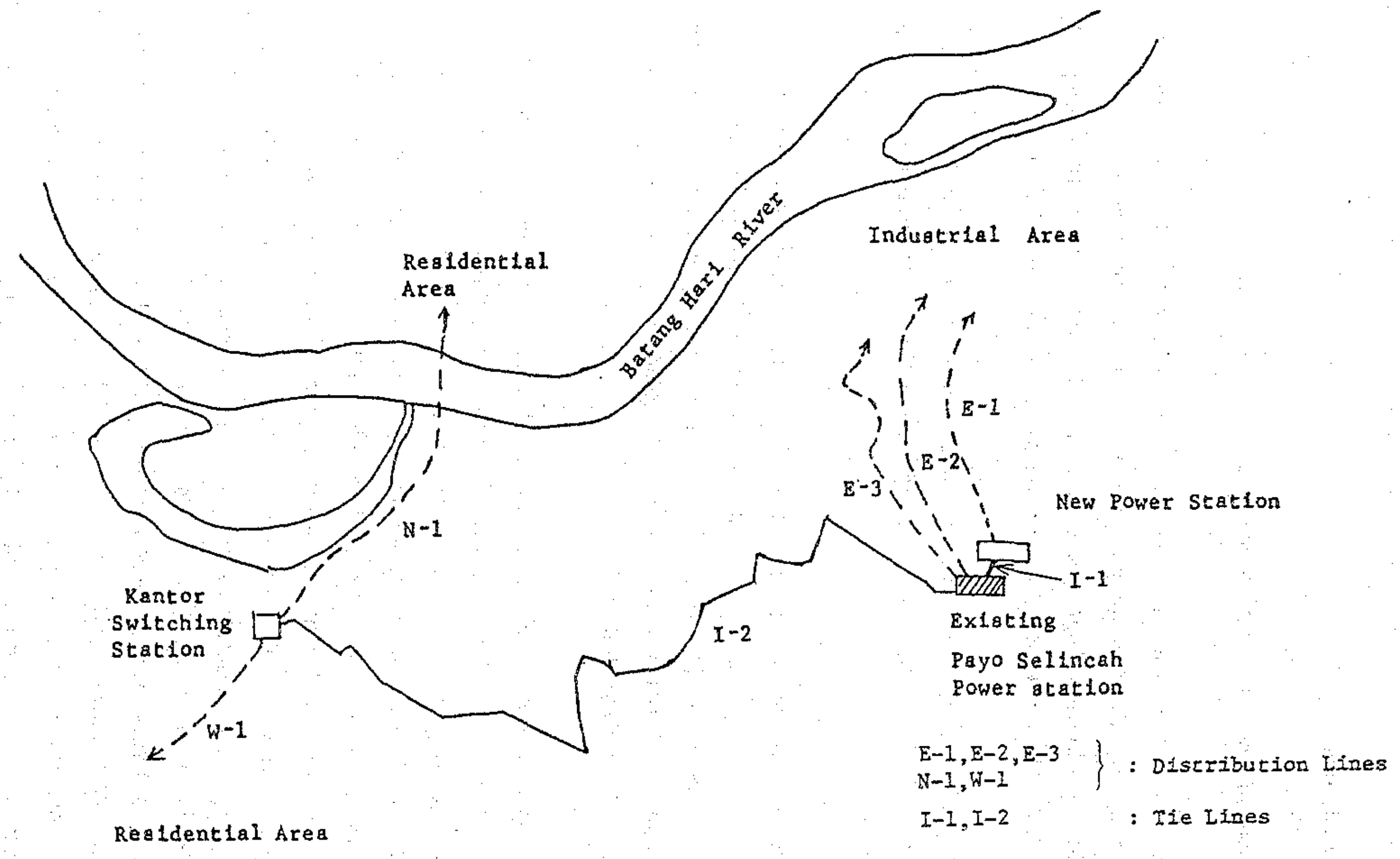


Figure 11-1 Distribution Lines and Tie Lines in the Jambi City Area after Completion of the Proposed Power Plant

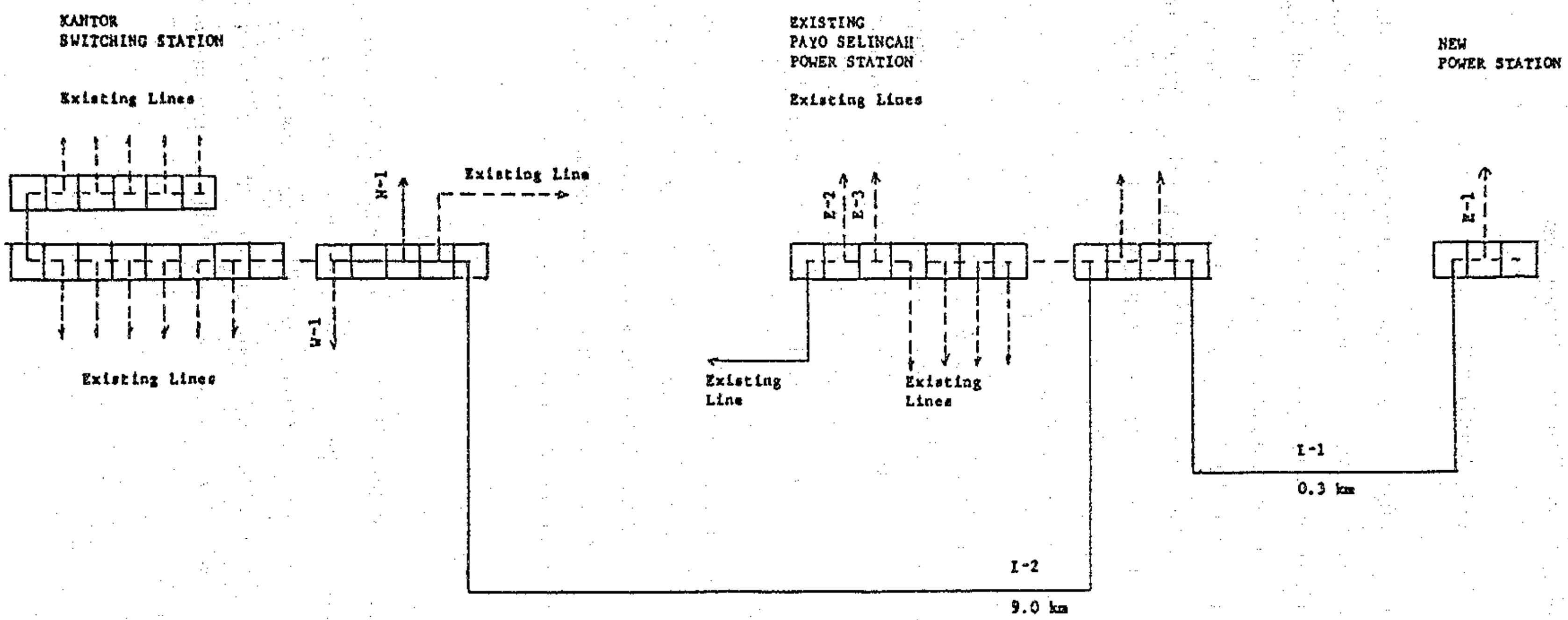


Figure 11-2 One-Line Diagrams of Expanded Distribution Systems and Tie Lines in the Jambi City Area

11-1-2 Meteorologic and Geologic Conditions

(1) Meteorologic Conditions

For designing of the transmission and distribution system, allowable value of temperature rise is defined based on 40°C ambient temperature and 88% relative humidity which are taken considering climate conditions in Jambi area. Maximum design wind velocity of 20.8 m/sec (75 km per hour) is adopted, which is standard value of PLN. Isokeraunic days are little less than 70 days per year in Jambi area (Refer to Figure 11-3).

(2) *Geologic Conditions*

Judging from soil data obtained for construction of the bridge across the Batang Hari river, the soil conditions in Jambi area in general are soil structure of old sand and silt layers inter-bedded with few meter of clayey layers. Boring operation of about 50 meter depth will not reach to a layer of bedrock masses.

Transmission and distribution facilities such as transformers mounted poles and other structures for 20 kV system have already been installed and in services for some years in the city and the soil conditions in the area will not pose any problems for erection of similar facilities.

11-1-3 Design Standards

PLN has established its own standards (SPLN), and these will apply to the design of transmission and distribution systems for this Project. Standards by the International Electro-technical Commission, JIS and JES of the Japan, and standards by the American National Standard Institute, will also apply, whenever there are no corresponding SPLN standards.

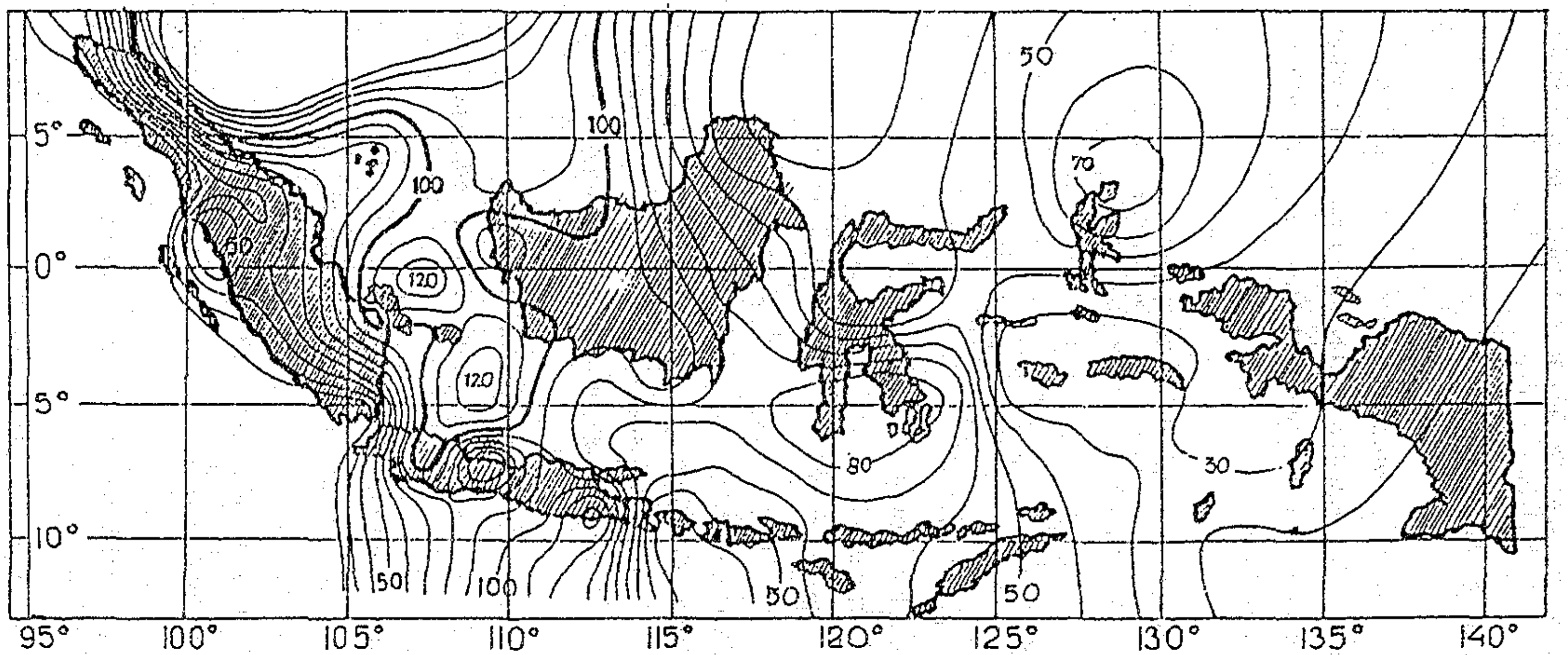


Figure 11-3 Isokeraunic Level (IKL) Map of Indonesia

Mentioned below are the design standards for principal items.

