Table 3 - 13 Analyses of Remaining Life of Runner Buckets (1/3)

1. Allowable length of runner buckets cracks

(1) Max. length and depth of runner buckets cracks

The following data are based on Table 3.6 (Remarkable Defects of Bukets).

Unit No.	Max. length of cracks	Max. depth of cracks
1	3 mm	5 mm
2	4 mm	4 mm
3	3 mm	2.5 mm
4	9 mm	3 mm

(2) Estimation of allowable length of runner bukets cracks

a) Basic design data of runner model

Head : 720 m
Out put : 42 MW
Pitch circular diameter of bucket : 2.04 m

b) Stress at root portion of runner bucket : $\sigma A = 3.3$ kgf/mm²

c) Local stress at root portion of runner bucket : $\sigma L = 3.3$ kgf/mm² x 2 = 6.6 kgf/mm²
Local max. stress amplitude : $\sigma a = \pm 3.3$ kgf/mm2

Note: The local stress was estimated on the basis of the stress analysis result on similar runner bucket to the Da Nhim power station.

d) Allowable crack length : 2.7 mm

Note: From relation curve between allowable crack length and stress amplitude shown in Figure 3.6, the allowable crack length was estimated.

2. Estimation of remaining life time of runner bucket

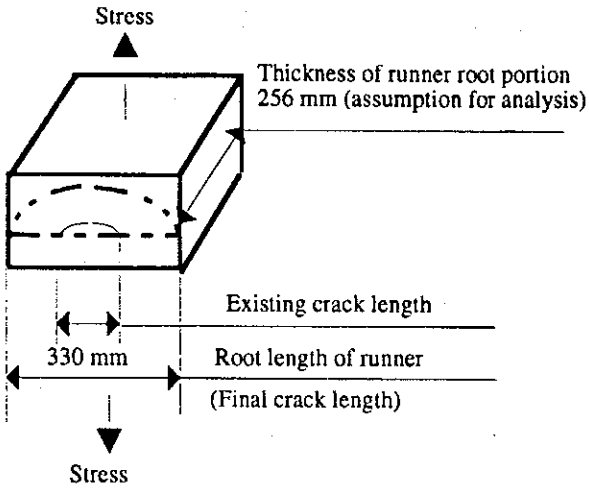
(1) Procedure of analysis

The duration to be expected to extend the existing crack up to overall length of runner are estimated considering the following factors.

- Analysis model formed on the basis of the existing defect condition of runner
- Average stress to be applied to the runner during operation
- Frequency of stress cycle to be applied to the runner during operation

Table 3 - 13 Analyses of Remaining Life of Runner Buckets (2/3)

1) Analysis model formed on the basis of the existing defect condition of runner



2) Average stress to be applied to the runner during operation

Average stress includes the following stresses:

- Stress at root portion of runner bucket (ref. to above item 1.(2). b)) : $\sigma A = 3.3$ kgf/mm2
- Stress due to centrifugal force of runner : $\sigma r = 0.8$ kgf/mm2
- Residual stress of runner : $\sigma R = 10$ kgf/mm2

Average stress = $\sigma A + \sigma r + \sigma R = 14.1$ kgf/mm2

3) Frequency of stress cycle to be applied to the runner during annual operation

$Ni = T \times N \times 60 \times ji = 8{,}000 \times 500 \times 60 \times 2 = 4.8 \times 10^8$ times

where, T : Assumed annual operation hour : 8,000 hrs.
N : Rated speed : 500 rpm
ji : Numbers of nozzele = 2

(2) Estimation of remaining life of runner

The frequency of stress cycle to be extended the existing crack up to overall root length of runner is estimated using the fatigue crack growth curve in Figure 3.6.

Table 3 - 13 Analyses of Remaining Life of Runner Buckets (3/3)

The estimated remaining life for each runner is as follows:

Unit Nos.	Existing crack length	Frequency of stress cycle to be extended the crack to overall root length of runner (N)	Estimated remaining life (Ni/N)	Result of crack growth curve
1 & 3	3 mm	3.7628×10^9 times	7.8 years	Figure 3.7
2	4 mm	3.4101×10^9 times	7.1 years	Figure 3.7
4	9 mm	9.7159×10^9 times	2.0 years	Figure 3.7

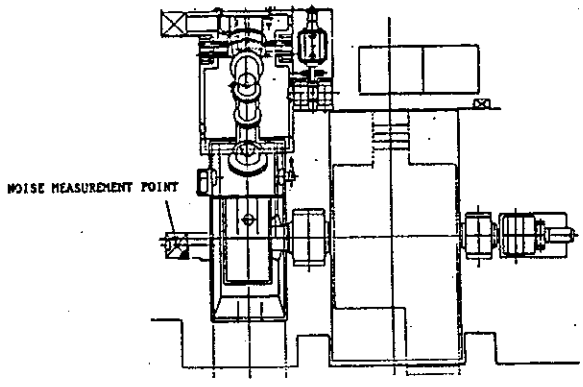
(3) Conclusion

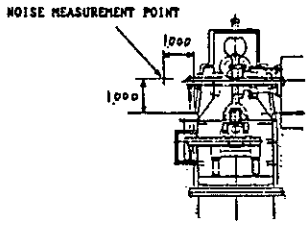
As a result of the above estimation, it is recommended that all the runners will be required to take proper measure within following period.

Unit No.4 : Two (2) years

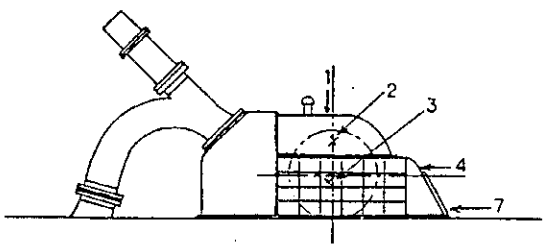
Unit No.1, 2 & 3 : Seven (7) years

Noise Measurement Point

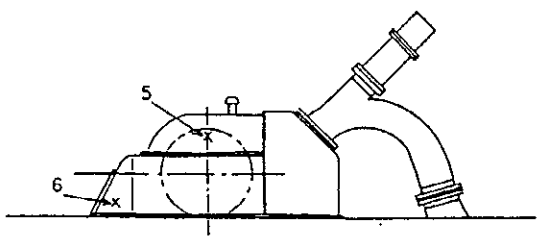




Vibration Measurement Point



VIEW FROM W/T

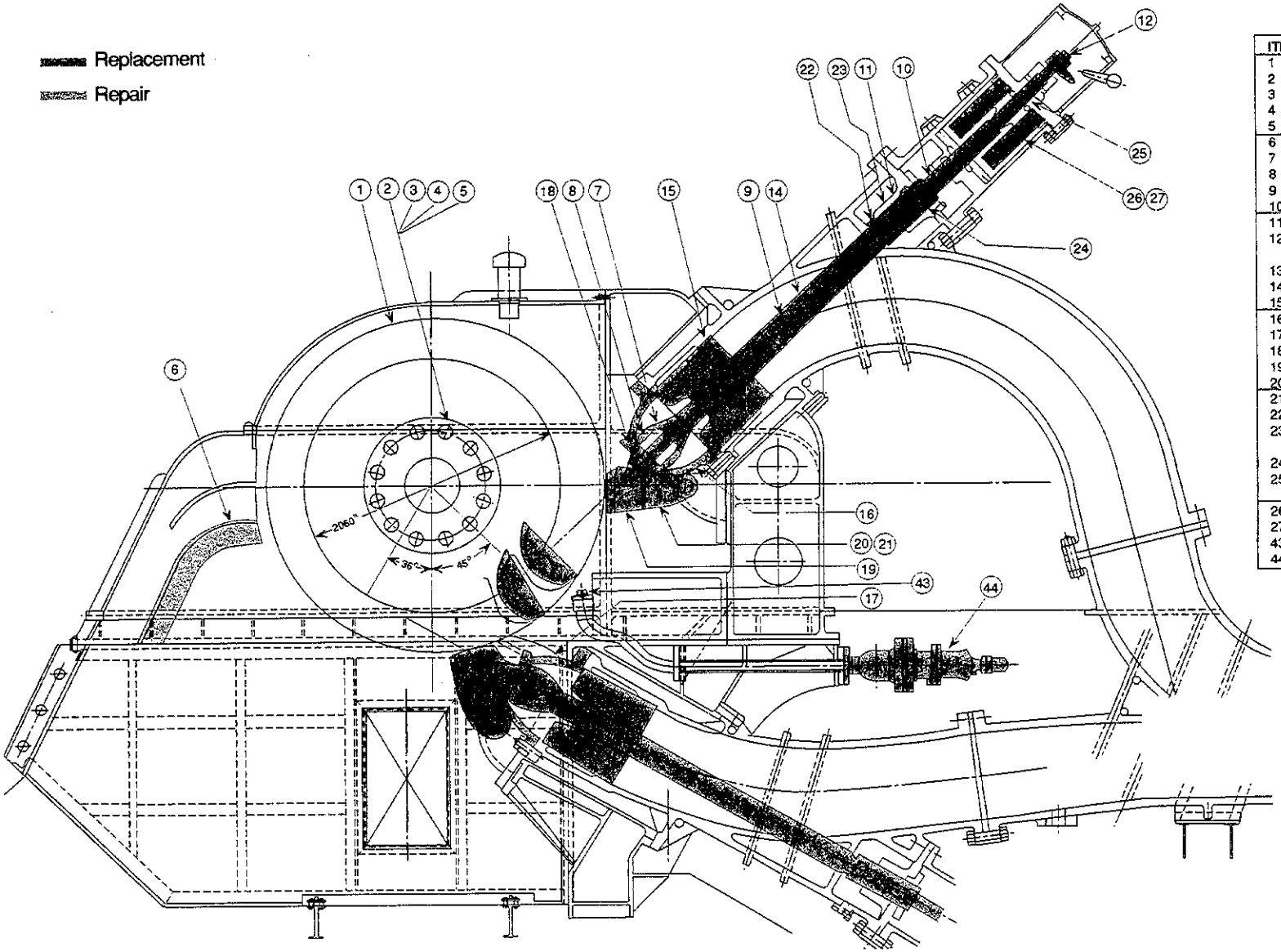


VIEW FROM GEN.

FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 3.1 Noise & Vibration Measurement Point

Replacement

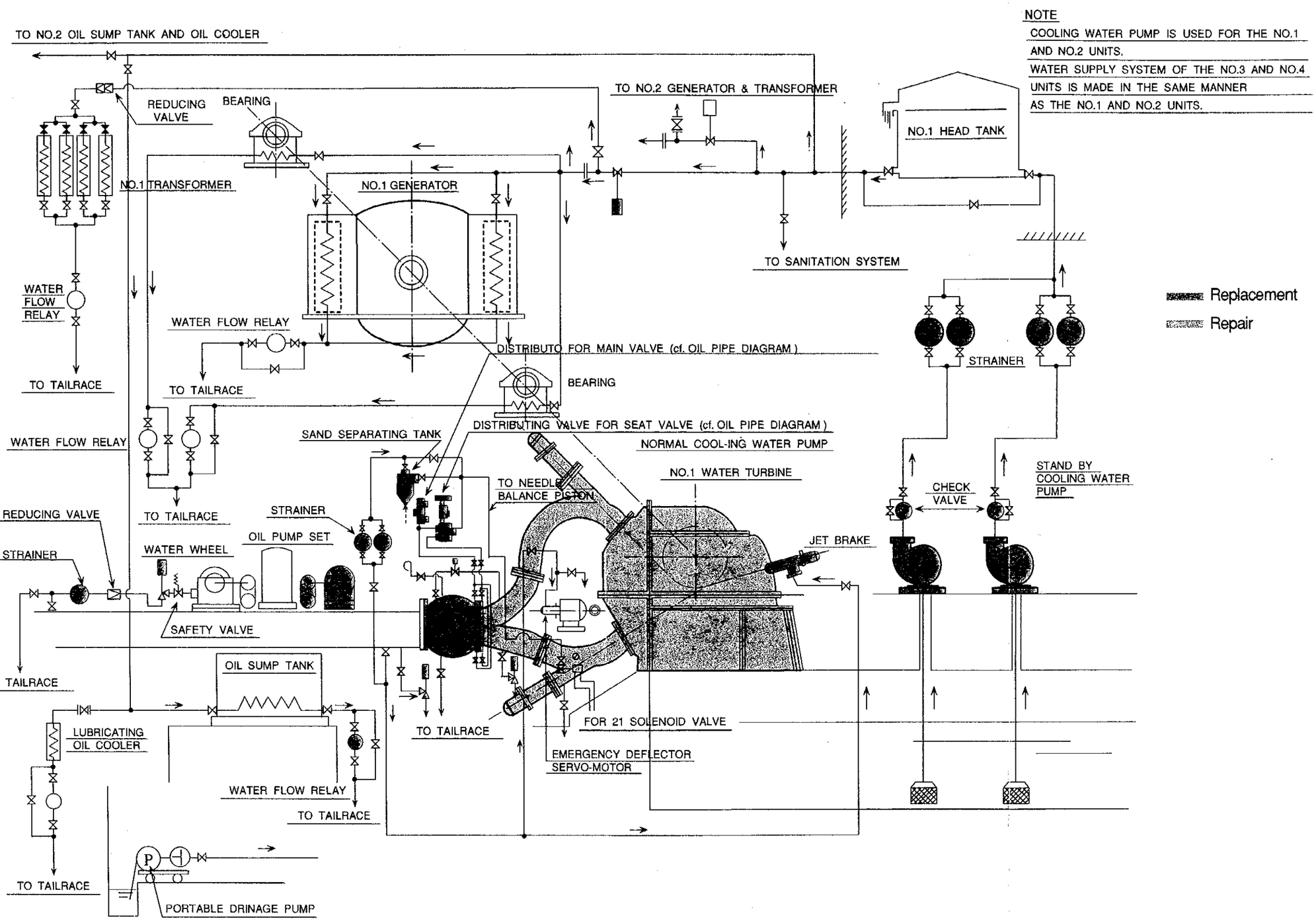
Repair



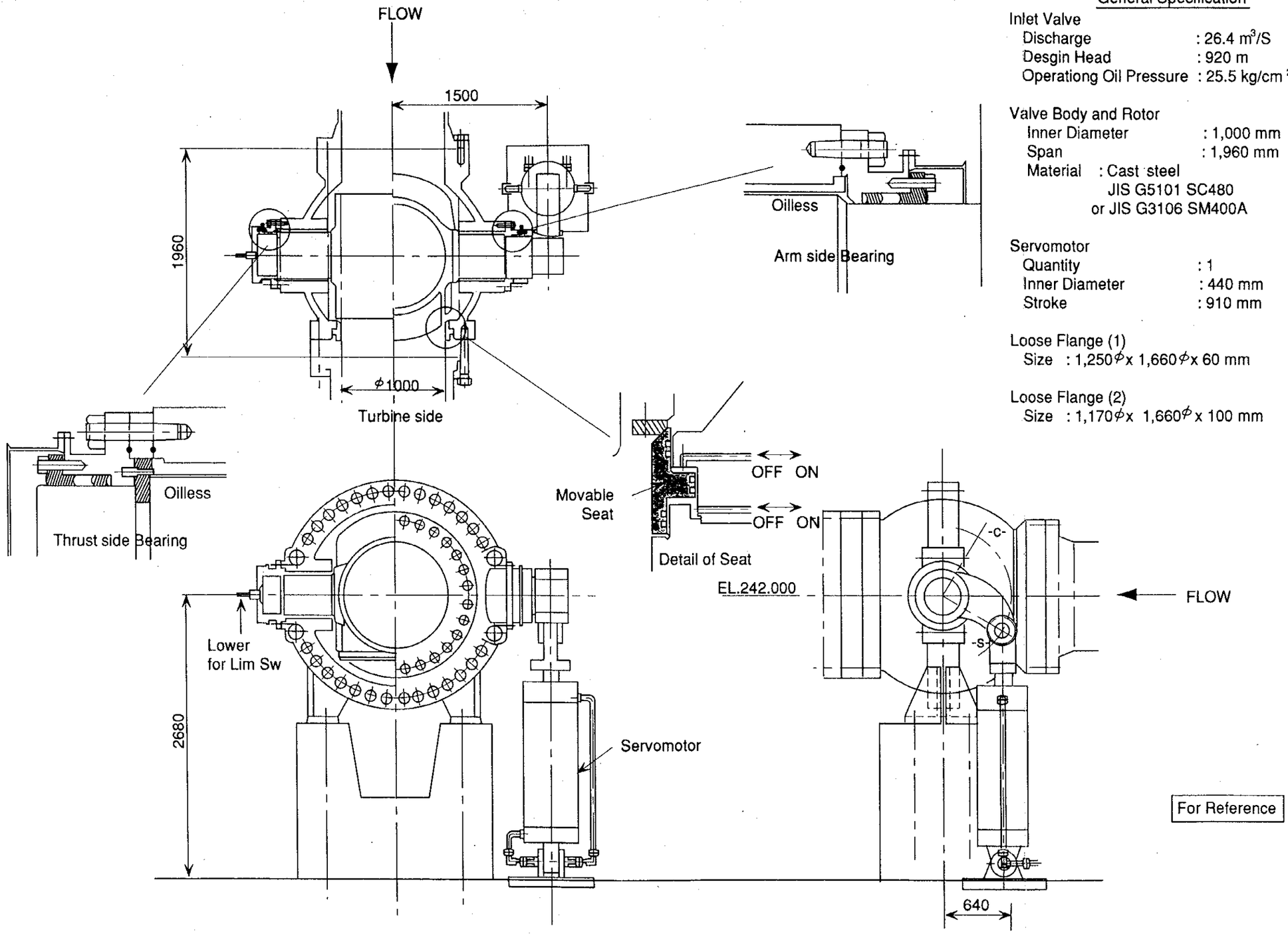
REPLACEMENT

ITEM	LIST OF PARTS
1	RUNNER
2	REAMER BOLT
3	LOCK PLATE
4	COVER
5	BOLT FOR COVER
6	BAFFLE PLATE
7	NEEDLE HEAD
8	NEEDLE TIP
9	NEEDLE SPINDLE SERVO-M
10	NEEDLE SPINDLE
11	BALANCE PISTON
12	STOPPER FOR NEEDLE & LOCK NUT SERVO SPINDLE
13	NEEDLE SPINDLE LINER
14	PROTECTING PIPE
15	NEEDLE GUIDE
16	UPPER NOZZLE
17	LOWER NOZZLE
18	NOZZLE TIP
19	DEFLECTOR TIP
20	DEFLECTOR HEAD
21	KEY FOR DEFLECTOR HEAD
22	BALANCE PISTON SLEEVE
23	BALANCE GUIDE PISTON BUSHING
24	V SHAPE GASKET
25	COVER BUSHING FOR NEEDLE SERVO
26	SPRING FOR NEEDLE SERVO
27	PISTON RING FOR NEEDLE SERVO
43	NOZZLE FOR JET BRAKE
44	NEEDLE VALVE FOR JET BRAKE

FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 3.2 Turbine



FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 3.3 Water Supply System



General Specification

Inlet Valve
- Discharge : 26.4 m^3/S
- Desgin Head : 920 m
- Operationg Oil Pressure : 25.5 kg/cm^2

Valve Body and Rotor
- Inner Diameter : 1,000 mm
- Span : 1,960 mm
- Material : Cast steel
  JIS G5101 SC480
  or JIS G3106 SM400A

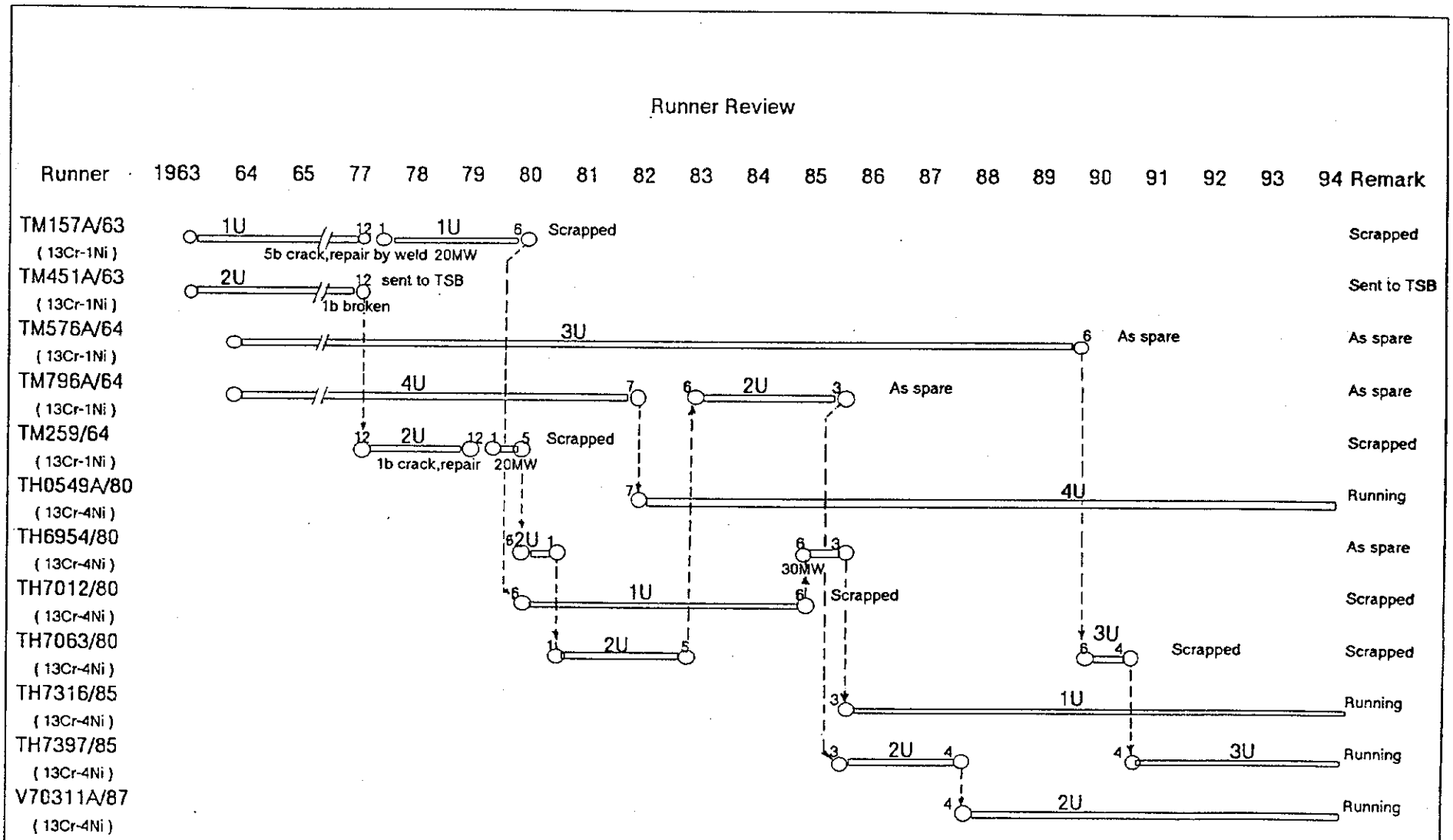
Servomotor
- Quantity : 1
- Inner Diameter : 440 mm
- Stroke : 910 mm

Loose Flange (1)
- Size : 1,250φx 1,660φx 60 mm

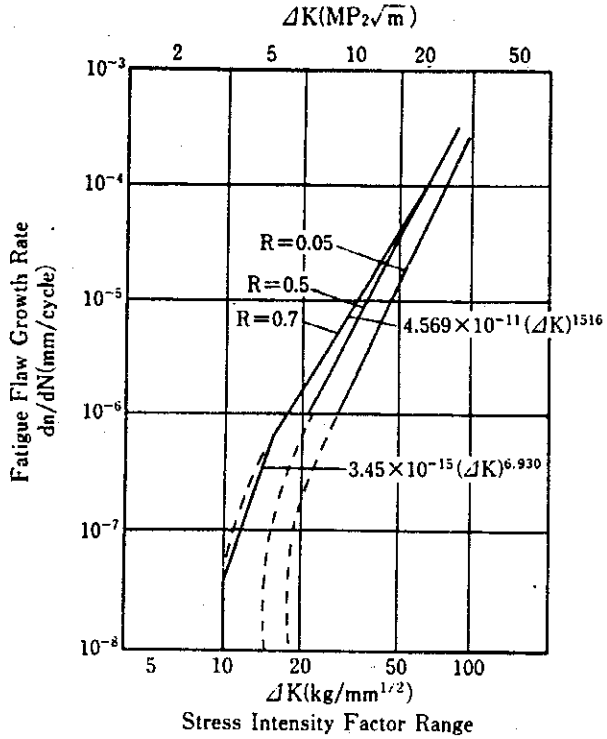
Loose Flange (2)
- Size : 1,170φx 1,660φx 100 mm

For Reference

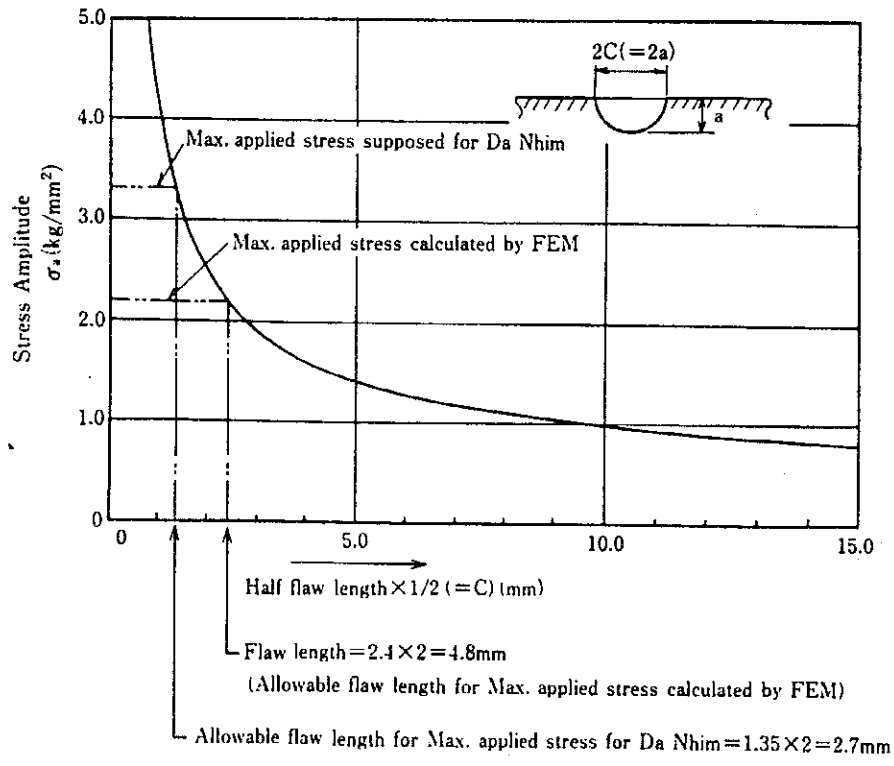
FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 3.4 Inlet Valve



FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 3.5 Runner Review

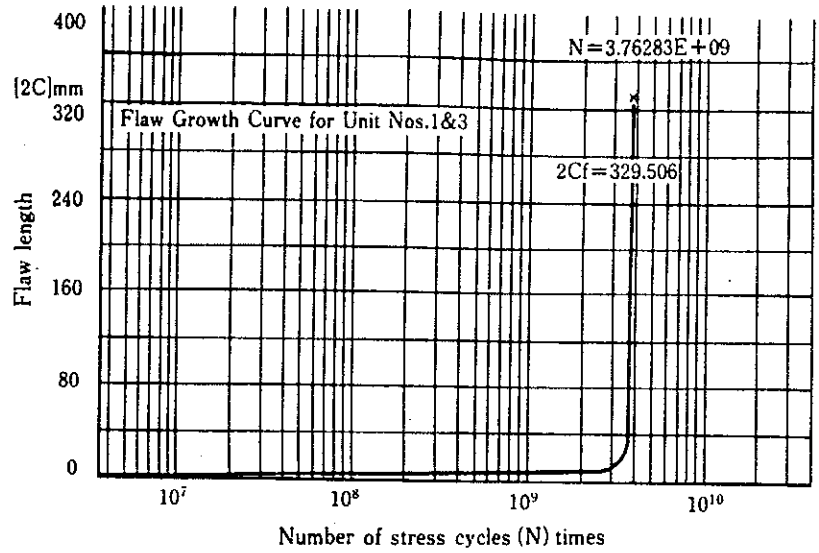


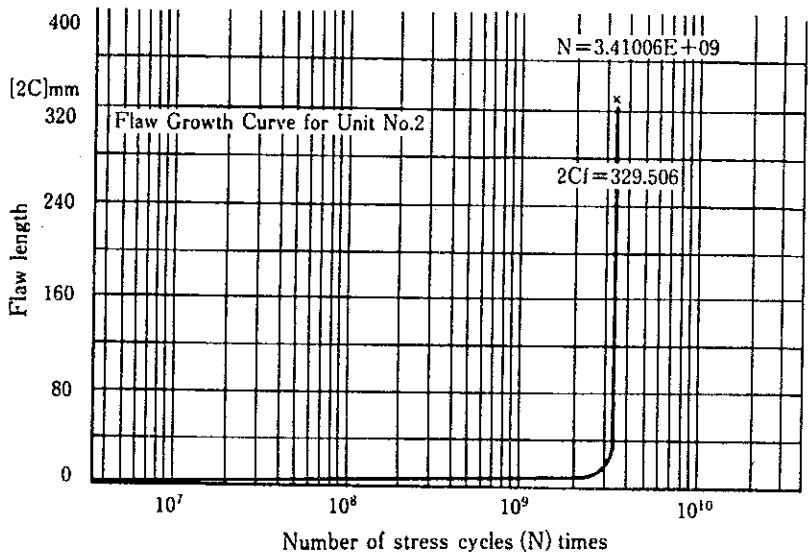
Fatigue Flaw Growth Curves for 13Cr~4Ni Stainless Steel Casting

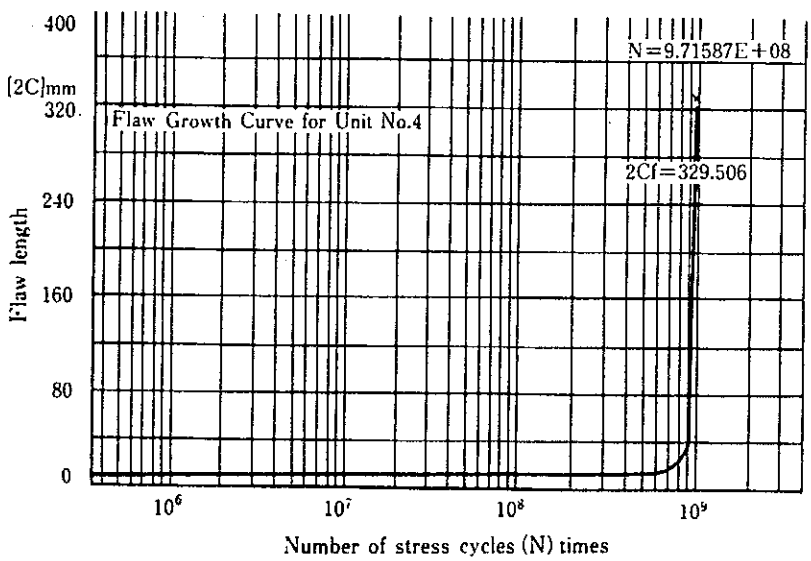


Result of Analysis on Applied Strees-Allowable Flaw Length

FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 3.6 Analysis of Remaining Life of Buckets (1/2)







FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 3.7 Analysis of Remaining Life of Buckets (2/2)

CHAPTER 4

GENERATOR AND ANCILLARY FACILITIES

CHAPTER 4 GENERATOR AND ANCILLARY FACILITIES

4.1 Approach and Result of The Study

4.1.1 Study Method

Main features of the generators and exciters are given below:

Generators

Rated output	45,000 kVA
Rated voltage	13.2 kV
Rated current	1,970 A
Frequency	50 Hz
Number of poles	12 poles
Rated speed	500 r.p.m
Insulation class of stator winding	B class

Exciters

Rated output	160 kW
Rated voltage	220 V

Date of commissioning

No.1 unit	November, 1963
No.2 unit	December, 1963
No.3 unit	October, 1964
No.4 unit	October, 1964

The field investigation for the generating facilities of the Study Team was carried out as follows:

(1) Inspection under the full load operation of the generating facilities

1) Overall inspection	Shaft voltage, displacement of shaft, vibration, sound, temperature, and oil lifter

2)	Visual inspection	Oil vapor, leakage of oil and water, and condition of brushes

(2) Inspection under the non-operation of the generating facilities

1)	Insulation of stator winding	Measurement of insulation resistance and tan δ, and polarization index measurement
2)	Insulation of rotor winding	Measurement of insulation resistance and checking of layer short on winding by balance voltage method
3)	Nondestructive test of generator shaft	Magnetic particle test and liquid penetrant examination on unit Nos.2 and 4
4)	Nondestructive test for bearing metal	Ultrasonic and liquid penetrant examination, and visual inspection on unit Nos. 2 and 4
5)	Measurement of gap	Measurement by lead wire, thickness gauge, taper gauge, and scale
6)	Visual inspection	Referring to check sheet 6

4.1.2 Period of Field Investigation

(1) Investigation under the full load operation of the generating facilities

1)	Before dismantling :	July 17, 1994
2)	After re-assembling :	August 17, 1994

(2) Investigation under the non-operation of the generating facilities

1)	No.1 and No.2 units :	July 18 to July 31, 1994
2)	No.3 and No.4 units :	August 1 to August 13, 1994

4.1.3 Results of Field Investigation

(1) Study under the full load operation of the generating facilities

1) Overall inspection

a) Measurement of shaft voltage

Results of the measured shaft voltage of the generators are satisfactory as seen below:

No.1 unit	4.6 V
No.2 unit	5.3 V
No.3 unit	8.3 V
No.4 unit	6.2 V

b) Displacement of shaft

The maximum horizontal displacement of the shaft was 0.15 mm measured by a dial gauge. The end play measured by a scale in the direction of the shaft was almost zero on No.3 and No.4 units, and 0.2 mm and 0.6 mm on No.1 and No.2 units respectively against the reference value of 1.0 mm.

c) Vibration of bearing

The maximum measured vibration was horizontally 19μ at the exciter side for No.1 unit. The vibration of the generators was generally little comparing with the reference value of 150μ, P-P.

d) Noise

The noise levels measured at the around of the air housing of the generators were considerably high as much as 106 to 108 decibels at all the units.

e) Temperature of stator winding

The temperature of the stator winding was measured by means of the search coils embedded between the upper and lower stator coils.

