FIG. 6-2-6(1) BULALO PLANT A STEAM SUPPLY PROJECTION

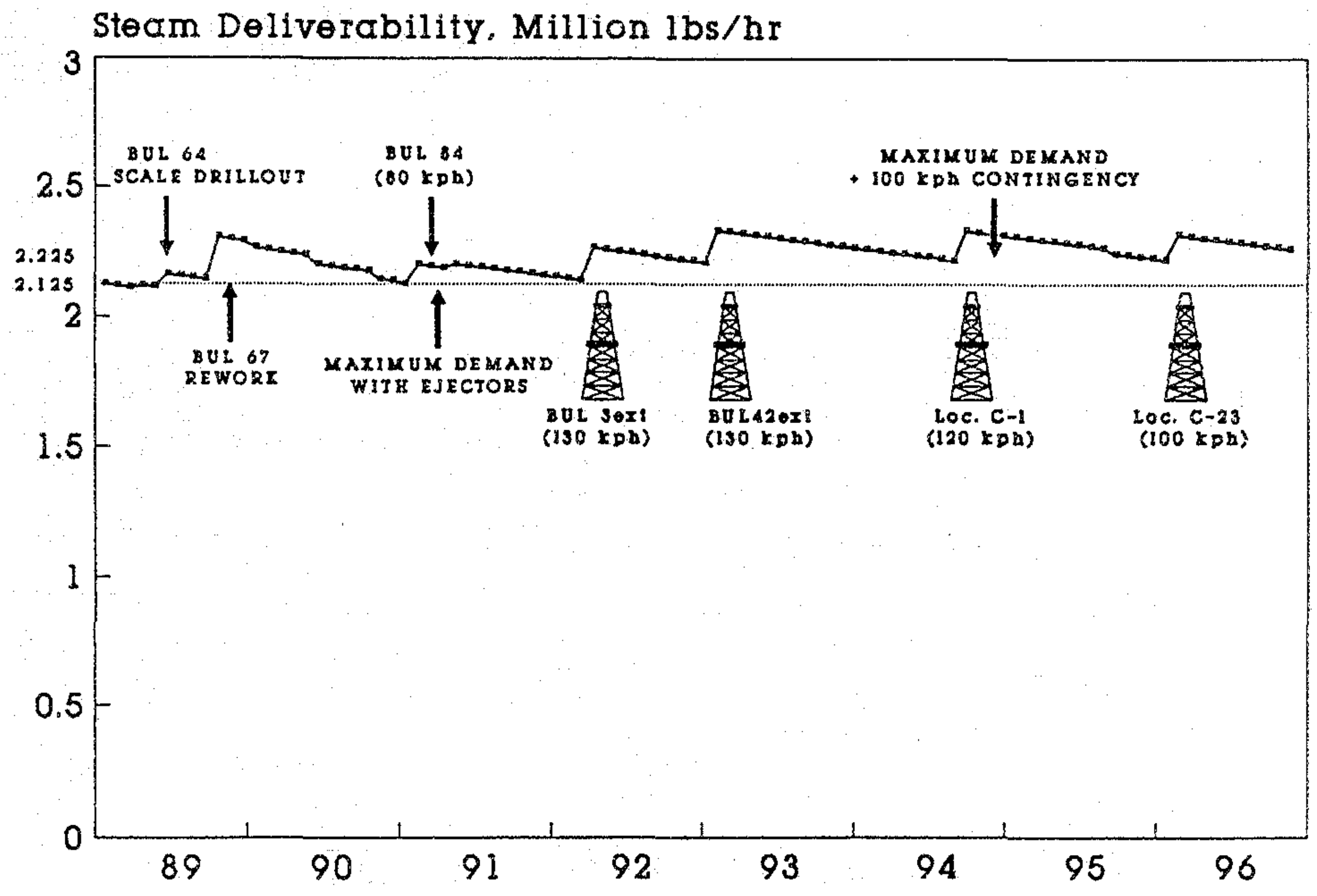


FIG. 6-2-6 (2) BULALO PLANT B STEAM SUPPLY PROJECTION

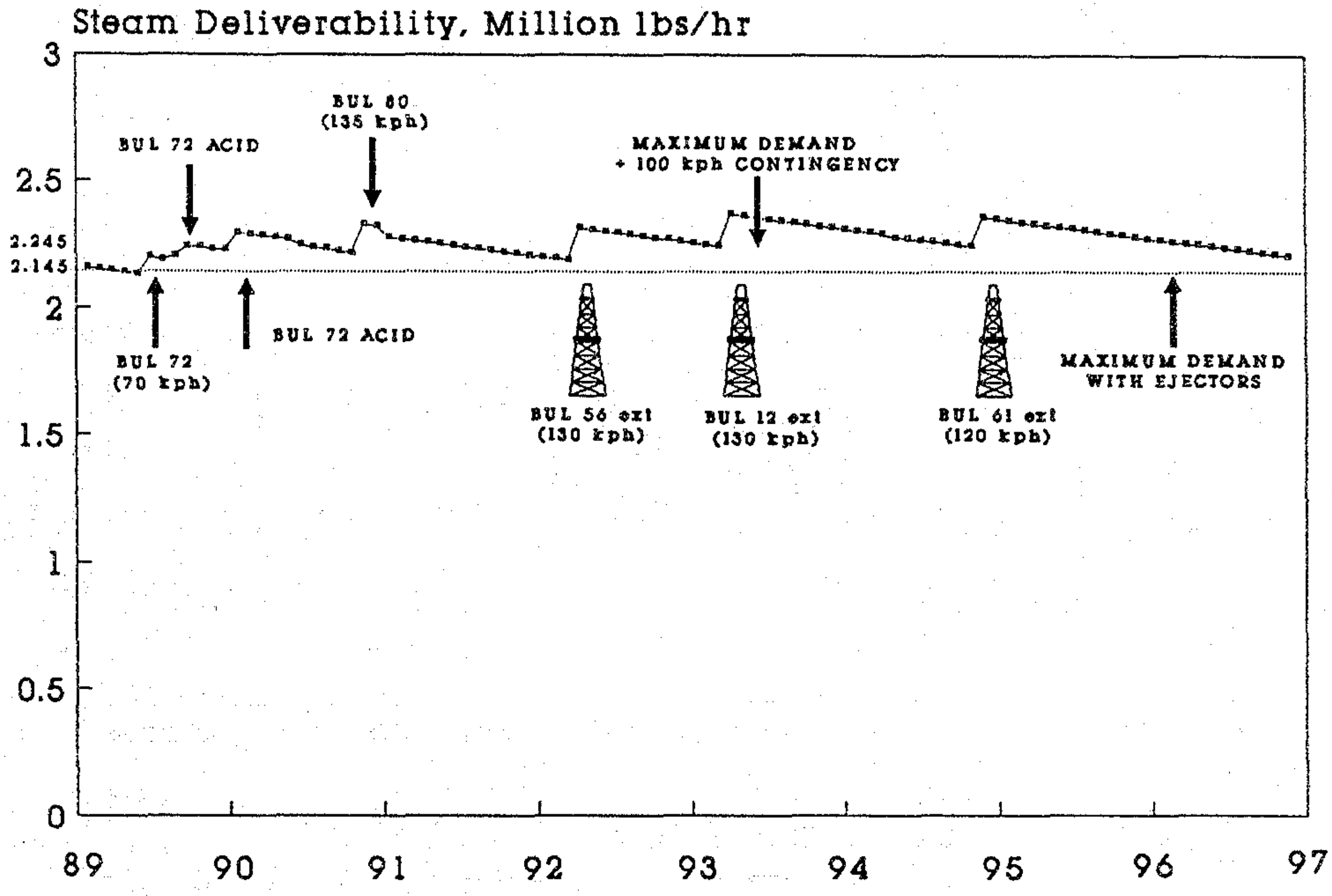
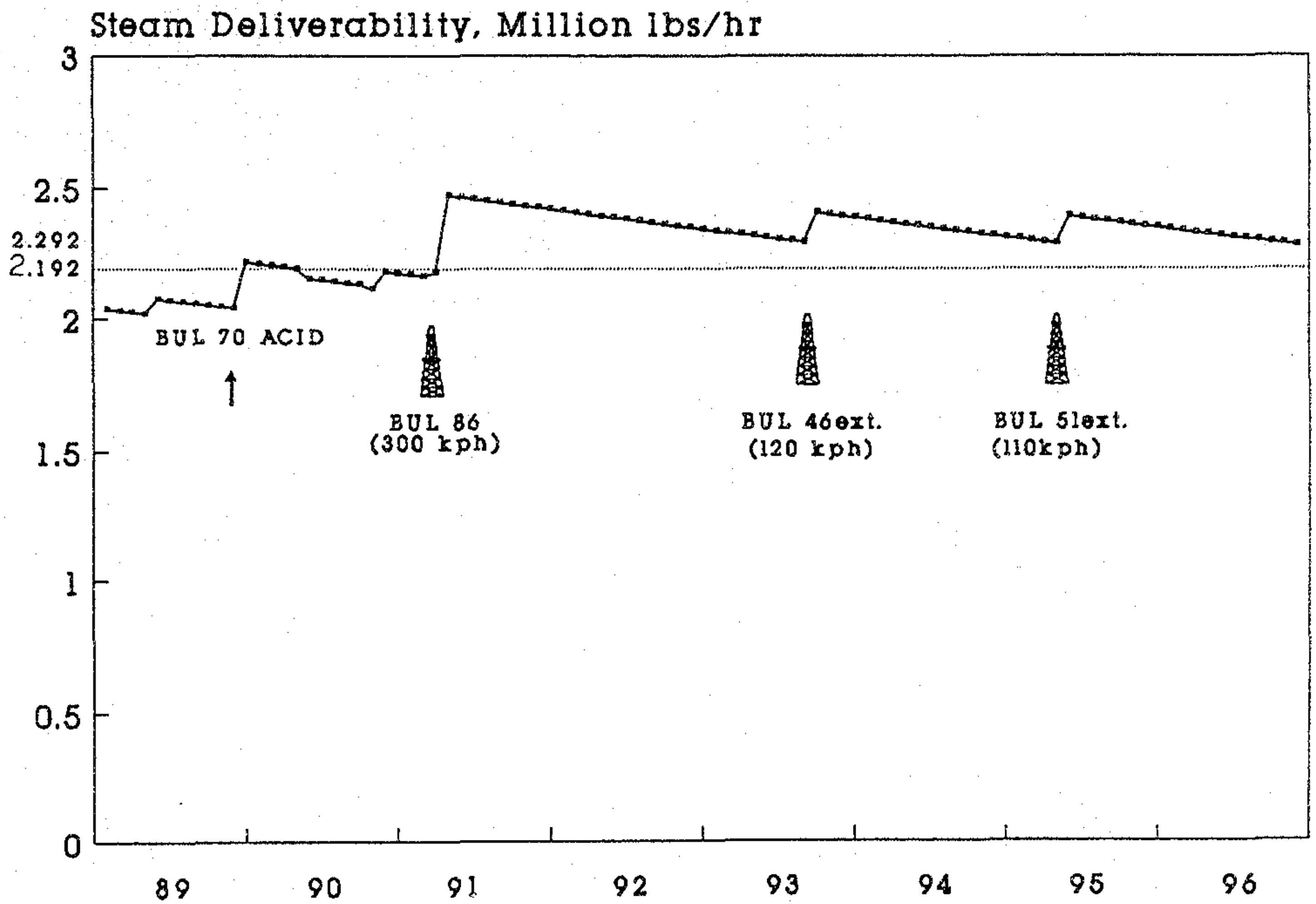
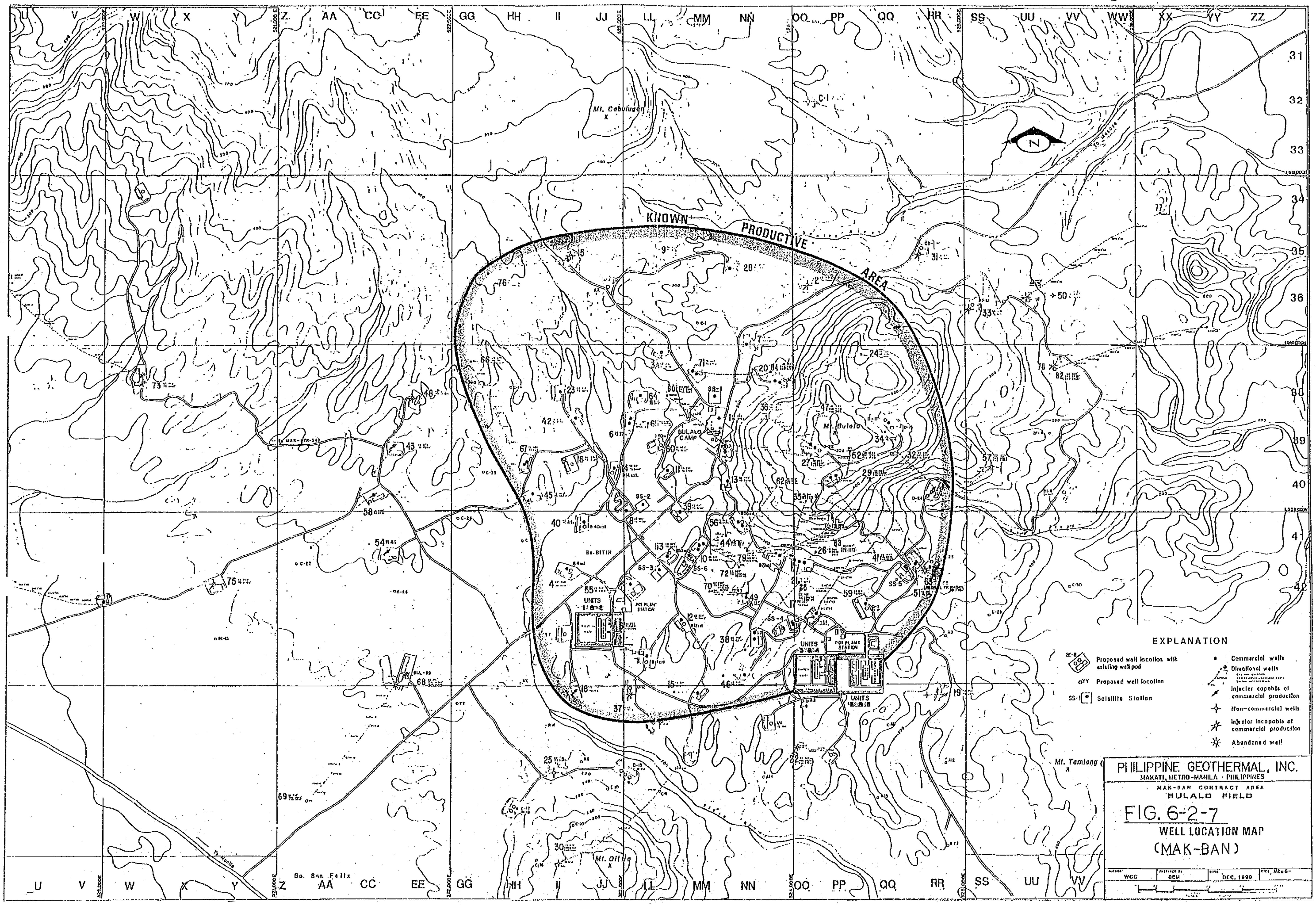


FIG. 6-2-6(3) BULALO FIELD PLANT C STEAM SUPPLY PROJECTION




KNOWN PRODUCTIVE AREA
Mt. Cabulugan
Mt. Bulalo
BULALO CAMP
Mt. Tamlong
Mt. Olila
Bo. San Felix
Bo. BITIN
SS-1
SS-2
SS-3
SS-4
SS-5
SS-6
UNITS 1 & 2
UNITS 3 & 4
UNITS 5 & 6
PGI PLANT STATION
To Manila
EXPLANATION
Proposed well location with existing well pad
Commercial wells
Directional wells
Proposed well location
Injector capable of commercial production
Satellite Station
Non-commercial wells
Injector incapable of commercial production
Abandoned well
PHILIPPINE GEOTHERMAL, INC.
MAKATI, METRO-MANILA · PHILIPPINES
MAK-BAN CONTRACT AREA
BULALO FIELD
FIG. 6-2-7
WELL LOCATION MAP
(MAK-BAN)
DEC. 1990

3. Present Status of Power Plant Facilities

(1) General

The frequency of shutdowns of Units No. 1 to 6 of Mak-Ban Geothermal Power Plant in 5 years from 1986 to 1990 was 239 times and the total shutdown days were 839, which is equivalent to 7.7% of the total operating days as shown in Table 6-2-6. (A plant shutdown of shorter duration than one day is counted as one day.)

The causes of shutdowns are classified in the following: (The ratio is shown in the percentage of shutdown days.)

Cause of the Plant Shutdown	Ratio
Plant overhaul/maintenance	58.8%
Plant electrical system faults	16.3%
Cooling water pipeline troubles	8.3%
Hydrogen gas cooler cleaning	5.5%
Troubles of PGI steam supply system	4.2%
Condenser vacuum low	3.9%
Spark of generator slip ring carbon brushes	1.3%
Governor system troubles	1.3%
Power System faults	0.5%

(2) Mechanical Facilities

a. Plant Overhaul and Maintenance

The shutdown days for the plant overhaul accounts for nearly 60% of the total shutdown days. The number of days required for one overhaul is generally a matter of 4 weeks, but more days are needed if the conditions of turbine rotor are serious. The maximum number of days recorded in this power plant is 12 weeks.

b. Cooling Water Pipe Troubles

Cooling water pipeline troubles and condenser vacuum low are caused by the pipe material. Cleaning of hydrogen gas cooler becomes necessary to restore the coefficient of overall heat transmission of the heat exchanger tubes by removing the algae growth and sludge.

c. Troubles of PGI Steam Supply System

Same as in Tiwi Geothermal Power Plant.

d. Governor System Troubles

Same as in Tiwi Geothermal Power Plant.

(3) Electric Facilities

The plant electric facilities are grouped into those within the powerhouse and those in the switchyard. Problems common to both facilities in this power plant are corrosion of conductors, terminals, insulations, supports, overhead ground wires, etc., due to H_2S gas contained in the non-condensable gas (NCG), which cause mis-operation of relays, mal-operation of the equipment, broken cables, insulation breakdown of insulators, etc.

Mak-Ban Power Plant is located in Laguna Province in Luzon Island, and it is connected with the major power demand area of Metropolitan Manila by relatively short transmission lines of about 70 km. Probability of plant trips due to transmission system faults is relatively low as compared with Tiwi Power Plant.

The problems with electric facilities and countermeasures are discussed in Subsection 4.

The frequency and number of days of the plant trips by the causes are shown in Table 6-2-7 "Summary of Plant Shutdowns". Most problems occurred in Plants A and B, and practically no problem was experienced in Plant C.