(1) Wind Pressure

The maximum wind velocity is set at 20.8 m/sec, on the average, according to SPLN standards. The wind pressures upon the conductors and poles at this wind velocity were obtained to be as follows:

One piece of conductors, 28 kg/m^2
One piece of poles, 28 kg/m^2

(2) Voltage

System Voltage
Medium voltage:

Nominal,	20 kV
Maximum,	24 kV

Insulation level
Medium voltage system:

Impulse withstand voltage,	125 kV
Power frequency withstand voltage,	50 kV

Limit of Voltage Fluctuation (SPLN-1)
Within plus 5% and minus 10% at consumer's end.

Limit of Voltage Drop

Medium voltage line,	5% or lower
Transformer,	3% or lower
Low voltage line,	3% or lower
Service line,	1.5% or lower

(3) Neutral Resistance of Medium Voltage Line

This will be equal to 40 ohm.

(4) Clearance Between Conductors and Other Objects

The clearances between the conductors of a distribution line and those of other lines, or between the conductors and the other objects, such as buildings and trees, should be taken in compliance with the limits set forth in Table 11-1, below.

Table 11-1 Clearance Between Conductors and Other Objects

	20 kV Line	380/220 V Line
Vertical clearance to the ground	6 m	5 m
Horizontal clearance to conductor of:		
a 380/220 V line	2 m	0.6 m*
a 20 kV line	2 m	2 m
a telephone line	2 m	1 m
Vertical clearance to conductors of a crossing 20 kV line	2 m	2 m
Vertical clearance to conductors on the same pole	1.2 m	1.2 m
Vertical clearance to buildings	3 m	3 m
Vertical clearance to trees	2 m	0.3 m

Note: The asterisked is based on the Japanese Standard.

11-2 Transmission and Distribution Modes

11-2-1 Transmission and Distribution Lines

There is no doubt that the electric demand in Jambi City will increase to a level substantially higher than the present level by the time this Project is implemented. Therefore, it is very important for PLN to expand and reinforce the existing transmission and distribution systems as required to keep in line with the increase in demand.

Assuming that a comprehensive study of the expansion and reinforcement requirements and programs will be made separately, this Feasibility Study Report will deal only with the addition of power delivery systems, as shown in Figures 11-1 and 11-2, and as described below in detail:

(1) Distribution Systems

It is assumed that electricity generated at the proposed power plant would be fed to the eastern industrial zone through a new 20 kV distribution circuit. The industrial zone would also be served by two new additional distribution circuits coming from the existing PLTD Payo Selincah. The two newly added distribution circuits originating from the existing switching station, PT Kantor, would serve the residential and school zones of the western region of the city. These new circuits are to be mainly of an overhead mode and will follow the method used for the existing distribution lines. The amount of power transmitted through one 20 kV circuit currently in use by PLN, without any further voltage drops than the limits set forth in Paragraph 11-1-3 (2) above, is normally in the range of 3,000 to 5,000 kW. Since the proposed power plant has a firm capacity of 17,000 kW, and this is to be shared by five circuits, the above per-circuit loading standard is expected to be easily met.

(2) Tie-line Between Power Plants

It is assumed that a 20 kV tie line would be installed to link the proposed power plant with the existing PLTD Payo Selincah, in order that they may be put into parallel operation or that the generated electricity may be interchanged between the two grids. It is further assumed that a tie line would be installed between the proposed power plant and existing switching station, PT Kantor, as required to serve loads in the western region of the city.

11-2-2 Protection System

(1) Protection from Lightning

As given in Figure 11-3, the Jambi Province is not very heavily lightning-ridden, but is subject to tropical rainfalls often accompanied with thunderbolts. It is, therefore, necessary to protect the electric delivery systems from the hazards of such natural phenomena in an appropriate manner.

Lightning takes place either "in and between the clouds" or "between the clouds and the ground." The type of lightning that poses a hazard for the electric delivery systems is the latter one. Damages of an overhead distribution line by lightning strokes include destruction of the equipment itself due to the destruction of insulations by unusually high voltage surge, or similar. But the seriousness of the problem is far bigger when the lightning actuates the circuit breakers at the power plants or the switching stations leading to a large scale black-out.

Measures to prevent damages by lightning strokes include mounting of grounding wires on a distribution line to suppress surge formation, and installation of arresters to breed off high voltage surge. Both of these measures, depending on the situation, may be used in combination.

The IKL in Jambi region is about 70 days per year, which is equivalent to about 1.5 to 1.8 times a year per km^2 in the probability of lightning occurrence.

Judging from the above level of probability, it is not considered to be necessary to install grounding wires on the overhead lines, but to only install arresters, at least, on the following equipment should be sufficient:

Circuit breakers at the power plant

: 10 kA rating arrester

Terminal of the outgoing feeder cables from the power plant

: 10 kA rating arrester

Pole transformer

: 5 kA rating arrester

Poles at the terminal of underground cables

: 5 kA rating arrester

Poles on either side of the pole mounted with a 20 kV switch (normally at the open position)

: 5 kA rating arrester

Dead-end poles of medium voltage line

: 5 kA rating arrester

The arresters should be of the valve resistance type with the following withstanding capacities by rating:

Rating	Surge Current Withstanding Capacity
10 kA	100 kA
5 kA	65 kA

The configuration of the valve resistance type arrester is given in Figure 11-4.

Under normal circumstances, the lower the grounding resistance of the arresters is, the larger the covering protection area becomes. It is said that in case of 10 ohm resistance arresters, there would be no flash-overs even if the arresters are installed at 150 meter intervals. Therefore, the arresters for this Project should have resistance rating no larger than 10 ohms.

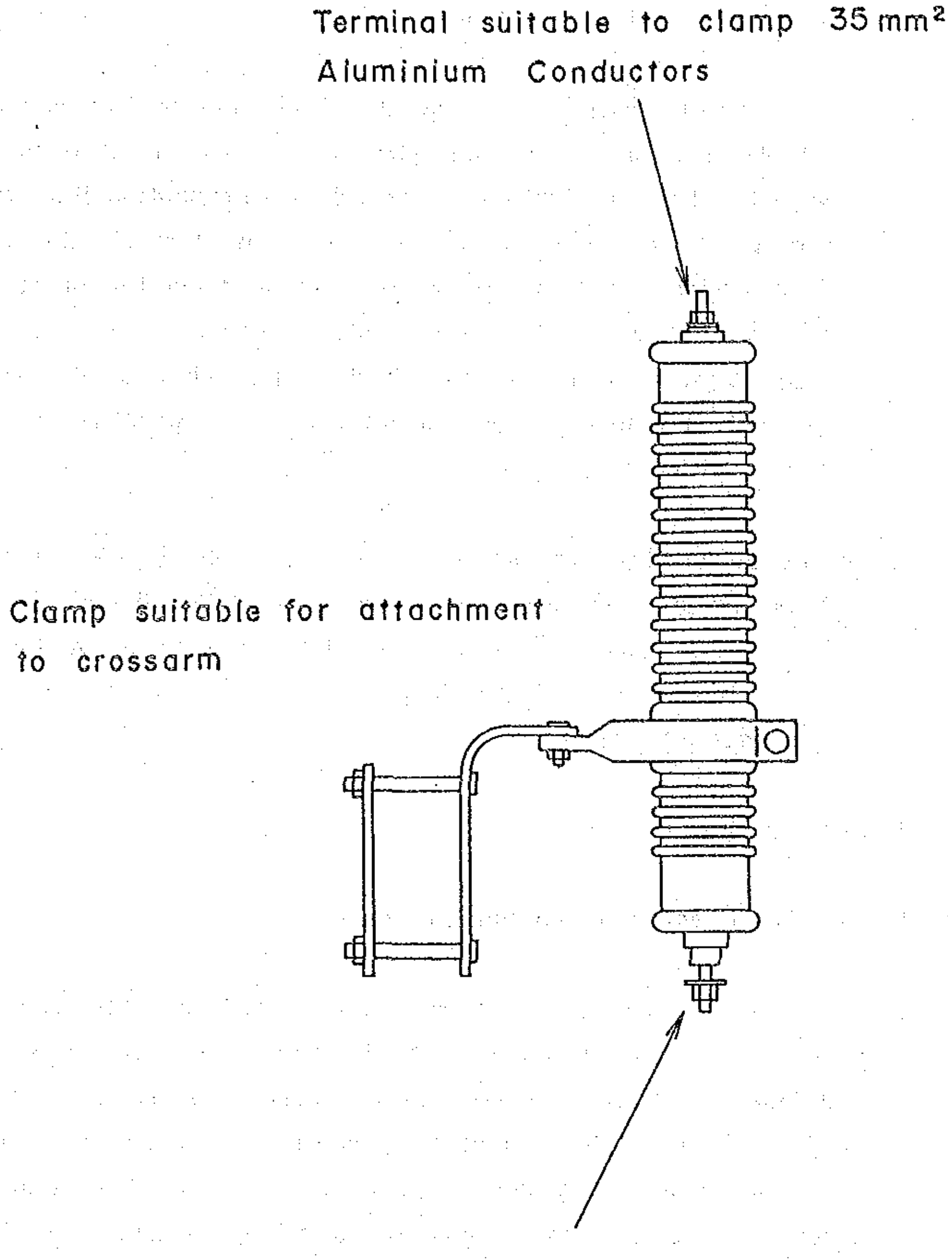


Figure 11-4 Valve Type Arrester

(2) Protection from Ground Fault

The neutral grounding of the 20 kV distribution line is made in 40 ohm resistance. In this case, if a ground fault occurs in a wire by the touch with a lower voltage distribution line, then, a current of as high as 290 amperes flow through the faulted wire, which results in a high voltage surge in the other wires. In order to protect the lower voltage distribution line from such hazards, it is stipulated by SPLN-3 that the neutral resistance be kept at a level lower than 0.2 ohms, or lower than 5 ohms if the conditions are different.

The circuit breakers at the terminal of the 20 kV feeder line from the proposed power plant should be provided with directional ground protection relays, so that a current between the generator and the distribution line may be cut off whenever a ground fault occurs.

11-3 System Analyses

11-3-1 Voltage Drops and Transmission Losses

It was assumed for this study that the electricity generated at the proposed power plant would be sent directly to the consumers through a distribution circuit, and sent to the existing PLTD Payo Selincah through a tie line, then be sent to consumers through two distribution circuits additionally connected to the same PLTD. It was also assumed that a tie line would be installed between PLTD Payo Selincah and the existing switching station ST Kantor, and that the tie line would be linked with the two distribution circuits additionally connected to the above station. The proposed line arrangement is as given in Figures 11-1 and 11-2.

The electricity demand in Jambi City is expected in the future to increase at an accelerated pace, year by year, as projected in Section 4-1 "Demand Forecast," and power flows from the proposed power plant may change in response to the increase in demand.

The electricity demand is higher in the residential and commercial quarters in the evening, while higher in the industrial zone during daytime. The electric current, therefore, varies with a time zone even in a single day.

In Paragraph 6-3, a relatively brief comparative study was made among alternatives, but this section deals with a more detailed study of Case C selected among three alternatives, including the associated transmission and distribution systems.

In the study made in Paragraph 6-3, it was assumed that the electricity transmitted to the consumers directly from the proposed power plant, through distribution line E-1, would continuously be in the amount of 3,000 kW. However, it is not practical to have the line carry the same amount of power all the time. It is, therefore, more reasonable to assume for this study that the additional electricity requirements in the industrial zone during daytime would be equally shared by the three distribution lines, E-1, E-2 and E-3.

In or prior to 1995, however, the increment of electricity requirements in the system would still be not very large, and the per circuit transmission power would accordingly be small, if the equal sharing policy is continued. In actuality, therefore, it would not be necessary to complete all the proposed distribution circuits by 1995, when the proposed power plant is expected to be commissioned.