Average temperature measured at the time of commencement of operation and the present condition are shown below.

Comparison of Stator Winding Temperature

	Average Temperature		Increase
	Commencement (A)	Present (B)	(B)-(A)
No.1 unit	68.0°C (Nov.18, '63)	75.8°C (Aug. 02, '94)	7.8°C (11.5%)
No.2 unit	68.2°C (Dec.14, '63)	74.0°C (Aug. 06, '94)	5.8°C (8.5%)
No.3 unit	63.7°C (Oct.27, '63)	71.8°C (Jul. 17, '94)	8.1°C (12.7%)
No.4 unit	65.2°C (Oct.31, '63)	71.8°C (Jul. 25, '94)	6.6°C (10.0%)

The above data show that the average temperature increased about 10% from the initial operation time of the generators.

f) Temperature of bearing metal

The main bearing metals are of direct water cooled type by means of the cooling water pipe embedded in the bearing metals. The bearing metal of the main exciter is of natural air cooled type.

The temperature rises of the bearing metals do not exceed the limit of 45°C for the main bearing metals and 40°C for the main exciter bearing metal. However, the measurement shows that the present temperatures of some metals are in a range of -4.0°C to +1.5°C from the initial temperature, but temperatures of the particular metals increase in comparison with those measured at the commencement of the operation as follows:

No.2 unit : turbines side metal of main bearing by 15°C exciter side metal of main bearing by 9°C main exciter bearing metal by 15.5°C
No.3 unit : exciter side metal of main bearing by 11°C
No.4 unit : main exciter bearing metal by 8.5°C

Comparison of Temperature Rise of Bearing Metal

	Time of Operation Commencement			Present		
	Temperature Rise			Temperature Rise		
	T/S	E/S	M/E	T/S	E/S	M/E
No. 1	15.1°C	13.1°C	17.7°C	14.5°C (-0.6°C)	11.5°C (-1.6°C)	15.7°C (-2.0°C)
No. 2	14.0°C	11.0°C	16.0°C	29.0°C (15.0°C)	20.0°C (9.0°C)	31.5°C (15.5°C)
No. 3	17.0°C	8.0°C	12.5°C	13.0 (-4.0°C)	19.0°C (11.0°C)	14.0°C (1.5°C)
No. 4	15.0°C	7.0°C	15.5°C	13.5°C (-1.5°C)	6.5°C (-0.5°C)	24.0°C (8.5°C)

Temperature rise of main bearing metal =
(metal temperature) - (cooling water temperature)
Temperature rise of main exciter bearing metal =
(bearing metal temperature) - (ambient temperature)

Figure in the bracket shows the difference between the temperature rises at the time of operation commencement and at the present.

g) Oil lifter

The shaft lifting values by oil lifter of No.1, 2 and 4 units are in a range from 0.15 mm to 0.18 mm against the values of 0.09 mm to 0.10 mm of No.3 unit.

The oil lift pump on the exciter side of No.2 unit is overheated immediately after starting operation of the generator and falls into such condition that it is unable to maintain the required oil pressure in 10 minutes time of the continuous operation. Besides, immediately after the stop of operation, the pump is unable to be re-started, in spite of the motor in a good condition.

2) Visual inspection

a) Oil vapor

Oil vapor around the bearing pedestal is little on both sides of turbine and exciter.

b) Oil leakage

Oil leakage in an amount of about 10 cc per day was observed on the turbine sides of No.1 and No.2 units, which seems to be originated from the bottom of the bearing pedestal.

c) Water leakage

Water leakage in about 10 litter per hour was observed from the air cooler installed on the penstock side of No.1 unit. During the operation of the generator, the water pan was filled up by the water leakage, and drainage is barely enough performed through the drainpipe.

d) Condition of brushes

No sparks on the brushes of all the units were observed. But chattering sounds were audible.

(2) Inspection under non-operation of the generating facilities

1) Insulation diagnosis of the stator windings

The measurement of insulation resistance, polarization index measurement, and dielectric loss tangent test were carried out for all units, under separation of each phase of the generator windings.

a) Measurement of insulation resistance

Each phase of the windings for all units was measured by the insulation resistance tester of 1,000 volt. The values of insulation resistance of the windings were measured to be normal as shown below.

Insulation Resistance

	U-phase	V-phase	W-phase
	(MΩ)	(MΩ)	(MΩ)
No.1 unit	1,500	1,500	1,600
No.2 unit	1,400	1,450	1,400
No.3 unit	1,400	1,500	1,500
No.4 unit	1,500	1,400	1,700

b) Polarization index (PI) measurement

The measurement was carried out by means of impression of D-C 2,000 volt to each phase of the stator windings. The PI values of the polarization index to judge the extent of moisture absorption of the windings are tabled below.

Polarization Index (PI. value)

	U-phase	V-phase	W-phase
No.1 unit	3.82	4.18	4.05
No.2 unit	4.00	4.10	4.10
No.3 unit	3.68	3.75	4.14
No.4 unit	3.76	4.13	3.80

PI. value: 10 minutes value in measurement/1 minute value in measurement of insulation resistance

Reference PI. value : more than 1.5

From the above test results, it was confirmed that the desiccative condition of the stator windings was to be normal.

c) Dielectric loss tangent test (tan δ test)

The tanδ test was carried out by means of the impression of the power frequency voltage (max. AC. 9.5 kV = 13.2 kV x $1.25/\sqrt{3}$) to each phase of the stator windings of the generators.

The tanδ values to be the balance (Δtan δ) between the tan δ value (tan δ0 value) at the impressed voltage 4 kV and the tan δ value at the impressed voltage 9.5 kV are shown below.

Values of Tan δ0 and ΔTan δ

	U-phase		V-phase		W-phase	
	tan δ0	Δtan δ	tan δ0	Δtan δ	tan δ0	Δtan δ
	(%)	(%)	(%)	(%)	(%)	(%)
No.1 unit	1.05	3.55	0.95	3.50	1.05	3.60
No.2 unit	1.05	3.35	1.06	3.14	1.13	3.07
No.3 unit	1.25	3.15	1.25	3.25	1.30	3.20
No.4 unit	1.50	3.30	1.55	3.55	1.60	3.30

Reference values: tan δ0 (tan δ/4 kV) < 6.0%
Δtan δ (tan δ/9.5 kV - tan δ0) < 2.5%

The Δtanδ values of all units exceed the reference value, and insulation aging of the stator windings is recognized.

2) Result of insulation test of rotor winding

After removing the brushes on the slip rings and disassembling the upper side of the sub-end-bell, the insulation resistance of the rotor windings and the voltage balance of each pole coil of No.2 and No.4 units were measured.

Although it was not programmed in the original investigation schedule, the measurement of the balance voltage of No.1 and No.3 units was carried out, since the balance voltage was able to measure without dismantling the sub-end-bell.

a) Measurement of insulation resistance

The rotor windings of all the units were measured by an insulation resistance tester of 500 volt.

Insulation Resistance

	No.1 unit	No.2 unit	No.3 unit	No.4 unit
	(MΩ)	(MΩ)	(MΩ)	(MΩ)
Insulation resistance	14.0	1.5	1.3	20.0

Reference of insulation resistance: 1 MΩ

The insulation resistance of the rotor windings of all units is within the reference value. However, the insulation resistance of No.2 unit at the first measurement was only 0.75 MΩ. After removal of the stains from the surface of the coils, the resistance increased to 1.5 MΩ. Insulation resistances of the windings of No.2 and No.3 units are not quite satisfactory.

b) Measurement of the balance voltage

To inspect the layer insulation of the pole coils, the voltage balances between the two poles were measured with pins stacked into the joint part of the pole coils under impressed AC 120V to the whole rotor windings.

The test results are summarized below and no abnormalities on the layer insulation are recognized.

Balance Voltage Values

	Balance voltage			Current	Ratio to average balance voltage	
	Max.	Min.	Average		Max.	Min.
	(V)	(V)	(V)	(A)	(%)	(%)
No.1 unit	20.30	20.00	20.10	1.26	+1.0	-0.5
No.2 unit	20.32	19.92	20.15	1.20	+ 0.8	-1.1
No.3 unit	20.26	19.92	20.11	1.20	+ 0.7	-0.9
No.4 unit	20.33	19.89	20.05	1.20	+ 1.4	-0.8

3) Nondestructive examination of generator shafts

The main shafts of No.1 and No.3 units had been replaced with new ones in 1977 due to the cracks occurred on the shafts. During the investigation, the nondestructive examination was carried out on the welded parts of the main shaft and the ribs of No.2 and No.4 units that the main shafts have not been replaced.

a) Magnetic particle test

The magnetic particle test was carried out on the welded pats of the ribs by means of yoke method using handy type electromagnet. There were no developing cracks observed.

b) Liquid penetrant examination

Though any abnormalities were not recognized by the magnetic particle test, the penetrant test was further carried out on the welded part and the results of the magnetic particle test were also confirmed to be normal.

4) Nondestructive examination of the main bearing metal

The main bearing metals on the turbine sides and the exciter sides of No.2 and No.4 units were disassembled and inspected on the existence of the damages on white metal, bubbles, cracks, and detachments by means of the visual inspection, liquid penetrant and ultrasonic examinations.

a) Visual inspection

Some slight streaks were observed on the inner sliding surfaces of the white metals on both the turbine and exciter sides of No.2 and No.4 units. However, no other traces such as burning and electrolytic corrosion were recognized, and contact surface with the shaft was also normal.

However, a deficit of the white metal of about 43 mm long exists on the upper part of the bearing metal on the turbine side of No.4 unit. Large crunched defects were observed on the spherical bearing on both turbine and exciter sides of No.2 and No.4 units. The defects might have been made in the time of disassembly and reassembly of the facilities.

b) Liquid penetrant examination

The interior surface of the white metal, and joining parts between the bearing base metal and the white metal were inspected by the liquid penetrant examination. The examination found the defects of more than 1 mm depth on the white metals of the turbine side of No.2 unit, on the metals of the turbine side and the exciter side of No.4 unit.

c) Ultrasonic examination

Whole surface of the white metal was inspected by means of the pulse reflection. No bubbles or detachments beyond the allowable values were found on the lower part except defects beyond twice the allowable value on the upper metal of the turbine side of No.2 and No.4 units as seen in Figure 4.1.

5) Measurement of gap

a) Gaps between the stator core and rotor pole core

All the units were measured from both sides of turbine and exciter by the taper gauge and venire caliper.

The mean values of the gaps for No.1 to No.4 units are 24.22 mm, 24.23 mm, 25.09 mm, and 25.05 mm, respectively. Although all values were within the reference value of 25.5±2.55 mm, the eccentricity of the gaps of No.1 and No.2 units are remarkable as seen in Figure 4.2.

b) Fan gaps

The gaps between the sub-end-bell and the center of the fan blade were measured from both sides of turbine and exciter by the scale. The mean values of gaps measured for all units except No.2 unit were over the reference value of 13±3.9 mm. In particular, the maximum gap at a local part was 25.5 mm.

c) Main bearing metal gaps and oil seal gaps

The gaps of the main bearing metal on both sides of turbine and exciter of the disassembled No.2 and No.4 units were measured by the micrometer and lead-wire. The gaps of both units were slightly over the reference value as seen below.

Gaps of Main Bearing Metal

(unit : mm)

	Turbine side	Exciter side
No.2 unit	1.25	0.91
No.4 unit	1.31	0.90
Reference value	1.05 - 1.19	0.80 - 0.93

The gaps between the bearing oil seal and shaft were measured on the upper metal by the thickness gauge and all measurements are over the reference value.

Maximum Gaps of Bearing Oil Seal

(unit : mm)

	Turbine side	Exciter side
No.2 unit	1.54	0.99
No.4 unit	1.40	1.50
Reference value	0.60 - 0.75	0.50 - 0.75

d) Gaps of bearing pedestal oil seal

The gap between the shaft and oil seal furnished on the bearing pedestal were measured by the thickness gauge and recorded as below. All the gaps are largely over the reference value.

Maximum Gaps of Bearing Pedestal Oil Seal

(unit : mm)

	No.1 unit	No.2 unit	No.3 unit	No.4 unit	Reference value
Turbine side	1.35	1.50	2.07	1.80	0.15 - 0.30
Exciter side	1.48	0.85	1.10	1.60	0.15 - 0.30

e) Gaps of air seal for air housing

The gaps of the shaft and the air seal for the air housing were measured by the thickness gauge on both sides of the turbine and exciter of all units.

All of the measured values exceeded largely the reference value and the air seals have no more practical function. In fact, the surfaces of the stator windings and rotor pole coils on the exciter side were stained with oil vapor and carbon dust from the brushes on the slip rings to be suctioned.

Gaps of Air Seal

(unit : mm)

	No.1 unit	No.2 unit	No.3 unit	No.4 unit	Reference value
Turbine side					
Max. value	4.90	5.20	3.95	3.00	0.15 - 0.20
Mean value	3.25	2.76	2.34	2.48	
Exciter side					
Max. value	5.10	3.50	4.30	3.25	0.15 - 0.20
Mean value	4.20	3.08	2.91	2.68	

f) Gaps of brush holder on slip ring

Although the gap measurement of the slip ring and brush holders were not able to measured exactly due to their worn away and rough surfaces, results of the measurement are beyond the reference value as seen below.

Gaps of Brush Holders

(unit :mm)

	No.1 unit	No.2 unit	No.3 unit	No.4 unit	Reference value
Max. value	3.8	4.1	4.5	6.3	
Min. value	2.2	2.9	2.5	3.2	4±0.5
Mean value	2.8	3.4	3.3	4.4	

6) Visual inspection

a) Stator cores

It was observed that only a little dust was accumulated and struck on the stator cores for a long period operation, and the air duct is not disturbed by the dust.

No looseness of the stator core teeth was found. However, some local over-heating was observed on the core end of each 1-block at both turbine and exciter sides of the all generator units, and the over-heated parts are discolored to blue. Detachments of the surface vanish was also observed.

b) Stator winding

At the slot ends of the stator cores, the white corona traces were found on the stator windings. These corona traces were found on both ends of the turbine side and the exciter side of all the units in addition to the parts of the layer insulation.

The surfaces of the stator windings were stained with oil vapor and carbon dust. But, the stain was not so much for the long years operation.

The tapes are wound between the low resistance paint and high resistance paint layers on the stator windings to prevent the generation of the corona discharge. But it was found that the tapes were detached on the part of about 50 mm away from the stator core end, and the insulation surfaces were little discolored around the parts.

Traces of repair for the parts damaged by the broken pieces of fan blade were observed on the stator winding end on the turbine side of No.1 unit.

There are the layer insulations between the upper and lower coils. Most of the layer insulations are displaced from their proper positions. The maximum displacement was about 50 mm.

The slot liners placed between the core slot of the stator and stator coil had broken and dropped out. Broken-down pieces of the liners are burnt out.

No looseness of the binding strings for the stator winding end was observed, but the white abraded dusts were observed among the coil support ring, the coil end, and support block on the turbine side of No.1 unit.

The stator slot wedges were inspected by the test hammer. Almost all the wedges on all units were loose and lost their proper function. One wedge per each slot for continuance of 10 slots at the rotor end on the turbine side of No.1 unit was damaged and slipped off. A part of the broken pieces had collected and it weighed at 150 gram (equivalent to 5-wedges).

It is considered that the damage of the wedges was caused by the breakdown of the fan blade in 1980. Broken pieces of 5 wedges had also

been collected at the time. Besides, the third wedges from the core end on the turbine side for No.4 unit have fallen off.

From the above facts, it is considered that the wedges made of bakelite admixed with cloth have been naturally deteriorated for a long years operation.

c) Rotor

The pole coils have neither gaps nor displacement of the insulation. However, surface of the pole coils of all the units were stained with oil vapor and dust. The pole coils on the exciter side are more stained due to additional carbon dust. In fact, the insulation resistances of No.2 and No.3 units have been lowered, and the measurements are barely beyond the reference value.

The traces of damage were found at the fin of the pole coil (Nos. 1, 2, and 12) on the turbine side of No.1 unit. It is assumed that the traces on the fin might have been made at the time when the breakdown of the fan blades had occurred.

Besides, some damages were observed on the insulation plates for spring washers to hold the pole coils of No.2 unit, and looseness of the cleats to hold the rotor lead wires of the same unit was found.

d) Fan

A blade (No.16) of the fan on the turbine side of No.1 unit was damaged and lost, in addition to the traces of welding for repair of the fan blade on the exciter side.

e) Air cooler

The air coolers for all the units have superannuated. Between the hole of the supporting plate of the cooling pipe and the cooler fin, the large gap was formed by wear and tear. Therefore, the air coolers are remarkably quaking.

The quake of the air cooler on the penstock side of No.1 unit of which water leakage was observed, is specially extreme. It was found that some broken pieces of the cooler fin were fallen down in the water pan.

f) Slip ring

Sliding surfaces of the slip ring of other units than No.3 unit have been defaced and lowered in the shape like the bottom of the ship.

The slip rings of No.1 and No.3 units are maintained in the smooth surfaced condition, however those of No.2 and No.4 units are rather in rugged surface.

The outside diameter of the slip ring on the exciter side of No.4 unit is smaller than that of the inside with a difference level of about 1.6 mm on the surface of the slip ring. The depth of the slots of slip rings on the lowered part is about 1 mm only without allowance.