Table 6-2-7 Summary of Plant Shutdowns

(1/4)

Cause of Shutdown	Year	Mak-Ban Power Plant													
		Unit 1		Unit 2		Unit 3		Unit 4		Unit 5		Unit 6		Total	
		Times	Days	Times	Days	Times	Days	Times	Days	Times	Days	Times	Days	Times	Days
Hydrogen Gas Cooler Cleaning	1986	0	0	1	4	0	0	1	1	0	0	0	0		
	1987	3	4	1	1	0	0	0	0	0	0	0	0		
	1988	2	2	0	0	3	3	0	0	0	0	0	0		
	1989	5	7	1	1	3	5	0	0	0	0	0	0		
	1990	5	13	2	3	0	0	1	2	0	0	0	0		
	Sub-total	15	26	5	9	6	8	2	3	0	0	0	0	28 (12.1%)	46 (5.5%)
Troubles of PGI Steam Supply System	1986	1	1	0	0	0	0	0	0	0	0	0	0		
	1987	1	1	3	3	2	2	1	1	1	5	1	5		
	1988	0	0	2	2	3	3	0	0	1	1	1	1		
	1989	0	0	1	1	0	0	0	0	0	0	0	0		
	1990	0	0	1	1	3	4	0	0	1	2	1	2		
	Sub-total	2	2	7	7	8	9	1	1	3	8	3	8	24 (10.3%)	35 (4.2%)
Power System Faults	1986	0	0	0	0	0	0	0	0	0	0	0	0		
	1987	1	2	1	1	1	1	0	0	0	0	0	0		
	1988	0	0	0	0	0	0	0	0	0	0	0	0		
	1989	0	0	0	0	0	0	0	0	0	0	0	0		
	1990	0	0	0	0	0	0	0	0	0	0	0	0		
	Sub-total	1	2	1	1	1	1	0	0	0	0	0	0	3 (1.3%)	4 (0.5%)

Table 6-2-7 Summary of Plant Shutdowns

(2/4)

Cause of Shutdown	Year	Mak-Ban Power Plant													
		Unit 1		Unit 2		Unit 3		Unit 4		Unit 5		Unit 6		Total	
		Times	Days	Times	Days	Times	Days	Times	Days	Times	Days	Times	Days	Times	Days
Plant Electrical System Faults	1986	0	0	1	1	2	3	0	0	0	0	0	0		
	1987	1	1	0	0	5	5	1	12	0	0	0	0		
	1988	6	7	7	10	4	4	3	4	1	1	0	0		
	1989	7	8	4	6	8	21	8	11	2	4	5	17		
	1990	3	3	4	5	3	3	3	3	3	3	4	4		
	Sub-total	17	19	16	22	22	36	15	30	6	8	9	21	85 (36.6%)	136 (16.3%)
Plant Overhaul/Maintenance	1986	1	4	-	-	1	29	-	-	1	25	1	5		
	1987	1	6	2	10	1	3	2	9	1	11	2	8		
	1988	3	56	2	28	3	18	3	42	3	34	2	12		
	1989	2	21	2	36	0	0	1	5	4	20	2	20		
	1990	1	1	1	1	1	29	2	18	3	8	3	34		
	Sub-total	8	88	7	75	6	79	8	74	12	98	10	79	51 (21.8%)	493 (58.8%)
Cooling Water Pipeline Troubles	1986	1	3	1	1	0	0	0	0	0	0	0	0		
	1987	0	0	0	0	1	1	0	0	0	0	1	4		
	1988	2	7	3	22	1	9	0	0	0	0	1	13		
	1989	0	0	0	0	0	0	0	0	0	0	0	0		
	1990	0	0	1	9	0	0	0	0	0	0	1	1		
	Sub-total	3	10	5	32	2	10	0	0	0	0	3	18	13 (5.6%)	70 (8.3%)

Table 6-2-7 Summary of Plant Shutdowns

(3/4)

Cause of Shutdown	Year	Mak-Ban Power Plant													
		Unit 1		Unit 2		Unit 3		Unit 4		Unit 5		Unit 6		Total	
		Times	Days	Times	Days	Times	Days	Times	Days	Times	Days	Times	Days	Times	Days
Spark of Generator Slipring Carbon Brushes	1986	0	0	0	0	0	0	0	0	0	0	0	0		
	1987	2	3	0	0	0	0	0	0	0	0	0	0		
	1988	0	0	1	1	1	1	0	0	0	0	0	0		
	1989	1	1	1	1	0	0	0	0	0	0	0	0		
	1990	0	0	0	0	0	0	3	4	0	0	0	0		
	Sub-total	3	4	2	2	1	1	3	4	0	0	0	0	9 (3.8%)	11 (1.3%)
Condenser Vacuum Low	1986	0	0	0	0	0	0	0	0	0	0	0	0		
	1987	0	0	0	0	3	4	0	0	0	0	0	0		
	1988	0	0	1	20	0	0	0	0	0	0	1	1		
	1989	1	2	0	0	0	0	0	0	2	3	0	0		
	1990	0	0	0	0	0	0	1	1	2	2	0	0		
	Sub-total	1	2	1	20	3	4	1	1	4	5	1	1	11 (4.7%)	33 (3.9%)
Governor System Troubles	1986	0	0	0	0	0	0	0	0	0	0	0	0		
	1987	1	1	0	0	0	0	0	0	0	0	0	0		
	1988	1	1	0	0	1	1	0	0	1	1	0	0		
	1989	0	0	0	0	0	0	3	4	0	0	0	0		
	1990	1	1	0	0	0	0	0	0	0	0	1	2		
	Sub-total	3	3	0	0	1	1	3	4	1	1	1	2	9 (3.8%)	11 (1.3%)

Table 6-2-7 Summary of Plant Shutdowns

(4/4)

Cause of Shutdown	Year	Mak-Ban Power Plant													
		Unit 1		Unit 2		Unit 3		Unit 4		Unit 5		Unit 6		Total	
		Times	Days	Times	Days	Times	Days	Times	Days	Times	Days	Times	Days	Times	Days
Grand Total		53	156	44	168	50	149	33	117	26	120	27	129	233 (100%)	839 (100%)

4. Problems with Power Plant Facilities and Countermeasures

(1) Mechanical Facilities

a. Overhaul

The steam quality at Mak-Ban Geothermal Power Plant has been improved since the commissioning, and further in 1990, the steam scrubbing system was added and good results are obtained. Based on the operation records to date, it is judged that the safety of the plant will be maintained with the overhaul once or twice a year. Actually, however, there occur the sticking of MSV and CV rather frequently, and further improvement of steam quality is needed.

b. Improvement of Steam Quality

In Tiwi and Mak-Ban Power Plants, the tests of the steam scrubbing system as a means of steam quality improvement have been continued. As it is one year since the tests were started, the advisability of the addition of the steam scrubbing system to other units was studied. The past record revealed that there was decline of the output due to scaling even with the steam scrubbing system. The improvement and maintenance of the steam quality should be carried out on the responsibility of PGI, the steam supplier.

Recently, the water washing system was developed, and it became possible to remove the scale deposited on the turbine nozzles and blades without shutting the unit down.

As a means of protection of the plant, the water washing system should be added for extension of the continuous operation time, prevention of decline of the output and prevention of rubbing of the rotor due to scaling.

c. Lining of Main Cooling Water Pipes

The main cooling water pipes and hot water pipes are severely corroded, and in the extreme case, as much as 75% of the tube wall thickness is corroded. These pipes are buried underground. Therefore, if the corrosion progresses at the present rate, it is feared that the pipes may collapse under the earth pressure.

It is necessary to line the pipes with stainless steel (SUS 304) pipes of wall thicknesses corresponding to the lost thicknesses and prevent collapsing and further progress of corrosion.

d. Replacement of Auxiliary Cooling Water Pipes

Epoxy-lined carbon steel pipes are used for the auxiliary cooling water pipes, and the lining has peeled off and the pipes have been corroded.

The Supercoat lined carbon steel pipe has been proved to be very stable against the cooling water in Tiwi Power Plant, and has a high anti-corrosive property. Therefore, it is advisable to replace the cooling water pipes with Supercoat lined pipes, SUS pipes or FRP pipes.

e. Suppression of Algae

Algae growth and mud deposited in the generator hydrogen gas cooler tubes decrease the coefficient of overall heat transmission. To recover this, tube cleaning is carried out with a decreased output or unit shutdown.

The following two methods are considered as the means of preventing this decrease of the coefficient, and the selection should be made in consideration of the economy and reliability.

Plan 1.

The cooling water system to the H_2 gas cooler and lubricating oil cooler will be modified from the existing open cycle to the closed cycle and the growth of algae will be suppressed by shielding from the sun light.

Plan 2.

The H_2 gas cooler will be equipped with cleaning brushes so that the interior of the tubes may be cleaned automatically and continuously.

f. Improvement of Labyrinth Packing Material

The labyrinth packings of the main shaft of the turbine suffered from severe corrosion, but since the packings were replaced with stainless steel packings, the trouble of the labyrinth packings has been remedied.

g. Diffusion of H_2S gas and Addition of After-condenser

With No. 1 Unit through No. 4 Unit, the steam ejectors are in normal use and the gas compressors are kept on standby.

At present, the gas compressors suffer surging and corrosion has progressed extensibly. Thus, it is judged that the gas compressors cannot be used any longer.

For the steam ejectors to be used normally without troubles, it is advisable to add after-condensers to the steam ejectors and protect the surrounding equipment from corrosion due to the discharged steam condensate. And further it is advised that the discharge from the ejectors be led to the outlet of forced draft of the cooling towers to effect better diffusion and decrease the ground concentration of H_2S gas. (Fig. 6-2-8 (1), (2) and (3))

h. Partial Modification of Cooling Towers

The forced draft fans, hubs and such rotating parts have suffered drain attacks and the fillers have been severely damaged by long use, and they are already in the condition needing drastic repair.

The cooling towers are of wooden structures and the ceiling boards, side boards, louvers, etc. have been corroded severely by the sputtering water and strong acid droplets scattered from the steam ejectors.

Since the power plant is located on the route of typhoons, the side boards, louvers, railings, stairs, etc. have been broken or deformed, and the performance of the cooling towers have been damaged and their safety is in danger.

All the fans, hubs, fillers, side boards, louvers, ceiling boards, railings, stairs, etc. that have been severely damaged should be replaced for recovering the performance of the cooling towers.

Also one third of the upper part of the cooling tower structures and one third of the fan motors should be replaced with new ones.

i. Procurement of Vehicles

At this Mak-Ban Power Plant, there are 271 employees composed of 135 operators, 63 maintenance crew and 73 others. And the power plant has one mobile allocated to Plants A, B and C combined, and the shift operators are reporting to the job getting a lift in the day-shift employees' cars.

The working mode of operators is by the 4 group 3 shift system, but the shift changes are difficult to be made regularly because of difficult transportation.

In some cases, operators cannot help working two shifts continuously. This is a serious problem in the operation of the power plant.

Since the power plant and the residential quarters of the employees are located in the mountains, there is no public transportation available.

And the number of vehicles assigned to the power plants is short, and they are all dilapidated by age and need to be replaced.

For smooth transportation of shift operators and speedy transportation of maintenance crew and security personnel in case of power plant troubles and emergency.

It is advisable to purchase one small bus (capacity: 29 persons) and a jeep (capacity: 7 persons) equipped with a winch.

(2) Electric Facilities

a. Electric Facilities within Powerhouse

(a) Generator equipment

No problem was found with both the stators and the rotors of the generators proper so far. However, as it is more than 10 years already since the commissioning of No. 1 to 4 units, a detailed study on the necessity of the rewedging of stator windings is essential, and rewinding of the rotor and detail inspection of retaining rings are necessary. Slip rings of the excitation circuit were found to have abrasion by sparks and the brush holders were also damaged by corrosion. Repair of the slip rings, and replacement of the brush holders and brushes are necessary. As in Tiwi Power Plant, the H_2 gas consumption was larger than usual. Therefore, H_2 gas seal at the generator stator temperature sensor terminals should be thoroughly inspected. Parts of the AVR also have been corroded to the degree needing replacement.

(b) 4.16 kV and 480 V switchgears and 480 V motor control centers

These equipment are installed in the electric room partitioned from the other sections in the powerhouse and kept at a little higher pressure than the atmosphere by the air conditioners to prevent the atmospheric air from entering. However, the centralized air conditioning system gets out of order once in a while, and the doors of the electric room are opened, when the air of the powerhouse containing H_2S gas enters and gives adverse affects of corrosion and deterioration to the electric equipment, relays, instruments, etc. Though the damage has not been serious so far by the periodical inspection, cleaning and polishing of contacts, but it is necessary to install the H_2S gas diffusion device and maintain the air conditioners.

The magneblast circuit breakers for the generator are installed outside the electric room and exposed to the air containing H_2S gas in the powerhouse.

The contact surfaces are corroded, and heating due to increased contact resistance once caused the burnt circuit breaker. Thus, the circuit breakers for No.2,3 and 4 Unit have been replaced with gas circuit breakers. It would be necessary to consider the replacement of the circuit breaker for No.1 Unit.

The 480 V motor control center has a problem in its design. When one of the cooling fan motors on the cooling tower is grounded, all the cooling fans are tripped, leading to the plant trip. Therefore, it is necessary to consider the selective tripping at grounding faults of this system.

And as there frequently occur the grounding faults and burns of the cooling fan motors, it is necessary to make a detailed investigation of the causes.

b. Electric Facilities in Switchyard

As mentioned before, the steam and H_2S gas in the ejector exhaust cause corrosion, insulation drop, and malfunctioning of the electric facilities in the switchyard, especially the exposed parts of conductors, insulators, disconnecting switches, overhead ground wires, circuit breakers, control equipment, etc. It is noted especially that soon after the commissioning of the plant, the dielectric strength of insulators dropped because of impurities in steam and steam mist deposited on the surface of insulators, and frequent flash-overs occurred. At present, the problem is solved by H.V.I.C. (High Voltage Insulation Compound) coated on the surface of insulators.

As a fundamental measures, the more effective means of diffusion of the ejector exhaust should be established. Some obsolete type OCB should also be replaced with SF6 type circuit breakers.

(3) Instrumentation and Control Equipment

Unlike Tiwi Power Plant, the air conditioning system for the central control room of Mak-Ban Power Plant are operating normally, and such corrosion and deterioration of the equipment and instruments as experienced in Tiwi Power Plant have not occurred. However, the instrumentation and control equipment installed at locations exposed to the atmosphere have been corroded by H_2S gas.

The detail of major problems with instrumentation and control equipment are described in the following.

a. Hotwell Level Control

The automatic level control sometimes malfunctions due to the poor quality of control air. Detailed inspection of the control air system is necessary.

b. Control Board Recorders

Several sets of recorders have been out of order because of servomotor trouble, etc. These recorders should be replaced.

c. Control Board Indicators and Transmitters

Several control board indicators are malfunctioning owing to corrosion and deterioration, and need repair or replacement.

d. Turbine Supervisory Instruments

At present, the turbine supervisory instruments are operating normally, but some of the sensors and pickups have been deteriorated owing to high vibration and high temperature, and should be replaced.

e. Control Air Supply

There are problems with the quality of the control air for No. 5 and No. 6 Units. Detailed inspection of the air supply system, replacement of filters, and check or dryers are necessary.

f. Chemical Dosing System

As the pH sensors and transmitters are installed outdoors, they have been deteriorated severely and should be replaced. Replacement of the automatic pH control should also be considered.

The above problems and their countermeasures are summarized in Tables 6-2-8 and 6-2-9.

Table 6-2-8 Problems and Basic Countermeasures (Mechanical)

Power Plant: Mak-Ban (1/2)

No.	Problem	Basic Countermeasure	Unit No. 1	2	3	4	5	6	Reh	OH	Remarks
M-1	Frequent and long overhaul/maintenance shutdowns	(1) Procurement of turbine spare rotor, nozzle and diaphragm	o	-	-	-	-	-	o	-	
		(2) Installation of water washing system	o	o	o	o	o	o	o	-	
		(3) Procurement of honing machine	-	o	-	-	-	-	o	-	
M-2	Corroded cooling water pipe and vacuum low and water leakage, entailing burst pipe in the future	(1) Internal lining of main cooling water pipe with stainless steel sheets	o	-	o	o	o	o	o	-	
		(2) Additional installation of electrolytic protection system	o	-	o	o	o	o	o	-	
		(3) In Replacement of aux. cooling water pipeline including the headers	o	-	o	o	o	o	o	-	
M-3	Decreased performance of H_2 gas cooler for turbine generator due to algae growth	Installation of automatic tube cleaner or modification of cooling water system from open cycle to closed cycle	o	o	o	o	o	o	o	-	

Note: Reh = Rehabilitation OH = Overhaul

Table 6-2-8 Problems and Basic Countermeasures (Mechanical)

Power Plant: Mak-Ban (2/2)

No.	Problem	Basic Countermeasure	Unit No. 1	2	3	4	5	6	Reh	OH	Remarks
M-4	Decreased performance of cooling tower resulting in high cooling water temperature	Replacement of erroded and poor materials	o	o	o	o	o	o	o	-	
M-5	Corroded surrounding equipment by steam splutter from steam ejector	Installation of aftercondenser and removal of exhaust steam discharge point to downstream of forced draft fans of cooling tower	o	o	o	o	-	-	o	-	
M-6	Sticking of MSV, CV and SCV	(1) Improvement of steam quality									
		(2) Remodeling of MSV, CV and SCV	o	o	o	o	o	o	o	-	
M-7	Difficult operator shift change because of car shortage	Procurement of new vehicles	o	-	-	-	-	-	o	-	
M-8	Steam supplier trouble										
	(1) Low steam quality	Installation of steam scrubber system	o	o	-	-	-	-	-	-	
	(2) Steam supply system trouble	Three (3) small size rupture disks to be fitted instead of one (1) large size rupture disk	o	o	o	o	o	o	-	-	

Table 6-2-9 Problems and Basic Countermeasures (Electrical and I & C)

Power Plant: Mak-Ban (1/3)

No.	Problem	Basic Countermeasure	Unit No. 1	2	3	4	5	6	Reh	OH	Remarks
E-1	Yearly deterioration of generator	(1) Rewedging of generator stator windings	o	o	o	o	-	-	o	-	Depends on the result of detailed inspec-
		(2) Detail inspection of generator rotor winding	o	o	o	o	-	-	o	-	tion during overhaul.
		(3) Pulling out of retaining ring for inspection	o	o	o	o	o	o	o	-	UT test should be conducted.
E-2	Leakage of H_2 gas	Replacement of generator stator temp. sensor terminal board, etc.	o	o	o	o	-	-	o	-	
E-3	Generator rotor slip ring spark and brush, brush holder corrosion	Repair and machining of the slip ring, and replacement of brushes and brush holders.	o	o	o	o	-	-	-	o	
E-4	Generator exciter AVR malfunction	Replacement of AVR	o	o	o	o	-	-	o	-	
E-5	Defective Generator circuit breaker	Existing magneblast circuit breaker should be replaced with SF6 gas circuit breaker	o	-	-	-	-	-	-	o	Existing conditions should be checked.
E-6	4.16 kV & 480 V switchgears and 480 V M.C.C. corrosion	(1) Replacement of corroded parts and servicing of contactors, relays, etc.	o	o	o	o	-	-	-	o	
		(2) Adoption of selective tripping system for CTF motor contorol center	o	o	o	o	o	o	o	-	

Table 6-2-9 Problems and Basic Countermeasures (Electrical and I & C)

Power Plant: Mak-Ban (2/3)

No.	Problem	Basic Countermeasure	Unit No. 1	2	3	4	5	6	Reh	OH	Remarks
E-7	Switchyard equipment corrosion										
	(1) Corroded disconnecting switches	(1) Replacement of defective parts of disconnecting switches	o	o	o	o	-	-	-	o	
	(2) Circuit breaker malfunction	(2) Replacement of OCB with SF6 circuit breaker	o	o	o	o	o	o	-	o	6sets
		(3) Installation of N.C.G. abatement system	o	o	o	o	o	o	o	-	
IC-1	Malfunction of hotwell level control	(1) Overhaul of hotwell level control system	o	o	o	o	o	o	-	o	
		(2) Servicing and repair of instrument/control air system	o	o	o	o	o	o	-	o	
IC-2	Malfunction of T.S.I. (Turbine Supervisory Instruments)	Total replacement	o	o	o	o	-	-	o	-	
IC-3	Deterioration of control board recorders	Replacement of control board recorders	o	o	o	o	-	-	o	-	Obsolete recorders
			o	o	o	o	o	o	o	-	shall be replaced.