It is, therefore, considered more reasonable to assume that the distribution circuit would be erected one by one in keeping in line with the increase of the electricity demand. The pace and timing of the erection of the five additional distribution circuits would be determined on the basis of about 3,000 kW average per-circuit capacity, assuming the peak and the average loads are in the ratio of 1:0.6.

Tabulated in Table 11-2 is the anticipated average transmission capacity of the proposed tie lines I-1 and I-2, and the proposed distribution circuits, E-1, E-2, E-3, W-1 and N-1, by year and by daily time zone, in line with the above policy.

Table 11-2 Transmission Capacity of the Proposed Tie Lines and Distribution Lines

	1995			1996			1997			1998			1999		
	Night-time A	Day-time	Night-time B	Night-time A	Day-time	Night-time B	Night-time A	Day-time	Night-time B	Night-time A	Day-time	Night-time B	Night-time A	Day-time	Night-time B
Tie Line															
I - 1	16,668	15,138	16,668	16,464	14,000	16,464	16,464	14,000	16,464	16,464	14,000	16,464	16,464	14,000	16,464
I - 2	614	241	958	1,291	507	2,014	2,003	789	3,129	2,777	1,095	4,341	3,630	1,429	5,671
Distribution Line															
E - 1	332	1,862	332	536	3,000	536	536	3,000	536	536	3,000	536	562	3,142	562
E - 2	-	-	-	115	811	115	516	2,892	516	536	3,000	536	562	3,142	562
E - 3	-	-	-	-	-	-	-	-	-	371	2,082	371	562	3,142	562
W - 1	614	241	958	1,291	507	2,014	2,003	789	3,129	1,920	756	3,000	1,920	756	3,000
N - 1	-	-	-	-	-	-	-	-	-	857	339	1,341	1,710	673	2,671

Note: Nighttime A : 0 hrs to 0700 hrs
Daytime : 0700 hrs to 1700 hrs
Nighttime B : 1700 hrs to 2400 hrs

Shown in Tables 11-3 and 11-4 are the transmission losses expressed in MW and MWh, respectively, of the proposed tie lines and distribution circuits by year and by daily time zone, estimated from the results tabulated in Table 11-2.

Input variables used for the above calculations are as follows:

(1) Conductors and Line Length:

Tie Line I-1:
Copper 325 mm^2 size underground cable; 300 meters in length.

Tie Line I-2:
Copper 400 mm^2 size underground cable; 9,000 meters in length.

Distribution Circuits (E-1, E-2, E-3, W-1 and N-1)
Aluminum alloy 150 mm^2 size overhead wires; 3,000 meters in length; 0.5824 ohm in resistance

(2) *Power Factor:*

80% at the receiving end

(3) Time Zone in a Day

Nighttime A	:	0 hr to 0700 hrs
Daytime	:	*0700 hrs to 1700 hrs*
Nighttime B	:	1700 hrs to 2400 hrs

(4) Annual Hours by Time Zone

Nighttime A	:	2,556.75 hrs
Daytime	:	3,652.5 hrs
Nighttime B	:	2,556.75 hrs

Table 11-3 Transmission Losses in MW of The Proposed Tie Lines and Ditribution Lines

	1995			1996			1997			1998			1999			Remarks
	Night-time A	Day-time	Night-time B	Night-time A	Day-time	Night-time B	Night-time A	Day-time	Night-time B	Night-time A	Day-time	Night-time B	Night-time A	Day-time	Night-time B	
Tie Line																
I - 1	11.64	9.60	11.64	11.36	8.22	11.36	11.36	8.22	11.36	11.36	8.22	11.36	11.36	8.22	11.36	R=0.01073Ω
I - 2	0.58	0.09	1.42	2.58	0.40	6.28	6.21	9.63	15.15	11.94	18.55	17.28	20.39	3.16	49.77	=0.3962Ω
Distribution Line																
E - 1	0.25	7.89	0.25	0.65	20.47	0.65	0.65	20.47	0.65	0.65	20.47	0.65	0.72	22.46	0.72	R=0.5824Ω
E - 2	-	-	-	0.03	1.50	0.03	0.61	6.06	0.61	0.65	20.47	0.65	0.72	22.46	0.72	"
E - 3	-	-	-	-	-	-	-	-	-	0.31	9.86	0.31	0.72	22.46	0.72	"
W - 1	0.86	0.13	2.09	3.79	0.58	9.22	9.13	1.42	22.27	8.39	1.30	20.47	8.39	1.30	20.47	"
N - 1	-	-	-	-	-	-	-	-	-	1.67	0.26	4.09	6.65	1.03	16.23	"

Table 11-4 Transmission Losses in MWH/Year of the Proposed Tie Lines and Distribution Lines

	1995	1996	1997	1998	1999
Tie Line					
I-1	94.58	88.11	88.11	88.11	88.11
I-2	5.44	24.11	89.79	142.46	190.92
Distribution Line					
E-1	30.10	78.09	78.09	78.09	85.72
E-2	-	5.63	25.25	78.09	85.72
E-3	-	-	-	37.60	85.72
W-1	8.02	35.38	85.48	78.54	78.54
N-1	-	-	-	15.68	62.26
Total	138.14	231.32	366.72	518.57	676.99
Losses as % of Total Generation	0.1	0.15	0.25	0.35	0.45

Table 11-5 Voltage Drops of the Proposed Tie Lines and Distribution Lines Under Normal Operation

	1995			1999		
	Night-time A	Day-time	Night-time B	Night-time A	Day-time	Night-time B
Tie Line						
I-1	0.03	0.03	0.03	0.03	0.03	0.03
I-2	0.03	0.01	0.05	0.20	0.08	0.32
Distribution Line						
E-1	0.01	0.07	0.01	0.02	0.11	0.02
E-2	-	-	-	0.02	0.11	0.02
E-3	-	-	-	0.02	0.11	0.02
W-1	0.02	0.01	0.03	0.07	0.03	0.11
N-1	-	-	-	0.06	0.02	0.09

Shown in Table 11-5 are the voltage drops of the proposed tie lines and distribution circuits estimated for 1995 and 1999 from the results of the corresponding years in Table 11-2.

Input variables for the calculation of the voltage drops are:

Inductance of underground cable:	0.372 mH/km
Capacitance of underground cable:	0.0345 μF/km
Inductance of overhead wire:	1.3 mH/km
Capacitance of overhead wire:	0.005 μF/km

A study should also be made of the case when the tie lines and the distribution circuits are required to transmit during the peak time a power of 1/0.6 times the average capacity shown in Table 11-2 (but in no case greater than 20,000 kW).

The average drops estimated on the typical case are as shown below:

Case	Transmission Power (kW)	Voltage Drop (kVA)
Tie Line I-1	20,000	0.04
Tie Line I-2	9,451	0.519
Distribution Circuit E-1	5,236	0.186

In designing complete transmission and distribution systems, a more elaborate and comprehensive study will have to be done by PLN, specifically for the electricity demand in the respective supply areas. Therefore, the outcome of such study could probably be different from the results of this study. However, it is very likely that the transmission and distribution systems planned and implemented by PLN would be of a large capacity than the one envisaged for this Project. The capacity of the tie lines and the distribution circuits proposed for this Project was determined as the minimum requirement for the supply of the electricity produced by the proposed power plant, without regard to the possible squeeze in the capacity of the existing distribution systems, in and around March 1995, when the proposed power plant is expected to be commissioned.

The results of this study indicate that the voltage drops of the proposed transmission and distribution lines would be well below the PLN Standard (SPLN-1) as referred to in Paragraph 6-1-3 (2), and that the transmission losses would be 0.45% or lower. It is, therefore, well conceivable that the actual voltage drops and transmission losses would be even lower than what is shown by the above results.

11-3-2 Service Reliability

(1) Reliability of the Distribution Lines

It was assumed that the distribution lines to be erected for this Project would be of a simple, tree-like configuration, and provided with automatic reclosing switches and manual sectionalizing switches to improve the service reliability as required in accordance with the PLN practice.

Supposing that there is a distribution line like the model given in Figure 11-5, and that any fault occurring in a section would not affect other healthy sections due to immediate isolation of the section by automatic reclosing switches, the rate of fault occurrences per consumer on such line can then be expressed as:

$$Rs = \frac{F \times [L1C1 + ... + (L1 + L2 + ... + Li)Ci + ... + (L1 + L2 ... + Ln)Cn]}{C1 + C2 + ... + Ci + ... + Cn}$$

.... (1)

Where:

Rs is the rate of fault occurrences per consumer
F is the rate of fault occurrences per circuit of 100 km per year.
n is the number of sections that can be isolated by automatic reclosing switches
Ci is the number of consumers in a section
Li is the line length of a section

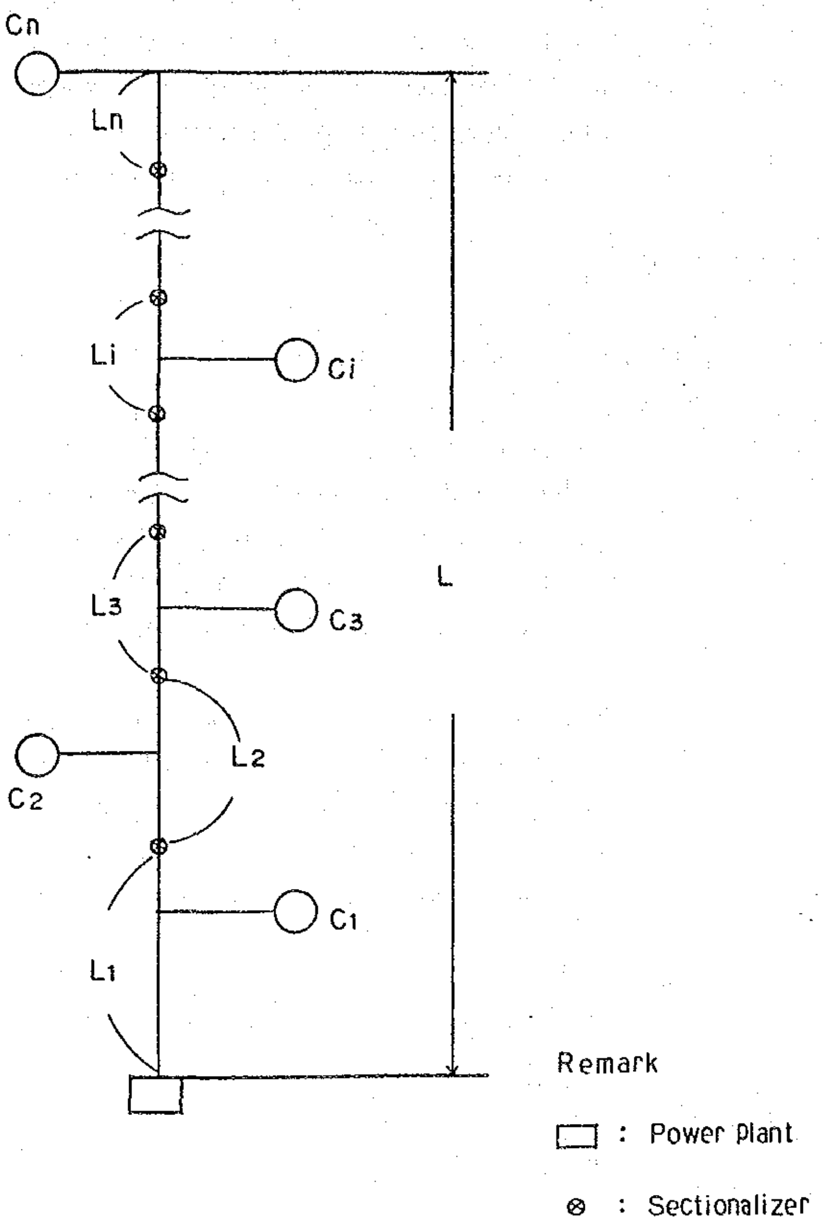


Figure 11-5 A Model of Tree-Like Distribution Line

This rate is less than the rate of fault occurrences in case no automatic reclosing switches are provided, which can be written as Ro = FL .... (2)

The line length equivalent to the decrease in the rate of fault occurrences can be written as:

$$Ls = \frac{Rs}{F} \quad \text{..................................} \quad (3)$$

This equation indicates that the shorter the Le, or the fault equivalent line length, is, the smaller the rate of fault occurrences becomes.