The wide gaps were observed between the holder boxes and brushes so that the brushes have been held at the improper position.

g) Inside rib of sub-end-bell

There were some damages and deformations on the inside rib of the sub-end-bell on the turbine side. It is assumed that the rib would have been hit by the broken blade at the time when the trouble of the fan blade had occurred.

h) Piping of cooling water

A part of the water piping system for oil cooler was disassembled for inspection of the interior of the water pipes. The inspection found considerable development of erosion on the inside surface of the pipes.

i) Meters and cables

All temperature dial gauges and the cooling water flow relays for all units were almost not working properly.

The cables for the meters and relays have been superannuated and the sheaths of these cables have cracks due to its deterioration. The reliability of some cables would lose.

j) Main and sub-exciters

Although the stator and armature of the exciters were little stained by carbon dust and other dusts, these facilities have been in general maintained well. The large raggedness and a lot of streaks were found on the surfaces of the commutators of all the units.

The brushes of the exciters have been held loosely due to the remarkable wear and tear of the boxes for the brush holders, and the brushes are also in the abnormal function. Springs of the brush holders of No.1 and No.3 units were damaged, but have been repaired by means of welding.

Maximum Worn Depth of Commutators

(unit : mm)

	Unit No.1	Unit No.2	Unit No.3	Unit No.4
Main Exciter	0.90	0.21	0.35	0.90
Sub-Exciter	0.30	0.80	0.50	1.20

k) Stocked Spares

No rust was observed on the stocked spare shafts for No.2 and No.4 units except coupling holes of the flanges. There is one set each of the main bearing metal on the turbine and exciter sides. The metal for the turbine side has been used and damaged. Besides, there are spares of slip rings (for 2 units), pole coils (one each for both poles), stator coil, stator wedge, liner, tightening strings, etc. The stator wedges and liners are of bakelite-made and have been superannuated.

7) Review on the Facilities

The initial overhaul inspection and maintenance of the generators such as manufactured about 30 years ago are usually carried out in disassembling the major parts in 3 to 5 years after the commissioning of the facilities. The periodical overhaul after then is to be conducted in every 5 to 10 years referring to the results of the initial overhaul inspection and the running condition of the unit. The proper overhaul as lifting out of the rotor has never been carried out to

No.2 and No.4 units for approximately 30 years after the completion. That to No.1 and No.3 was once carried out in time of replacing their shafts in 1977, and after then no overhaul has been done for 17 years.

In spite of the situation, all the units are running without remarkable troubles. Such operation of the generators may depend on the following operational condition and maintenance.

a) Number of starting and stopping of the machines is less.

b) Main bearing metals are provided with an oil lifter and are well covered by oil film automatically formed through the oil lifter in the low speed condition (less than 50% of the rated rotational speed) at the time of starting and stopping of the machines.

c) The generators are excellently maintained through the daily inspection and timely repaired using locally available materials and parts. The bearing metals are also frequently disassembled and repaired.

It is very difficult to make clear the reason why cracks have been produced on the old main shafts of units No.1 and No.3 only. Considering the light of these facts that four shafts have been manufactured in the same design and the same materials but at the different factories, this cracks may be caused by quality control during manufacturing, such as welding, heat treatment, etc..

However, many problems were found out through the field investigation of the Study Team. Some of the problems may extend to the large troubles in future, if any countermeasures may not be taken.

Following are major problems that need the drastic measures.

a) Partial overheat of stator core

An end part near the magnetic pole of the stator core is overheated due to eddy current generated by effect of the leakage flux from the rotor poles. The part is discoloured to blue, from which the part is assumed to be subjected to extremely high temperature. It is assumed that insulating vanish on both faces of the core plates on the extremely overheated portion would have been burned out and the insulation effect would almost be

lost. In addition, some damages might be occurred on the inside of slots of the stator cores due to corona discharge from the stator coils.

It is recommended to improve the overheating condition that the end portion of the cores should be remodeled and the stator cores should be reformed with the newly designed cores.

b) Deterioration of insulation of stator coils

Dielectric breakdown is estimated on the inside of the slots due to the partial overheat on the end portion of the cores, corona discharge, and vibration caused by loosening of wedges. In fact, the insulation test carried out during the investigation period by the Study Team resulted in the higher value of $\Delta\tan\delta$ beyond the standard value and in the sign on the deterioration of insulation.

It is recommended to fully replace the stator coils, accordingly.

c) Modification of the type of exciter to static thxristor type

In order to resolve the problems for maintenance of the commutators and wear of the brushes and improvement of performance, it is recommended to replace the existing exciter with the static thxristor exciter.

4.2 Situation of Operation and Maintenance and Countermeasures

4.2.1 Present Situation of Operation and Maintenance

Most of the problems found during the investigation period is those that could be prevented or repaired in the short period and at comparatively less cost if the periodical inspection, maintenance and overhaul have properly been performed.

The maintenance works presently carried out are not preventive but only daily observation as a routine work. Therefore, the preventive measures have not been taken and repair has been done only at the time when the troubles had occurred.

It is necessary to introduce the preventive operation and maintenance procedures for prevention of troubles that may cause a serious damage.

At present, the generators are operated under the following conditions.

- No.1 unit: water leakage on the air coolers and deficit of 10 stator wedges
- No.2 unit: improper function of oil lift pump
- No.4 unit: serious damages on the exciter commutators

The power station records the following major repair works for the generator units.

(1) 1977: Cracked main shafts of No.1 and No.3 units were replaced with new shafts disassembling the stators and lifting up the rotors under assistance of the experts of the manufacturer.

(2) 1980: Repair of damaged blades of the fans for No.1 unit.

(3) 1982: Replacement of a cracked shaft of the main exciter of No.2 unit.

(4) 1983: Correction of displacement of main bearing pedestal and repair of surface damages of the slip rings of No.4 unit.

(5) 1990: Repair of surface damages of the slip rings of No.3 unit.

Other maintenance works such as disassembling and repair of main bearing metal, processing on the commutators of the main exciter and sub-exciter, etc., have been carried out by the maintenance group of the station in the time of the generators being out of operation. Maintenance ability of the group seems to be high. This is proved during the Team's investigation through the works of disassembly and reassembly of main bearing metal, and disconnection, reconnection and insulation of the neutral of the stator coils. To further raise their ability, it is recommended that the staffs should be trained by the experts during the period of the urgent rehabilitation project.

4.2.2 Special Rehabilitation Works

The generators are operated with a lot of problems at the present. If operation of the generators will be continued without any countermeasures for the particular problems, sudden faults may possibly occur on the facilities any time.

Unless any repair will be carried out to the deficit of wedges of the stator coils, for example, succeeding deficit of the wedges will occur making the insufficient holding of the stator coils. It will cause vibration of the coils, breakdown of insulation and then a complete fault.

While, the present corona discharge will further increase and erode the insulating layers, which will cause a grounding fault.

The draft plan of the urgent rehabilitation stated in the section 4.3 is formulated under the condition that the existing major facilities such as the frame of the stator, rotor, main shaft bearing pedestal, air housings will not be replaced but repaired only.

Until the urgent rehabilitation will be implemented, the generator units should be operated and maintained without any serious trouble. For the purpose, special works for the following items are indispensable and recommended to be urgently implemented.

(1) Supplement of the missing wedges of No.1 and No.4 units, and replacement of the wedges of all units extremely loosened at their ends with new wedges.

(2) Repair of water leaking parts of the air-cooler for No.1 unit on the penstock-side.

(3) Renewal of the oil lift pump on the exciter side of No.2 unit.

(4) Stone finishing, mica-cut, and smoothening of surfaces of the commutators of the main exciter and sub-exciter for No.4 unit.

(5) Repair of the defected parts of blades of fans on the turbine-side of No.1 unit.

(6) Disassembly, inspection (Liquid Penetration Examination), and repair of the main bearing metal of No.1 and No.3 units.

(7) Procurements of such spare parts as one set of main bearing metal on the turbine and the exciter sides, slip ring, brush for the exciters, oil lift pump, relays for fire extinguishing system, and others.

Notes:
Following inspection and maintenance should be carried out once a year at least (once every 6 month normally).

- Cleaning of the stator and rotor
- Disassembling inspection of the main bearing metal
- Stone finishing, mica-cut, and smoothening of surfaces of the commutators of the main exciter and sub-exciter
- Surface finishing of the slip ring
- Inspection and maintenance of the wedges of the stator
- Inspection of water leakage of the air-cooler and oil cooler

These works will require disassembly of the air housings at both ends of the turbine side and the exciter side, disassembly and lifting-up of the sub-end bell, and removal of the fan-boss.

4.3 Urgent Rehabilitation Plan

The plan is formulated for prevention of the further deterioration and troubles of the facilities and restoration of the proper functions of the facilities. Following are taken into consideration in formulating the plan.

- cost and delivery time of the supplemented facilities
- easiness of maintenance and transfer of technical knowledge
- maximum utilization of the existing major facilities (frame of the stator, main shaft, rotor center, pole of the rotor, main bearing pedestal, air duct, etc.).
- works mostly to be executed locally

Scope of the rehabilitation of the generators and ancillary facilities is as follows:

(1) Renewal of the stator cores (disassembly of the stator coils and cores, local assembly of the new ring type stator core, utilization of the existing frame of the stator)

(2) Renewal of the stator coils (local assembling work of new coils)

(3) Replacement of the existing exciters with the static exciters (including replacement of sliprings, brushgear and AVR)

(4) Improvement of lifting method of the rotor (Refer to Figure 4.3)

(5) Remodeling of upper part of the air housing (improvement of disassembly and lifting method of the end bells)

(6) Renewal of the main bearing metal for all units

(7) Renewal of the air-cooler

(8) Renewal of the lubricating oil cooler with new design (large capacity)

(9) Renewal of the pump for lubricating oil circulation of the bearing

(10) Renewal of the shaft oil lifting pump

(11) Renewal of all the meters and relays (dial thermometer, resistance thermometer, flow meter, relays, etc.)

(12) Renewal of the oil seal and air seal

(13) Renewal of wiring in the air housing

(14) Renewal of piping

(15) Renewal of insulation of the shaft current and gasket

(16) Correction of level and center

(17) Repair of the main bearing pedestal at oil leaking parts

(18) Prevention of noise

(19) Repair of painting

(20) Procurement of spare parts

4.4 Basic Design of Urgent Rehabilitation Plan

This section states the basic design of the generators to be rehabilitated. Each generator shall be rehabilitated so as to meet following minimum requirements.

1)	Rating	- Continuous
2)	Rated output	- 45,000 kVA
3)	Rated voltage	- 13.2 kV
4)	Rated current	- 1,970 Amp
5)	Rated frequency	- 50 Hz
6)	Rated power factor	- 0.89 lagging
7)	Rated speed	- 500 rpm
8)	Efficiency	- Not less than 98 % at rated output, voltage, speed and power factor.
9)	Short circuit ratio	- More than 1.1
10)	Wave form	- Wave form distortion less than 5 %
11)	Inherent voltage regulation	- Less than 30 % at rated condition
12)	Temperature rise	- Not more than 80 °C for stator winding
13)	Temperature	- Not more than 65 °C for bearing
14)	Insulation	- Class F
15)	Connection	- Star, neutral point grounded through distribution transformer

(1) Renewal of the stator cores and improvement of stator frame

The new stator cores will be built up using thin, high-grade, and nonaging-silicon-steel laminations. Each lamination will be coated on its both sides with an insulating varnish or other materials for minimizing eddy current losses, after punching.

New stator cores will be stacked up with overlapping in a ring shape on the existing stator frame as to be one piece and tightened by firmly bolts and nuts as to not produce a noise and vibration during operation.

Adequate cooling air ducts will be arranged in stator cores. The existing stator frame is separable into two parts at the horizon center line. After improvement, the upper and lower parts of stator frame are incorporate in one piece and four jacking pads will be provided on the stator frame to lift up the stator together with the rotor about 450m/m to draw out the rotor to exciter side.

(2) Renewal of stator winding

The stator winding shall be of one-turn coil and star-connected with three terminals as same as existing one.

The coil insulation shall be of class F materials and noninflammable and be properly vacuumed impregnated with high grade insulating synthetic resine.

The entire coil shall be able to withstand exposure to dampness, have adequate corona shielding with a semi-conducting compound, and withstand specific continuous temperature. The coil shall be formed wound and interchangeable. All coils shall be installed at the site, and their ends shall be connected and insulated with suitable materials and free from air pocket.

Stator coil conductor shall be electrolytic copper with a conductivity not less than the value for annealed copper specified in IEC standard or other International standards.

(3) Replacement of the existing exciter with static thyristor type one

For the generator of the Da Nhim power station, three excitation methods which are of dc. exciter, brushless exciter and static thyristor exciter, were considered and compared with each other technically and economically as follows:

	DC. exciter	brushless	Thyristor
1) Site work			
a. Remov. of exist. dc. exciter	Necessary	Necessary	Necessary
b Inst. of new dc. exciter	Necessary	-	-
c. Inst. of brushless exciter	-	Necessary	-
d. Machin. of shaft hole for rotor lead wires	-	Necessary	-
e. Machin. of shaft end for attaching of SSG	-	-	Necessary
f. Renewal of slipring and brushgear	Necessary	-	Necessary
g. Remov. of exist. AVR & MG	Necessary	Necessary	Necessary
h. Inst. of new AVR cub.	Necessary	Necessary	Necessary
i. inst. of thyristor cub.	-	-	Necessary
j. Inst. of exciter tr.	-	-	Necessary
k. Reconst. of 13.2 kV cub. for connect of power cable of exciter tr.	-	-	Necessary
2) Performance			
a. Response ratio	Normal	Normal	High
b. Addition of aux. function	Easy	Easy	Easy
3) Maintenance			
a. Commutator & brushes	Necessary	-	-
b. Slipring & brushes	Necessary	-	Necessary
c. Cooling fans of thyristor	-	-	Necessary (renewal of fans in every several years)
4) Cost			
a. Total cost	High	Base	Low

As a result of the above, the static thyristor excitation method will be adopted because it is little inferior to the brushless type one but superior to other methods in performance and cost.

Existing dc. exciters shall be with static thyristor exciter consisting of excitation transformer, thyristor rectifiers, field breakers, field flashing equipment, automatic voltage regulating equipment complete with all necessary accessories.

(4) Improvement of lifting method of the rotor

At present, lifting up of the generator rotor at the time of overhaul inspection is made in the method of separation of the stator into two parts at the horizontal center line. Therefore, disconnection and re-connection of stator coil ends at the separation portion of the stator are required at every overhaul inspection and the cost and time for this separation form a major part of the overhaul ones.

The rotor draw-out method will be improved to the method without separation of the stator in co-operation with the improvement of excitation system. The draw-out of generator rotor will be made basically in the following order.

1) After dismantling of turbine housing cover, runner, generator air housing, end-bell, upper bearing metals, exciter etc., an extension shaft is connected to the turbine side of the main shaft.

2) The generator stator is lifted up by jack about 450 m/m height from the base plate together with the rotor.

3) The exciter side bearing pedestal is removed from its position and the main shaft of exciter side is placed on the rotor draw-out truck set on the rails.

4) The turbine side of rotor is suspended by the overhead travelling crane (120/30/5T) at the extension shaft and the rotor is moved to the exciter side together with the crane and truck.

5) The rotor will be shifted to the temporary support and lifted at its center by a crane, and then moved to the working place.

The insertion of rotor is carried out in reverse order of the above.

For this purpose, improvement of stator frame, provision of jacks, a rest device, a truck, embedded rails, an extension shaft etc. are necessary.

(5) Remodeling of upper parts of the air housing

The upper parts of the air housing shall be remodeled so as to easily disassemble and to move the end bell in order to inspect the coil ends.

(6) Renewal of main bearing metals

The new bearing metals shall be superior in performance to the existing ones in the same in dimension.

(7) Renewal of the air coolers

The new air coolers shall be of long life and high efficiency type and mounted to fit the existing stator.

(8) Renewal of lubricating oil cooler

The new lubricating oil cooler shall have 120 % cooling capacity in compared with existing one. It is desirable to increase cooling capacity by replacement of only cooling element.

(9) Renewal of lubricating oil circulating pump

The pump shall be replaced with new one having the same specification (pressure 3 kg/cm^2, discharge 100l/min., delivery dia. 50 mm) and suitable for the existing driving motors of AC 3.7 kW and DC 3 kW.

(10) Renewal of shaft oil lifting pump

The new shaft oil lifting pump shall have a same or superior performance (pressure 100 kg/cm^2, discharge 8.5 l/min.) and suitable for the existing driving motor of dc. 1.5 kW and for forming the oil film enough for the generator starting.

(11) Renewal of all meters and relays

Following meters, relays and detectors for each unit will be renewed.

1) Dial type thermometers (with alarm and trip contacts)

- main bearing metal	2 nos.	mounted on the turbine control panel
- air cooler inlet & outlet	2 nos.	

2) Search coils (100 ohms at 0°C, platinum)

- stator coil	12 nos.	including 6 nos of spares
- main bearing	2 nos.	
- air cooler, inlet & outlet	2 nos.	

3) Temperature Recorder (12 elements)

	1 set	mounted on the control panel

4) Flow relays

- air cooler	1 no.
- main bearing	2 nos.
- lubricating oil cooler	1 no.

5) Thermo sensing detector

- fire protection	4 nos.

(12) Renewal of oil seals and air seals

The oil seals between the main shaft and the bearing pedestal and air seals between the main shaft and the air housing at the both turbine and exciter sides shall be renewed.

(13) Renewal of wiring in the air housing

The wiring including a terminal box in the air housing shall be renewed. Wiring route and method shall not disturb the ordinary and overhaul inspection.