Table 6-2-9 Problems and Basic Countermeasures (Electrical and I & C)

Power Plant: Mak-Ban (3/3)

No.	Problem	Basic Countermeasure	Unit No.						Reh	OH	Remarks
			1	2	3	4	5	6			
IC-4	Deterioration/corrosion of control board indicators/transmitters	Replacement/repair of control board indicators/transmitters	o	o	o	o	-	-	o	-	
IC-5	Malfunction of turbine governor system	Overhaul/servicing of turbine governor system	o	o	o	o	o	o	-	o	
IC-6	Malfunction of chemical dosing system	Replacement of automatic dosing system	o	o	o	o	o	o	o	-	

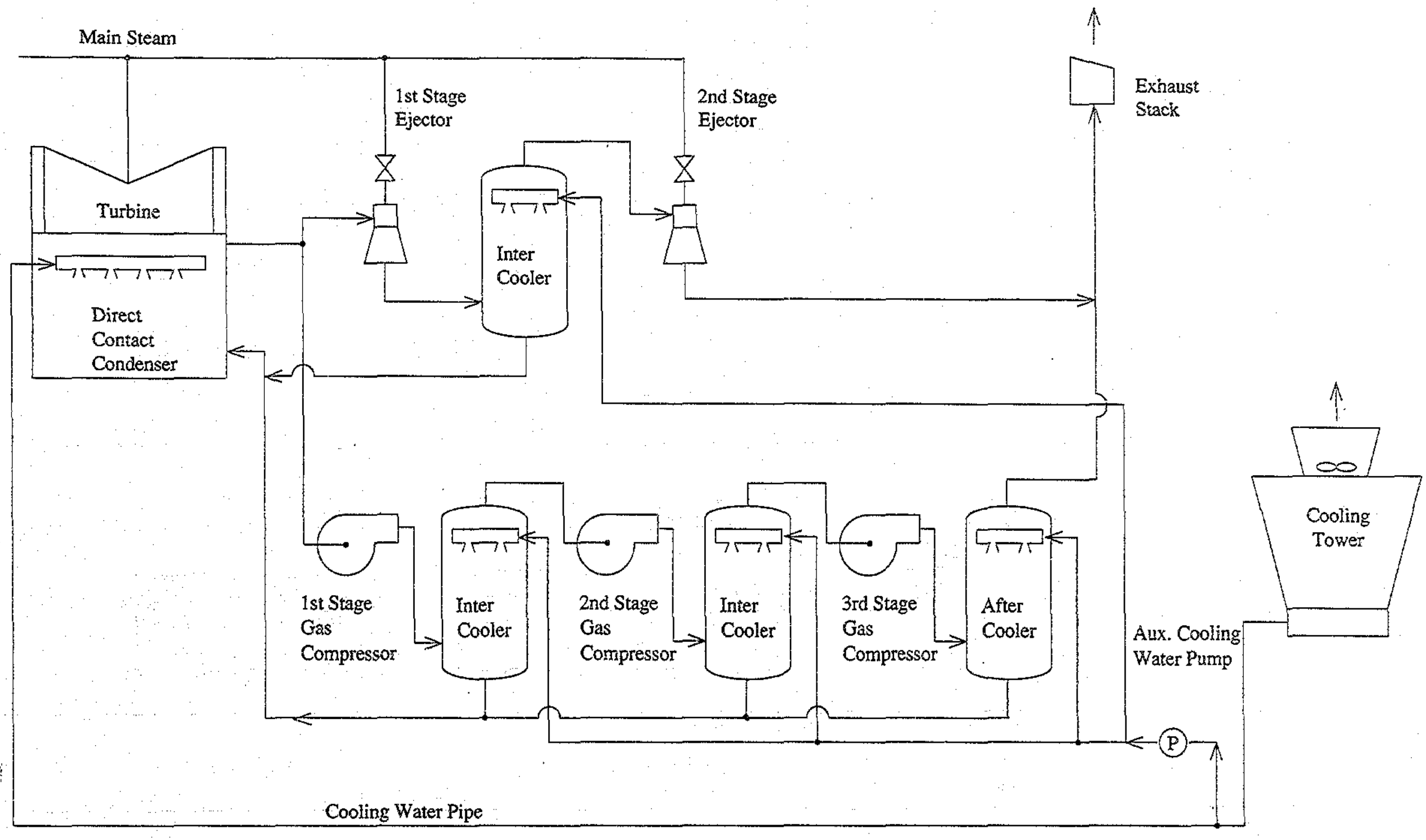


Fig. 6-2-8 (1) Mak-Ban Geothermal Power Plant Gas Extraction System Diagram (Existing)
(No.1~No.4 Unit)

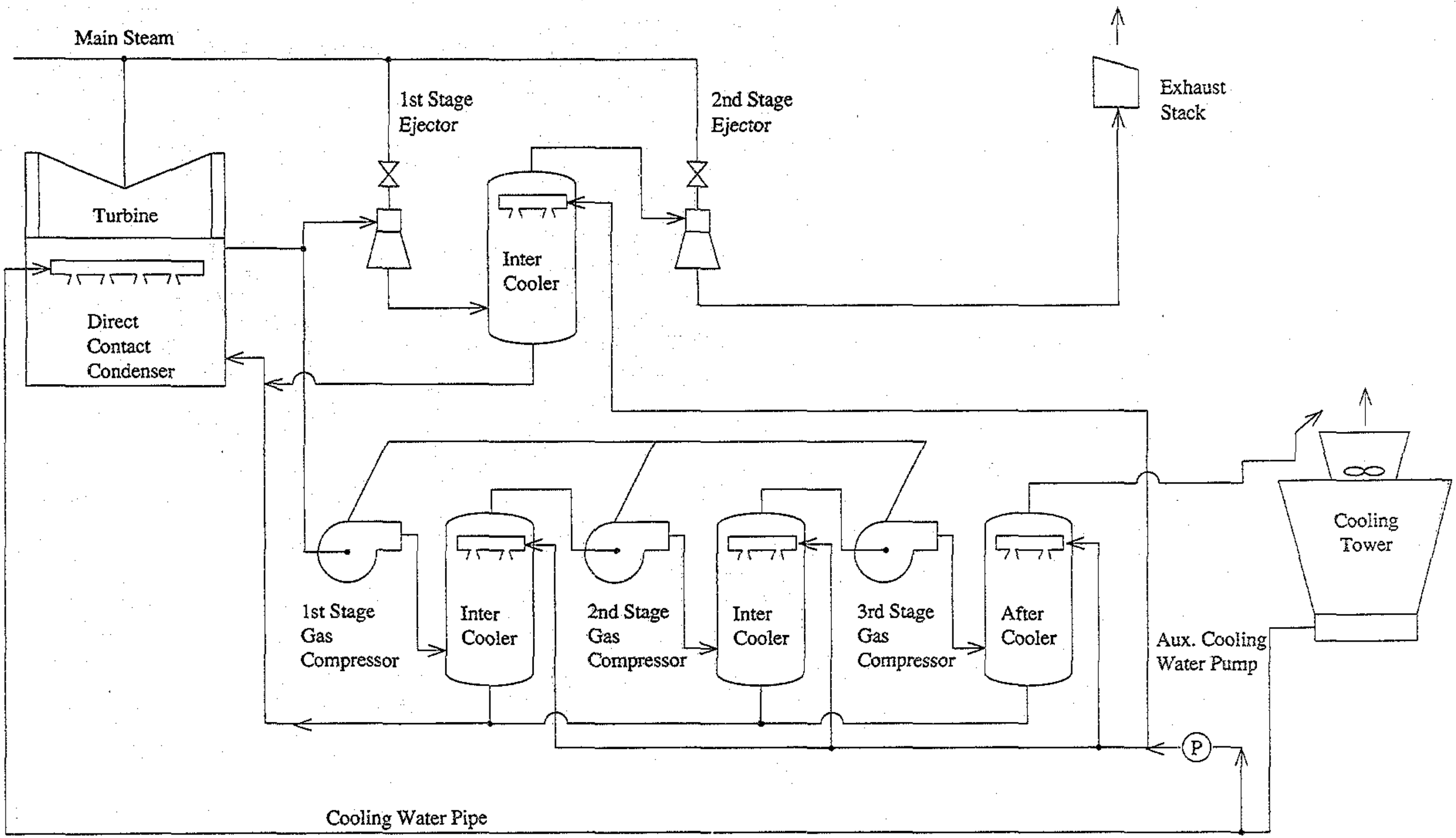


Fig. 6-2-8 (2) Mak-Ban Geothermal Power Plant Gas Extraction System Diagram (Existing)
(No.5~No.6 Unit)

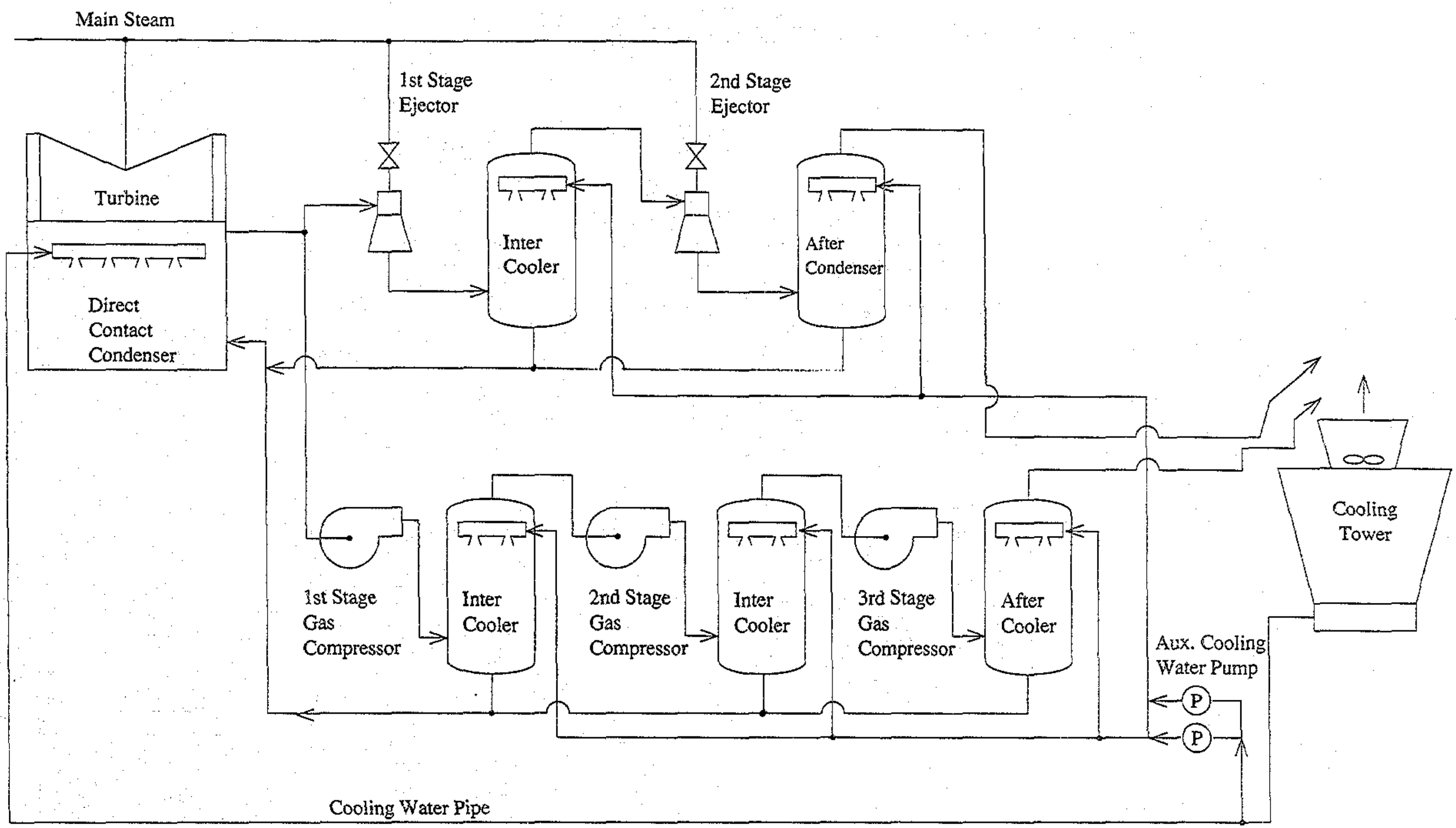


Fig. 6-2-8 (3) Mak-Ban Geothermal Power Plant Gas Extraction System Diagram (Improvement Plan)
(No.1～No.4 Unit)

6.2.3 Formulation of Rehabilitation Plan

1. Criteria for Selection of Rehabilitation Items

The rehabilitation work items and the priority are determined based on the following fundamental concepts for the rehabilitation, the frequency of shutdowns, and the days of the troubles tabulated in Tables 6-2-4 and 6-2-7.

(1) Improvement and repair items aiming at eliminating the causes of faults which resulted in long forced shutdowns.

(2) Replacement or improvement items against troubles or failures which may not only lead to serious plant troubles but also need a long time and excessive expenses for restoration.

(3) Improvement items which are necessary for prevention of pollution or environmental preservation.

(4) Advance replacement of obsolete equipment which are indispensable for proper operation of the plant and spare parts which are or will become unavailable.

(5) Items which are, if adopted in the rehabilitation program, economically advantageous for increase of generated energy with less overhaul frequency and shorter overhaul period.

(6) Improvement items which will economize the operation and maintenance expenses largely.

(7) Replacement or supply of parts which may need a considerable time and expenses if the maintenance is deferred.

2. Rehabilitation Work Items for Tiwi Geothermal Power Plant

The problems with regard to the reliable operation of Tiwi Power Plant for stable power supply can be classified into two categories, those related to the improvement of the power plant facilities and those related to the steam supply.

(1) Rehabilitation Items for Power Plant Facilities and Priority

The rehabilitation items for the mechanical, electrical and instrumentation and control facilities of the power plant and their priority are described in Table 6-2-10.

Table 6-2-10 Power Plant Rehabilitation Items and Priority (Mechanical Part)

Power Plant: Tiwi (1/4)

No.	Rehabilitation Item	Unit No.						Priority			Remarks
		1	2	3	4	5	6	1st	2nd	3rd	
M- 1	Procurement of turbine spare rotor, nozzle and diaphragm	-	-	-	-	o	-	o	-	-	
M- 2	Installation of water washing equipment	o	o	o	o	o	o	o	-	-	
M- 3	Main cooling water pipe inner lining with stainless steel and addition of electrolytic protection system	o	o	o	o	o	o	o	-	-	
M- 4	Replacement of aux. cooling water pipeline including the headers	o	o	o	o	o	o	o	-	-	
M- 5	Installation of hybrid type gas extraction system including removal of ejector steams discharge point to downstream of cooling tower fans	-	-	o	o	-	-	o	-	-	
M- 6	Partial replacement of cooling tower materials	o	o	o	o	o	o	o	-	-	
M- 7	Installation of automatic tube cleaner for generator H_2 gas cooler	o	o	o	o	o	o	o	-	-	
M- 8	Procurement of vehicles	o	-	-	-	-	-	o	-	-	
M- 9	Procurement of honing machine	-	o	-	-	-	-	o	-	-	

Table 6-2-10 Power Plant Rehabilitation Items and Priority (Mechanical Part)

Power Plant: Tiwi (2/4)

No.	Rehabilitation Item	Unit No.						Priority			Remarks
		1	2	3	4	5	6	1st	2nd	3rd	
M-10	Additional steam production wells	o	o	o	o	o	o	o	-	-	Scope of PGI, steam supplier
M-11	Installation of steam scrubber system	-	-	o	o	-	-	o	-	-	ditto
M-12	Modification of rupture disk blowout line	o	o	o	o	o	o	o	-	-	ditto

Table 6-2-10 Power Plant Rehabilitation Items and Priority (Electrical Part)

Power Plant: Tiwi (3/4)

No.	Rehabilitation Item	Unit No.						Priority			Remarks
		1	2	3	4	5	6	1st	2nd	3rd	
E-1	Inspection of generator rotor windings	o	o	o	o	o	o	o	-	-	Detail study is needed.
E-2	Inspection of retaining ring of generator rotor	o	o	o	o	o	o	o	-	-	
E-3	Rewedging of generator stator windings	o	o	o	o	o	o	o	-	-	
E-4	AVR replacement	o	o	o	o	o	o	o	-	-	
E-5	Adoption of selective tripping for CTF motor control center ground faults	o	o	o	o	o	o	o	-	-	

Table 6-2-10 Power Plant Rehabilitation Item and Priority (I & C Part)

Power Plant: Tiwi (4/4)

No.	Rehabilitation Item	Unit No.						Priority			Remarks
		1	2	3	4	5	6	1st	2nd	3rd	
IC-1	Replacement of control board recorders	o	o	o	o	o	o	o	-	-	
IC-2	Repair or replacement of air conditioning system	o	o	o	o	o	o	o	-	-	
IC-3	Repair or replacement of control board indicators/transmitters	o	o	o	o	o	o	o	-	-	
IC-4	Replacement of TSI	o	o	o	o	o	o	o	-	-	
IC-5	Replacement of automatic chemical dosing system	o	o	o	o	o	o	-	o	-	
IC-6	Addditional imstallation of control air compressor	o	-	o	-	o	-	o	-	-	3sets

(2) Securing of Steam Supply

a. All units of Tiwi Power Plant use steam ejectors for NCG extraction, and NAPOCOR is now carrying out the replacement works of the steam gas ejectors of Units No. 1, No. 2, No. 5, and No. 6 with the hybrid type gas extraction system. Upon completion of the works, the necessary steam supply for 330 MW generation will decrease to 2,892 t/hr and 233 t/hr of steam saved will become available for additional generation. As a result, 29 MW of output increase is expected. (Refer to Table 6-2-11)

b. In the conference concerning steam supply held in July 1991 PGI disclosed that it planned to supply 2,700 t/hr of steam to Tiwi Power Plant by the early part of 1992 and 2,900 t/hr by the early part of 1994. (Refer to Fig. 6-2-1.)

c. In order to secure and maintain the steam supply to generate 330 MW, PGI plans to drill the following number of production wells, but no mention was made regarding the financing of the necessary fund for drilling.

   (a) Steam supply increase from the present 2,360 t/hr to 2,900 t/hr is necessary for 330 MW power generation, and the number of necessary additional production wells is estimated to be 20.

   (b) As the production of steam decreases year by year, it is estimated that 8 or more additional wells per year will be necessary to maintain 2,900 t/h of steam supply.

(c) Assumptions for the above estimation

- Steam production per well is assumed to be 30 t/hr, based on 77 production wells now producing 2,360 t/hr.

- Annual deterioration rate of production well of Tiwi Power Plant is assumed to be 7.3%.

- The rate of unsuccessful drilling of production wells is assumed to be 10%.

Table 6-2-11
Reduction in Steam Consumption and Plant Output Increase by Adoption of Hybrid Type Gas Compressor for N.C.G. Extraction

Unit No.	Steam for Ejector			Output Increase by Reduction in Steam Consumption (MW)	Power Consumption by Gas Compressor (MW)	Remarks
	Present Consumption (t/hr)	After Replacement (t/hr)	Reduction in Steam Consumption (t/hr)			
1	71	15.1	55.9	6.8	(1.05)	
2	71	15.1	55.9	6.8	(1.05)	
3	71	71	0	0		
4	71	71	0	0		
5	88.8	27.99	60.81	7.7	(1.05)	
6	88.8	27.99	60.81	7.7	(1.05)	
Total	461.6	228.18	233.42	29	(4.2)	

3. Rehabilitation Work Items for Mak-Ban Geothermal Power Plant

(1) Rehabilitation Items for Power Plant Facilities and Priority

The rehabilitation items for the mechanical, electrical, and instrumentation and control facilities of the power plant and their priority are described in Table 6-2-12.