If the number of consumers of each section is the same, and so is the line length of each section, Eq. (1) can be written as:

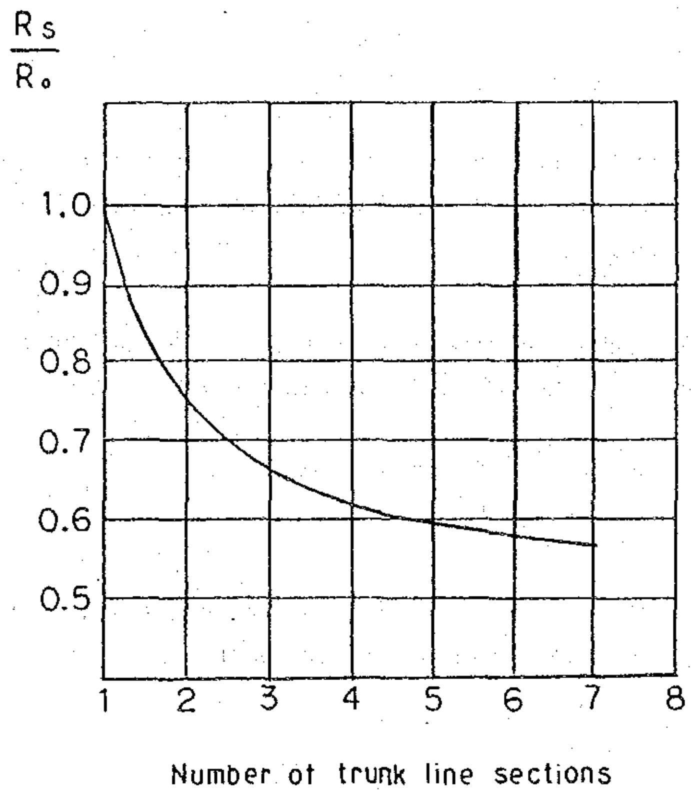
$$Rs = \frac{F \times L/n\ (1 + 2 + 3 + \ldots\ldots + n)}{n}$$

Now that Ro (the rate of fault occurrences in case no automatic reclosing switches are provided) = FL, the following relation can be obtained:

$$\frac{Rs}{Ro} = \frac{n + 1}{2n} \quad \text{...............................} \quad (4)$$

Figure 11-6 gives the relation of Rs/Ro with n shown on the abscissa.

It is obvious from Figure 11-6 that the rate of fault occurrences per consumer can be reduced by increasing the number of automatic reclosing switches.



Note : Rs : Fault rate per consumer per year with automatic sectionalizer

Ro : Fault rate per consumer per year without automatic sectionalizer

Figure 11-6 The Relation between Number of Automatic Reclosing Switches and Reliability of Tree-like Type Distribution Line

Table 11-6 shows the fault equivalent line length and the rate of fault occurrences per consumer of the proposed distribution lines and tie lines. The fault equivalent line length was obtained by applying probable figures to the coefficient L and n. The rate of fault occurrences per consumer was obtained by multiplying the fault equivalent line length by the coefficient F, which, according to the PLN practices, can be represented by:

20/100 km/year for the 20 kV overhead line
5/100 km/year for 20 kV underground cable

Table 11-6 Probability of Fault Occurrences of the Proposed Tie Lines and Distribution Lines

	Number of Sections	Line Length	Fault Equivalent Line Length	Probably of Fault Occurrences per Consumer
	n	L (km)	L (km)	Rs Occurrence/Year
Tie Line:				
I-1	1	0.3	0.3	0.015
I-2	1	9.0	9.0	0.45
Distribution Line:				
E-1				
E-2	2	3.0	2.25	0.45
E-3				
W-1 N-1	3	3.0	2.0	0.4

11-3-3 Short Circuit Current

When short circuit occurs anywhere in the electric system, an excess current passes through the equipment and/or the line conductors, which can cause severe damages. In order to protect the line conductors and the equipment from the hazards of such excess current, each power plant is provided with circuit breakers of adequate capacity. If the breaking capacity of the circuit breakers is not adequate, the affected circuit may keep alive and the excess current passing through the circuit may melt down the line conductors.

The following study deals with the probable short circuit current for the proposed Jambi City grid in order to determine the most adequate breaking capacity of the circuit breakers for the proposed power plant as required for the complete safety of the line conductors. The calculation of the short circuit current was made on the assumption that a short circuit would occur somewhere in the system at the time when all power plants, including the proposed plant, are put into a parallel operation.

It should be noted, however, that, as the purpose of the study was only to make a conceptual design, the calculation was performed considering inductance without regard to the resistance. This produced a resultant short circuit current relatively higher than the one which might actually occur.

(1) Input Variables and Assumptions used in the Calculations

The input variables and assumptions used in making the calculations are as shown below:

a. Impedance of the Equipment:

Subtransient impedance of the generator:	20%
Impedance of step-up transformers:	
3,125 kVA transformer for PLTD Kasang generator:	6.06%

6,250 kVA transformer for the
proposed power plant generator: 7.5%

6,500 kVA transformer for the
PLTD Payo Selincah generator: 7.5%

Note:

Impedance based on 10,000 kVA capacity.
No resistance taken into account.

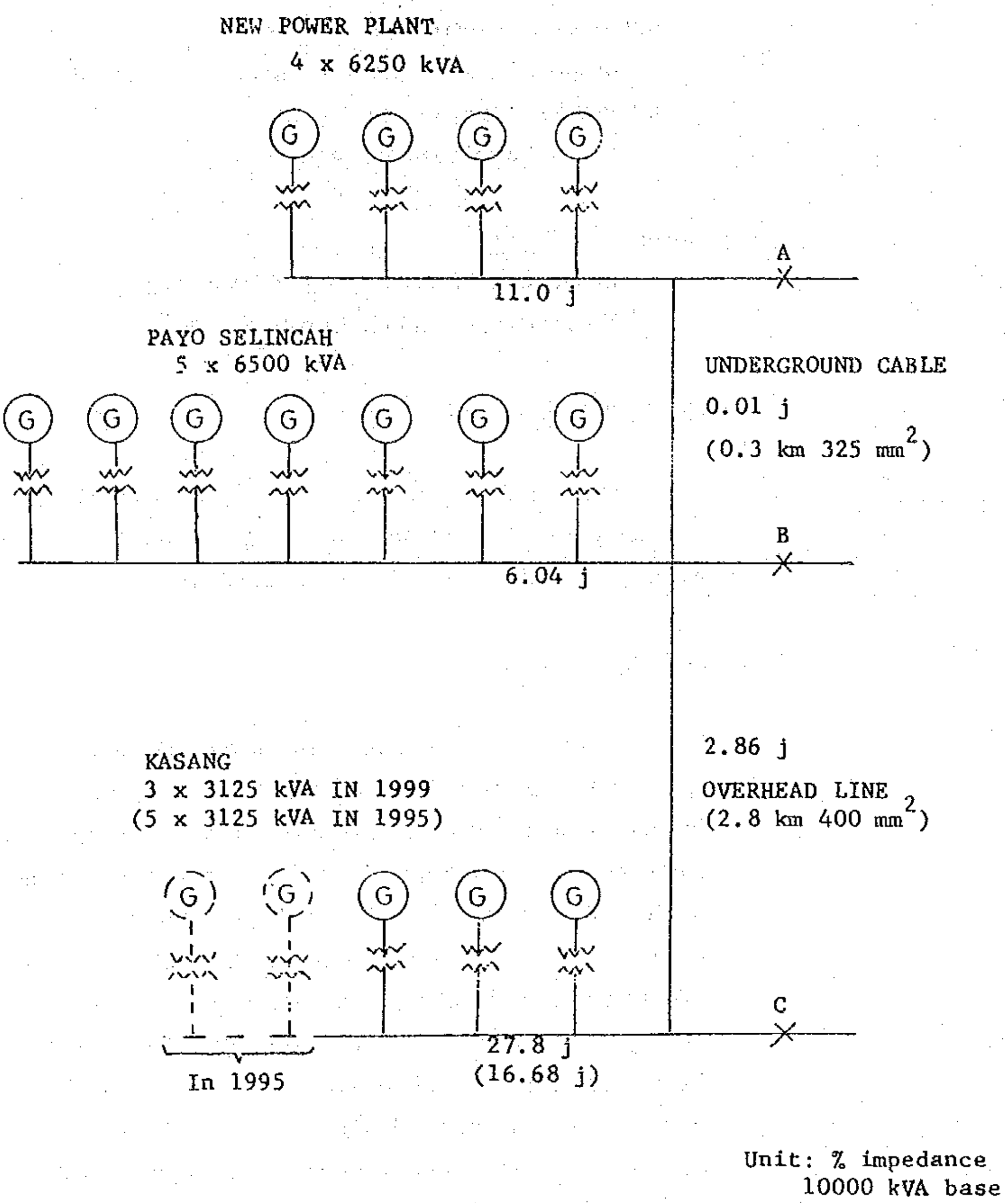
b. Impedance of the Line Conductor

Underground cable (copper, 325 mm^2) : 0.11687 jΩ/km
Overhead line (aluminum, 150 mm^2) : 0.4084 jΩ/km
Note: No resistance taken into account.

c. System Capacity

The interconnection between the power plants, after completion of the proposed power plant, was assumed to be made in accordance with the diagram shown in Figure 11-7. As mentioned in Paragraph 6-2-5, it was assumed that the capacity of the existing PLTD Payo Selincah would be increased until 1992 by another 10,000 kW. It was further assumed that the anticipated decrease in the system capacity during the period from 1995 through 1999, as indicated in Paragraph 4-1, would be effected by the retirement of two units of the existing PLTD Kasang. In other words, the system capacity would become the biggest ever during a brief period in 1995 after the proposed power plant is commissioned, but before the Kasang's two units are retired.

The short circuit current was, therefore, calculated for the system capacity as of both 1999 and 1995, the year when the system capacity would become the largest ever. For a comparative study, calculations were also made for the case when the system capacity is increased in 1992 by 10,000 kW.



Remark :

Figurers in ( ) and simbols shown in dotted line shows condition in 1995

Figure 11-7 Interconnection between Power Plants As of 1999 and 1995

d. Location of the Short Circuit

For the calculation of the short circuit current, it was assumed that the short circuit could occur, independently, at three points, A, B, and C, i.e., close to the sending end of the proposed power plant, the existing PLTD Payo Selincah, and PLTD Kasang, respectively, as indicated in Figure 11-7.