(14) Renewal of piping

The cooling water piping including dew condensation preventive materials and lubrication oil piping are renewed.

(15) Renewal of insulation plates and gasket for prevention of shaft current

The insulation plates between the bearing pedestal and base plate and insulation gaskets on the pipes around the bearing pedestal for prevention of shaft current shall be replaced with new ones.

(16) Correction of level and center

The level and center of generator and turbine shall be checked on the existing generator rotor and turbine runner. The level and center of generator stator shall be corrected and the dowels are renewed in the final corrected positions, if necessary

(17) Repair of the main bearing pedestal at oil leaking parts

The oil leaking parts on the main bearing pedestals of turbine side for unit Nos. 1 and 2 shall be repaired by welding method.

(18) Prevention of noise

In co-operation with the previous item (5) remodeling of upper parts of the air housing, sound absorbing materials shall be attached to the inside of air housing for prevention of noise.

(19) Repair of painting

The repainting on the whole generator will be carried out.

4.5 Implementation Programme of Urgent Rehabilitation Plan

4.5.1 Implementation Programme

The rehabilitation work of generators should be conducted urgently, efficiently and economically in co-operation with other related rehabilitation works such as for water turbines, transformers, switchgear, penstocks and civil structures.

The urgent rehabilitation works should be planned so minimize the interruption of to the power supply and the spill out of the water from the reservoir.

Following formation is recommended to implement the urgent rehabilitation works.

(1) Design, preparation of the pacification of the equipment and materials to be procured from the outside of Vietnam, and the supervision of the works will be carried out by the consultants.

(2) Supply of equipment, parts and materials from the outside of Vietnam including technical services of erection at site and training of Vietnamese engineers and technicians in the manufacturer's works will be made by the manufacturer(s) selected in the international competitive tender or by the particular manufacturer(s)..

(3) The rehabilitation work at site including dismantling, reassembling, repairing or renewal of equipment will be carried out by the Vietnamese erection team mainly organized from the maintenance group of the Da Nhim Power Station.

4.5.2 Preparatory Works

Greater portion of the generator rehabilitation work will be carried out unit by unit in parallel with the turbine rehabilitation work in the machine room under operating condition of other generating units.

Prior to the commencement of the rehabilitation work, following preparatory works should be carried out to ensure the well progress and safety work.

(1) Proper arrangement in the machine room

Disassembling and reassembling works of the generator and turbine will be carried out at the same time in the machine room. In addition, it is conceivable that in a certain period, the works for transformers, switchgear equipment will also be carried out in the erection bay. Accordingly, non-essential equipment, parts and materials should be moved from the machine room for keeping necessary spaces for each work. Especially, the inside of erection pit shall be kept clean to disassemble and reassemble the stator cores and coils. The floor space to set the dismantled equipment and parts should be shown on the drawings for the every work stage.

(2) Maintenance and repair of erection equipment

Erection tools and equipment including an overhead crane (120/30/5 ton), special tools, slings, testing and measuring equipment should be maintained in well condition and repaired, if any. Especially slings for handling of the generator rotor and stator should have an enough strength.

(3) Equipment, parts and materials to be used

It should be ensured that all equipment, parts and materials to be used for the work should be checked in their quantities, specifications and workable conditions.

(4) Organization of working groups

It should be ensured that all the working groups including those for other related works would have been organized as planned, ad all persons concerned completely understood the purpose, ways and procedure of the works.

4.5.3 Site Work Schedule

Although the period required for the rehabilitation of the generators depends on the conditions of erection forces, erection tools and equipment, etc., it is estimated at 6 months per unit and the work will be done unit by unit in series in two months overlupping over about 18 months for four (4) units.

The generators may need the longest period for the rehabilitation at the Da Nhim Power Station compared with those for the turbines, transformers, switchgear, penstock lines, etc. Therefore, the work schedule of the generators may bind the completion of the whole rehabilitation works at the Da Nhim Power Station.

The flow of generator rehabilitation work to be executed at site is shown in the attached Figure 4.4. In this figure, the critical path is shown with the thick line and 3 months out of 6 months of the total work period per unit will be spent for the renewal of stator cores and coils. Therefore, the work for the stator takes an important part of the whole generator facilities.

4.6 Long Term Rehabilitation Plan

The long term rehabilitation will be planned based on the preventive maintenance to remove any harmful condition and more positive maintenance to obtain the merit by improvement of facilities.

As a long term rehabilitation plan, the following are recommended.

(1) Renewal of rotor pole coils

Although the result of visual inspection on rotor pole ends, shows no serious damage on the pole coils was observed, heavy dirt on the surface of rotor coils, an abrasion by a cooling fan bade broken were found and an insulation resistances were decreased to near their lower limit at the normal temperature.

Depending on to the results of detailed inspection to the rotors during the urgent rehabilitation, renewal of pole coils should be considered.

(2) Replacement of existing shafts of units No. 2 and No.4 with spare ones

The main shafts of units No.1 and No.3 have bean replaced with new ones in 1977 because of crack. The new shafts for units No.2 and No.4 were also supplied from the original manufacturer as spare and stored in well condition in the power station.

No crack was observed on the existing main shafts for units No.2 and No.4 and confirmed by non-destructive examination, so that, replacement of the shafts for units No.2 and No.4 was excepted from the urgent rehabilitation of generator.

However, from the view of the long term operation, replacement of the new shafts that are more strong and reliable than the old ones is recommended. The time of replacement will be decided in consideration of the results of periodical non-destructive examination and the time of renewal of rotor coils stated in above (1).

(3) Automatic Control

Although the Da Nhim hydro power station has been designed and constructed 30 years ago as a modern one-man control station, now the station become an old fashioned. As an automation of the Da Nhim power station, following will be planned.

1) automatic recording of operation data and log sheets

2) automatic load allotment system for the high efficiency operation

3) automatic switching over of station power supply system

4) computerization of control system

4.7 Recommendation of Operation and Maintenance

4.7.1 Improvement of Operation and Maintenance

Owing to the urgent rehabilitation, it is expected that the generators will recover their proper functions and prolong their life time. In addition, the following merits on operation and maintenance are expected due to the improvement performed during the urgent rehabilitation.

(1) Easy overhaul inspection

Since the commencement of the operation in 1964, the overhaul inspection has not been carried out except that for replacement of shafts of units No.1 and No.3 in 1977 by the method of separation of stator.

By the improvement of rotor draw out method, overhaul inspection of generator can be made easily and economically without separation of stator.

(2) Static thyristor type excitation system

According to the modification of excitation system to static thyristor type, dc. commutators, high frequency generators, etc. can be removed, and operation and maintenance of the excitation system will become simple and economical.

(3) Improvement of air housing and end bell

Improvement of air housing to take out the end bell bring an easy inspection of coil ends of stator and rotor.

(4) Automatic record of generator temperature

Record of temperatures of the generator, stator coils, bearing metals, air coolers and main transformer oil will be improved from the present method of reading and recording on the log sheet by operator to the method of automatical and continuous record on the recording meter. It will lead to the simplification of operation and the quick judgment to the conditions of the facilities.

4.7.2 Inspection and Maintenance

In accordance with the operation and maintenance manuals which will be amended based on the recommendation of the manufacturers, EVN's standards, etc. during the urgent rehabilitation stage, the facilities will be regularly inspected for maintaining and restoring their proper functions aiming at the prevention of troubles.

In general, the standard interval of the regular inspection on the generators is about two (2) times that specified at the time of commencement of Da Nhim power station in 1964 due to the advanced materials and design and manufacturing technique.

Standard periodical inspection after the urgent rehabilitation is recommended as follows:

(1) Nominal inspection (to be mainly executed from the outside to confirm and maintain the function)

1)	once two years	- stator core and coil ends and rotor ends - air coolers including piping - oil lubrication equipment including piping - insulation resistance of static exciter and AVR - insulation resistance of neutral grounding device - general inspection
2)	once a year	- oil lifter including piping
3)	once six months	- CO_2 fire extinguishing equipment and detector

(2) Overhaul inspection (to be executed in draw-out of rotor)

once 10 years (but once 5 or 6 years for the first overhaul)	- stator winding and cores - main bearing metal and cooling pipes - insulation diagnostic test - measurement of shaft current - non-destructive examination of main shaft and bearing metals

4.7.3 Recommendation to the Operation and Maintenance

(1) Operation method

It is strongly recommended to carry out the high efficiency operation of the power station by control of number of generating units corresponding to the required load for the loss reduction.

At present, the power to the 66 kV system is supplied from the generator busses No.3 and No.4. Accordingly, the operation stoppage of generator units No.3 and No.4 is restricted by the 66 kV demanding condition.

Owing to the grading up of the 66 kV system to 110 kV system, the power supply to those areas covered by the 110 kV system is to be changed from the generator busses to the 230 kV bus. Consequently the restriction for the high efficiency operation of the power station will almost be dissolved.

(2) Maintenance and inspection

The following are recommendation to on the maintenance and inspection.

1) To enrich the maintenance manuals and standards.

2) To execute the periodical inspection, especially overhaul inspection.

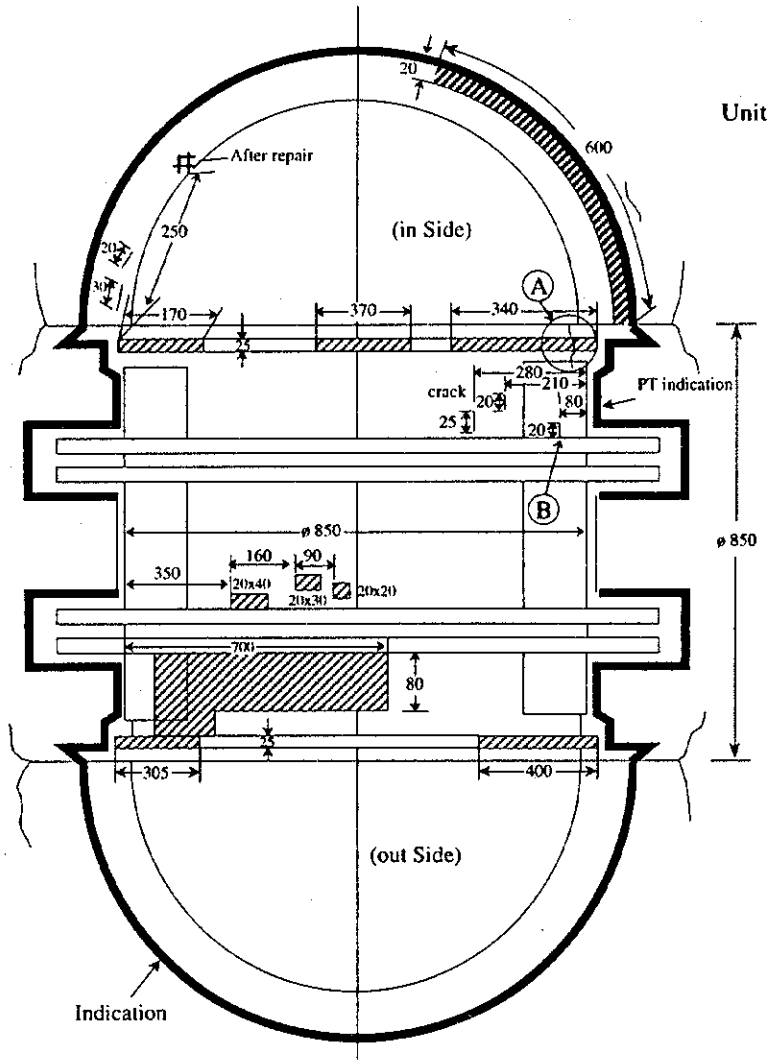
3) To master the technique of the non-destructive examination and the insulation diagnosis and to provide the equipment for the purposes .

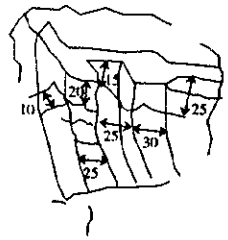
4) To promote the automation of turbine-generator control.

It seems that the policy of the present maintenance to the facilities at the Da Nhim power station has a tendency to the breakdown maintenance.

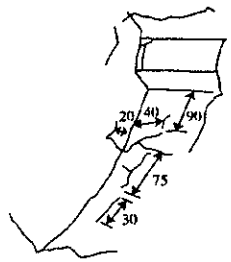
After the urgent rehabilitation, the maintenance cost should rather be allocated to the preventive and corrective maintenance.

Unit No. 2 Turbine Side upper half Bearing





Detail (A)



Detail (B)

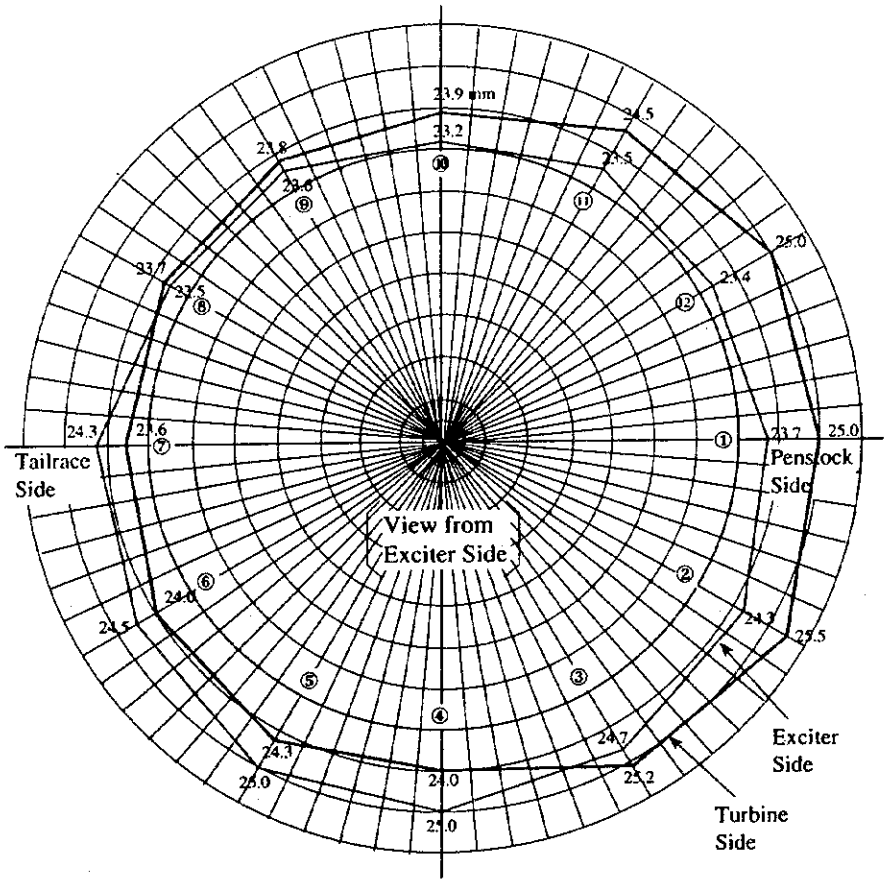
PT indication

UT defect

Unit: mm

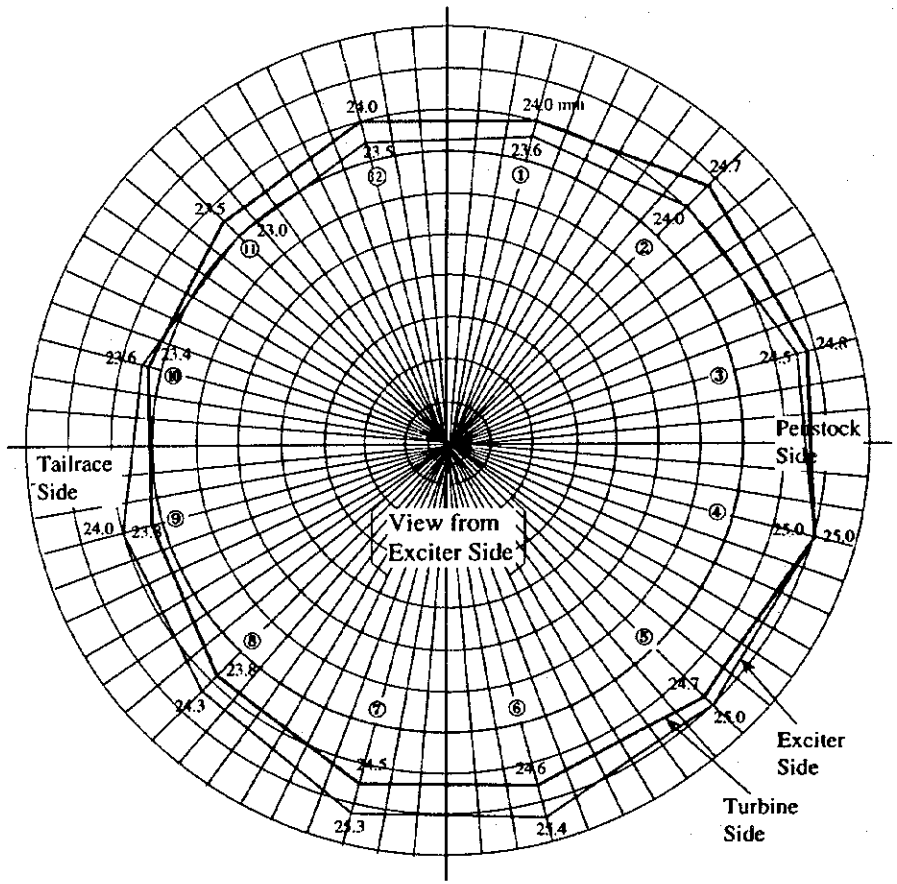
FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 4.1 Liquid Penetrant and Ultrasonic Examination Record