Table 6-2-12 Power Plant Rehabilitation Items and Priority (Mechanical Part)

Power Plant: Mak-Ban (1/3)

No.	Rehabilitation Item	Unit No.						Priority			Remarks
		1	2	3	4	5	6	1st	2nd	3rd	
M- 1	Procurement of turbine spare rotor, nozzle and diaphragm	o	-	-	-	-	-	o	-	-	
M- 2	Installation of water washing system	o	o	o	o	o	o	o	-	-	
M- 3	Main cooling water pipe inner lining with stainless steel and addition of electrolytic protection system	o	-	o	o	o	o	o	-	-	
M- 4	Replacement of aux. cooling water pipeline including the headers	o	o	o	o	o	o	o	-	-	
M- 5	Installation of automatic tube cleaner for generator H_2 gas cooler	o	o	o	o	o	o	o	-	-	
M- 6	Installation of after-condenser including removal of ejector steam discharge point to downstream of cooling tower fans	o	o	o	o	-	-	o	-	-	
M- 7	Partial replacement of cooling tower materials	o	o	o	o	o	o	o	-	-	
M- 8	Remodeling of main stop valve	o	o	o	o	o	o	o	-	-	
M- 9	Procurement of vehicles	o	-	-	-	-	-	o	-	-	
M-10	Procurement of honing machine	-	o	-	-	-	-	o	-	-	

Table 6-2-12 Power Plant Rehabilitation Items and Priority (Electrical Part)

Power Plant: Mak-Ban (2/3)

No.	Rehabilitation Item	Unit No.						Priority			Remarks
		1	2	3	4	5	6	1st	2nd	3rd	
M-11	Installation of steam scrubber system	-	-	o	o	-	-	o	-	-	Scope of PGI, steam supplier
M-12	Modification of rupture disk line	o	o	o	o	o	o	o	-	-	ditto
E-1	Inspection of generator rotor windings	o	o	o	o	o	o	o	-	-	
E-2	Inspection of retaining ring of generator rotor	o	o	o	o	o	o	o	-	-	
E-3	Rewedging of generator stator windings	o	o	o	o	o	o	o	-	-	
E-4	AVR replacement	o	o	o	o	o	o	o	-	-	
E-5	Replacement of generator stator temperature sensor terminal board	o	o	o	o	o	o	o	-	-	
E-6	Replacement of defective disconnecting switches in switchyard	o	o	o	o	-	-	o	-	-	
E-7	Replacement of switchyard circuit breakers	o	o	o	o	o	o	o	-	-	6sets
E-8	Adoption of selective tripping for CTF motor control center ground faults	o	o	o	o	o	o	o	-	-	

Table 6-2-12 Power Plant Rehabilitation Items and Priority (I&C Part)

Power Plant: Mak-Ban (3/3)

No.	Rehabilitation Item	Unit No.						Priority			Remarks
		1	2	3	4	5	6	1st	2nd	3rd	
IC-1	Replacement TSI sensors/parts	o	o	o	o	-	-	o	-	-	
IC-2	Replacement of control board recorders	o	o	o	o	-	-	o	-	-	
IC-3	Replacement of control board indicators/ transmitters	o	o	o	o	-	-	o	-	-	
IC-4	Replacement of chemical dosing system	o	o	o	o	-	-	-	o	-	

ANNEX 1. PLANT OPERATIONAL DATA

Tiwi Geothermal Power Plant

Mak-Ban Geothermal Powre Plant

ANNEX 1. PLANT OPERATIONAL DATA

TIWI GEOTHERMAL POWER PLANT UNIT No. 1

	ITEMS		1986	1987	1988	1989	1990
1.	RATED CAPACITY	(MW)	55	55	55	55	55
2.	DEPENDABLE CAPACITY	(MW)	50.49	52.44	48.21	48.42	47.71
3.	AVERAGE LOAD	(MW)	46.11	44.23	43.44	47.88	46.94
4.	GROSS GENERATION	(MWH)	353,821.51	273,472.14	311,887.40	380,976.00	327,648.48
5.	OPERATING HOURS	(Hr)	7,673.83	6,197.12	7,179.63	7,957.60	6,946.72
6.	TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	54,206.38	60,403.50	67,583.13	75,540.73	82,487.45
7.	TOTAL OUTAGE HOURS	(Hr)	*1	2,562.88	1,604.37	802.40	1,813.28
	(1) FORCED OUTAGE	(Hr)	*1	83.70	142.21	255.76	28.96
	(2) MAINTENANCE OUTAGE	(Hr)	*1	121.37	95.35	386.78	266.61
	(3) PLANNED OUTAGE	(Hr)	*1	1,339.02	1,324.36	0	1,500.54
	(4) ECONOMIC SHUTDOWN	(Hr)	*1	202.21	0	0	0
	(5) OUTSIDE TROUBLE	(Hr)	*1	816.58	42.45	159.86	17.17
8.	STATION USED POWER RATIO	(%)	*1	6.06	6.00	5.76	5.94
9.	CAPACITY FACTOR	(%)	*1	56.76	64.56	79.08	68.01
10.	AVAILABILITY FACTOR	(%)	93.25	82.73	81.74	90.84	79.30
11.	HEAT RATE (GROSS)	(BTU/KWH)	*1	26,297	26,755	26,145	25,932
12.	THERMAL EFFICIENCY (GROSS)	(%)	*1	12.98	12.76	13.05	13.16
13.	NUMBER OF STARTS (YEAR)		15	16	20	22	9

COMMISSIONING: MAY 1979 *1: NO DATA AVAILABLE

ANNEX 1. PLANT OPERATIONAL DATA

TIWI GEOTHERMAL POWER PLANT UNIT No. 2

	ITEMS		1986	1987	1988	1989	1990
1.	RATED CAPACITY	(MW)	55	55	55	55	55
2.	DEPENDABLE CAPACITY	(MW)	50.82	49.88	45.68	44.16	45.76
3.	AVERAGE LOAD	(MW)	44.10	40.49	42.08	44.02	44.74
4.	GROSS GENERATION	(MWH)	381,268.84	285,497.90	319,679.67	335,757.75	312,621.48
5.	OPERATING HOURS	(Hr)	8,644.58	7,051.10	7,597.14	7,626.90	6,777.43
6.	TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	57,314.24	64,365.34	71,962.48	79,589.38	86,366.81
7.	TOTAL OUTAGE HOURS	(Hr)	*1	1,708.90	340.94	1,133.10	1,982.57
	(1) FORCED OUTAGE	(Hr)	*1	90.46	231.54	449.17	350.69
	(2) MAINTENANCE OUTAGE	(Hr)	*1	42.64	19.16	107.01	134.72
	(3) PLANNED OUTAGE	(Hr)	*1	1,001.25	52.38	396.60	1,474.09
	(4) ECONOMIC SHUTDOWN	(Hr)	*1	0	0	0	0
	(5) OUTSIDE TROUBLE	(Hr)	*1	574.55	37.86	180.32	23.07
8.	STATION USED POWER RATIO	(%)	*1	6.70	6.20	5.92	5.58
9.	CAPACITY FACTOR	(%)	*1	59.25	66.17	69.67	65.01
10.	AVAILABILITY FACTOR	(%)	96.05	86.98	86.49	87.06	77.37
11.	HEAT RATE (GROSS)	(BTU/KWH)	*1	27,153	27,405	25,940	26,348
12.	THERMAL EFFICIENCY (GROSS)	(%)	*1	12.53	12.45	13.16	12.95
13.	NUMBER OF STARTS (YEAR)		12	17	13	17	18

COMMISSIONING: AUG 1979 *1: NO DATA AVAILABLE

ANNEX 1. PLANT OPERATIONAL DATA

TIWI GEOTHERMAL POWER PLANT UNIT No. 3

	ITEMS		1986	1987	1988	1989	1990
1.	RATED CAPACITY	(MW)	55	55	55	55	55
2.	DEPENDABLE CAPACITY	(MW)	50.34	53.62	51.60	48.94	41.80
3.	AVERAGE LOAD	(MW)	44.25	39.48	39.90	44.96	40.75
4.	GROSS GENERATION	(MWH)	173,871.45	281,864.52	228,412.58	382,304.68	264,944.35
5.	OPERATING HOURS	(Hr)	3,929.14	7,140.09	5,725.28	8,502.59	6,349.34
6.	TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	48,856.09	55,996.18	61,721.46	70,224.05	76,573.39
7.	TOTAL OUTAGE HOURS	(Hr)	*1	1,030.71	1,594.72	257.41	2,410.66
	(1) FORCED OUTAGE	(Hr)	*1	26.72	73.60	207.36	41.60
	(2) MAINTENANCE OUTAGE	(Hr)	*1	32.11	70.29	10.36	0
	(3) PLANNED OUTAGE	(Hr)	*1	20.50	1,326.90	0	2,210.55
	(4) ECONOMIC SHUTDOWN	(Hr)	*1	274.41	0	0	0
	(5) OUTSIDE TROUBLE	(Hr)	*1	676.97	123.93	39.69	158.51
8.	STATION USED POWER RATIO	(%)	*1	7.10	6.48	6.03	6.19
9.	CAPACITY FACTOR	(%)	*1	58.50	47.28	79.35	55.08
10.	AVAILABILITY FACTOR	(%)	90.52	92.47	65.18	97.06	72.48
11.	HEAT RATE (GROSS)	(BTU/KWH)	*1	29,146	27,451	26,101	26,129
12.	THERMAL EFFICIENCY (GROSS)	(%)	*1	11.71	12.43	13.08	13.06
13.	NUMBER OF STARTS (YEAR)		11	12	9	12	11

COMMISSIONING: APR 1980 *1: NO DATA AVAILABLE

ANNEX 1. PLANT OPERATIONAL DATA

TIWI GEOTHERMAL POWER PLANT UNIT No. 4

ITEMS		1986	1987	1988	1989	1990
1. RATED CAPACITY	(MW)	55	55	55	55	55
2. DEPENDABLE CAPACITY	(MW)	53.34	53.77	53.67	54.25	40.11
3. AVERAGE LOAD	(MW)	45.37	37.60	41.49	34.06	39.25
4. GROSS GENERATION	(MWH)	281,931.90	130,359.30	259,900.30	73,344.34	304,261.40
5. OPERATING HOURS	(Hr)	6,214.04	3,467.13	6,264.83	2,153.47	7,594.06
6. TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	49,578.12	53,045.25	59,310.08	61,463.55	69,057.61
7. TOTAL OUTAGE HOURS	(Hr)	*1	5,292.87	335.17	4,422.53	1,165.94
(1) FORCED OUTAGE	(Hr)	*1	12.00	90.48	2.30	752.08
(2) MAINTENANCE OUTAGE	(Hr)	*1	15.55	36.37	0	98.73
(3) PLANNED OUTAGE	(Hr)	*1	0	164.92	787.80	0
(4) ECONOMIC SHUTDOWN	(Hr)	*1	5,115.87	0	2,928.00	296.40
(5) OUTSIDE TROUBLE	(Hr)	*1	149.45	43.40	704.43	18.73
8. STATION USED POWER RATIO	(%)	*1	7.19	6.52	5.07	6.61
9. CAPACITY FACTOR	(%)	*1	27.05	53.80	15.23	63.26
10. AVAILABILITY FACTOR	(%)	94.08	83.24	71.32	24.58	86.69
11. HEAT RATE (GROSS)	(BTU/KWH)	*1	24,146	27,064	26,645	26,239
12. THERMAL EFFICIENCY (GROSS)	(%)	*1	14.13	12.61	12.81	13.01
13. NUMBER OF STARTS (YEAR)		11	8	9	6	8

COMMISSIONING: JUL 1980 *1: NO DATA AVAILABLE

ANNEX 1. PLANT OPERATIONAL DATA

TIWI GEOTHERMAL POWER PLANT UNIT No. 5

	ITEMS		1986	1987	1988	1989	1990
1.	RATED CAPACITY	(MW)	55	55	55	55	55
2.	DEPENDABLE CAPACITY	(MW)	49.18	45.36	50.83	52.34	46.72
3.	AVERAGE LOAD	(MW)	43.34	39.84	47.20	51.98	46.38
4.	GROSS GENERATION	(MWH)	342,230.93	259,793.46	305,236.40	440,695.39	404,971.89
5.	OPERATING HOURS	(Hr)	7,895.74	6,520.95	6,467.21	8,478.47	8,719.13
6.	TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	39,802.18	46,323.13	52,790.34	61,268.81	69,987.94
7.	TOTAL OUTAGE HOURS	(Hr)	*1	2,234.66	2,316.79	281.53	40.87
	(1) FORCED OUTAGE	(Hr)	*1	243.97	146.32	54.31	0
	(2) MAINTENANCE OUTAGE	(Hr)	*1	172.17	57.32	59.55	40.87
	(3) PLANNED OUTAGE	(Hr)	*1	1,385.32	1,083.48	0	0
	(4) ECONOMIC SHUTDOWN	(Hr)	*1	0	0	0	0
	(5) OUTSIDE TROUBLE	(Hr)	*1	433.20	1,029.67	167.67	0
8.	STATION USED POWER RATIO	(%)	*1	7.03	5.74	5.39	6.13
9.	CAPACITY FACTOR	(%)	*1	53.92	63.18	91.45	84.05
10.	AVAILABILITY FACTOR	(%)	86.89	79.37	73.62	96.79	99.53
11.	HEAT RATE (GROSS)	(BTU/KWH)	*1	28,876	27,366	26,728	26,761
12.	THERMAL EFFICIENCY (GROSS)	(%)	*1	11.82	12.47	12.77	12.75
13.	NUMBER OF STARTS (YEAR)		16	11	16	6	1

COMMISSIONING: FEB 1982 *1: NO DATA AVAILABLE

ANNEX 1. PLANT OPERATIONAL DATA

TIWI GEOTHERMAL POWER PLANT UNIT No. 6

	ITEMS		1986	1987	1988	1989	1990
1.	RATED CAPACITY	(MW)	55	55	55	55	55
2.	DEPENDABLE CAPACITY	(MW)	49.63	43.35	49.50	51.26	51.98
3.	AVERAGE LOAD	(MW)	43.11	37.27	46.24	50.53	50.62
4.	GROSS GENERATION	(MWH)	337,568.80	248,670.52	399,686.98	391,270.88	342,258.04
5.	OPERATING HOURS	(Hr)	7,830.76	6,673.46	8,643.03	7.743.36	6,723.70
6.	TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	38,880.05	45,553.51	54,196.54	61,939.90	68,663.60
7.	TOTAL OUTAGE HOURS	(Hr)	*1	2,086.54	104.77	1,016.96	2,036.30
	(1) FORCED OUTAGE	(Hr)	*1	359.70	4.33	18.95	158.24
	(2) MAINTENANCE OUTAGE	(Hr)	*1	7.94	53.94	142.07	24.00
	(3) PLANNED OUTAGE	(Hr)	*1	1,685.33	0	817.75	1,842.26
	(4) ECONOMIC SHUTDOWN	(Hr)	*1	0	0	0	0
	(5) OUTSIDE TROUBLE	(Hr)	*1	33.57	46.50	37.79	11.80
8.	STATION USED POWER RATIO	(%)	*1	7.18	6.16	5.63	5.63
9.	CAPACITY FACTOR	(%)	*1	51.61	82.73	81.21	71.04
10.	AVAILABILITY FACTOR	(%)	85.13	76.43	98.40	88.40	76.75
11.	HEAT RATE (GROSS)	(BTU/KWH)	*1	28,681	27,659	26,735	26,491
12.	THERMAL EFFICIENCY (GROSS)	(%)	*1	11.90	12.34	12.77	12.88
13.	NUMBER OF STARTS (YEAR)		12	12	7	6	8

COMMISSIONING: APR 1982 *1: NO DATA AVAILABLE

ANNEX 1. PLANT OPERATIONAL DATA

MAK-BAN GEOTHERMAL POWER PLANT UNIT No. 1

	ITEMS		1986	1987	1988	1989	1990
1.	RATED CAPACITY	(MW)	55	55	55	55	55
2.	DEPENDABLE CAPACITY	(MW)	50	53	52.45	53.03	54.53
3.	AVERAGE LOAD	(MW)	49.57	52.50	50.92	52.46	54.14
4.	GROSS GENERATION	(MWH)	394,606.42	444,013.90	340,890.30	392,245.53	457,720.59
5.	OPERATING HOURS	(Hr)	7,959.96	8,457.05	6,694.25	7,476.90	8,453.56
6.	TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	58,083.42	66,540.47	73,234.72	80,711.62	89,165.18
7.	TOTAL OUTAGE HOURS	(Hr)	800.04	302.95	2,084.41	1,283.10	300.19
	(1) FORCED OUTAGE	(Hr)	45.01	51.73	191.92	361.35	68.60
	(2) MAINTENANCE OUTAGE	(Hr)	231.80	236.49	804.05	21.73	105.93
	(3) PLANNED OUTAGE	(Hr)	507.38	0	1,085.44	896.89	125.66
	(4) ECONOMIC SHUTDOWN	(Hr)	0	0	0	0	0
	(5) OUTSIDE TROUBLE	(Hr)	15.85	14.73	3.00	3.13	6.25
8.	STATION USED POWER RATIO	(%)	6.64	5.31	5.93	5.17	5.06
9.	CAPACITY FACTOR	(%)	81.90	92.16	70.56	81.41	95.00
10.	AVAILABILITY FACTOR	(%)	90.87	96.54	76.27	85.39	96.57
11.	HEAT RATE (NET)	(BTU/KWH)	23,728	23,257	23,595	23,513	22,513
12.	THERMAL EFFICIENCY (NET)	(%)	14.38	14.68	14.46	14.52	15.16
13.	NUMBER OF STARTS (YEAR)		9	11	12	17	*1

COMMISSIONING: SEP 1979 *1: NO DATA AVAILABLE

ANNEX 1. PLANT OPERATIONAL DATA

MAK-BAN GEOTHERMAL POWER PLANT UNIT No. 2

	ITEMS		1986	1987	1988	1989	1990
1.	RATED CAPACITY	(MW)	55	55	55	55	55
2.	DEPENDABLE CAPACITY	(MW)	43	53	53.33	53.78	53.53
3.	AVERAGE LOAD	(MW)	42.43	52.99	52.13	53.39	53.14
4.	GROSS GENERATION	(MWH)	186,307.13	451,773.01	361,640.81	410,725.40	446,156.10
5.	OPERATING HOURS	(Hr)	4,391.41	8,526.36	6,937.03	7,692.76	8,395.95
6.	TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	50,433.58	58,959.94	65,896.97	73,589.73	81,985.68
7.	TOTAL OUTAGE HOURS	(Hr)	4,368.59	233.64	1,846.97	1,067.24	361.82
	(1) FORCED OUTAGE	(Hr)	49.50	27.75	772.38	79.77	227.66
	(2) MAINTENANCE OUTAGE	(Hr)	163.88	150.73	0	0	*1
	(3) PLANNED OUTAGE	(Hr)	4,126.75	45.78	1,044.78	841.95	*1
	(4) ECONOMIC SHUTDOWN	(Hr)	0	0	0	0	*1
	(5) OUTSIDE TROUBLE	(Hr)	28.46	9.38	29.81	145.52	*1
8.	STATION USED POWER RATIO	(%)	4.80	5.28	5.50	5.41	5.42
9.	CAPACITY FACTOR	(%)	38.67	93.77	74.86	85.25	92.60
10.	AVAILABILITY FACTOR	(%)	50.13	97.44	79.31	89.48	95.87
11.	HEAT RATE (NET)	(BTU/KWH)	22,285	23,580	23,048	23,556	22,993
12.	THERMAL EFFICIENCY (NET)	(%)	15.32	14.47	14.81	14.49	14.84
13.	NUMBER OF STARTS (YEAR)		10	6	12	10	*1

COMMISSIONING: NOV 1979 *1: NO DATA AVAILABLE

ANNEX 1. PLANT OPERATIONAL DATA

MAK-BAN GEOTHERMAL POWER PLANT UNIT No. 3

ITEMS		1986	1987	1988	1989	1990
1. RATED CAPACITY	(MW)	55	55	55	55	55
2. DEPENDABLE CAPACITY	(MW)	49	50	49.47	53.84	51.60
3. AVERAGE LOAD	(MW)	48.66	50.11	49.41	53.43	52.68
4. GROSS GENERATION	(MWH)	372,412.0	419,959.52	378,678.76	453,334.95	417,999.80
5. OPERATING HOURS	(Hr)	7,653.95	8,380.68	7,663.63	8,485.37	7,934.51
6. TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	52,151.19	60,531.87	68,195.50	76,680.87	84,615.38
7. TOTAL OUTAGE HOURS	(Hr)	1,106.05	379.32	1,120.37	274.63	825.49
(1) FORCED OUTAGE	(Hr)	57.92	22.16	38.28	63.92	12.27
(2) MAINTENANCE OUTAGE	(Hr)	35.00	5.62	204.27	48.10	85.15
(3) PLANNED OUTAGE	(Hr)	1,011.32	78.82	873.83	125.75	667.85
(4) ECONOMIC SHUTDOWN	(Hr)	0	0	0	0	0
(5) OUTSIDE TROUBLE	(Hr)	1.81	272.72	3.99	36.86	59.52
8. STATION USED POWER RATIO	(%)	6.69	5.56	5.60	5.43	5.38
9. CAPACITY FACTOR	(%)	77.30	87.16	78.38	94.09	86.76
10. AVAILABILITY FACTOR	(%)	87.37	95.67	87.29	97.39	91.27
11. HEAT RATE (NET)	(BTU/KWH)	23,405	23,843	23,615	23,425	23,282
12. THERMAL EFFICIENCY (NET)	(%)	14.59	14.31	14.45	14.57	14.66
13. NUMBER OF STARTS (YEAR)		8	10	8	14	9

COMMISSIONING: AUG 1980

ANNEX 1. PLANT OPERATIONAL DATA

MAK-BAN GEOTHERMAL POWER PLANT UNIT No. 4

	ITEMS		1986	1987	1988	1989	1990
1.	RATED CAPACITY	(MW)	55	55	55	55	55
2.	DEPENDABLE CAPACITY	(MW)	48	50	48.62	49.57	50.32
3.	AVERAGE LOAD	(MW)	47.02	50.22	48.43	49.25	49.95
4.	GROSS GENERATION	(MWH)	347,082.68	220,443.37	356,567.05	402,577.35	407,936.38
5.	OPERATING HOURS	(Hr)	7,381.26	4,389.18	7,362.39	8,173.70	8,199.75
6.	TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	52,971.43	57,360.61	64,723.0	72,896.70	81,096.45
7.	TOTAL OUTAGE HOURS	(Hr)	1,378.74	4,370.82	1,421.61	575.50	560.25
	(1) FORCED OUTAGE	(Hr)	32.61	0	179.29	490.48	57.60
	(2) MAINTENANCE OUTAGE	(Hr)	242.72	0	84.36	0	127.28
	(3) PLANNED OUTAGE	(Hr)	1,083.85	975.02	1,155.65	85.02	367.65
	(4) ECONOMIC SHUTDOWN	(Hr)	0	0	0	0	0
	(5) OUTSIDE TROUBLE	(Hr)	19.56	3,395.80	2.31	10.80	7.72
8.	STATION USED POWER RATIO	(%)	6.58	5.46	5.40	5.43	5.57
9.	CAPACITY FACTOR	(%)	72.04	45.75	73.81	83.56	84.67
10.	AVAILABILITY FACTOR	(%)	84.26	49.90	83.84	93.43	93.69
11.	HEAT RATE (NET)	(BTU/KWH)	24,494	24,342	24,241	24,791	25,025
12.	THERMAL EFFICIENCY (NET)	(%)	13.93	14.02	14.08	13.77	13.64
13.	NUMBER OF STARTS (YEAR)		11	7	6	15	13