(2) Calculation Results

The results of the calculations made on the above basis were as follows:

i. For the system capacity as of 1999:

a. When the short circuit occurs at Point A:

$$\frac{1}{27.8 + 2.86} + \frac{1}{6.04} = \frac{1}{5.05}$$

$$\frac{1}{5.05 + 0.01} + \frac{1}{11.0} = \frac{1}{3.46}$$

$$I = \frac{100}{3.46} \times \frac{10,000}{\sqrt{3} \times 20} = 8,334A$$

b. When the short circuit occurs at Point B:

$$\frac{1}{11.0 + 0.01} + \frac{1}{6.04} + \frac{1}{27.8 + 2.86} = \frac{1}{3.46}$$

$$I = \frac{100}{3.46} \times \frac{10,000}{\sqrt{3} \times 20} = 8,343A$$

c. When the short circuit occurs at Point C:

$$\frac{1}{11.0 + 0.01} + \frac{1}{6.04} = \frac{1}{3.90}$$

$$\frac{1}{3.90 + 2.86} + \frac{1}{27.8} = \frac{1}{5.44}$$

$$I = \frac{100}{5.44} \times \frac{10,000}{\sqrt{3} \times 20} = 5,309A$$

ii. For the system capacity as of 1995:

a. When the short circuit current occurs at Point A:

$$\frac{1}{16.68 + 2.80} + \frac{1}{6.04} = \frac{1}{4.62}$$

$$\frac{1}{4.62 + 0.01} + \frac{1}{11.1} = \frac{1}{3.26}$$

$$I = \frac{100}{3.26} \times \frac{10,000}{\sqrt{3} \times 20} = 8,859A$$

b. When the short circuit current occurs at Point B:

$$\frac{1}{16.68 + 2.86} + \frac{1}{6.04} + \frac{1}{11.0 + 0.01} = \frac{1}{3.59}$$

$$I = \frac{100}{3.59} \times \frac{10,000}{\sqrt{3} \times 20} = 8,039A$$

c. When the short circuit occurs at Point C:

$$\frac{1}{11.0 + 0.01} + \frac{1}{6.04} = \frac{1}{3.90}$$

$$\frac{1}{3.90 + 2.86} + \frac{1}{16.68} = \frac{1}{4.81}$$

$$I = \frac{100}{4.81} \times \frac{10,000}{\sqrt{3} \times 20} = 6,000A$$

iii. For the system capacity after 10,000 kW are added to the system in 1992:

a. When the short circuit occurs at Point B:

$$\frac{1}{16.68 + 2.86} + \frac{1}{6.04} = \frac{1}{4.61}$$

$$I = \frac{100}{4.61} \times \frac{10,000}{\sqrt{3} \times 20} = 6,256A$$

b. When the short circuit occurs at Point C:

$$\frac{1}{6.04 + 2.86} + \frac{1}{16.68} = \frac{1}{5.80}$$

$$I = \frac{100}{5.80} \times \frac{10,000}{\sqrt{3} \times 20} = 4,974A$$

(3) Conclusions

It is obvious from the above results that the short circuit current would tend to increase with the operation of the proposed power plant, but it is not expected to exceed the level of 9,000A. Such level of short circuit current would not pose any particular problem to the existing circuit breakers and line conductors.

11-3-4 System Stability

The longest of all the proposed power delivery systems for this Project will be tie line I-2 between the proposed power plant and the existing switching station, ST Kantor (some 9 km in pole line length). Hence, there would be no particular problem in maintaining the system stability. However, to make sure of this matter, a brief study as described below was made with regard to the stability of the above tie line.

(1) Input Variables and Assumptions used in the Calculations

To simplify the calculations, it was assumed that the proposed power plant and the existing PLTD Payo Selincah would be a single power source. The voltage was assumed to be 21 kV at the sending end, and 20 kV at the receiving end. The Transformer losses were set at 0.5%, and the reactance at 7.5%. The impedance and capacitance of the line conductor were set at 0.3962 + 1.0518j(Ω) and 0.0000975j(s), respectively, the same as used in the calculations covered in Paragraph 11-3-1.

(2) Calculation of the Steady-State Stability

The transformer impedance is expressed as follows:

$$Zt = \frac{(0.5 + 7.5j) \times 10 \times 21^2}{83{,}000} = 0.026566 + 0.39849j$$

The general circuit constants of the tie line, obtained by applying the T-circuit calculation method, are:

A = 0.9999487 + 0.00001933j
B = 0.3962 + 1.0518j
C = 0.000097546j
D = 0.9999487 + 0.00001933J

Hence, the composite constants are:

$$Ao = A + CZt = 0.9999513 + 0.00005820j$$
$$Bo = B + DZt = 0.42275 + 1.4503j$$
$$Co = C = 0.00009546j$$
$$Do = D = 0.9999487 + 0.00001933j$$

The electric power circle can be obtained by applying the above constants to the following equation:

$$Pr + jQr = \frac{1}{Bo} Vs \cdot Vr e^{-j\delta} - \frac{\bar{A}o}{\bar{B}o} Vr^2$$

Then,

The center of the circle (R),

$$\text{or } \frac{\bar{A}o}{\bar{B}o} Vr^2 = -\frac{0.999448 - 0.00002192}{0.42275 - 1.4503j} \times 20^2$$

$$= 74.06 - 254.1j \text{ (MVA)}$$

The radius of the circle (RB),

$$\text{or } \frac{1}{\bar{B}o} Vr \cdot Vs = \frac{20 \times 21}{0.42275 - 1.4503j}$$

$$= 77.79 + 266.9j \text{ (MVA)}$$

Figure 11-8 gives the electric power circle diagram for tie line 1-2 obtained in the above manner.

From this diagram, it can be confirmed that tie line 1-2 is capable of transmitting a power of some 27,000 kW.

(3) Transient Stability

When a fault occurs in a circuit of a distribution system, consisting of two or more circuits, the load from this circuit is transferred to the other circuit(s), thus causing transient turbulence in the system. In such event, the system is transiently forced to transmit a substantially greater amount of power than the one obtained from the steady-state stability calculations.

The amount of such power varies with the nature of the fault and the time required for the actuation of the protective relays and circuit breakers, but it can generally be considered the power increase to be about 1.2 to 2 times the amount of the steady-state power, if regular function relays and breakers are used.

As shown in Figure 11-8, tie line I-2 has a sufficient allowance in transmitting power even in the event of such transient turbulence in the system, and could pose no problems in maintaining the transient stability.

However, it may be necessary to make a system-wide transient stability study separately for the tie line to be installed by PLN along tie line I-2 for connection of ST Kantor with the same power source.

(4) Conclusion

Tie line I-2 is designed to be installed as underground cable, which is much higher in the reliability than the overhead line as described in Paragraph 11-3-2. Besides, it is also proposed that 400 mm^2 size copper conductors be used for the tie line, which will enable the line to transmit a large amount of power as shown on Figure 11-8.
In conclusion, it can be said that the proposed tie line would have a very high stability factor in all respects.

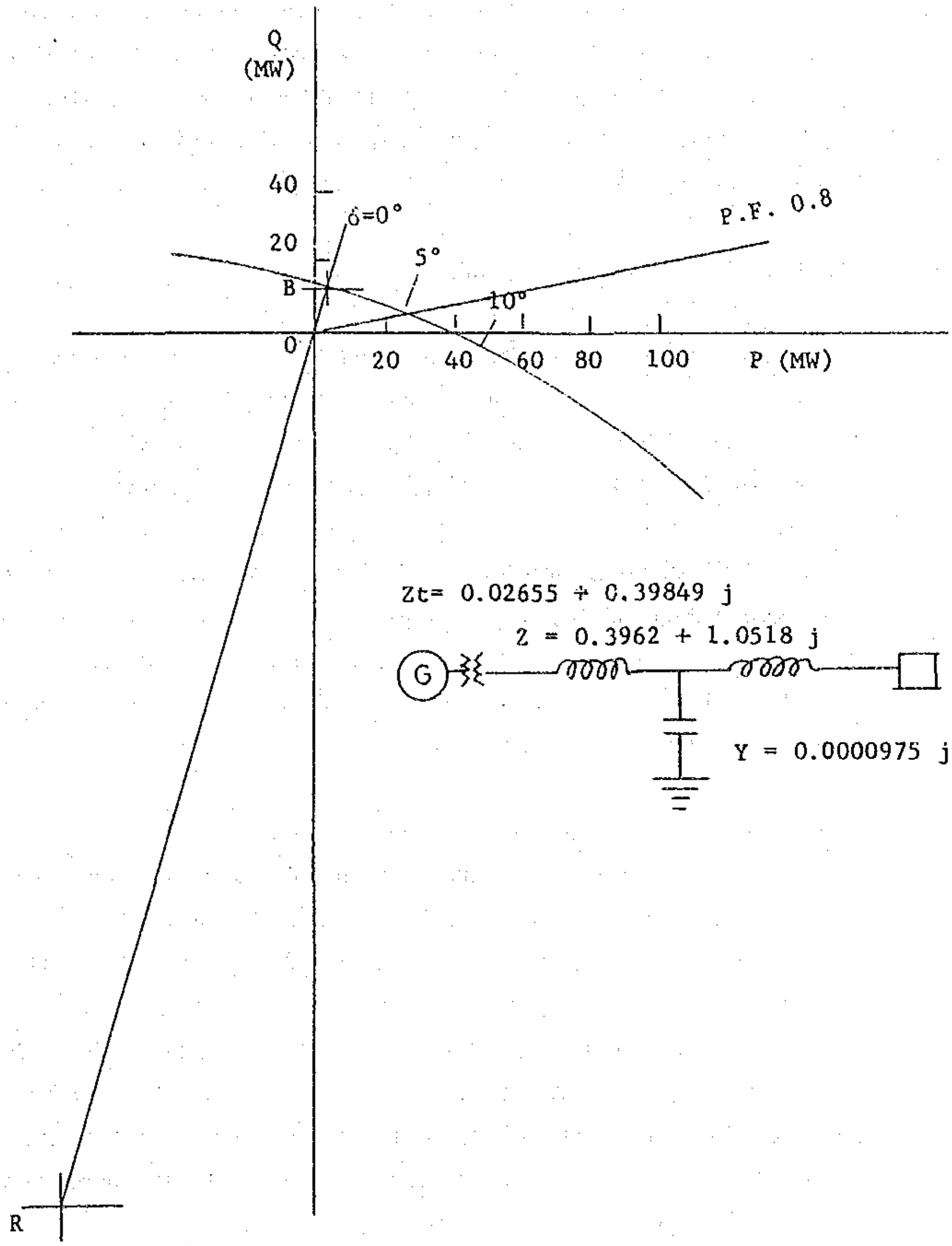


Figure 11-8 Electric Power Circle Diagram for the Proposed Tie Line I-2

11-4 Hardwares of the Proposed Transmission and Distribution Systems

This section deals with the hardwares of the proposed distribution lines and the tie lines, on the assumption that locally available materials and equipment should be used for these installations to the greatest possible extent. Imported goods, as necessary, would limited to those as standardized by PLN.

11-4-1 Supports of Distribution Systems

The proposed distribution lines for this Project will be assumed to be installed in the eastern and western regions of Jambi City. A span between the poles of the lines in these regions will be about 40 meters according to the existing PLN practice. Eleven meter poles will be needed for supporting the distribution line, consisting of two 20 kV (MV) circuits and one 380 V (LV) circuit, with the required clearance taken as shown in Table 11-1. In case of crossing of a line over the other line or erecting the pole at a special location, a thirteen meter pole will be needed. Figure 11-9 shows poles of both dimensions with the required clearance.

The eleven meter hollow reinforced concrete poles with a diameter of 190 mm at the top, supporting one circuit of a 150 mm^2 size conductor, will carry a load of 83 kgf at the top, when a wind pressure acting on it is 28 kg/m^2 as given in Paragraph 11-1-3 (1). The thirteen meter pole under the same conditions will carry a 90 kgf load. As the above poles may also have to carry some additional load, such as an additional circuit of the same size conductor and possibly other installations, such as transformers and LV lines, it is proposed that their capacity be increased to 200 daN (deca newton, 1 deN = 1.0197 kgf).