UNIT No. 1



Average Air Gap Turbine side : 24.38 mm
Exciter side : 24.06 mm

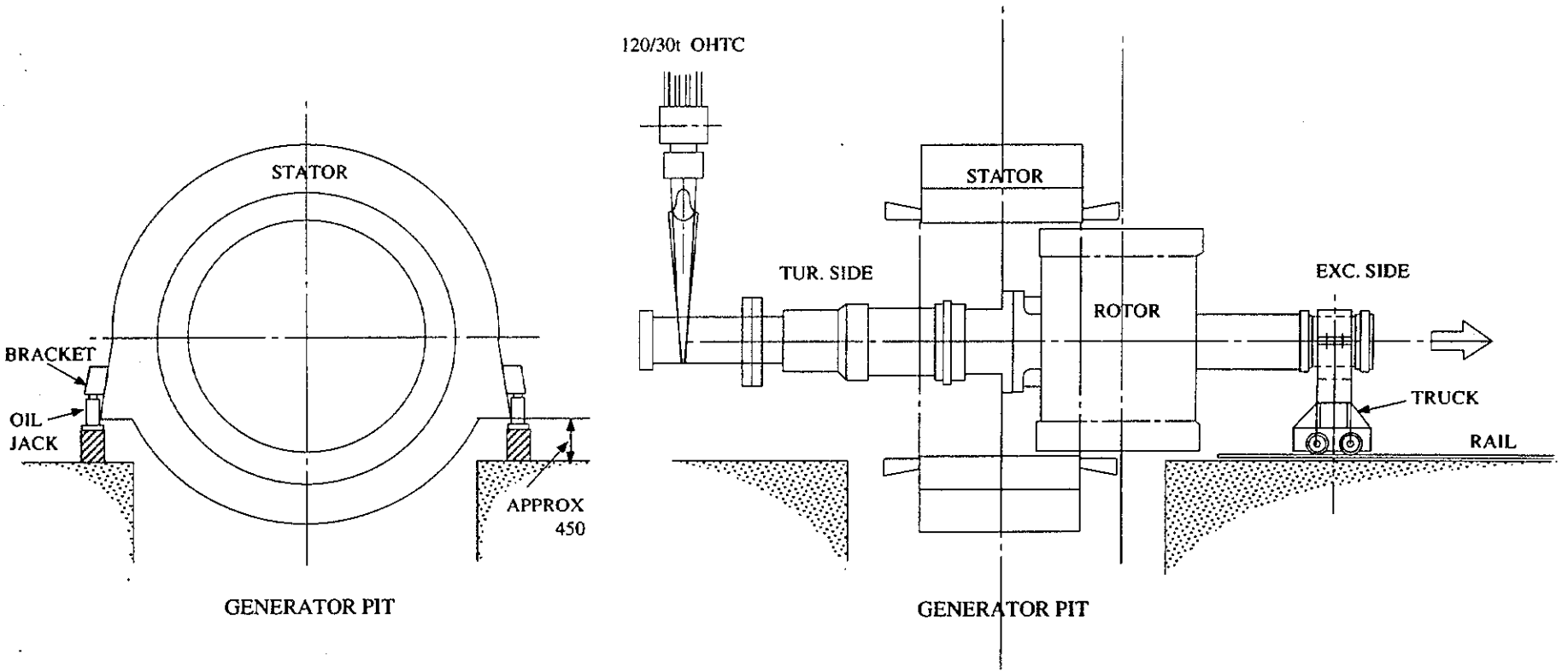
UNIT No. 2



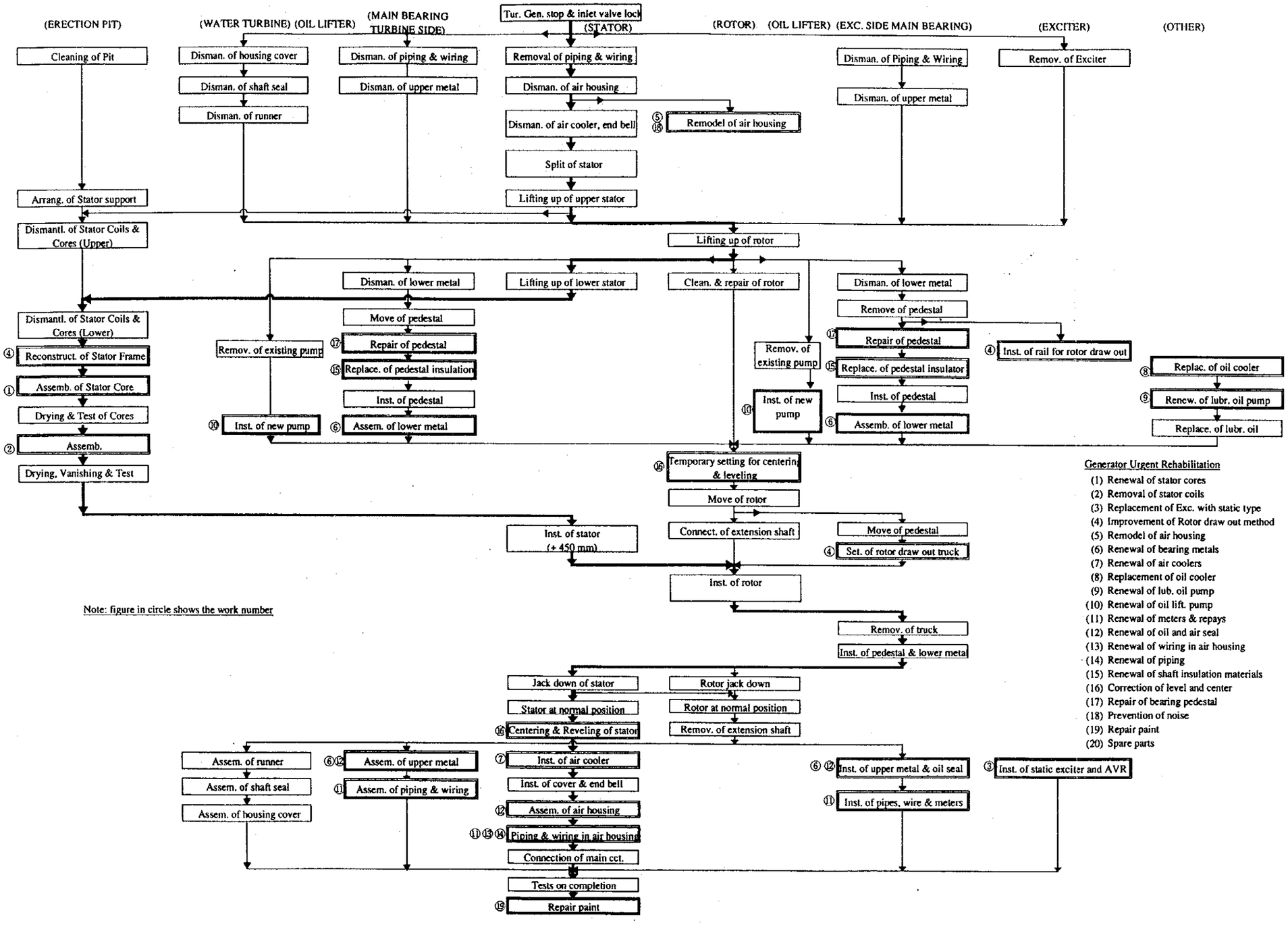
Average Air Gap Turbine side : 24.19 mm
Exciter side : 24.27 mm

Design Air Gap : 25.5 mm ± 10%

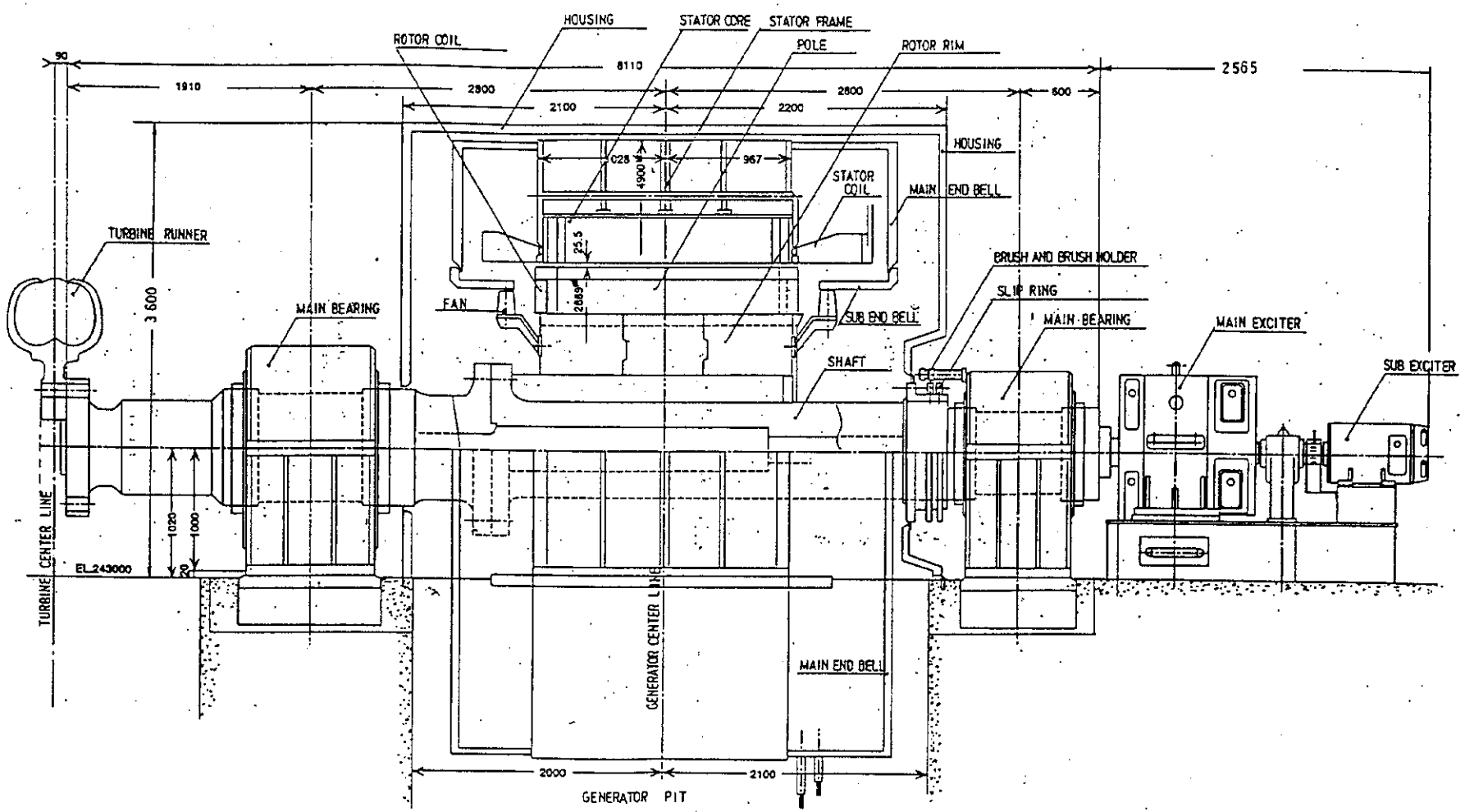
FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 4.2 Measurement of Rotor Air Gap



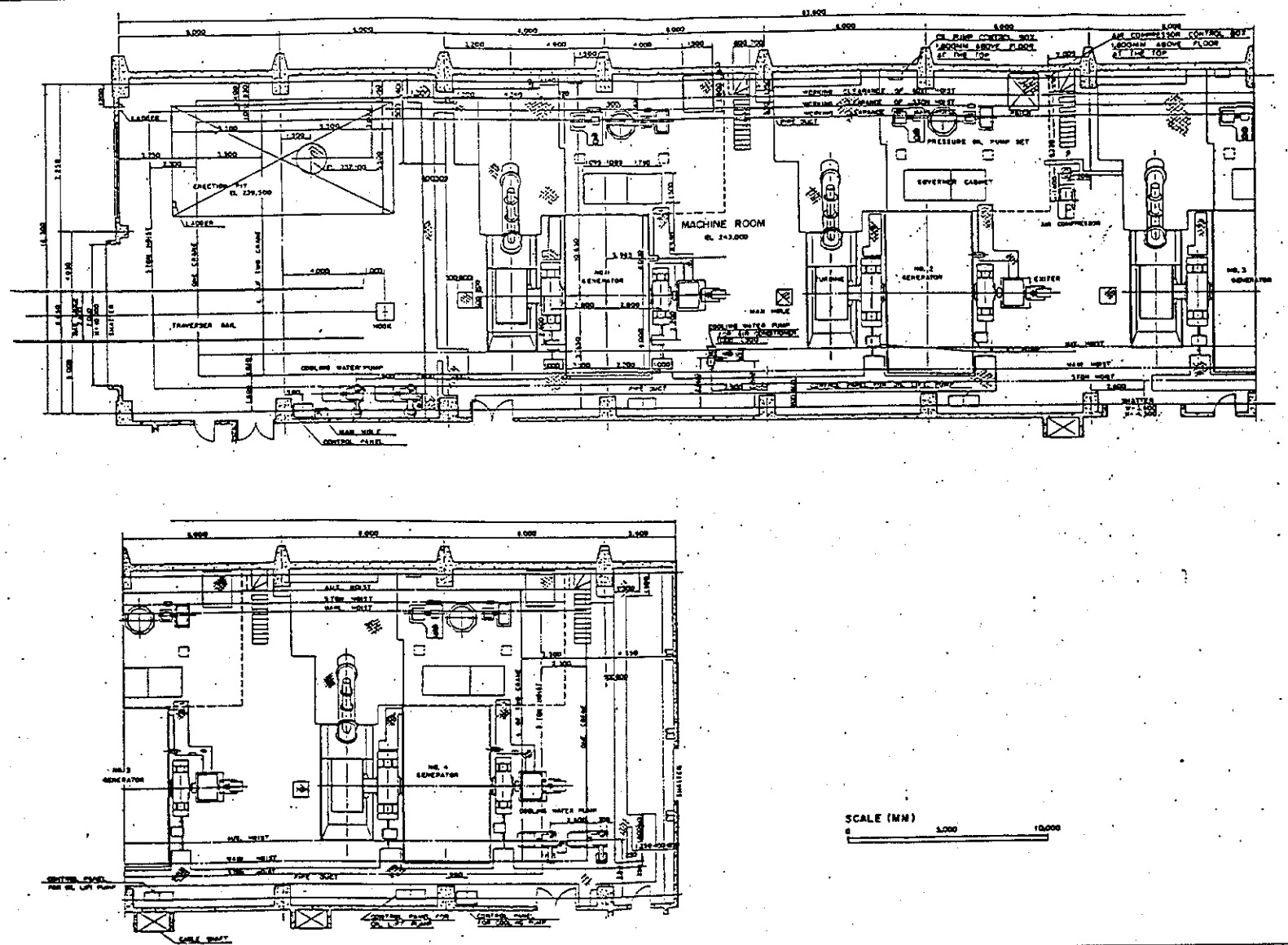
FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 4.3 Rotor Carring Out Method



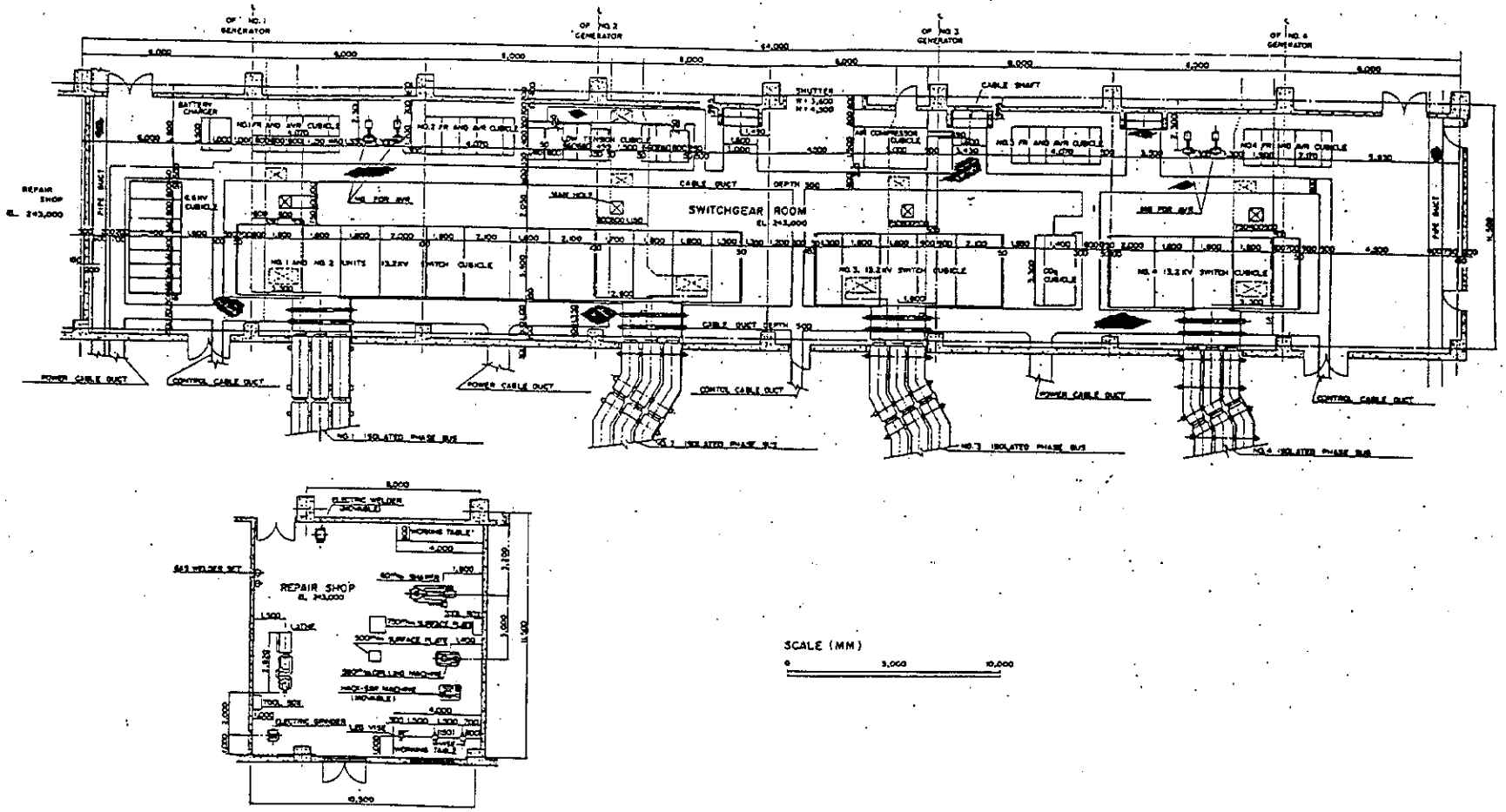
FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 4.4 Flow Chart of Generator Urgent Rehabilitation Works



FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 4.5 Generator Section



FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 4.6 Arrangement of Machine Room



FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 4.7 Arrangement of Switchgear Room and Repair Shop

CHAPTER 5

WATERWAY AND ANCILLARY FACILITIES

CHAPTER 5 WATERWAY AND ANCILLARY FACILITIES

5.1 Approach, Results and Analysis of Study

5.1.1 Approach of Study

The main purposes of the Study is to formulate an overall rehabilitation plan on the waterway and ancillary facilities such as gates, valves, trash racks and penstock which have been provided to the Da Nhim dam and power station. The Study has been initiated as the waterway and ancillary facilities have been operated for about thirty (30) years after construction and the aging, erosion and deterioration of these facilities have been observed in recent years.