COMMISSIONING: OCT 1980

ANNEX 1. PLANT OPERATIONAL DATA — MAK-BAN GEOTHERMAL POWER PLANT UNIT No. 5

ITEMS		1986	1987	1988	1989	1990
1. RATED CAPACITY	(MW)	55	55	55	55	55
2. DEPENDABLE CAPACITY	(MW)	45.14	50.03	46.68	49.99	52.04
3. AVERAGE LOAD	(MW)	44.78	49.61	46.20	49.31	51.43
4. GROSS GENERATION	(MWH)	354,617.56	371,589.83	369,721.85	405,492.266	416,114.90
5. OPERATING HOURS	(Hr)	7,919.54	7,490.62	8,002.71	8,223.49	8,083.64
6. TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	18,901.6	26,392.22	34,394.93	42,618.42	50,702.06
7. TOTAL OUTAGE HOURS	(Hr)	840.46	1,269.38	781.29	536.51	674.94
(1) FORCED OUTAGE	(Hr)	29.05	0	9.57	96.56	23.99
(2) MAINTENANCE OUTAGE	(Hr)	0	8	70.32	73.11	14.92
(3) PLANNED OUTAGE	(Hr)	802.06	1,170.15	666.88	365.26	614.36
(4) ECONOMIC SHUTDOWN	(Hr)	0	0	0	0	0
(5) OUTSIDE TROUBLE	(Hr)	9.35	91.23	34.52	1.58	23.09
8. STATION USED POWER RATIO	(%)	7.31	5.96	6.24	6.47	6.67
9. CAPACITY FACTOR	(%)	73.60	77.12	76.53	84.16	86.37
10. AVAILABILITY FACTOR	(%)	90.40	85.51	91.50	93.89	92.54
11. HEAT RATE (NET)	(BTU/KWH)	22,774	23,502	24,505	23,519	22,308
12. THERMAL EFFICIENCY (NET)	(%)	14.99	14.52	13.93	14.51	15.30
13. NUMBER OF STARTS (YEAR)		*1	*1	*1	*1	*1

COMMISSIONING: SEP 1984 *1: NO DATA AVAILABLE

ANNEX 1. PLANT OPERATIONAL DATA

MAK-BAN GEOTHERMAL POWER PLANT UNIT No. 6

	ITEMS		1986	1987	1988	1989	1990
1.	RATED CAPACITY	(MW)	55	55	55	55	55
2.	DEPENDABLE CAPACITY	(MW)	48.14	48.35	48.45	51.24	50.56
3.	AVERAGE LOAD	(MW)	47.08	47.64	47.48	50.34	49.77
4.	GROSS GENERATION	(MWH)	363,069.26	339,287.38	392,191.10	366,796.72	392,310.10
5.	OPERATING HOURS	(Hr)	7,712.08	7,122.55	8,260.08	7,286.47	7,803.90
6.	TOTAL OPERATING HOURS SINCE INITIAL SYNCHRO.	(Hr)	17,137.41	24,259.96	32,520.04	39,806.51	47,610.41
7.	TOTAL OUTAGE HOURS	(Hr)	1,047.92	1,637.45	523.92	1,473.53	937.35
	(1) FORCED OUTAGE	(Hr)	51.91	552.37	92.00	301.30	78.40
	(2) MAINTENANCE OUTAGE	(Hr)	90.38	47.20	77.90	0	73.18
	(3) PLANNED OUTAGE	(Hr)	864.75	918.52	351.15	1,169.83	743.18
	(4) ECONOMIC SHUTDOWN	(Hr)	0	0	0	0	0
	(5) OUTSIDE TROUBLE	(Hr)	40.88	119.36	2.87	2.4	42.59
8.	STATION USED POWER RATIO	(%)	6.58	6.84	6.63	6.47	6.27
9.	CAPACITY FACTOR	(%)	75.34	70.42	81.18	76.13	81.42
10.	AVAILABILITY FACTOR	(%)	88.04	81.31	94.07	83.20	89.79
11.	HEAT RATE (NET)	(BTU/KWH)	22,707	23,302	21,271	22,597	21,849
12.	THERMAL EFFICIENCY (NET)	(%)	15.03	14.65	16.05	15.10	15.62
13.	NUMBER OF STARTS (YEAR/TOTAL)		*1	*1	*1	*1	*1

COMMISSIONING: DEC 1984 *1: NO DATA AVAILABLE

6.3 Hydro Power Plants

6.3.1 Current Status and Problems of Hydro Power Plants

The current status and problems of hydro power plants revealed in the present study are as follows:

1. Outline of Hydro Power Plants in the Luzon Grid

    There are 11 hydro power plants with a total capacity of 1,226.16 MW in the Luzon Grid, of which 6 plants (875 MW) are under the control of NLRC (Northern Luzon Regional Center) and 5 plants (351.16 MW) are under the control of SLRC (Southern Luzon Regional Center) (refer to Table 6-3-1). In the grid, the generated energy by hydro power plants reached 2,369 GWh (2,924 GWh including the pumped storage generation of Kalayaan Power Plant) in 1990, and the annual plant capacity factor for the year was 27.3% (see Table 6-3-2). The percentage of hydro power generation to the total generation in the Luzon Grid, was 28.4% in the plant capacity and 12.6% in the generated energy in 1990.

    Most hydro power plant dams are owned by NIA (National Irrigation Administration) and used for irrigation. Some of them are also used for water supply, and accordingly the plant capacity factor is low, particularly in the dry season between April and June.

    Ambuklao Power Plant (75 MW) is currently undergoing rehabilitation because the silt deposit overreached the level of the intake, and in addition, the civil structures were damaged and the generator room was flooded by the earthquake in July 1990. The rehabilitation is scheduled to be completed in 1995.

    All other hydro power plants were in operation, excepting Botocan Power Plant (16.96 MW) in southern Luzon which was out of operation for replacement of circuit breakers.

2. Civil Structures of Hydro Power Plants

(1) Dams

NAPOCOR's large-scale reservoir type power plants consist of main dams and regulating reservoirs downstream of the power plants.

Out of the dams and reservoirs for hydro power generation, Ambuklao, Binga, Caliraya and Botocan Dams are managed by NAPOCOR. The remaining Magat, Pantabangan, Masiway and Angat Dams are managed mainly by NIA, and NAPOCOR is using them for generation and sharing the expenses.

Rehabilitation works have been started for NAPOCOR owned dams which have problems. A particularly prominent problem discovered in the study is the silt deposit in Ambuklao and Binga Dams. The volume of deposits has already exceeded 45% of the reservoir capacity in both dams.

As the intake of Ambuklao Power Plant became unusable in June 1990 because of the silt deposit, the rehabilitation project is currently implemented. The scheduled dredging by the project is 300,000 m^3 for the short-term, 4,000,000 m^3 for the medium-term, and 1,000,000 m^3/year for the long-term. The dredging is scheduled to start shortly. However, the above-mentioned volumes of dredging would be insufficient to handle the 3,600,000 m^3 of annual deposits inflow into the Ambuklao reservoir. Moreover, it would be very difficult to dredge roughly 1,000,000 m^3/year of silt over long years in consideration of the location of the power plant, disposal of dredged silt, road condition, etc. Therefore, the Ambuklao Power Plant intake should be reconstructed so that the intake level may be raised with the rising level of silt deposit.

At the Binga Power Plant, since the silt deposit reached the level of the intake in 1991, rehabilitation is under way. The scheduled dredging volume amounts to 1,500,000 m^3 for the first year, and 700,000 m^3 for the second year. The apron of the spillway has already been completed. Since the volume of deposits inflow into the Binga reservoir is less than that into the Ambuklao reservoir, it is likely that the dredging work will maintain the intake operation for some time. However, reconstruction of the intake will be needed in the long run.

Water leakage from the service spillway at the Caliraya Dam has drastically increased since August 1991. As the current leakage is 0.5 m^3/sec. (1,800 m^3/hour, 43,200 m^3/day), it is difficult to approach the leaking point from inside. The JICA conducted the study on this spillway leakage in 1986 and rehabilitation was commenced in 1989. The current progress rate of rehabilitation is 88%. However, the above-mentioned drastic increase in leakage has brought the rehabilitation work to a standstill, and countermeasures are being studied by NAPOCOR.

(2) Other Structures

For the civil structures of NAPOCOR owned hydro power plants, some defects were pointed out in the past studies. The following problems were found with civil structures in the present survey.

. Magat Power Plant	:	Water leakage around No. 3 water turbine
. Pantabangan Power Plant	:	Water leakage around No. 2 water turbine
. Masiway Power Plant	:	Water leakage from headrace
. Caliraya Power Plant	:	Repair of the inlet valve pit
. Kalayaan Power Plant	:	Improvement of the boom for tailrace

- Botocan Power Plant : Water leakage from dam gate, improvement of the boom for intake and replacement of trash removers
- Barit Power Plant : Repair of trash removers at the intake

(3) On-Going and Planned Rehabilitation Projects

- Dredging of Ambuklao reservoir
- Dredging of Binga reservoir
- Rehabilitation of Caliraya service spillway

3. Electrical Equipment of Hydro Power Plants

(1) Water Turbines and Generators

a. The frequency of forced outages in 1990 summarized from data collected in the survey was 89, and the duration of outages was 777.46 hours (refer to Table 6-3-3). Since there are some cases of unknown outage hours, the actual outage hours are suspected to exceed this figure. The longest outage was 143.60 hours, caused by the air cooler failure of No. 1 generator (12 MW) at Masiway Power Plant, followed by 138.95 hours which was the result of trouble with the oil lifting system of No. 2 generator (150 MW) at Kalayaan Power Plant.

b. It is noted that the same kind of water turbine and generator faults have occurred repeatedly. Generators at Magat Power Plant (90 MW x 4 units) have had frequent faults of static exciters. A total of 16 times of faults, including burnt thyristors and exciting transformers, occurred in 1990.

At Binga Power Plant (25 MW x 4 units), 21 times of breaking element troubles of water turbine guide vanes occurred in 1990. These were caused by the load fluctuation during operation and are considered to be abnormal.

These repeated occurrences of the same troubles are mostly attributable to defective design, manufacture or installation. When the cause and solution cannot be found, it is necessary to go back to the starting point and investigate whether the affected equipment conforms to the specifications or not. In some cases, it may be advisable to explain the circumstances of faults to the manufacturers of the equipment and ask them for solutions. In any case, it is necessary to thoroughly identify the causes of faults in order to prevent further occurrence of faults. For this purpose, it is essential to record the details of faults and the operating conditions. Based on the detailed records by type of equipment and type of causes, the causes of faults must be fully studied and the results of study should be reflected on the equipment and maintenance improvements.

(2) Switchyard Equipment

The current status, including problems, of switchyard equipment is described in Item 3 "Substation and Hydro Power Plant Switchyard Equipment" of Sub-clause 6.4.1.

(3) Other Equipment

a. Water leakage was observed around water turbine covers at some power plants in operation, but it was not so serious as to hinder their operation immediately. It is impossible to draw a conclusion on the conditions of all the equipment by this short-term survey, but it seemed that power plants were maintained relatively well, without serious vibration and other harmful phenomena.

b. At a small power plant (Barit Power Plant, 1.8 MW) in southern Luzon, the replaced old runner, which had been used for more than 30 years, was observed. Judging from the abrasion on the runner blades, it is believed that the replacement should have been done a little earlier.

(4) On-Going Rehabilitation Project

- Rehabilitation of water turbines and generators at Ambuklao Power Plant

6.3.2 Formulation of Rehabilitation Plan

Among the problems described in Sub-clause 6.3.1, the plan has been made to reconstruct the intake of the Ambuklao Power Plant, which is the biggest problem with the civil structures. And with the electrical equipment, replacement of the excitation transformer at the Magat Power plant, which had frequent failures and has technical problems, has been planned. The remaining problems which are not serious can be covered by the preventive maintenance programs.

1. Civil Structures

The annual deposits inflow into the Ambuklao reservoir amounts to 3,600,000m^3 and fine silt is concentratedly deposited around the intake. The silt level has reached 699 m, 13 m higher than the intake level of 686 m, and the plant has been out of service since 1990.

Although NAPOCOR plans to dredge around the intake, the dredging work entails many problems as stated in Item 2 of Sub-clause 6.3.1, and is not economically advantageous. Therefore, the plan has been made to reconstruct the present submarine type intake so that the intake level may be changed with the rising level of silt deposit.

Regarding the countermeasures against the silt deposit in the Ambuklao reservoir, the JICA conducted the study and prepared the report in March 1988. In this report, the following five alternatives were studied and alternative "e", Vertical Intake Tower, was recommended in consideration of construction costs, duration of plant outages, construction methods, maintenance costs, and other economic factors (refer to Table 6-3-4).

a. *Large Scale Dredging*
b. Raising of Intake Tower
c. Sediment Discharge Tunnel
d. Inclined Intake Tower
e. Vertical Intake Tower

In the present study, the JICA report was reviewed based on the results of the survey, and the same conclusion was reached. The presently progressing Ambuklao Power Plant rehabilitation is scheduled to be completed in 1995 and thus, the earliest commencement of this reconstruction project is recommended.

2. Electrical Equipment

(1) Water Turbines and Generators

As mentioned in Item 3 of Sub-clause 6.3.1, the dry-type transformers for the static exciters of the Magat Power Plant have had frequent failures. As it is suspected that the transformers have problems in the design and structure, replacement with molded transformers has been planned.

Molded excitation transformer 4 units

Rated capacity		1,400 kVA (continuous rating)
Rated voltage	primary	13,800 V
	secondary	940 V
Rated frequency		60 Hz
Phase		3 phase
Connection	primary	Delta
	secondary	Star

(2) Switchyard Equipment

Switchyard equipment are described in Item 2 "Substation and Hydro Power Plant Switchyard Equipment" of Sub-clause 6.4.2.

6.3.3 Priority Criteria and Priority

The order of priority is (1) the reconstruction of Ambuklao Power Plant intake, and (2) the replacement of Magat Power Plant excitation transformer.

Table 6-3-1 HYDRO POWER PLANT GENERATOR AND TURBINE TECHNICAL DATA (1)

(1/2)

Power Plant	Unit	Installed	Date of	Generator				Water Turbine				Remarks
	Nos.	Capacity (MW)	Commis.	Rated Cap. (MVA)	Rat. Volt. (kV)	Power Factor	Manufac-turer	Rated Output	Type	Speed (RPM)	Manufac-turer	
Magat	1	90	1983	112.5	13.8	0.8	T. I. B. B.	126,000 HP	VF-1RS	180	VOEST-ALP.	
	2	90	1983	112.5	13.8	0.8	T. I. B. B.	126,000 HP	VF-1RS	180	VOEST-ALP.	
	3	90	1983	112.5	13.8	0.8	T. I. B. B.	126,000 HP	VF-1RS	180	VOEST-ALP.	
	4	90	1983	112.5	13.8	0.8	T. I. B. B.	126,000 HP	VF-1RS	180	VOEST-ALP.	
Sub Total	(4)	(360MW)										
Ambuklao	1	25	1956	27.8	13.8	0.9	G. E.	39,500 HP	HF-1RS	360	NEYRPIC. A.	
	2	25	1956	27.8	13.8	0.9	G. E.	39,500 HP	HF-1RS	360	NEYRPIC. A.	
	3	25	1957	27.8	13.8	0.9	G. E.	39,500 HP	HF-1RS	360	NEYRPIC. A.	
Sub Total	(3)	(75MW)										
Binga	1	25	1960	27.8	13.8	0.9	OERLIKON	40,500 HP	VF-1RS	327	C.M. RIVA	
	2	25	1960	27.8	13.8	0.9	OERLIKON	40,500 HP	VF-1RS	327	C.M. RIVA	
	3	25	1960	27.8	13.8	0.9	OERLIKON	40,500 HP	VF-1RS	327	C.M. RIVA	
	4	25	1960	27.8	13.8	0.9	OERLIKON	40,500 HP	VF-1RS	327	C.M. RIVA	
Sub Total	(4)	(100MW)										
Pantabangan	1	50	1977	55.555	13.8	0.9	MITSUBISHI	70,000 HP	VF-1RS	180	MITSUBISHI	
	2	50	1977	55.555	13.8	0.9	MITSUBISHI	70,000 HP	VF-1RS	180	MITSUBISHI	
Sub Total	(2)	(100MW)										
Masiway		12	1981	13.333	13.8	0.9	MEIDENSHA	16,800 HP	VK-1RS	150	TOSHIBA	
Sub Total	(1)	(12MW)										
Angat	1	50	1967	55.555	13.8	0.9	ASEA	70,000 HP	VF-1RS	277	TOSHIBA	
	2	50	1967	55.555	13.8	0.9	ASEA	70,000 HP	VF-1RS	277	TOSHIBA	
	3	50	1968	55.555	13.8	0.9	ASEA	70,000 HP	VF-1RS	277	TOSHIBA	
	4	50	1968	55.555	13.8	0.9	ASEA	70,000 HP	VF-1RS	277	TOSHIBA	

Table 6-3-1 HYDRO POWER PLANT GENERATOR AND TURBINE TECHNICAL DATA (2)

(2/2)

Power Plant	Unit Nos.	Installed Capacity (MW)	Date of Commis.	Generator Rated Cap. (MVA)	Generator Rat. Volt. (kV)	Generator Power Factor	Generator Manufac-turer	Water Turbine Rated Output	Water Turbine Type	Water Turbine Speed (RPM)	Water Turbine Manufac-turer	Remarks
Angat	Aux1	6	1967	6.667	4.16	0.9	TOSHIBA	8,500 HP	VF-1RS	600	TOSHIBA	
	Aux2	6	1967	6.667	4.16	0.9	TOSHIBA	8,500 HP	VF-1RS	600	TOSHIBA	
	Aux3	6	1978	6.667	4.16	0.9	SHINKO	8,500 HP	VF-1RS	600	A.C.EBARRA	
	Aux4	10	1986	11.111	13.8	0.9	SHINKO	10,000 KW	VF-1RS	600	A.C.EBARRA	
Sub Total	(8)	(228MW)										
Kalayaan	1	150	1982	167	13.8	0.9	MARELLI	150 MW	VF-1RS	300	HYDROART	
	2	150	1982	167	13.8	0.9	MARELLI	150 MW	VF-1RS	300	HYDROART	
Sub Total	(2)	(300MW)										
Caliraya	1	8	1945	10	13.8	0.8	G.E.	12,500 HP	VF-1RS	720	PELTON W.W.	
	2	8	1945	10	13.8	0.8	G.E.	12,500 HP	VF-1RS	720	PELTON W.W.	
	3	8	1947	10	13.8	0.8	G.E.	12,500 HP	VF-1RS	720	PELTON W.W.	
	4	8	1950	10	13.8	0.8	G.E.	12,500 HP	VF-1RS	720	PELTON W.W.	
Sub Total	(4)	(32MW)										
Botocan	1	8	1948	10	13.8	0.8	G.E.	10,950 HP	VF-1RS	720	S.MORGAN	
	2	8	1948	10	13.8	0.8	G.E.	10,950 HP	VF-1RS	720	S.MORGAN	
	3	0.96	1946	1.2	13.8	0.8		1,300 HP	HP-1R1N	720	S.MORGAN	
Sub Total	(3)	(16.96MW)										
Barit		1.8	1957	2.0	2.4	0.9	AEG	2,960 HP	VF-1RS	277	J.M. VOITH	
Sub Total	(1)	(1.8MW)										
Cawayan		0.4	1959	0.5	2.4	0.8	ELECTRO MCKANA	595 HP	HF-1RS	1200	J.M. VOITH	
Sub Total	(1)	(0.4MW)										
TOTAL	(33)	1,226.16MW										