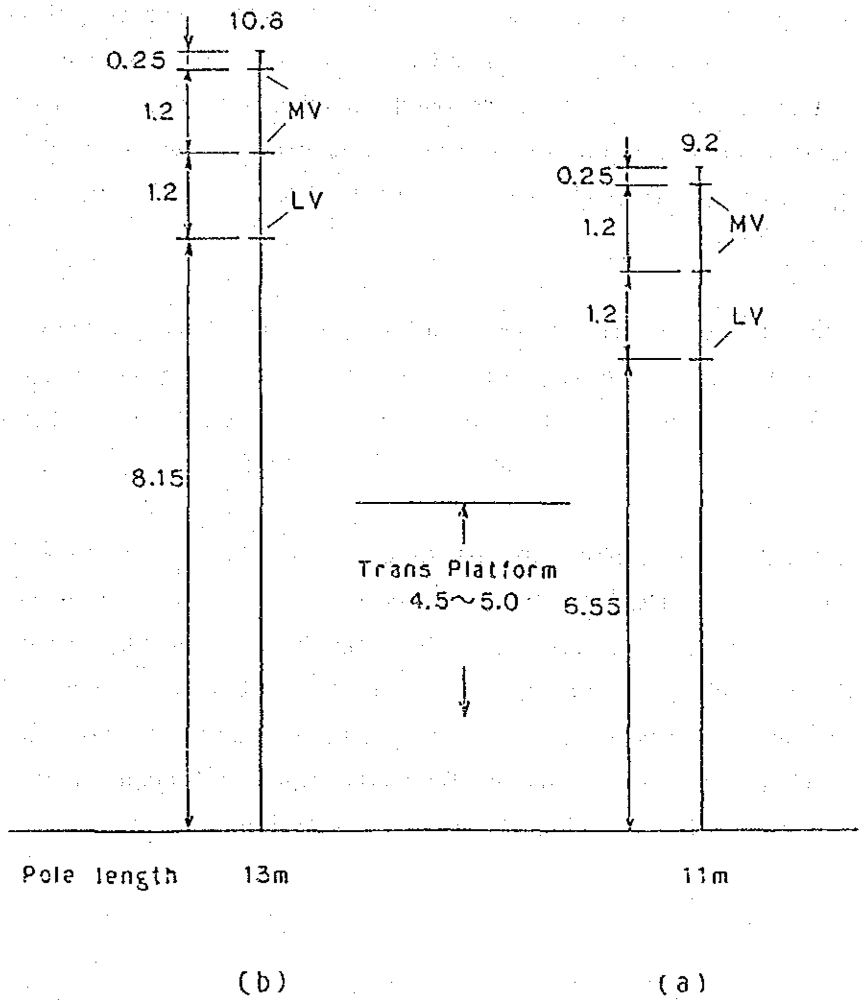


Figure 11-9 Above-the-Ground Dimensions of 13-meter and 11-meter Poles and Vertical Clearance Needed for Selection of the Pole Size

The distribution lines are assumed to be erected on a low hill south of the Batang-Hari river.

The existing 20 kV distribution lines in the Jambi City area are all supported by steel poles, but in the rest of Indonesia, hollow reinforced concrete poles have gradually displaced steel poles because of their cost advantage. These concrete poles are fabricated by local manufacturers, and it is anticipated that such concrete poles would be easily obtainable in the Project area by the time this Project is implemented. For the proposed distribution lines, therefore, it is recommended that hollow reinforced concrete poles be used. The configuration of the 11 and 13 meter poles of this type is given in Figure 11-10.

Poles should be strengthened below the ground by provision of a concrete footing in cases when they have to be erected on a ground with poor subsoils. Reinforcement coefficients for determining the size of the concrete footings are as shown in Figure 11-11.

Arms to be attached to the poles should be either square pipes or channel steel shapes. Both are relatively light in weight and easy to install. These products are fabricated by local manufacturers and are widely available. The dimensions are 75 x 75 x 3.5 mm and 75 x 75 x 2.3 mm, for square pipes, and 125 x 65 x 6 mm and 100 x 56 x 5 mm, for channel shapes. Any of the above types and shapes will be acceptable as available during the time of erection.

11-4-2 Conductors

(1) Overhead Line

Aluminum alloy wires should be used for the conductors of the overhead lines because of the cost advantage over the copper wires, the ease in handling because of the lightweight, and the availability from the local manufacturers. The same types of wires have been widely used by PLN as a standard item for the

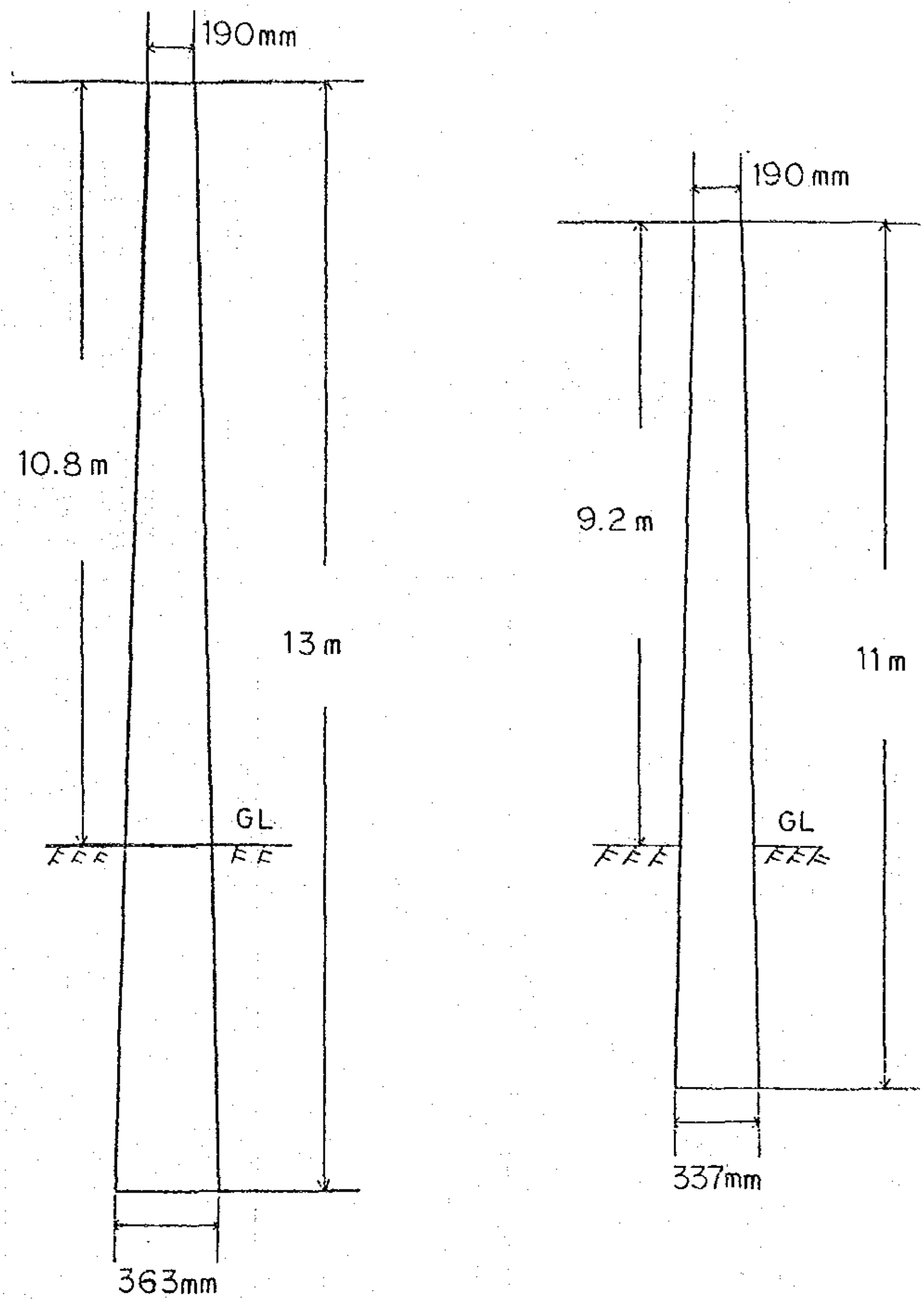
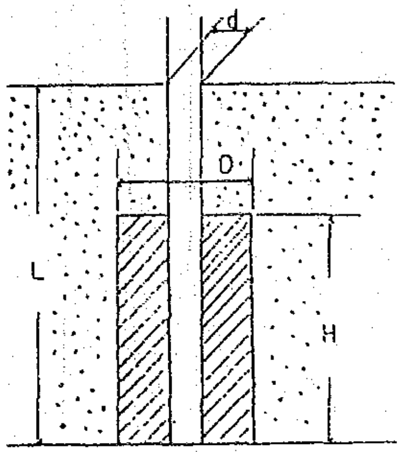


Figure 11-10 Dimensions of 13-meter and 11-meter Concrete Poles

$$\beta = \frac{\text{Height of footing : H}}{\text{Burried depth of pole}}$$

$$\alpha = \frac{\text{Diameter of footing : D}}{\text{Pole diameter at ground level}}$$



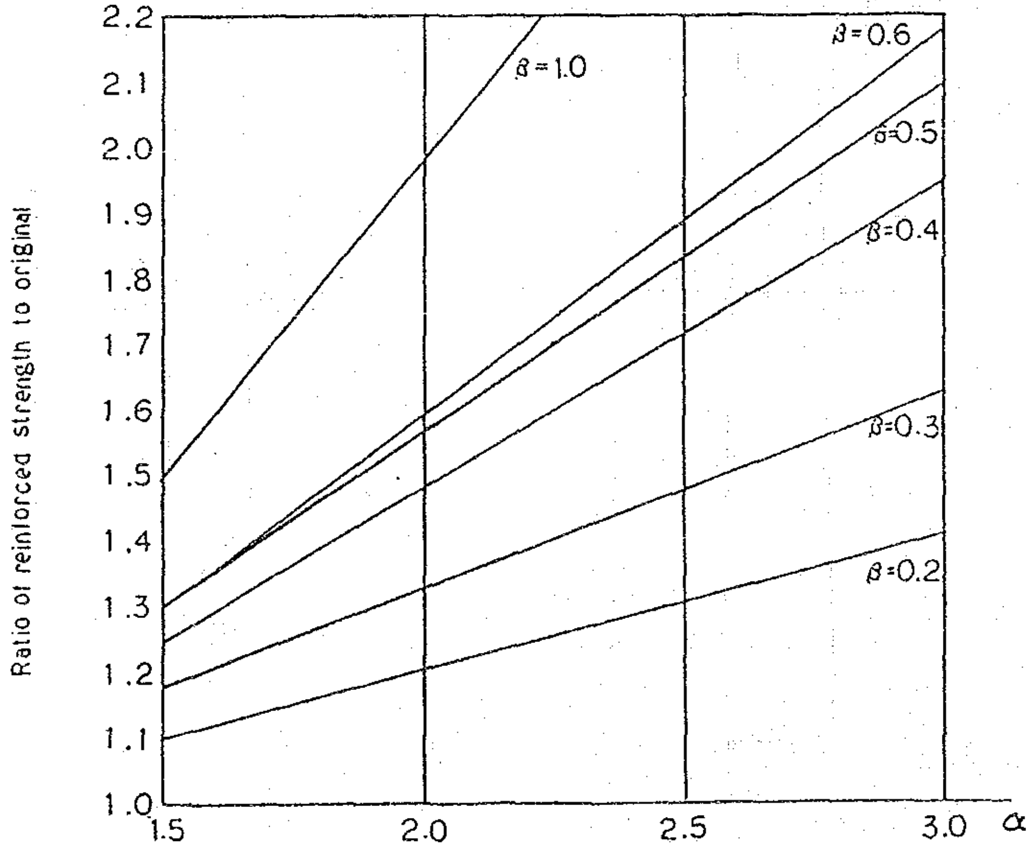


Figure 11-11 Pole Foundation Strengthening in Poor Soil

construction of the existing 20 kV distribution lines of the power system.