Some facilities have been damaged during the civil war. After the end of the war, the facilities damaged were restored by Viet Nam under the circumstances of shortage of materials. Taking the fact into consideration, the Study was carried out in Viet Nam and Japan with the following three (3) phases to confirm accurately the existing condition of facilities and to formulate proper rehabilitation plan.

(i) Field investigation
(ii) Analysis of field investigation results
(iii) Formulation of rehabilitation plan

In Viet Nam, the field investigation on the facilities and the transfer of technology to the counterparts of Power Company No.2 (hereinafter referred to as PC-2) were performed by the Study Team.

On the basis of the above study, the rehabilitation plan was formulated for the urgent rehabilitation plan and the long term rehabilitation plan.

5.1.2 Field Investigation

(1) Confirmation of Facilities subjected to Investigation

Prior to the field investigation, the Study Team explained to PC-2 the way of approach, procedure and analysis of the Study on the basis of the Inception Report and confirmed the agreement of PC-2 to those. The following facilities were agreed by PC-2 to inspect during the field investigation :

1) Spillway radial gates and hoists

2) Spillway irrigation outlet facilities

3) Intake fixed trash racks

4) Intake movable trash rack and hoist

5) Intake caterpillar gate and hoist

6) Surge tank and penstock tunnel drain facilities

7) Penstock and butterfly valves

8) Cooling water pipes

9) Other facilities

The main design data of the original facilities are shown on Table 5.1.

(2) Procedure of Field Investigation

Prior to the execution of the field investigation, the data for the gates, valves and penstock were collected from PC-2 to confirm the present conditions and to achieve effective field investigation of the facilities. Referring to the data collected, the facilities repaired and renovated by PC-2 after commission of the Da Nhim dam and power station were identified. Besides, the records of the operation and maintenance on the facilities were also examined to confirm the present operational condition of the facilities. The detailed investigation of the facilities were carried out under the de-energizing and dewatering condition of the power station to inspect accurately the degree of the deterioration and damages of the facilities. The intake fixed trash racks, intake movable trash rack guide frames and intake caterpillar gate guide frames which are difficult to lift over the water, were inspected visually by divers. Some equipment were disassembled and overhauled partly for the investigation purpose. The investigation items and methods, which are generally applied to the power plants in Japan, were applied to the field investigation of the facilities for the Study.

General work flow of the field investigation is shown in Figure 5.1 .

5.1.3 Defects and Issues Identified By Field Investigation

The main defects and issues on the facilities, which are clarified through the field investigation are summarized in Table 5.2 and discussed below.

The outlines of the facilities subjected to the field investigation are shown in Figure 5.2 to Figure 5.7.

(1) Spillway Radial Gates and Hoists

The detailed investigation of the spillway gates and hoists were carried out under the water level of EL.1,023 m below the top elevation of the dam crest. No leakage inspection of gate leaves was performed, accordingly.

Through the visual inspection to the gate leaves, the corrosion due to removal of the paint material was observed on the surfaces of skin plate and gate girders, and some seal rubbers damaged due to aging and deterioration in the quality of rubber were also observed. Through the inspection of side guide frames, a few marks of leakage were identified on the surfaces of guide frames. According to such present condition on the seal portions, a possibility of leakage from seal rubbers was considered. Besides, the remote control panel, local control panels and auxiliary mechanical and electrical parts such as limit switches, oil level gauges of gear reducer are remarkably aged and deteriorated, while the proper operational function of hoists is confirmed by the operation test. During the operation test of gates, it was observed that the wire rope hangers at both sides of gate leaf could not be operated to tense evenly due to corrosion of rope hanger bracket shafts and thus the bending moment was occurring at the joint portion between wire rope and rope hanger bracket.

In discussion, PC-2 staff reported that they have their future plan to apply a new centralized control system associated with flood forecast system for the Da Nhim dam and power station in the near future. From the plan, it is noted that the present control panels and auxiliary electric parts of the hoists will be renewed inevitably to satisfy the requirement of the new control system when the plan would be realized.

Considering the present defecting condition identified during the field investigation, the following are essential to rectify for ensuring the reliable operation of spillway gates.

- Remote control panel and local control panels to be renewed with cabling system
- Seal rubbers of gate leaves to be renewed
- Auxiliary mechanical and electrical parts of hoists to be renewed
- Corrosion of wire rope hanger shafts to be changed and replacement of the movable parts
- Skin plate and gate girders to be repainted

- Oil level gauge of gear reducer to be renewed

(2) Spillway Irrigation Outlet Facilities

The spillway irrigation outlet facilities with a 600 mm diameter sluice type valve, a 600 mm diameter butterfly type valve and two (2) water supply pumps for the dam area are provided in the valve chamber and the pump chamber of the spillway, respectively, and a fixed trash rack is also provided at the inlet of steel conduit. Through the visual inspection of these facilities, the Study Team observed that the valve chamber was completely submerged at the time so that the detailed inspection required for the irrigation outlet valves was impossible. PC-2 staff reported that the present submerged condition of the valve chamber occurred about thirty (30) years ago, and it might be caused due to entering of rain water through the operation shaft under blockage of drainage pipe in the chamber. In view of such long duration of submerged condition of outlet facilities, the Study Team considered the necessity of total replacement of the present valve facilities with new valves as early as possible.

In addition, PC-2 staff reported that out of two (2) water supply pumps, one (1) pump was completely removed from the pump chamber due to the damage of the pump unit and other pump unit can not satisfy the specified value of the water transmission capacity due to aging of the pump unit. .

Through visual inspection of the fixed trash rack for the outlet facilities at water level of EL.1,023 m, it was observed that the degree of corrosion of screen bars was almost same as those of the intake fixed trash racks.

Through the discussion with PC-2 at the site, the Study Team confirmed intention of PC-2 that the function of spillway irrigation valves is to be normalized early to enable to supply the water for the irrigation purposes of the downstream area of dam and the operation of outlet valves is to be changed with the application of electrical motor driving system to achieve the remote control operation in view of convenient operation of valves.

Considering the present defects identified during the field investigation, the following are essential to rectify for ensuring the reliable operation of irrigation outlet facilities.

- Valve chamber to be dewatered
- Reliable drainage system to be provided in the valve chamber

- Irrigation outlet valves to be renewed totally with the application of electric motor driven system
- New remote and local control panels to be provided with necessary cable system
- Watertight door to be provided at the entrance of the operation shaft
- Two (2) water supply pumps with auxiliary electrical equipment to be replaced and renewed.
- Corroded trash rack bars to be worked out necessary rehabilitation plan with the stress analysis.

(3) Intake Fixed Trash Racks

The detailed investigation was carried out at water level of EL.1,023 m which is below top elevation of trash rack at EL.1,024.5 m. In the preliminary investigation stage, the Study Team had a plan to carry out the underwater photographic recording investigation by divers for the submerged trash racks portions. However, due to muddy water of the reservoir, the Study Team was obliged to cancel the application of such inspection method. Accordingly, the detailed investigation for the submerged portion of trash rack was visually carried out by divers. Visual, gauge and thickness inspections were applied for the exposed portion of trash rack above EL.1,023 m to measure the corrosion degree of screen bars. From these inspections, it was observed that the thickness of screen bars was deducted by 3 mm in average from the original design thickness (12 mm) owing to the extended corrosion. Besides, according to the results of the visual inspection by divers, the corrosion was extended to the submerged portion of trash rack at the same degree with the exposed portion. Thus, the rehabilitation works of screen panels was considered to be worked out finally after necessary stress analysis for screen bars would be completed by the theoretical method on the basis of the results of the field investigation.

A diver reported that the deformation of screen bars which might be caused by a crash of large floating log from the upstream of the fixed trash racks, was observed at the left upper panel of the left trash rack. However, it is considered from the degree of such deformation that the function of trash rack will not be obstructed at the moment.

The Study Team was informed by PC-2 that PC-2 has their schedule to replace the upper trash rack panels (above EL.1,020.8 m) with new panels in 1996 by themselves when the water level reached below EL. 1,019 m.

Considering the present defects identified during the field investigation, the following are essential to rectify for ensuring the reliable operation of generating equipment.

- Corroded screen bars to be worked out necessary rehabilitation plan with the stress analysis.

(4) Intake Movable Trash Rack and Hoist

The detailed investigations of the intake movable trash rack and hoist were carried out at water level of EL. 1,023 m. The visual inspection by divers was also applied for the submerged guide frames. Besides, the visual, gauge, dye penetrant and thickness inspections were carried out for two (2) trash rack panels for upstream and downstream guide frames after both panels were lifted over EL. 1,045 m concrete floor in the intake operating shaft.

(Trash rack panels)

Prior to the investigation, PC-2 staff reported that both trash rack panels have been damaged several times in the past, due to vibration of trash rack panel which might occurred with a high flow velocity of tunnel, and renewed two (2) times by PC-2 since the year 1990. They also reported that the vibration was detected remarkably when the water turbines were operated below EL. 1,030 m of water level under the full load operation of turbines with the condition of the trash/floating logs accumulated in front of trash rack panel. During the field inspection, the Study Team attempted to observe such vibration at water level of EL. 1,023 m, but failed to do it. In order to inspect damage on the trash rack panels, the visual inspection was carried out after the panels were lifted above EL. 1,045 m floor in the operation shaft and thus the Study Team confirmed the following conditions on the upstream trash rack panel.

1) Deformation of trash rack bars
2) Loosing and damage of distance piece for trash rack bars
3) Corrosion of trash rack frame due to removal of paint

It is considered that the rehabilitation work on the trash rack panels is essential to work out after the possibility of vibration was pursued theoretically by the vibration analysis on the panels.

(Guide Frames)

As a result of the visual inspection by divers, the large breakage (approx. 3.1 m high x 15 cm deep) of secondary concrete was observed at left side of a front guide frame for the downstream trash rack panel. So far, no operational obstruction of intake movable trash rack was considered under such concrete condition. However, there is such

possibility that the corrosion of guide frame and deformation of guide frame at the concrete breakage position might be induced in the future.

The urgent rehabilitation work on the guide frame is recommended to apply some filling materials into the concrete breakage portion when the reservoir level reached below EL. 1,019 m to ensure the operation of movable trash rack.

(Hoist)

The control panel and auxiliary electrical parts of the hoist are remarkably aged and deteriorated, while the proper operational function of the hoist is confirmed by the operation test. Besides, the oil leakage from gear reducer was also observed due to the aging of oil seal.

Considering the present defects identified during the field investigation, the following are essential to rectify for ensuring the reliable operation of generating equipment.

- Upstream trash rack panels and frames to be repaired and supported
- Breakage of secondary concrete of guide frame to be repaired by civil works
- Control panel and cabling system to be renewed
- Gear reducer to be renewed

(5) Intake Caterpillar Gate and Hoist

The gate leaf was inspected at the fully raised and fully closed positions. The operation test was attempted to confirm the operational condition of gate leaf and hoist and the satisfactory operational condition was confirmed. Besides, a minor leakage from the gate was measured at the fully gate closed position in the leakage test. Through these tests, the following conditions of gate and hoist were confirmed.

1) Occurrences of the minor corrosion on the gate leaf due to removal of the paint material
2) Aging and deterioration of the control panel and auxiliary electrical part with cabling system
3) Observation of minor leakage from gate seal portions
4) Aging of seal rubber quality

Considering the present defects identified during the field investigation, the following are essential to rectify for ensuring the reliable operation of gate and hoist.

- Control panel with cabling system to be renewed
- Auxiliary electrical parts of hoists to be renewed
- Seal rubbers of gate leaf to be replaced
- Gate leaf to be repainted

(6) Surge Tank and Penstock Tunnel Drain Facilities

During dewatering work of headrace tunnel for the purpose of the detailed inspection of generating equipment and penstock by the Study Team, the visual and operational inspections of the drain valves and conduit were performed, and it was confirmed that the operational conditions of valves and conduit were satisfactory and no water leakage from valve seat was also observed.

The minor corrosion were observed on all the surfaces of drain facilities, and therefore the overall repainting works on facilities is recommendable to improve the corrosion protection.

(7) Butterfly Valves

The operation test of No.1 and No.2 butterfly valves was carried out under the dewatering condition of both headrace tunnel and penstock. In the parallel with the operation test of butterfly valves, the auxiliary equipment of butterfly valves such as air valves, bypass pipe and valves and over velocity tripping devices was also checked and tested.

The leakage from the butterfly valve seat was inspected at inside of butterfly valve for ensuring the safety of the inspection works for the inner surface of the penstock. No leakage from No.1 butterfly valve and minor leakage (approx. 4.5 l/min) from No.2 butterfly valve were confirmed. It was also confirmed through the visual inspection of butterfly valves and auxiliary equipment that the aging of the seat rubber quality of butterfly valve disk and air valves is in progress and the deterioration of the over velocity tripping devices was remarkable due to occurrences of corrosion. The damaged pressure gauge and transmitter located at the upstream of No.2 butterfly valves were observed.

On the other hand, as a result of the operation test of butterfly valves, the No.2 butterfly valve was confirmed on the difficulty of smooth operation of valve closure by the counter-weight due to increase of seat rubber friction. Through the inspection on paint at the outer surfaces of butterfly valves, the occurrences of minor corrosion were observed.

It was observed that the local control panel with cabling system, oil pressure unit, auxiliary electrical parts, etc. for the butterfly valve operation are also aging and deteriorating on the mechanical and electrical parts of the gate facilities.

Considering the present defects identified during the field investigation, the following are essential to rectify for ensuring the reliable operation of butterfly valves.

- Control panels with cabling system to be renewed
- Auxiliary electrical parts of butterfly valves and auxiliary equipment to be renewed
- Hydraulic oil unit to be renewed with oil piping arrangement
- Seat rubber of valve disc to be replaced under the supervision of a specialist
- Over velocity tripping device to be renewed
- Outer surfaces of butterfly valves and auxiliary equipment to be repainted
- Pressure gauge and its transmitter to be renewed

(8) Penstock

The inspections of penstock were carried out under both dewatering and operational conditions of penstock. The inside of penstock was inspected visually and recorded photographically after dewatering of penstock. Through the inspection of the penstock No.2 line, the Study Team had concern about the quality of steel material and the construction condition of the penstock for the portions between anchor block BL.No.2 and BL.No.3 and No.82 unit pipe between anchor block BL.No.4 and BL.No.5 which have been restored by Viet Nam in 1976 since the confirmation for the restoration condition of the penstock will be seriously related with a safety of the penstock. According to the consideration, the detailed inspection methods such as thickness inspection by ultrasonic testing method and material test by micro testing and chemical testing methods were applied for such portion to clarify the kind of the materials, the mechanical property of the material and the reliability of the repairing structural condition of penstock. Test samples obtained from the detailed inspection are analyzed in Japan.

1) Appearance inspection

For the performance of the detailed inspection using the measuring instruments, the appearance inspection was carried out to confirm the degree of the deterioration and damages at both outer and inner surfaces of penstock and the following results were obtained ;

a) Inner surface

Penstock No.1 line :

PC-2 staff reported that they carried out the repaint work on all the inner surfaces of penstock below butterfly valves using the epoxy resin paint material in 1993. From the results of the paint inspection, it was confirmed that the paint condition of the shell surface is effectively maintained while a few paint removal position with max. 300 mm width x 800 mm length is only observed at the portion between BL No.6 and BL.No.7. Acceptable paint thickness of more than 400 micron of epoxy resin paint was measured.