Table 6-3-2 GENERATION RECORDS OF HYDRO POWER PLANT

1. Gross Generation (GWh)

Plants	1989	1990	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ambuklao	202.9	91.1	6.5	8.6	11.0	17.5	15.1	16.0	16.4	—	—	—	—	—
Angat	520.7	478.9	23.3	21.9	20.0	16.7	11.5	12.8	29.3	36.4	105.3	51.3	93.9	56.5
Binga	493.7	431.1	9.1	13.6	16.4	17.2	21.7	30.4	58.8	69.6	77.6	59.9	34.4	20.4
Magat	994.2	980.7	67.2	41.2	19.4	0	0	34.4	89.8	141.8	169.7	150.4	181.5	85.4
Pantabangan	161.0	135.2	31.3	30.6	28.7	21.8	5.9	0.8	3.4	0	0	0	7.9	6.8
Masiway	33.2	37.2	7.7	6.9	7.2	8.0	2.8	0.2	1.3	0	0	0.7	1.4	1.2
Kalayaan	596.5	713.7	63.6	59.9	66.3	57.5	54.5	53.5	52.6	55.0	60.0	68.1	59.9	62.6
Caliraya	15.1	9.1	1.2	1.0	2.4	0.5	0.3	0.3	0	0	0.1	1.5	1.6	0.2
Botocan	57.9	46.6	2.9	3.0	2.4	1.9	2.0	4.5	3.2	4.0	3.8	5.7	6.4	6.8
Total	3,075.2	2,923.6	212.8	186.7	173.8	141.1	113.8	152.9	254.8	306.8	416.5	337.6	387.0	239.9

2. Plant Capacity Factor (%)

Plants	1989	1990	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ambuklao	30.9	13.9	11.7	15.4	21.3	31.3	28.0	28.7	30.4	0	0	0	0	0
Angat	26.1	24.0	13.8	12.9	13.1	9.8	7.0	7.5	17.8	21.4	62.1	31.3	55.4	34.4
Binga	56.4	49.2	12.2	18.3	27.4	23.1	30.1	40.8	81.7	93.6	104.3	83.3	46.2	28.3
Magat	31.5	31.1	25.1	15.4	8.0	0	0	12.8	34.6	52.9	63.4	58.0	67.8	32.9
Pantabangan	18.4	15.4	42.0	41.1	39.7	29.3	8.2	1.1	4.7	0	0	0	10.6	9.5
Masiway	31.5	35.4	85.9	76.7	89.1	89.1	32.4	2.6	14.7	0.2	0	7.6	15.2	14.0
Kalayaan	22.7	27.2	28.5	26.8	32.9	25.8	25.2	24.0	24.4	24.7	26.7	31.5	26.8	29.0
Caliraya	5.4	3.2	5.2	4.2	11.0	2.0	1.3	1.2	0	0	0.5	6.5	6.8	0.9
Botocan	39.0	31.4	23.1	23.4	20.7	15.5	16.4	35.7	26.0	31.5	29.9	47.0	50.7	56.0
Total	28.9	27.3	23.4	20.5	21.1	15.5	12.9	16.8	28.9	33.7	45.7	38.3	42.5	27.2

Table 6-3-3 FORCED OUTAGE RECORDS OF HYDRO POWER PLANT IN 1990 (1)

Plants	Units	Date	Hours	Causes
Ambuklao	1	7/ 2	3.87	Governor trouble
	2	12/27		High thrust bearing temperature
		3/26		Emulsification of thrust bearing oil
		5/20		Generator differential relay
		7/ 1		Leak at thrust bearing cooling oil
	3	3/ 5	3.18	Governor oil pump trouble
		7/ 8	35.75	Low oil tank pressure
Magat	1	1/10	2.87	Stator EF indication
		8/15	0.78	Burnt out excitation Tr of unit 2
		8/29		Not available due to Excit. Tr.
		10/ 8	6.07	Trouble at thyristor fan motor
		10/17	12.00	Excitation transformer trouble
		10/17	47.32	Excitation transformer trouble
		10/20	8.42	Burnt thyristor
		10/20	15.07	Loss of excitation
		11/ 3	9.63	Actuation of rotor EF protection
		11/ 7		Excitation trouble
		11/ 9	2.77	Thyristor trouble
	2	1/10	2.87	Stator EF indication
		8/15	69.00	Burnt out excitation Tr of unit 2
		10/ 8	2.33	Thyristor fan motor
		10/20	1.48	
	3	8/15	0.70	Burnt out excitation Tr of unit 2
		9/28	1.68	Busted thyristor
		10/ 7	1.35	Trouble at thyristor fan motor
		10/ 8	0.48	Thyristor fan motor
		10/20	1.00	
		11/ 7	2.45	Thyristor trouble
	4	8/15	1.00	Burut out excitation Tr of unit 2

Table 6-3-3 FORCED OUTAGE RECORDS OF HYDRO POWER PLANT IN 1990 (2)

Plants	Units	Date	Hours	Causes
Binga	1	12/27	0.27	Damaged breaking element
		2/ 9		Broken breaking element
		3/ 2	0.83	Broken breaking element
		8/30		Tripping of transformer A
		9/ 1	34.92	Leak on bypass of butterfly valve
		10/ 9	0.18	
		11/19	2.58	Broken breaking element
	2	5/ 1	0.17	High thrust bearing temperature
		8/16	3.63	Sheared breaking element
		8/30		Tripping of transformer A
		10/15	4.73	AVR trouble
		12/ 4	0.27	Damaged breaking element
		12/ 6	0.50	Broken breaking element
	3	2/28	0.83	Broken breaking element
		4/25	0.17	Generator ground indication
		5/30	1.52	Broken breaking element
		6/28	1.27	Broken breaking element
		7/20	4.17	
		9/23		Broken breaking element
		10/25	1.35	Damaged breaking element
		11/14	0.93	Broken breaking element
		11/19	3.67	Breaking element trouble
		11/25	0.70	Damaged breaking element
		12/ 7	2.23	Broken breaking element
		12/ 9		Damaged breaking element
		12/13	0.83	Broken breaking element
		12/20	1.07	Broken breaking element
	4	1/16	0.15	Malfunctioning of turbine bearing thermal relay
		7/20	4.08	
		10/ 6	5.50	Turbine vibration test
		11/25		Damaged breaking element

Table 6-3-3 FORCED OUTAGE RECORDS OF HYDRO POWER PLANT IN 1990 (3)

Plants	Units	Date	Hours	Causes
Angat	M1	3/ 8		Generator field ground indication
		9/27	7.42	High thrust bearing temperature
		10/16	10.92	Generator field ground indication
	M2	3/ 8		Generator field ground indication
		9/21	4.28	Shear pin trouble
	M3	3/ 8	5.55	Erratic control of AVR
	A3	3/28		Bus duct phase B flashover
Pantabangan	2	2/23	0.47	Broken shearing pins
Masiway		2/ 7	143.60	Leak at generator air cooler
		2/27	1.00	Leak on air coolers
		11/28	15.35	Leak at generator surface cooler
Kalayaan	1	10/17	0.08	PLC failure
		11/10	16.50	Leak at servomotor spherical valve
		11/12	5.22	Governor trouble
		11/13	14.10	Trouble at air oil accumulator
		11/19	0.20	Overspeed relay
		12/13	8.43	Misaligned guide vane
		12/18	0.17	Low oil at LBG
	2	4/17	0.20	High stator temperature
		8/13	28.52	Oil leak at hydraulic servomotor
		10/ 4	138.95	Oil lifting system failure
		10/11	4.38	AVR trouble
		11/22		Alignment of wicket gates
Caliraya	1	10/ 3		Trouble on transformer #2
	2	10/ 3		Trouble on transformer #2
		11/19		Leak at by-pass valve
	4	10/ 4		Leak at thrust bearing
Botocan	1	10/ 3	31.75	Flashover fuse of Gen. #2PT
	2	10/ 3	31.75	Flashover fuse of Gen. #2PT

Table 6-3-4 SUMMARY OF REHABILITATION SCHEMES

Scheme	Brief Description	Outline of facility	Approx. cost (US$)	Approx. Time Required & & Remarks
(a) Large Scale Dredging	- Dredging about 62% of annual sediment inflow and discharge to downstream	Dredger - 1100kW/12"×3 Pipeline - 12"×5300m×3 Silt basin - 314,000m²	Equipment 22,640×10³ Civil work 1,400×10³ Total 24,050×10³ Annual OM 4,500×10³	2 years Manufacture, delivery, installation and civil work
(b) Raising of Intake Tower	- Rainsed by 1.7m high Ring in order to prevent sediment inflow to inlet.		Metal work 10,320×10³ Civil work 25,550×10³ Total 35,870×10³	5 years · Fabrication 2 seasons 9 months Installation 2 seasons 5 months · Power Interruption 5 months×5 seasons · No Intake Gate · Reinforcement around intake tower by steel pipe pile · Much underwater work
(c) Sediment Discharge Tunnel	- Construct new sand discharge tunnel	- Tunnel φ5m×410m×2 - Downstream river Channel protection work 1,200m - Roller gate 5m×15m×2 - Radial gate 5m×7m×2	Civil work 32,550×10³ Metal work 17,150×10³ Total 49,700×10³	5 years · Underwater work is necessary at the reservoir side · Difficulty in connection work of intake portion and tunnel
(d) Inclined Intake tower	Inclined steel intake tower to be constructed on the slope of bedrock and to be connected to the existing tower	- Foudation work - Horizontal steel pipe φ7m×70m - Inclined steel pipe φ7m×78m	Civil work 11,870×10³ Metal work 14,240×10³ Total 26,110×10³	4 years · Execution of foundation work · Power interruption - 5 months× 4 seasons · Connection with existing tower · Much underwater work
(e) Vertical Intake tower	Vertical intake tower to be constructed above the existing headrace and to be connected thereto	- Shaft work φ7m×86.7m	Civil work 7,650×10³ Metal work 11,700×10³ Total 19,350×10³	4 years · Power interruption - 5 months× 2 seasons · 80m vertical shaft excavation · Blockade work of existing waterway

Source : 1988,3 JICA Report

6.4 Transmission Lines and Substations

6.4.1 Current Status and Problems of Transmission and Substation Facilities

The current status and problems of transmission and substation facilities revealed in the present study are as follows:

1. Outline of the Luzon Grid

As shown in Fig. 6-4-1, the Luzon Grid consists mainly of 230 kV system which runs through the island from north to south, with 115 kV system used in some parts of the island. The secondary transmission voltage is 69 kV. Data on the 230 kV transmission lines are shown in Table 6-4-1, and the length of transmission lines and the substation capacity for each area office are shown in Table 6-4-2.

As for the power sources, hydro power plants are located mainly in the north of the island, thermal, geothermal and pumped storage power plants in and around Manila, and a geothermal power plant is located in the south.

The 230 kV system is divided into the following five systems.

- Northern System, which extends from Magat Power Plant to Bauang Substation through Ambuklao and Binga Power Plants
- Central System, which extends from Binga Power Plant to San Jose and Balintawak Substations through Mexico Substation
- Midwest System, which extends from Bauang Substation to San Jose Substation through Hermosa Substation
- Manila Outer Link System, which extends from San Jose Substation to Sucat Power Plant through Kalayaan Power Plant and Binan Substation

. Southern System, which extends from Tiwi Power Plant to Kalayaan Power Plant.

The Midwest System was commissioned in December 1991.

Most of the 230 kV lines are in loop configuration with one or two circuits per route, but some of the lines are in radial configuration with a single circuit per route. All of the lines are supported by steel towers, with single, double and four conductors of ACSR 795 MCM.

For the 115 kV lines, steel towers and wooden poles are used for supports. Steel tower lines have two circuits per route, while wooden pole lines have a single circuit per route, with the conductors of ACSR 795 MCM and 336.4 MCM.

The MERALCO system in and around Manila is formed with 115 kV transmission lines which are supplied from Balintawak, San Jose, Dolores and Binan substations, and Malaya and Sucat power plants.

The 69 kV lines are mostly supported by wooden poles and are in radial configuration with a single circuit per route, with the conductors of ACSR 336.4 MCM and 4/0.

The circuit lengths of transmission lines and the number and capacity of substations in the Luzon Grid as of the end of 1990 are shown below.

	Transmission Line	Substation	
	Circuit Length (km)	Number	Capacity (MVA)
230 kV	3,232	22	3,485
115 kV	442	6	310
69 kV	2,976	46	467
34.5 kV & below	524		
Total	7,174	74	4,262

2. Transmission Facilities

(1) 230 kV System

a. For the 230 kV system, line faults have occurred frequently, posing problems as described below. However, there is no big problem concerning the system formation.

b. In the Northern System, separation of the hydro power plants from the grid caused by transmission line faults and voltage drop during the dry season are the problems of the system. In the Southern System, separation of the Tiwi Power Plant from the grid occurred due to broken ground wires.

The problems of the Northern System will be eliminated by completion of the Midwest System. With regard to the Southern System, the overhead ground wires need to be replaced with aluminum-clad steel wires.

The transmission and substation expansion projects are shown in Tables 6-4-8 and 6-4-9, respectively. These projects include the expansion of the 230 kV system to meet the power source developments and increasing power demand, the commissioning of the southern 500 kV system in 1997 in connection with the interconnection to Leyte Island, and the construction of the northern 500 kV system in 2000. The major projects for the 69 kV system are system expansion on the isolated islands and interconnection with the Luzon Grid. These projects also include the following renovation/rehabilitation projects.

- Reinforcement of the San Jose - Balintawak Line

- Uprating of the Binan - Sucat Line voltage

- Two-circuit pi connection at the Bayombong Substation

- Voltage improvement in the metropolitan area when the thermal power plants in and around Manila are out of operation

- Rehabilitation of the 500 kV Naga-Kalayaan Line

c. The average frequency of line faults per 100 km was 5.6 in 1990, which is roughly 6 times larger than the frequency in Japan. The maximum frequency was 24.8 for the Binga - San Manuel Line (refer to Table 6-4-7). As described in Clause 7.5, it is imperative to investigate the causes of the faults and to push forward the countermeasures for fault reduction.

d. Corrosion of Overhead Ground Wires in the Southern System

Galvanized steel wire is used for the overhead ground wire, but in some places, the corrosion has occurred in just a few years, causing broken wires.

Corroded overhead ground wires are being partly replaced. However, scheduled replacement with aluminum-clad steel wire should be carried out.

Zinc coating of a new galvanized steel wire obtained during the survey was a maximum value of 71 g/m^2 and a minimum value of 44 g/m^2. As these values are significantly smaller than the specified value of 240 g/m^2, it is suspected that galvanized steel wires not to the specification were purchased. Therefore, the standardization of specifications and distribution of the specifications to all related organizations and departments, as well as strict testing of purchased materials are necessary.

e. Corrosion of Insulator Pins in the Southern System

As with the overhead ground wires, corrosion of insulator pins is widespread. This is the galvanic corrosion caused by the direct current component of the leakage current.

Replacement of corroded insulators is conducted in accordance with the annual preventive maintenance program. However, composite insulators are partly used, despite the fact that the zinc sleeved insulator isspecified as the standard. As with the overhead ground wires, standardization of the specifications is required.

f. Voltage Drop in the Northern System at the Time of the Shutdown of Hydro Power Plants in the North

In the north, there are three hydro power plants, Magat (360 MW), Ambuklao (75 MW) and Binga (100 MW) Power Plants, with a total capacity of 535 MW. Of these power plants, Magat Dam is an irrigation dam owned by NIA and the plant is shut down for a month in the dry season due to NIA's canal maintenance. Since the generation of the other power plants is small in the dry season, power is supplied from power plants in and around Manila, causing a large voltage drop in the Northern System.

As mentioned before, this problem will be solved upon completion of the Midwest System.

g. Steel Tower Failures by Typhoons

According to meteorological observation records, maximum gust wind velocities of more than 200 km/hour have been recorded many times.

The Naga - Tiwi Line (failed in 1987) and Santiago - Bayombong Line (failed in 1989) have the design wind velocity of 165 km/hour and, accordingly, lack sufficient strength.

Steel towers of Santiago - Bayombong Line failed by structural failures just above the ground, and evidences of lifted foundations were observed with the Naga - Tiwi Line.

There are two possible countermeasures. One is to reinforce the steel towers with additional members and reinforce the foundations, and the other is to reinforce by the use of guy wires. As the former is not considered technically and economically feasible, the reinforcement with guy wires is deemed advisable.

h. Problems with the Design and Construction of Steel Towers

Misapplication of strain towers and suspension towers was observed. In some cases, suspension towers are used where strain towers should be used. More attention must be paid to the clearance in consideration of the local conditions such as frequent typhoons and high IKL (Isokeraunic Level).

i. Arcing Horns

Considering the high IKL, arcing horns should be installed.

(2) 115 kV System

a. 115 kV lines supported by wooden poles have a single circuit per route and have had frequent faults, but cause no major problems as the lengths of the lines are limited.

b. In 1990, the average frequency of line faults per 100 km was 5.2 with steel tower lines, 20.9 with wooden pole lines and 14.1 as a total of 115 kV lines. This is roughly 5 times larger than the frequency in Japan.

c. The San Esteban - Bantay - Laoag Line, which is the longest of the wooden pole lines, is being converted to two-circuits.

(3) 69 kV System

a. Most of the 69 kV lines are supported by wooden poles and in radial configuration with a single circuit per route. There have been numerous faults, causing very long outages. The average frequency of line faults per 100 km in 1990 was 58.5, which is roughly 12 times larger than the frequency in Japan, with the average duration of 7.0 hours per fault. As mentioned in Clause 7.5, the causes of the faults must be investigated, and the measures for fault reduction should be promoted.

b. There are lines interrupted for extremely long durations at the time of typhoons (refer to Tables 6-4-7-(5) and (6)). Among them, there are some sections where the restoration works were delayed due to difficulties in transporting the wooden poles. For these sections, rerouting will be necessary.

c. There is a line interrupted for long duration due to broken conductors caused by drifting logs during floods (refer to Table 6-4-7-(6)). This is attributable to lack of the clearance, and therefore, conversion to steel towers will be necessary.

d. There were insulators damaged by flash-over. As the arcing horn is not used, insulators are apt to be damaged. Hot-line detection of defective insulators should be adopted.

e. There were a large number of wooden poles felled by typhoons and other accidents. Preventive maintenance of the wooden poles should be promoted.

3. Substation and Hydro Power Plant Switchyard Equipment

(1) 230 kV Substations

a. According to the data collected in the survey, the frequency of substation faults in 1990 was 21, and the duration of outage was 4.8 hours per fault (refer to Table 6-4-7).

The frequency is not so large as compared with faults of other facilities, in consideration of the fact that there are many aged equipment at the 230 kV substations. However, there are no detailed records of the faults and their causes. It is necessary to identify the causes of these faults based on detailed records classified by the type of equipment and causes, and to reflect them on the equipment and maintenance improvements.

b. Power Transformers

Data on the transformers of 230 kV substations are shown in Table 6-4-3. Oil leakage from the cooling system and transformer proper was observed at some of the substations, but it was not so serious as to hinder the operation immediately. The distribution transformer (50 MVA, 115/34.5 kV, Osaka, 1978) at San Jose Substation was overloaded even with an additional cooling fan, and the adjacent Angat Power Plant was supplying a part of the load of San Jose Substation.

c. Circuit Breakers and Disconnecting Switches

The bus system of 230 kV substations employs the 1-1/2 breaker system. Therefore, there are more circuit breakers and disconnecting switches per circuit.

Data on the circuit breakers of 230 kV substations are shown in Table 6-4-4. There are 165 units of 230 kV circuit breakers, 32 units of 115 kV circuit breakers and 99 units of 69 kV circuit breakers, or a total of 296 circuit breakers. These circuit breakers classified by the years of manufacture are shown in the tables below. There are many aged OCBs and ACBs. Most of the 69kV circuit breakers are OCBs.

Number of 230 kV Circuit Breakers by Years of Manufacture

Mfg. Years	-1960	1961-70	1971-80	1981-	Total (%)
OCB	1	11	17	0	29 (17.6)
ACB	0	9	7	0	16 (9.7)
GCB	0	0	59	61	120 (72.7)
Total	1	20	83	61	165 (100)

Number of 115 kV Circuit Breakers by Years of Manufacture

Mfg. Years	-1960	1961-70	1971-80	1981-	Total (%)
OCB	0	0	11	0	11 (34.4)
ACB	0	0	3	0	3 (9.4)
GCB	0	0	15	3	18 (56.2)
Total	0	0	29	3	32 (100)

Number of 69 kV Circuit Breakers by Years of Manufacture

Mfg. Years	-1960	1961-70	1971-80	1981-	Total (%)
OCB	1	13	56	14	84 (84.8)
ACB	0	2	7	0	9 (9.1)
GCB	0	0	4	2	6 (6.1)
Total	1	15	67	16	99 (100)

Number of Circuit Breakers by Years of Manufacture (Total)

Mfg. Years	-1960	1961-70	1971-80	1981-	Total (%)
OCB	2	24	84	14	124 (41.9)
ACB	0	11	17	0	28 (9.5)
GCB	0	0	78	66	144 (48.6)
Total	2	35	179	80	296 (100)

There are some circuit breakers with oil or gas leakage. Since there are some circuit breakers which will lack breaking capacity in the near future, replacement of circuit breakers is in progress at some of the substations.