The diameter of the conductor of the overhead lines should be determined upon confirmation of the magnitude of the current flowing through the lines and the drop of the voltage. Table 11-7 shows the ampacity of the two different kinds of aluminum alloy conductors by size and temperature limit. One is the bare all aluminum alloy conductor and the other is the cross-linked polyethylene insulated all aluminum alloy conductor.

The ampacity of the conductors was obtained by calculating their self radiations under such conditions as the ambient temperature of 35°C, solar radiation of 0.1 W/cm^2 (1 kW/m^2), and the wind velocity of 0.5 m/sec. All these input variables for the calculations correspond to the meteorological conditions in Jambi City as mentioned in 11-1-2.

Figure 11-12 shows the relation between the power transmission capacity and the line length with the cross section of the conductors taken as a parameter, when the voltage drop is kept at 5% or lower.

From the above table and figure, it can be seen that the 150 mm^2 size aluminum alloy conductor is well capable of transmitting a power of 3,000 to 5,000 kW (110-180A in current) per circuit. Table 11-8 shows the specifications of the two different types of aluminum alloy conductors.

Table 11-7 Ampacity of the Aluminum Alloy Conductors

Temperature Limit	Bare All Aluminum Alloy Conductor (AAAC)					Cross-Linked Polyethylene (XLPE) Insulated All Aluminum Alloy Conductor (AAAC)			
	35 mm^2	70 mm^2	120 mm^2	150 mm^2	240 mm^2	70 mm^2	120 mm^2	150 mm^2	240 mm^2
90°C	156	244	347	402	545	247	348	412	546
75°C	129	199	280	323	435	201	282	332	439
60°C	92	138	188	214	279	137	188	218	279

Input Variable for Calculation:

Ambient temperature	:	35°C
Wind velocity	:	0.5 m/sec
Solar radiation	:	0.1 W/cm^2
Specific thermal resistance of cross-linked polyethylene	:	450°C cm/W

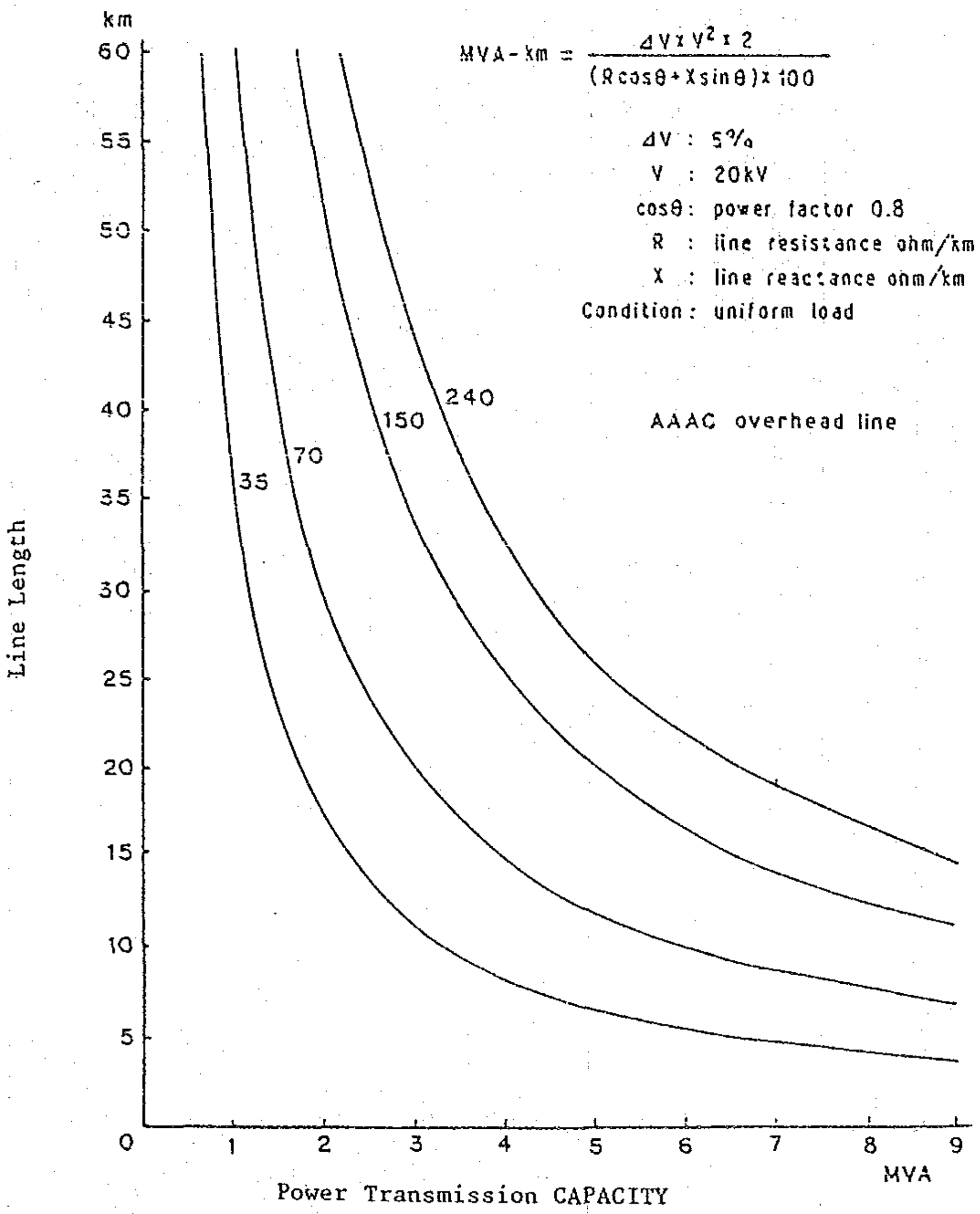


Figure 11-12 Relation between Power Transmission Capacity and Line Length

Table 11-8 Specifications of the Aluminum Alloy Conductors

	Bare All Aluminum Alloy Conductor (AAAC)	Cross-Linked Polyethylene (XLPE) Insulated All Aliminum Alloy Conductor (AAAC)
	150 mm^2	150 mm^2
Nominal cross section (mm^2)	150	150
Actual cross section (mm^2)	147.11	147.11
Composition (strands & diameter)	37 x 2.25	37 x 2.25
Weight (kg/km)	406	603
Rated breaking strength (kg)	4,190	3,772
Diameter (mm)	15.8	15.8
Coefficient of linear expansion (x 10^{-6} per °C)	23	23
Resistance at 20°C (ohm/km)	0.2272	0.2272
Resistivity (ohm.mm^2/m)	0.0334	0.0334

(2) Underground Cables

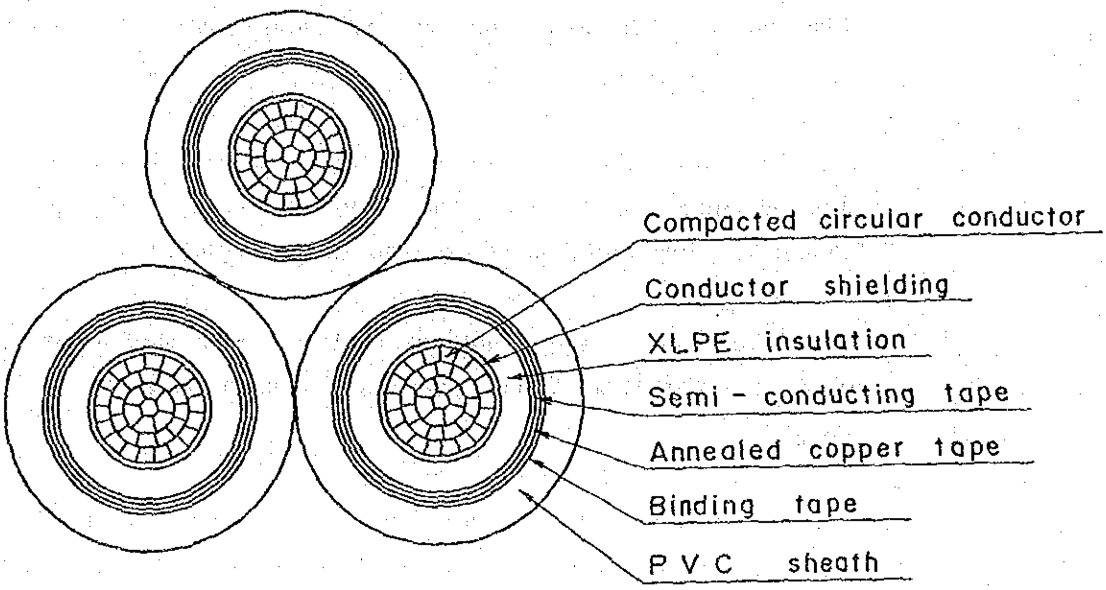
The tie line linking the proposed power plant with the existing PLTD Payo Salincah should be of the underground type, and, for this type, a 325 mm^2 size copper cable conductor should be used.

For the feeder line within the compound of the power plant and the outgoing cable from the transformer, a 240 mm^2 size aluminum alloy cable conductor should be employed.

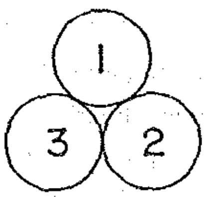
The underground cable should be of the cross-linked polyethylene insulated type, with a cross-sectional profile as given in Figure 11-13.

Table 11-9 gives the ampacity of the cross-linked polyethylene insulated cable conductors both of aluminum alloy and copper, for the case when their self radiation is kept at 90°C or lower. It should be noted that the self radiation of the conductors is subject to soil quality, and so is their ampacity. The cable laying depth should be 0.8 meters.

Per phase current of the underground cable of the tie line will be 613.4A with the transmission capacity being set at 17,000 kW and power factor at 80%. Per phase current of the underground cable of the outgoing feeder line will be 361A with the transmission capacity being set at 10,000 kW, taking into account the additional amount of power needed for emergency interchange, and power factor at 80%. A 240 mm^2 size aluminum alloy cable conductor will be needed for the double laying installation.



Identification



1 : Black
2 : Red
3 : Yellow

Colour or sheath : Grey

Figure 11-13 Cross-Sectional Profile of the Cross-Linked Polyethylene Insulated Copper Cable Conductor

Table 11-9 Ampacity of the Cross-Linked Polyethylene Insulated Undergound Cable Conductor

(Ampere)

Material	Aluminum Alloy				Copper	
Size mm² / Laying	70mm²	150mm²	240mm²	300mm²	325mm²	400mm²
Single laying	233	355	469	531	743	836
Double laying	200	203	399	452	627	703

Input Variables for Calculations:

Specific thermal resistance of insulation	:	350 (°C cm/W)
Specific thermal resistance of sheath	:	600 (°C cm/W)
Specific thermal resistance of soil	:	120 (°C cm/W)
Specific thermal resistance of surface	:	810-900 (°C cm/W)
Base temperature	:	30 (°C)
Conductor max. temperature		90 (°C)
Cable laying depth	:	0.8 (m)
Loss factor	:	0.65

There would be no problem of voltage drops in the above cases because of the short line length.

Table 11-10 shows the specifications for the underground cables for both above purposes.

11-4-3 Insulators

Majority of the insulators used in the existing PLN distribution lines are of the porcelain type, although, occasionally, glass insulators have also been used. The glass insulators are cheaper than the porcelain ones, but are fragile and breakable.

Therefore, for the proposed distribution lines, the porcelain type should be used. They should satisfy the insulation level requirements set forth in Paragraph 11-1-3 (2). The rigid type insulators are expected to resist a bending load of up to 1,250 daN (1 daN = 1.0197 kgf). The strain type insulators should resist a tension load of up to 7,000 daN. These two types of insulators are of the profile and dimensions as shown in Figures 11-14 and 11-15.

11-4-4 Pole Assembling of the Proposed Distribution Line

Figures 11-16 through 11-20 show details of the pole assembling for the proposed distribution lines with hardwares and fittings as mentioned above.