Most disconnecting switches are of the manual operation type, and some are difficult to open and close due to tight operating mechanism, and there are some with pin insulators.

d. Other Equipment

Bolted type connectors are used for the branch connections of 230 kV bus bars at some substations with which discoloration due to overheating was observed. Since the connections are overheated and cooled repeatedly by the load fluctuation, imperfect contact is accelerated by metal annealing. Compression type connectors should be used because bolted type connectors are difficult to install properly due to nonconformity to the conductor size and insufficient tightening force, often resulting in the falling off of conductors.

e. On-Going and Planned Renovation/Rehabilitation Project

- Replacement of 230 kV circuit breakers at Mexico Substation
- Replacement of 230 kV circuit breakers at San Manuel Substation
- Two-circuit pi connection at Bayombong Substation
- Uprating of voltage to 230 kV at Sucat Power Plant

(2) 69 kV Substations

The equipment of NAPOCOR's 69 kV substations could not be inspected during the present survey, but they have small installed capacities of 3 to 10 MVA and are equipped with minimal equipment. Consequently, it seems that they pose no problem.

The NAPOCOR's 69 kV substations have been transferred to cooperatives one by one.

(3) Switchyard Equipment of Hydro Power Plants

a. According to the data collected in the survey, the frequency of switchyard equipment faults of hydro power plants in 1990 was 4, and the average outage duration was 40.6 hours per fault (refer to Table 6-4-7). The faults include those caused by the earthquake in July 1990, and are small in number. But, as with the case of 230 kV substation equipment, there are no detailed records of the faults and their causes. Statistical data on faults classified by the type of equipment and causes should be maintained.

b. Power Transformers (Generator Transformers)

Most of the transformers at the hydro power plants, excepting Magat Power Plant in northern Luzon, were manufactured in the 1950's. Data on the transformers at the hydro power plants are shown in Table 6-4-5.

As with the case of the substation equipment, there is oil leakage from transformer proper, radiators, oil pumps, etc. However, it is not so serious as to hinder the operation immediately. Hydro power plants in the south, except for Kalayaan Power Plant, are equipped with aged small-capacity transformers, but they have no particular problem.

c. Circuit Breakers and Disconnecting Switches

The bus bar system of 230kV switchyards employs the 1-1/2 breaker system, as does the substation.

Data of the circuit breakers of hydro power plants are shown in Table 6-4-6. There are 46 units of 230 kV circuit breakers, 15 units of 115 kV circuit breakers and 4 units of 69 kV circuit breakers, or a total of 65 circuit breakers. These circuit breakers classified by the years of manufacture are shown in the table below.

Number of 230 kV Circuit Breakers by Years of Manufacture

Mfg. Years	-1960	1961-70	1971-80	1981-	Total (%)
OCB	8	0	0	0	8 (17.0)
ACB	0	0	0	0	0 (-)
GCB	0	0	28	10	38 (83.0)
Total	8	0	28	10	46 (100)

Number of 115 kV Circuit Breakers by Years of Manufacture

Mfg. Years	-1960	1961-70	1971-80	1981-	Total (%)
OCB	1	3	0	0	4 (26.7)
ACB	0	10	0	0	10 (66.6)
GCB	0	0	0	1	1 (6.7)
Total	1	13	0	1	15 (100)

Number of 69 kV Circuit Breakers by Years of Manufacture

Mfg. Years	-1960	1961-70	1971-80	1981-	Total (%)
OCB	0	1	1	2	4 (100)
ACB	0	0	0	0	0 (-)
GCB	0	0	0	0	0 (-)
Total	0	1	1	2	4 (100)

Number of Circuit Breakers by Years of Manufacture (Total)

Mfg. Years	-1960	1961-70	1971-80	1981-	Total (%)
OCB	9	4	1	2	16 (24.6)
ACB	0	10	0	0	10 (15.4)
GCB	0	0	28	11	39 (60.0)
Total	9	14	29	13	65 (100)

Hydro power plants in the north, excepting Magat Power Plant, are equipped with 230 kV OCBs manufactured in the 1950's and 115 kV ACBs manufactured in the 1960's. The circuit breakers in the hydro power plants in the south, except for Kalayaan Power Plant, are mostly 115 kV OCBs manufactured in the 1940's and 1950's.

Most disconnecting switches are of the manual operation type, and some are difficult to open and close due to tight operating mechanism, and there are many equipment with pin insulators.

(4) Provision of Spare Parts

The equipment of substations were purchased from various manufacturers in various countries. Consequently, it is difficult to keep the many types of spare parts needed for all the equipment. In many cases, the parts for old equipment are not manufactured any longer.

In the Philippines, procurement of spare parts takes two or three years because of the time-consuming procedures of foreign currency application and purchase formalities, and consequently, it is difficult to expect timely supply of imported spare parts. In addition, a high-level of skill is required in the replacement of the inner parts (such as moving and fixed contacts) of GCB, which is well-known as maintenance free. Since the skill of replacement affects the performance of the equipment after replacement, the guidance of expert engineers will be required even if spare parts are available at hand. Therefore, with 230 kV breakers, which are the most important for system operation, it is recommended that spare equipment of standard specifications be kept in strategic locations and that the whole of the equipment be replaced in case of emergency.

6.4.2 Formulation of Renovation Plan

For the problems described in Sub-clause 6.4.1, the following renovation plans which would be effective for improvement of supply reliability and rationalization of maintenance works have been formulated. With the respective site, the detailed survey should be made during the feasibility study.

1. Transmission Facilities

(1) Replacement of Overhead Ground Wires

Replacement of 566 km of overhead ground wires of the 230 kV transmission lines with 55 mm^2 aluminum-clad steel wires has been planned as follows.

Kalayaan - Gumaca Line	204 km
Gumaca - Labo Line (#1-#138)	128 km
Kalayaan - San Jose Line	234 km
Total	566 km

(2) *Adoption of Steel Towers for River or Road Crossings (69 kV line)*

Adoption of steel towers for 20 river crossings and 9 road crossings, which were requested by the area offices, has been planned. Respective sites are as shown in Table 6-4-10. The design conditions are a single circuit of ACSR 336.4 mm^2 for the conductor, and span lengths of 350 m for river crossings and 250 m for road crossings.

(3) Rerouting of the Section of 69 kV line where Restoration Works are Difficult

Rerouting of the section between the structure Nos. #307 and #345, 10 km, of the Tuguegarao - Camalaniugan Line has been planned.

(4) Provision of Defective Insulator Detectors

Provision of defective insulator detectors, one set for each power transmission line maintenance group, totaling 22 sets, has been planned.

2. Substation and Hydro Power Plant Switchyard Equipment

(1) Replacement of Circuit Breakers

The circuit breaker replacement plan for the substations and that for the hydro power plants are given in Tables 6-4-11 and 6-4-12, respectively. The respective circuit breaker replacement plans are as explained below. It has been planned to replace circuit breakers with GCBs (gas circuit breakers) which are the most reliable and effective for rationalization of maintenance works.

a. Replacement Plan of Circuit Breakers which will Lack Breaking Capacity in the Near Future

Out of the 230 kV and 115 kV circuit breakers, the replacement of 11 circuit breakers which will lack breaking capacity by 1995 has been planned. There is no 69 kV circuit breaker which will lack breaking capacity.

San Jose Substation	230 kV GCB	2 sets
Binan Substation	230 kV GCB	4 sets
Dolores Substation	115 kV OCB	5 sets
Total		11 sets

b. Replacement Plan of 230 kV OCBs (oil circuit breakers) and ACBs (air circuit breakers)

There are 211 sets of 230 kV circuit breakers, comprising 158 GCBs, 37 OCBs and 16 ACBs. Of these, as the OCBs and ACBs have deteriorated and have maintenance problems, the replacement of 33 circuit breakers has been planned, except for the 20 circuit breakers which are now being replaced.

Bauang Substation	230 kV ACB	3 sets
Cabanatuan Substation	230 kV ACB	2 sets
Hermosa Substation	230 kV OCB	12 sets
Olongapo Substation	230 kV ACB	4 sets
San Jose Substation	230 kV OCB	4 sets
Binga Power Plant	230 kV OCB	8 sets
Total		33 sets

c. Replacement Plan of GCBs (gas circuit breakers) with Structural Problems (gas leakage, etc.)

Gumaca Substation	230 kV GCB	3 sets (Merlin, 1975)
Naga Substation	230 kV GCB	1 set (Merlin, 1975)
Total		4 sets

In addition, the replacement of three 230 kV GCBs at Santiago Substation (made by BBC in 1982) and two 230 kV GCBs at Pantabangan Power Plant (made by NISSIN in 1976) was requested. However, since the reason for the replacements was not clear, and since the same kind of circuit breakers are operating without any problem at other substations and power plants, they were not included in the current replacement plan. These circuit breakers should be examined further during the feasibility study.

d. Replacement Plan of 115 kV and 69 kV Circuit Breakers

There are 150 sets of 115 kV and 69 kV circuit breakers, comprising 25 GCBs, 103 OCBs and 22 ACBs. Of these, replacement of 19 OCBs and 14 ACBs has been planned as requested by the area offices and power plants.

San Esteban Substation	115 kV ACB	2 sets
La Trinidad Substation	69 kV OCB	2 sets
San Manuel Substation	69 kV OCB	1 set
San Manuel Substation	69 kV ACB	2 sets
Olongapo Substation	69 kV OCB	5 sets
Mexico Substation	69 kV OCB	9 sets
Gumaca Substation	69 kV OCB	1 set
Angat Power Plant	115 kV ACB	10 sets
Caliraya Power Plant	115 kV OCB	1 set
Total		33 sets

(2) Replacement of Disconnecting Switches

Most of the disconnecting switches connected in series with the foregoing circuit breakers to be replaced are difficult to open and close, use pin insulators, or have structural problems due to extreme deterioration through years of use. Thus, replacement of these disconnecting switches has been planned. The respective replacement plans will be reviewed further during the feasibility study.

230 kV	86 sets
115 kV	36 sets
69 kV	40 sets
Total	162 sets

(3) Provision of Spare Circuit Breakers

As mentioned in Item 3 of Sub-clause 6.4.1, the provision of 230 kV GCBs (gas circuit breakers) of standard specifications as spare circuit breakers has been planned.

230 kV 40 kA GCB 3 sets (two for NLRC, one for SLRC)

6.4.3 Priority Criteria and Priority

In consideration of the influence of faults, safety, and operation and maintenance problems, the priority is set as follows.

1. Replacement of overhead ground wires

2. Replacement of circuit breakers which will lack breaking capacity in the near future

3. Replacement of 230 kV circuit breakers

4. Adoption of steel towers for river or road crossings

5. Rerouting of transmission line section where restoration works are difficult

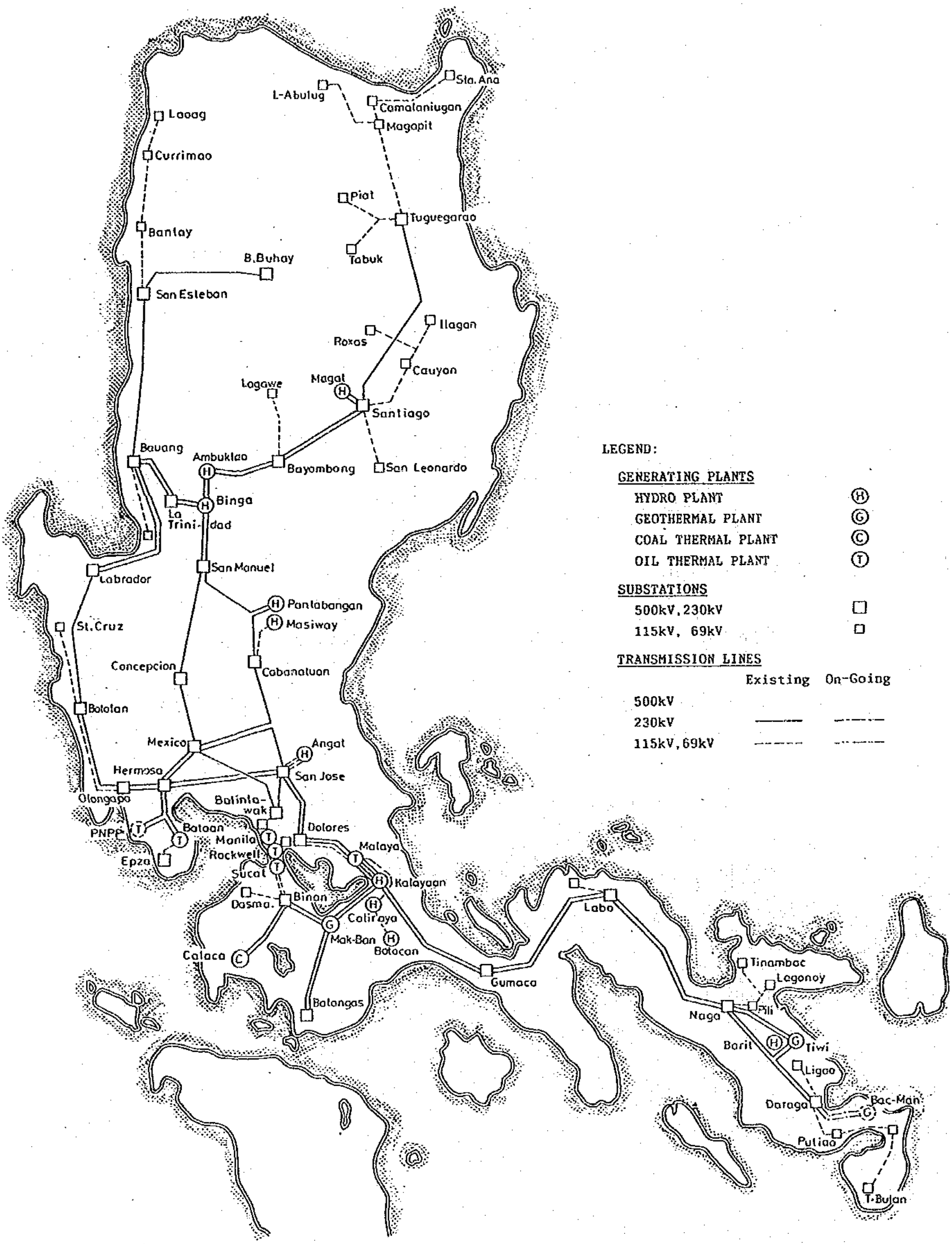
6. Provision of defective insulator detectors

7. Replacement of 115 kV and 69 kV circuit breakers

8. Replacement of disconnecting switches

9. Provision of spare circuit breakers

Fig. 6-4-1 LUZON GRID POWER SYSTEM DIAGRAM



LEGEND:

GENERATING PLANTS

HYDRO PLANT	Ⓗ
GEOTHERMAL PLANT	Ⓖ
COAL THERMAL PLANT	Ⓒ
OIL THERMAL PLANT	Ⓣ

SUBSTATIONS

500kV, 230kV	□
115kV, 69kV	▫

TRANSMISSION LINES

	Existing	On-Going
500kV		
230kV	——	—·—·—
115kV, 69kV	------	-·-·-·-

Table 6-4-1 LUZON GRID TRANSMISSION LINE DATA (1)

(100MVA Base)

From	To	Ckt. No.	kV	MVA	Length (km)	Positive		Zero		MVAR	Structure	Conductor	Comm. Year
						%R	%X	%R	%X				
Magat	Santiago	1	230	300	15.37	0.2551	1.3920	1.0273	4.3735	2.8020	ST-DC	1-795	1983
Magat	Santiago	2	230	300	15.37	0.2551	1.3920	1.0273	4.3735	2.8020	ST-DC	1-795	〃
Santiago	Tuguegarao	1	230	300	116.29	1.9304	11.2147	8.0709	31.6879	20.1119	ST-SC	1-795	1981
Bayombong	Santiago	1	230	300	42.68	0.7085	3.8753	2.8516	12.1262	7.7598	ST-DC	1-795	〃
Ambuklao	Santiago	1	230	300	105.01	1.7432	9.6000	7.0052	29.7141	18.9623	ST-DC	1-795	〃
Ambuklao	Bayombong	1	230	300	62.34	0.8992	4.9609	3.6125	15.3121	9.7640	ST-DC	1-795	〃
Ambuklao	Binga	1	230	300	8.28	0.1374	0.8147	0.5706	2.2293	1.4066	ST-SC	1-795	1956
Ambuklao	Binga	2	230	300	9.34	0.1549	0.9041	0.6358	2.5514	1.6156	ST-SC	1-795	1981
Bauang	San Esteban	1	230	300	95.17	1.5798	8.7565	6.3384	26.8254	17.0753	ST-DC	1-795	1983
Baguio	Bauang	1	230	300	35.88	0.5956	3.2932	2.3913	10.1286	6.4532	ST-DC	1-795	1977
Baguio	Bauang	2	230	300	35.88	0.5956	3.2932	2.3913	10.1286	6.4532	ST-DC	1-795	1989
Baguio	Binga	1	230	300	11.96	0.1985	1.1104	0.7948	3.3525	2.1261	ST-DC	1-795	1976
Baguio	Binga	2	230	300	11.96	0.1985	1.1104	0.7948	3.3525	2.1261	ST-DC	1-795	〃
Binga	San Manuel	1	230	300	34.30	0.5694	3.1365	2.2975	9.7026	6.1979	ST-DC	1-795	1956
Binga	San Manuel	2	230	300	34.30	0.5694	3.1365	2.2975	9.7026	6.1979	ST-DC	1-795	〃
Pantabangan	San Manuel	1	230	300	66.22	1.0969	6.0714	4.4070	18.8497	12.0793	ST-SC	1-795	1957
Concepcion	San Manuel	1	230	300	79.66	1.3223	7.6708	5.5262	21.7305	13.7969	ST-SC	1-795	1956
Concepcion	Mexico	1	230	300	37.42	0.6212	3.5984	2.5984	10.2147	6.4878	ST-SC	1-795	〃
Cabanatuan	Pantabangan	1	230	300	52.47	0.8687	4.7445	3.4565	15.1009	9.7012	ST-SC	1-795	1957
Cabanatuan	Mexico	1	230	300	67.31	1.1150	6.3239	4.4579	18.8886	12.0338	ST-SC	1-795	〃
Mexico	San Jose	1	230	300	54.04	0.8971	4.9666	3.6735	15.2182	9.7508	ST-SC	1-795	1959
Bauang	Labrador	1	230	300	114.00	1.8924	10.4766	7.6722	32.1480	20.5200	ST-DC	1-795	1991
Bauang	Labrador	2	230	300	114.00	1.8924	10.4766	7.6722	32.1480	20.5200	ST-DC	1-795	〃
Labrador	Botolan	1	230	300	112.71	1.8710	10.3580	7.5854	31.7842	20.2878	ST-SC	1-795	〃

Table 6-4-1 LUZON GRID TRANSMISSION LINE DATA (2)

(100MVA Base)

From	To	Ckt. No.	kV	MVA	Length (km)	Positive		Zero		MVAR	Structure	Conductor	Comm. Year
						%R	%X	%R	%X				
Botolan	Olongapo	1	230	300	60.55	1.0051	5.8462	4.2019	16.4856	10.4584	ST-DC	1-795	1985
Hermosa	Mexico	1	230	300	37.65	0.6212	3.1287	2.2967	11.5548	7.5187	ST-DC	1-795	1972
Hermosa	Mexico	2	230	300	37.65	0.6212	3.1287	2.2967	11.5548	7.5187	ST-DC	1-795	〃
Hermosa	Olongapo	1	230	300	25.58	0.4221	2.1257	1.5597	7.8505	5.1058	ST-DC	1-795	〃
Hermosa	Olongapo	2	230	300	25.58	0.4221	2.1257	1.5597	7.8505	5.1058	ST-DC	1-795	〃
Hermosa	PNPP	1	230	600	27.19	0.2257	1.5455	1.4626	7.6134	7.9410	ST-DC	2-795	1983
Hermosa	San Jose	1	230	600	74.98	0.6223	4.7192	4.4079	19.5507	19.6075	ST-DC	2-795	1984
Hermosa	San Jose	2	230	600	74.98	0.6223	4.7192	4.4079	19.5507	19.6075	ST-DC	2-795	〃
BTPP	Hermosa	1	230	300	37.19	0.6137	3.0916	2.2739	11.4075	7.4223	ST-DC	1-795	1959
BTPP	PNPP	1	230	300	40.03	0.6615	3.4275	2.4917	12.0158	7.7656	ST-DC	1-795	1983
BTPP	EPZA	1	230	300	14.79	0.2455	1.3628	0.9851	4.1652	2.6489	ST-DC	1-795	1976
Balintawak	Mexico	1	230	300	55.03	0.9135	5.2987	3.8206	15.0087	9.5286	ST-SC	1-795	1958
Balintawak	San Jose	1	230	300	30.18	0.4995	2.7052	1.9685	8.7476	5.6259	ST-SC	1-795	1956
Dolores	San Jose	1	230	1200	38.34	0.1610	2.2678	2.0758	9.5238	10.7246	ST-DC	4-795	1981
Dolores	San Jose	2	230	1200	38.34	0.1610	2.2678	2.0758	9.5238	10.7246	ST-DC	4-795	〃
Dolores	Malaya	1	230	1200	39.00	0.1638	2.2172	2.1274	9.8532	11.3694	ST-DC	4-795	〃
Dolores	Malaya	2	230	1200	39.00	0.1638	2.2172	2.1274	9.8532	11.3694	ST-DC	4-795	〃
Binan	Makban	1	230	300	32.74	0.5435	2.9312	2.1946	9.3795	6.0352	ST-DC	1-795	1979
Binan	Makban	2	230	300	32.74	0.5435	2.9312	2.1946	9.3795	6.0352	ST-DC	1-795	〃
Binan	Calaca	1	230	600	61.47	0.5102	3.9778	3.5973	15.8279	15.6434	ST-DC	2-795	1985
Binan	Calaca	2	230	600	61.47	0.5102	3.9778	3.5973	15.8279	15.6434	ST-DC	2-795	〃
Makban A	Makban B	1	230	300	1.16	0.0192	0.1021	0.0917	0.3305	0.2202	WP-SC	1-795	〃
Makban B	Makban C	1	230	300	0.62	0.0103	0.0542	0.0484	0.1779	0.1188	WP-SC	1-795	1986
Batangas	Makban A	1	230	300	35.17	0.5838	3.1426	2.3585	10.0871	6.4954	ST-DC	1-795	1979

Table 6-4-1 LUZON GRID TRANSMISSION LINE DATA (3)

(100MVA Base)

From	To	Ckt. No.	kV	MVA	Length (km)	Positive		Zero		MVAR	Structure	Conductor	Comm. Year
						%R	%X	%R	%X				
Batangas	Makban B	1	230	300	35.07	0.5822	3.1327	2.3520	10.0602	6.4790	ST-DC	1-795	1979
Kalayaan	Malaya	1	230	300	28.93	0.4802	2.6672	1.9263	8.1446	5.1792	ST-DC	1-795	1977
Kalayaan	Malaya	2	230	300	28.93	0.4802	2.6672	1.9263	8.1446	5.1792	ST-DC	1-795	〃
Kalayaan	Malaya	3	230	1200	28.87	0.1213	1.7081	1.5631	7.1709	8.0765	ST-DC	4-795	1984
Kalayaan	Malaya	4	230	1200	28.87	0.1213	1.7081	1.5631	7.1709	8.0765	ST-DC	4-795	〃
Kalayaan	Makban A	1	230	300	41.90	0.6955	3.7795	2.8037	11.9511	7.6678	ST-DC	1-795	1979
Kalayaan	Makban A	2	230	300	41.90	0.6955	3.7795	2.8037	11.9511	7.6678	ST-DC	1-795	〃
Gumaca	Kalayaan	1	230	300	94.11	1.5622	8.5093	6.2945	26.8054	17.1809	ST-DC	1-795	1977
Gumaca	Kalayaan	2	230	300	94.11	1.5622	8.5093	6.2945	26.8054	17.1809	ST-DC	1-795	〃
Gumaca	Labo	1	230	300	88.96	1.4767	8.0899	5.9439	25.2526	16.1458	ST-DC	1-795	〃
Gumaca	Labo	2	230	300	88.96	1.4767	8.0899	5.9439	25.2526	16.1458	ST-DC	1-795	〃
Labo	Naga	1	230	300	99.09	1.6449	8.8816	6.6412	28.3690	18.2447	ST-DC	1-795	〃
Labo	Naga	2	230	300	99.09	1.6449	8.8816	6.6412	28.3690	18.2447	ST-DC	1-795	〃
Naga	Tiwi A	1	230	300	60.54	1.0050	5.4662	4.0508	17.2581	11.0674	ST-DC	1-795	1978
Naga	Tiwi C	1	230	600	59.30	0.4922	3.8374	3.4703	15.2692	15.0912	ST-DC	2-795	1987
Naga	Tiwi C	2	230	600	59.30	0.4922	3.8374	3.4703	15.2692	15.0912	ST-DC	2-795	〃
Tiwi A	Tiwi B	1	230	300	1.50	0.0249	0.1404	0.0995	0.4184	0.2645	ST-SC	1-795	
Tiwi A	Tiwi C	1	230	300	1.35	0.0224	0.1264	0.0895	0.3765	0.2380	ST-SC	1-795	
Tiwi B	Tiwi C	1	230	300	1.29	0.0214	0.1207	0.0855	0.3598	0.2274	ST-SC	1-795	
Naga	Daraga	1	230	300	71.09	1.1801	6.5332	4.7844	20.0474	12.7962	ST-DC	1-795	1980
Daraga	Tiwi	1	230	300	74.45	1.2359	6.8420	5.0105	20.9950	13.4010	ST-DC	1-795	〃

Table 6-4-1 LUZON GRID TRANSMISSION LINE DATA (4)

(100MVA Base)

From	To	Ckt. No.	kV	MVA	Length (km)	Positive		Zero		MVAR	Structure	Conductor	Comm. Year
						%R	%X	%R	%X				
Currimao TP	Laoag	1	115	150	26.82	1.7766	8.9888	7.0367	32.5741	1.3245	WP-SC	1-795	1967
Currimao TP	Bantay	1	115	150	55.34	3.6664	18.5592	14.6939	67.0602	2.7325	WP-SC	1-795	1972
Currimao	Currimao TP	1	115	150	0.50	0.0332	0.1688	0.1704	0.5771	0.0246	WP-SC	1-795	1981
Angat	San Jose	1	115	150	17.39	1.1530	5.7822	4.2974	21.3243	0.8678	ST-DC	1-795	1967
Angat	San Jose	2	115	150	17.39	1.1530	5.7822	4.2974	21.3243	0.8678	ST-DC	1-795	〃
Angat	San Jose	3	115	150	16.00	1.0622	5.7185	5.0419	18.0463	0.7419	WP-SC	1-795	1960
Balintawak	San Jose	1	115	150	29.82	1.9771	10.4499	8.0258	34.9611	1.4151	ST-DC	1-795	1967
Balintawak	San Jose	2	115	150	29.82	1.9771	10.4499	8.0258	34.9611	1.4151	ST-DC	1-795	〃
Binan	Sucat	1	115	300	15.49	0.5146	3.9677	3.6329	16.0290	0.9956	ST-DC	2-795	1985
Binan	Sucat	2	115	300	15.49	0.5146	3.9677	3.6329	16.0290	0.9956	ST-DC	2-795	〃
Binan	Dasmarinas	1	115	150	14.46	0.9596	4.8821	4.3529	17.0830	0.7115	ST-DC	1-795	〃
Binan	Dasmarinas	2	115	150	14.46	0.9596	4.8821	4.3529	17.0830	0.7115	ST-DC	1-795	〃
Sun Esteban	Bantay	1	115	150	38.21	2.5353	12.8985	11.5004	45.1332	1.8798	WP-SC	1-795	1972

Table 6-4-2 **TRANSMISSION LINE LENGTH AND SUBSTATION CAPACITY** (1)

Regional Center	Voltage (kV)	Transmission Line				Substation		
		Route Length (km)		Circuit Length (km)		Number of Substation	Transformer	
		S T	Total	S T	Total		Unit	MVA
N L R C	230	1,328.23	1,328.23	1,891.09	1,891.09	16	20	2,095
	115	39.91	239.07	79.82	278.98	3	4	110
	69	54.97	1,928.52	109.94	1,985.09	27	41	328
	Below 69		423.20		445.20			
	Total	1,423.11	3,919.02	2,080.85	4,600.36	46	65	2,533
S L R C	230	670.46	670.46	1,340.42	1,340.42	6	11	1,390
	115	60.27	133.12	90.54	163.39	3	4	200
	69		978.43		991.20	19	23	138.5
	Below 69		75.76		78.91			
	Total	730.73	1,857.77	1,430.96	2,573.92	28	38	1,728.5
Total	230	1,998.69	1,998.69	3,231.51	3,231.51	22	31	3,485
	115	100.18	372.19	170.36	442.37	6	8	310
	69	54.97	2,906.95	107.94	2,976.29	46	64	466.5
	Below 69		498.96		524.11			
	Total	2,153.84	5,776.79	3,511.81	7,174.28	74	103	4,261.5

(Note) S T : Steel Tower

Table 6-4-2 TRANSMISSION LINE LENGTH AND SUBSTATION CAPACITY (2)

Regional Center	Area Office	Voltage (kV)	Transmission Line				Substation		
			Route Length (km)		Circuit Length (km)		Number of Substation	Transformer	
			S T	Total	S T	Total		Unit	MVA
N L R C	Area-1	230	159.56	159.56	178.36	178.36	2	2	100
		115		125.16		125.16	3	3	60
		69		182.57		182.57	1	7	45
		Below 69		5.77		5.77			
		Total	159.56	473.06	178.36	491.86	6	12	205
	Area-2	230	85.80	85.80	158.90	158.90	1	1	75
		115							
		69		354.94		354.94	2	2	50
		Below 69		90.11		90.11			
		Total	85.80	530.85	158.90	603.95	3	3	125
	Area-3	230	164.00	164.00	193.00	193.00	3	4	200
		115							
		69		397.29		397.29	9	10	55
		Below 69		234.38		234.38			
		Total	164.00	795.67	193.00	824.67	12	14	255
	Area-4	230	220.14	220.14	324.35	324.35	3	3	120
		115							
		69		443.54		443.54	3	6	80
		Below 69							
		Total	220.14	663.68	324.35	767.89	6	9	200

Table 6-4-2 TRANSMISSION LINE LENGTH AND SUBSTATION CAPACITY (3)

Regional Center	Area Office	Voltage (kV)	Transmission Line				Substation		
			Route Length (km)		Circuit Length (km)		Number of Substation	Transformer	
			S T	Total	S T	Total		Unit	MVA
NLRC	Area-5	230	210.57	210.57	304.49	304.49	3	3	150
		115							
		69	25.00	245.50	50.00	272.10	7	9	50
		Below 69		25.34		25.34			
		Total	235.57	481.41	354.49	601.93	10	12	200
	Area-6	230	179.36	179.36	263.53	263.53	2	3	250
		115							
		69	29.97	239.68	59.94	269.65	4	6	38
		Below 69		33.60		33.60			
		Total	209.33	452.64	323.47	566.78	6	9	288
	Area-7	230	308.80	308.80	468.46	468.46	2	4	1,200
		115	39.91	113.91	79.82	153.82		1	50
		69		65.00		65.00	1	1	10
		Below 69		34.00		56.00			
		Total	348.71	521.71	548.28	743.28	3	6	1,260
	Total	230	1,328.23	1,328.23	1,891.09	1,891.09	16	20	2,095
		115	39.91	239.07	79.82	278.98	3	4	110
		69	54.97	1,928.52	109.94	1,985.09	27	41	328
		Below 69		423.20		445.20			
		Total	1,423.11	3,919.02	2,080.85	4,600.36	46	65	2,533

Table 6-4-2 TRANSMISSION LINE LENGTH AND SUBSTATION CAPACITY (4)

Regional Center	Area Office	Voltage (kV)	Transmission Line				Substation		
			Route Length (km)		Circuit Length (km)		Number of Substation	Transformer	
			S T	Total	S T	Total		Unit	MVA
SLRC	Area-1	230	78.00	78.00	156.00	156.00	1	1	100
		115	14.47	85.62	28.97	100.09	3	4	200
		69		261.88		261.88	5	8	46.5
		Below 69		31.48		31.48			
		Total	92.47	456.98	184.94	549.45	9	14	346.5
	Area-2	230	298.14	298.14	595.78	595.78	2	6	1,140
		115	45.80	47.50	61.60	63.30			
		69		261.38		261.38	5	6	45
		Below 69		44.28		47.43			
		Total	343.94	651.30	657.38	967.89	7	12	1,185
	Area-3	230	294.32	294.32	588.64	588.64	3	3	150
		115							
		69		455.17		467.94	9	9	47
		Below 69							
		Total	294.32	749.49	588.64	1,056.58	12	12	197
	Total	230	670.46	670.46	1,340.42	1,340.42	6	11	1,390
		115	60.27	133.12	90.54	163.39	3	4	200
		69		978.43		991.20	19	23	138.5
		Below 69		75.76		78.91			
		Total	730.73	1,857.77	1,430.96	2,573.92	28	38	1,728.5

Table 6-4-3 230kV SUBSTATION TRANSFORMER TECHNICAL DATA (1)

NORTHERN LUZON REGIONAL CENTER (1/3)

Name of Substations	Bank Nos.	Capacity (MVA)	Rated Voltage (kV)	Connec-tions	Manufac-turer	Mfg. Date	Remarks
AREA 1							
Bauang	T1	50	220/69-13.8	Y-Y-D	INDUSTRIE	1975	
	T2	(5)	67/13.8	D-Y	ATELIERS	1977	Distri. Tr.
San Esteban	T1	20	110/69-13.8	Y-D	ITALTRAFO	1977	
	T2	50	220/115-13.8	Y-Y-D	TAKAOKA	1980	
	T3	(5)	67/13.8	D-Y	OSAKA	1972	Distri. Tr.
AREA 2							
La Trinidad	T1	75	220/69-13.8	Y-Y-D	OSAKA	1982	
	T2	75	220/69-13.8	Y-Y-D	OSAKA	1978	
AREA 3							
San Manuel	T1	50	220/69-13.8	Y-Y-D	MITSUBISHI	1968	
Cabanatuan	T1	50	220/69-13.8	Y-Y-D	INDUSTRIE	1973	
	T2	50	220/69-13.8	Y-Y-D	OSAKA	1975	
Labrador	T1	50	220/69-13.8	Y-Y-D	HYUNDAI	1988	
AREA 4							
Tuguegarao	T1	40	230/69-13.8	Y-Y-D	MEIDENSHA	1979	
	T2	(15)	69/13.8	D-Y	AICHI	1979	Distri. Tr.
Santiago	T1	40	230/69-13.8	Y-Y-D	MEIDENSHA	1979	
	T2	(15)	69/13.8	D-Y	AICHI	1979	Distri. Tr.

Table 6-4-3 230kV SUBSTATION TRANSFORMER TECHNICAL DATA (2)

NORTHERN LUZON REGIONAL CENTER (2/3)

Name of Substations	Bank Nos.	Capacity (MVA)	Rated Voltage (kV)	Connec-tions	Manufac-turer	Mfg. Date	Remarks
Bayombong	T1	40	230/69-13.8	Y-Y-D	MEIDENSHA	1979	
	T2	(15)	69/13.8	D-Y	AICHI	1979	Distri. Tr.
AREA-5							
Hermosa	T1	50	220/69-13.8	Y-Y-D	FUJI	1977	
Olongapo	T1	50	220/69-13.8	Y-Y-D	INDUSTRIE	1973	
	T2	50	220/69	D-Y	MEIDENSHA	1972	
Botolan	T1	50	220/69-13.8	Y-Y-D	TAKAOKA	1973	
AREA 6							
Concepcion	T1	50	220/69-13.8	Y-Y-D	FUJI	1980	
Mexico	T1	100	220/69-13.8	Y-Y-D	FUJI	1979	
	T2	100	220/69-13.8	Y-Y-D	FUJI	1982	
	T3	100	220/69-13.8	Y-Y-D	TAKAOKA	1975	
	T4	(5)	69/13.8	D-Y	OSAKA	1971	Distri. Tr.
AREA 7							
San Jose	T1	300	220/115-13.8	Y-Y-D	FUJI	1977	
	T2	(50)	115/34.5	Y-Y	OSAKA	1978	Distri. Tr.
Dolores	T1	300	220/115-13.8	Y-Y-D	FUJI	1983	
	T2	300	220/115-13.8	Y-Y-D	FUJI	1983	
	T3	300	220/115-13.8	Y-Y-D	FUJI	1985	

Table 6-4-3 230kV SUBSTATION TRANSFORMER TECHNICAL DATA (3)

SOUTHERN LUZON REGIONAL CENTER (3/3)

Name of Substations	Bank Nos.	Capacity (MVA)	Rated Voltage (kV)	Connec- tions	Manufac- turer	Mfg. Date	Remarks
AREA 1							
Batangas	T1	50	220/69-13.8	Y-Y-D	FUJI	1978	
	T2	50	220/69-13.8	Y-Y-D	FUJI	1978	
AREA 2							
Binan	T1	100	220/115-13.8	Y-Y-D	FUJI	1978	
	T2	300	220/115-13.8	Y-Y-D	FUJI	1982	
	T3	300	220/115-13.8	Y-Y-D	FUJI	1982	
	T4	300	220/115-13.8	Y-Y-D	FUJI	1982	
	—	100	220/115-13.8	Y-Y-D	FUJI	1978	Stand-by
Gumaca	T1	40	230/69-13.8	Y-Y-D	MEIDENSHA	1979	
AREA 3							
Labo	T1	50	220/69-13.8	Y-Y-D	ITALTRAFO	1977	
Naga	T1	50	230/69-13.8	Y-Y-D	ITALTRAFO	1977	
Daragag	T1	50	220/69-13.8	Y-Y-D	FUJI	1977	

Table 6-4-4 230kV SUBSTATION FAULT LEVELS AND TECHNICAL DATA OF CIRCUIT BREAKERS (1)

NORTHERN LUZON REGIONAL CENTER

(1/7)

Substation Bus	Fault Level in 1995 (MVA/kA)		Breaker Nos.	Units	Type	Rated Voltage (kV)	Rated Current (A)	Rated Int. Capacity (MVA/kA)		Int. Time (Cy's)	Manufacturer	Mfg. Date	Remarks
AREA 1													
Bauang 230	2,223	5.6	82BG4/124/8 84BG4/124	5	GCB	230	2,000	10,000	(25)	3	NISSIN Elect.	1988	
			83BG4/124/8	3	ACB	230	1,200	5,000	(12.5)	3	NISSIN Elect.	1975	
			85BG8/124	2	GCB	230	1,200	10,000	(25)	3	FUJI Elect.	1980	
Bauang 115	409	2.1	61BG4	1	ACB	115	1,200	5,000	(25)	3	NISSIN Elect.	1975	
Bauang 69	420	3.5	51BG4, 54BG4 55BG4, 56BG4	4	OCB	69	1,200	2,500	(20)	5	NISSIN Elect.	1975	
			57BG4	1	OCB	69	1,200	(2,500)	20	5	INOUE Elect.	1988	
San Esteban 230	743	1.9	82SE4/124/8 83SE124/8	5	GCB	230	1,200	10,000	(25)	3	FUJI Elect.	1987	
San Esteban 115	324	1.6	61SE4	1	GCB	115	1,200	7,500	(36)	3	FUJI Elect.	1975	
			63SE4, 64SE4	2	ACB	115	2,000	5,000	(25)	3	B.B.C.	1976	
San Esteban 69	200	1.7	51SE4, 52SE4 53SE4	3	ACB	69	2,000	3,500	(30)	3	B.B.C.	1976	
AREA 2													
La Trinidad 230	2,663	6.7	81LT8 82LT4/124/8 83LT4/124/8	7	GCB	230	2,000	10,000	(25)	3	NISSIN Elect.	1978	
			81LT4/124	2	GCB	230	2,000	15,000	(37.5)	3	NISSIN Elect.	1983	
La Trinidad 69	941	7.9	52LT4, 56LT4 57LT4, 58LT4	4	OCB	69	1,200	2,500	(20)	5	NISSIN Elect.	1975	
			53LT4, 54LT4	2	OCB	69	1,200	2,500	(20)	5	TAKAOKA	1975	
			51LT4, 55LT4	2	OCB	69	1,200	2,500	(20)	5	INOUE Elect.	1983	