Figure 11-16 shows the top of a standard pole to be erected on a straight line routing. Figure 11-17 shows the top of the dead end or the terminal pole of a distribution line.

Figure 11-18 shows the top of the pole to be erected at a location at which the line routing turns at a large angle.

Table 11-10 Specifications of Underground Cables

	Tie Line		Outgoing Feeder
Type	A strand of three single XLPE insulated cables		A strand of three single XLPE insulated cables
Material	Copper	Copper	Aluminum alloy
Size (mm^2)	325	400	240
Diameter (mm)	98	103	86
Resistance at 20°C (ohm/km)	0.0579	0.0462	0.125
Weight (kg/km)	13,400	15,700	6,100
Ampacity (A)			
Single laying	743	836	469
Double laying	627	703	399

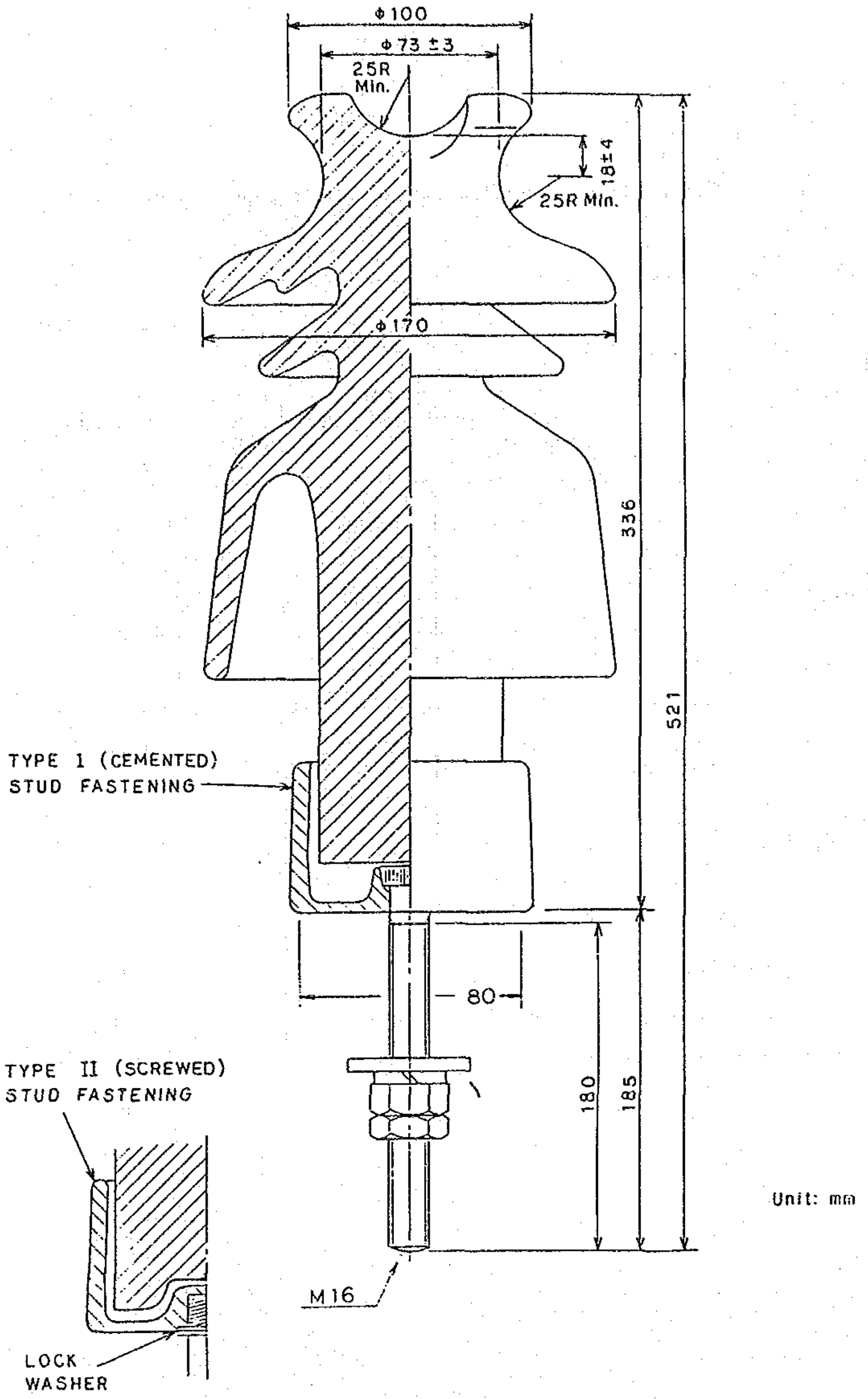
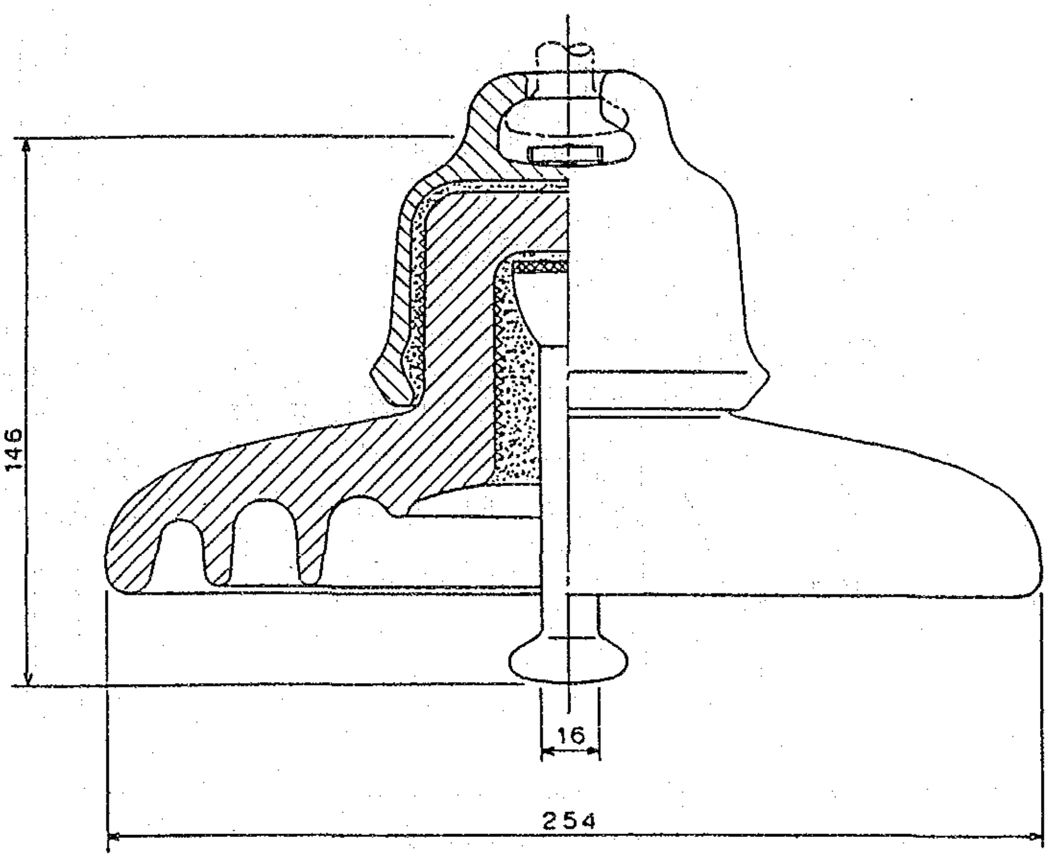


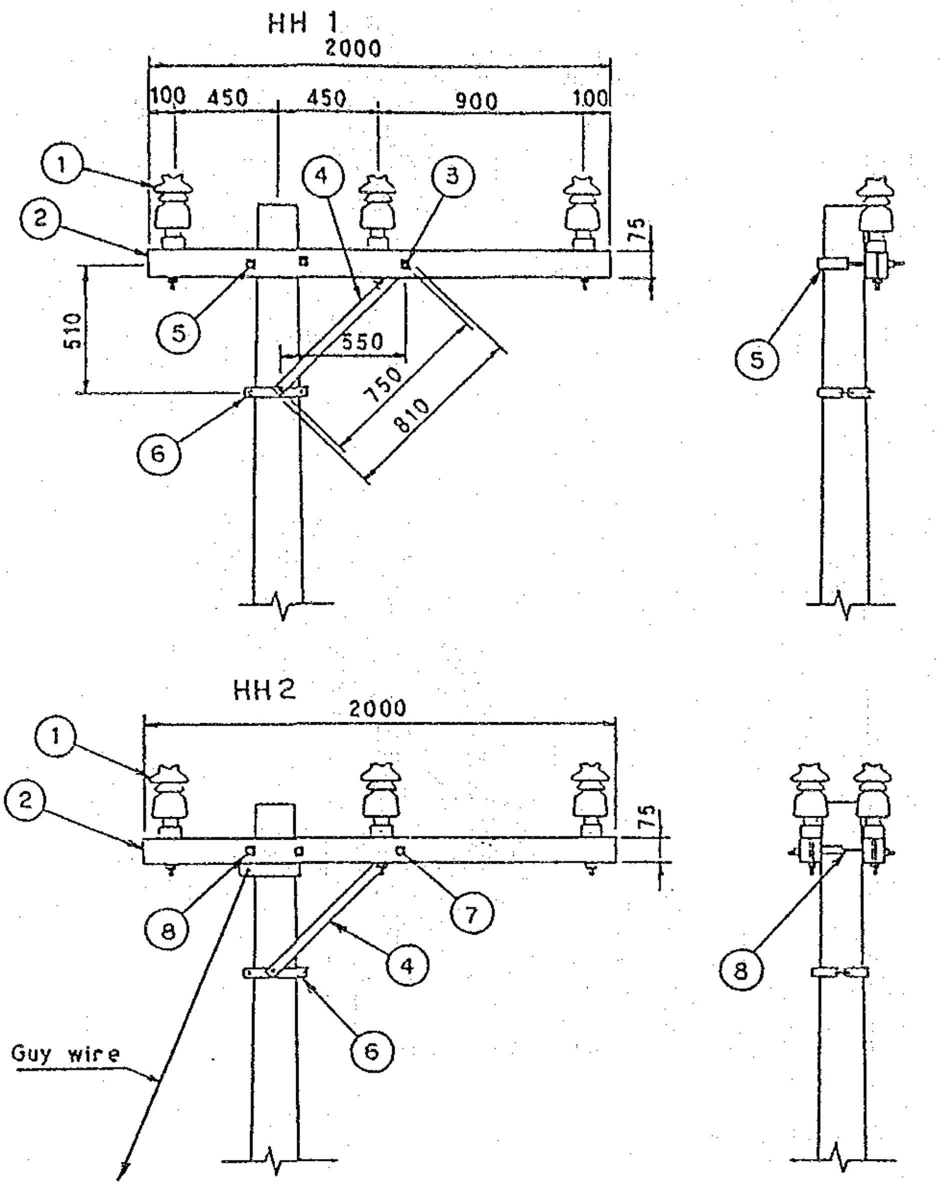
Figure 11-14 Rigid Type Insulation



"PORCELAIN SHALL HAVE STRAIGHT CYLINDRIAL HEAD WITH SANDED FACE"

Unit: mm

Figure 11-15 Strain Type Insulator



8		1	Double arm band
7		1	Double arming bolts & nuts M16×400
6	1	1	Arm tie band
5	1		Single arm band
4	1	2	Arm tie type-750
3	1		Bolts & Nuts M16×120
2	1	2	Cross arm type-2000A
1	3	6	P.P. type insulator with tie
Item	HH 1	HH 2	Components
	Q'ty		

Note:
To channel crossarms the same components applied.

Figure 11-16 Pole Assembly on Straight Line Routing