Penstock No.2 line :

PC-2 staff reported that they have no record of repair paint work. However, from the paint inspection on the shell surface it seemed that the repair painting work had been carried out a long time ago, because the different quality of the paint material was visually detected on the original paint surface. The present paint condition of the shell surface was not effective for corrosion protection and the serious corrosion were also observed on the shell surface. The paint condition on each portion are recorded as follows:

- Corrosion due to removal of the paint material is observed at the overall length of the penstock bottom between BL.No.3 and BL.4 with 800 mm width.

- Corrosion between BL.No.3 and BL.No.6 is seriously in progress and the pit corrosions at max. 3 mm deep is observed on the shell surface.

- Removal and damages of paint material are observed on the shell surface between BL.No.8 and BL.No.9.

- Cracks due to aging of paint material are observed on the paint surface below BL. No.10.

In view of the above corrosion condition, the repairing paint on all surfaces of penstock below butterfly valves is recommendable as soon as possible.

Penstock at upstream of butterfly valves:

From the visual inspection, no damage on paint material was confirmed.

b) Outer surfaces

PC-2 staff reported that the repair paint was applied for all the external surface of penstock No.1 and No.2 lines below butterfly valves two (2) years ago. From the results of the paint inspection, it was confirmed that the paint condition on the both penstock lines is effectively maintained at the moment. However, as a result of the inspection on the exposed portion at the upstream of butterfly valves, the occurrences of the corrosion due to the removal of paint material, which are required to be made the repair painting early, are observed.

Defects and damages owing to the fallen stones from the side slop wall of penstock trench, were observed at some ring girder portions. These ring girder portions are recommended to be repaired with correct manner along with the protection work at the side slop wall of penstock trench by civil work to avoid the furthre fallen stones.

Deformed positions which have been repaired with the backing plate, were also observed at the surface of pipe shell below anchor block BL. No.4 of both penstock lines. From the visual inspection on such positions, it was considered that the reliable repair works have been carried out by PC-2.

Due to a aging of seal rubber quality of the present expansion joints, the leakage from expansion joints was observed. Therefore, the present seal rubbers and gaskets are recommended to be replaced with a high quality material to ensure reliable water tightness of expansion joints.

2) Shell thickness inspection

From the results of the ultrasonic shell thickness inspection, the thickness of pipe shell was confirmed to be within allowable design value.

3) Welding quality inspection

The ultrasonic inspection was applied for three (3) field welding joints on each anchor block span and ten (10) field welding joints between BL.No.2 and BL.No.3 of the penstock No.2 line. As a result of the ultrasonic inspection, it

was confirmed that the quality of the field welding joints on both penstock lines are within the acceptable range.

In addition to the ultrasonic inspection, the dye penetrant inspection was applied for the ring girder No.28 of the penstock No.1 line and the ring girder Nos.20, 40 and 54 of the penstock No.2 line which were damaged seriously by the fallen stones from side slop wall of penstock trench, to inspect the damaged degree of those ring girders. It was also confirmed from the result of the inspection that the small cracks were being occurred in the fillet welding line of the ring girder No.54 and those should be repaired as early as possible.

4) Inspection of Penstock Portions repaired by Viet Nam

The penstock portions repaired by Viet Nam after the end of war are located between BL.No.2 and BL.No.3 of the penstock No.2 line and No.82 unit pipe between BL.No.4 and BL.No.5 of the penstock No.2 line, respectively. From the visual inspection on these portions, it was found that the following penstock types were applied for the repair.

- BL No.2 and BL No.3 : Butt welding joint type single layer penstock
- No.82 unit pipe : Butt welding joint type double layer penstock

In view of the double layer type penstock of No.82 unit pipe applied by Viet Nam, the Study Team deemed that the restoration work of penstocks have been carried out under the circumstances of difficult procurement of thick steel plate and thus the double layer type penstock have been obliged to apply for No.82 unit pipe at high pressure portion to compensate the shortage of thick steel plate and to withstand the pressure of the penstock, instead of single layer type penstock .

In order to perform effectively the detailed inspection by the measuring instrument on the these portions, the report of PC-2 titled as " Report of Restoration Works of Penstock No.2 of Da Nhim hydro - power System" of 15th February 1976 was preliminary reviewed by the Study Team to confirm the design drawings, design calculation, inspection results, etc. on such portions. The examination on the safety of penstock was made in comparison between the design information from the PC-2 report and the results of the penstock stress estimated from the analysis on a result of the following material tests.

a) SUMP test (Suzuki Universal Metal Print) : Ten (10) metal prints were collected from the portion.

b) Chemical analysis : Twelve (12) samples of material were collected from the portion for clarification of the micro structural constituent of material.

5) Rope haulage

Ten (10) ton capacity rope haulage was provided along the existing penstock line for the purpose of the penstock maintenance when the Da Nhim power station was commissioned in 1963. However, the penstock line was partially destructed in 1967 during the civil war and the runway of the rope haulage between BL. No.4 and BL. No.7 was washed away by the flood water from the damaged penstock portion. Since the incident, PC-2 was forced to accept the condition that no utilization of the rope haulage was possible for the penstock maintenance.

In discussion with PC-2, the Study Team understood the PC-2's preference to renovate the rope haulage for facilitating the penstock maintenance work to the portion located on such steep slope as 48° at maximum between the valve house and BL. No.8.

6) Defects to be rectified

Considering the present defects identified during the field investigation, the following are essential to rectify for ensuring the reliable operation of power station.

- Inner surface of the penstock No.2 line to be repainted
- Outer surface of the penstock upstream portion of butterfly valves to be repainted
- Damaged ring girder No.28 of the penstock No.1 line and ring girder Nos. 40 and 54 of the penstock No.2 line to be repaired
- Seal rubbers and gaskets of all expansion joints to be renewed
- Seal gaskets of all manholes to be renewed
- Renovation of rope haulage

(9) Cooling water pipes

The results of the visual inspection on the outer surfaces of cooling water pipes revealed that the corrosion due to the removal paint material had extended remarkably

to all the outer surface of pipes. Besides, the results of the ultrasonic shell thickness inspection confirmed that the thickness of the pipes was reduced from the original thickness (6.9 mm) by average of approx. 1 mm. However, no replacement of pipes is required at the moment, since the pipes are subjected to the low pressure only.

Considering the present defects identified during the field investigation, the following defects are essential to rectify for ensuring the reliable operation of power station.

- Repainting works on all external surfaces of pipes

(10) Other facilities

1) Spare parts and tools

PC-2 staff reported that there are no stock of spare parts in the power station at the present and some parts inevitably required are principally procured in at Viet Nam. From the present procurement and stock conditions of spare parts, the Study Team considers that the provision of a high quality spare parts from Japan are recommendable to ensure the reliable operation of the facilities.

It is considered that the tools for the normal maintenance and repair of the facilities are stocked by PC-2.

2) Testing equipment

The Study Team observed insufficient provision of the testing equipment for the inspection of paint, mechanical and eletrical parts,etc. The provision of the testing equipment is recommendable in view of the reliable maintenance work of the facilities.

5.1.4 Analysis of Field Investigation Results

(1) Procedure of analysis

As shown in Table 5.2, some defects were required to be analyzed in detail in Japan to clarify accurately the degree of the deterioration and damages of the facilities and to establish the proper rehabilitation plan for extension of the remaining lifetime of the facilities. Judgment on the degree of deterioration and damages were based on the Japanese standards, technical ordinance and authorized technical reports that are commonly applied to the diagnosis for deterioration of the electrical power equipment and mechanical facilities.

The approach of the analysis to be applied for the equipment and facility are summarized as follows:

1) Trash rack panel for spillway irrigation outlet facilities

On the basis of the data for corrosion degree and thickness of trash rack bars from the result of the visual inspection, the stress analysis on the trash rack will be made by the theoretical stress calculation method.

2) Intake fixed trash racks

On the basis of the data for corrosion degree and thickness of trash rack bars from the result of the visual inspection, the stress analysis on the trash racks was made by the theoretical calculation method.

3) Intake movable trash rack

a) In order to clarify vibration effect to trash rack bars, the possibility of vibration was investigated by the theoretical vibration analysis method subjected to the Karman Vortex.

b) On the basis of the data for corrosion degree and thickness of trash rack bars as a result of the visual inspection, the stress analysis on the trash rack was made by the theoretical stress calculation method.

c) Examining the present operation procedure of trash rack panels reported by PC-2, the proper operation procedure of intake movable trash rack is recommended to minimize the damage of trash rack panels.

4) Penstock

a) Damaged ring girder

The stress analysis was made for the No.54 ring girder which was damaged seriously and was made by the theoretical stress calculation method of the ring girder.

b) Penstock portion repaired by Viet Nam

The analysis on the safety of penstock was carried out by the following processes.

First step : Clarification of materials

SUMP test and chemical test on the material samples obtained during the field investigation were made to clarify a feature and kind of materials. Besides, from the results of these tests, the mechanical property of the material such as yield strength and tensile strength was estimated applying the theoretical stress calculation method of the penstock.

Second step : Stress calculation of pipe shell

The stress calculation of pipe shell was made basically by the same procedure as mentioned in the PC-2 report of " Report of Restoration Works of Penstock No.2 of Da Nhim hydro - power System" of 15th February 1976" to facilitate the comparison of the penstock condition between the design stress values obtained from the PC-2 report and the penstock stress values estimated from the calculation on a result of the material tests.

(2) Result of Analysis

The analysis mentioned in the foregoing sub-clause (1) of this clause are resulted as follows:

1) Trash rack panel for spillway irrigation outlet facilities

As a results of the theoretical stress analysis of trash rack panel under the occurrences of maximum 3 mm corrosion of trash rack bars, it was confirmed that maximum bending stress of the trash rack bars was 510 kgf/cm^2 and below the allowable stress of 1,150 kgf/cm^2.

Thus, it was confirmed that no urgent rehabilitation work on the trash rack panel was required at the moment as the trash rack panel has still enough strength.

The analysis result of trash rack panel is shown in Table 5.3.

2) Intake fixed trash racks

From the result of the theoretical stress analysis of trash rack panel under the occurrences of maximum 3 mm corrosion of trash rack bars and of maximum 1.5 mm corrosion of supporting girder, it was confirmed that the maximum bending stresses of trash rack panel and supporting girder were 702 kgf/cm^2 and 1,085 kgf/cm^2 respectively and below allowable stress of 1,150 kgf/cm^2.

The stress analysis of trash racks is shown in Table 5.3.

Thus, it was confirmed that no urgent rehabilitation work on the trash racks was required at the moment as the trash racks have still enough strength.

3) Intake movable trash rack

a) Vibration effect to trash rack

The vibration effect to the upstream movable trash rack was examined using the theoretical analysis method for the vibration of trash rack panel induced due to the Karman Vortex. The examination was performed to the following parts of trash rack and under the following conditions.

Case	Parts	Analysis condition
1	Trash rack bars	Support condition : Fixed at both end Distance of supports : 52.7 cm
2	Horizontal girder	Support condition : Fixed at both ends Distance of supports : 362.2 cm
3	Trash rack bars	Support condition : Hinged at both bar ends Distance of supports : i) 52.2 cm ii) 104.3 cm iii) 156.5 cm

The analysis results are shown in Table 5.4 and summarized as follows :

Case	Natural frequency (Hz)	Frequency due to Karman Vortex (Hz)	Safety Factor
1	1,346	42.9	31.4 > 2.5
2	69.9	2.4	29.1 > 2.5
3. i)	58.5	42.9	1.4 < 2.5
ii)	14.7	42.9	0.3 < 2.5
iii)	6.5	42.9	0.2 < 2.5

It is noted from the results of the case 3 that there is possibility of occurring the damages of the trash rack panel due to resonance of trash

rack bars as the safety factor for the frequency value is less than 2.5. Thus the rehabilitation on the trash rack is required urgently.

b) Stress analysis of trash rack bars

It was considered from the results of the field investigation that the corrosions of the trash rack bars were induced from the loosing of distance pieces of the trash rack panels due to vibration of trash rack bars, and the degree of the corrosion is not serious. Thus, it was considered that the corrosion would not be effect to the structural condition of the trash rack bars.

c) Operation procedure of movable trash rack

The Study Team observed during the field investigation that the upstream movable trash rack panel provided for the service was continuously utilized over a long period of more than two weeks. In view of the proper operation procedure of the trash rack, the present utilization method of the upstream trash rack is not proper, because the upstream trash rack is operated only at the time when the trash accumulated on the front face of the downstream trash rack is removed.

Therefore, it is recommended that the downstream trash rack panel should be normally utilized and PC-2 would establish the proper operation rule of the downstream trash rack panel so as to remove the trash at least once a day during the flood season in order to minimize the damage of the movable trash rack .

4) Penstock

a) Damaged ring girder

The stress analysis was carried out on the No.54 ring girder on the basis of the present damaged condition. The stress analysis, resulted that the maximum stress of the ring girder was 1,755 kgf/cm^2 and less than 2,610 kgf/cm^2 of the allowable stress. The result of the stress analysis is shown in Table 5.5.

Although the maximum stress of the damaged ring girder is within the allowable stress, it was considered that minor repairing work is necessary to the damaged portion to avoid the further extension of damages.

b) Penstock portion repaired by Viet Nam

i) Clarification of materials

The analysis results of SUMP test and chemical test on the materials are shown in Table 5.6.

From the above results, the materials on the related portion are clarified and classified into the following qualities specified in Japanese Industrial Standards (JIS).

Position	Thickness (mm)	Materials
BL. No.2 - BL. No.3 (Outer pipe of No.82)	9.53	JIS - SS 490 class
BL. No.2 - BL. No.3	11.988	JIS - SS 400 class
BL. No.2 - BL. No.3	12.7	JIS - SS 490 class
BL. No.2 - BL. No.3	14.0	JIS - SS 400 class
BL. No.2 - BL. No.3 (Inner pipe of No.82)	19.0	JIS - SS 490 class

ii) Stress analysis

The stress calculation was carried out on the penstock portion between BL. 2 and BL. 3 on the basis of the mechanical property for the material of penstock clarified by the above tests and using the same design calculation mentioned in the foregoing PC-2 report. The result of the calculation concluded that the maximum stress of penstock was 863 kgf/cm^2 and was within 926 kgf/cm^2 of the allowable stress.

The calculation results is shown in Table 5.7.

Thus, it was confirmed that no urgent rehablitation work on the related portion was required at the moment as the penstocks have still sound condition.

5.2 Formulation of Rehabilitation Plan

5.2.1 General

As discussed in the foregoing subsection 5.1.3, the rehabilitation plan is required to establish each component of the waterway and ancillary facilities, while it is considered from the results of the preliminary study in the field investigation that there are no sign of serious damages on the facilities due to the proper maintenance works of PC-2 despite of the facilities constructed over thirty (30) years ago. In view of the present defects of the facilities, the rehabilitation plan was formulated as follows:

5.2.2 Formulation of Urgent Rehabilitation Plan

The main defects identified by the field investigation are (i) the corrosion on the facilities and (ii) the aging and deterioration of the auxiliary mechanical and electrical parts of the facilities. In view of the observation on the kind of the defects identified, all the defects are categorized into the minor defects. However, from the practical viewpoint that such defects can be deemed as a preliminary indications of serious damage, it is considered that the rehabilitation works on these defects are definitely important to improve the technical state of the aged equipment and facilities and to extend the remaining life time of the facilities despite of a minor rehabilitation works. Therefore, the rehabilitation works on the defects listed on Table 5.2 are recommended to be carried out as a matter of urgency and to be categorized into the urgent rehabilitation plan.

In conjunction with the rehabilitation work to the defects, PC-2 has the improvement plans such as the application of a new central control system for Da Nhim dam and power station and the replacement of the intake trash racks. Under the circumstances, the optimum formulation of rehabilitation plan on the defects is beneficial to establish along with these improvement plan of the PC-2 on the facilities.

5.2.3 Formulation of Long - Term Rehabilitation Plan

Despite confirmation that there are no signs of serious damages on the facilities, it is beneficial for the Da Nhim dam and power station to work out the long-term rehabilitation plan to facilitate the establishment of the future maintenance schedule on the facilities on the basis of the present defect condition as a results of the field investigation and the analysis on the defects. On the other hand, it is noticed from the practical theory that the life time of the gates and penstock is usually estimated at fifty (50) years for calculation of depreciation cost

of these facilities in the feasibility study of the hydro-power project. Considering the practical theory and the equipment and facilities constructed over thirty (30) years ago, the defect points on the facilities are forecasted to increase probably in the future due to aging, even though no urgent rehabilitation work is required at the moment.

On the basis of the above general understanding on the long-term rehabilitation plan, the facilities to be rehabilitated in the future due to the forecasted aging and unreasonable function may be recommended. It is noted that the implementation of long - term rehabilitation work is subject to a strict periodical check by PC-2 for the observation of function of the facilities.

5.3 Urgent Rehabilitation Plan

5.3.1 General

In view of the foregoing Subsection 5.2.2, the proposed rehabilitation works on the defects which are categorized as the urgent rehabilitation plan, are summarized in Table 5.8.

As seen in the Table, the rehabilitation works on the waterway and ancillary facilities are required at such places as related with civil structures and the generating equipment. Thus, it is recommended that the defects on the facilities can be rehabilitated conveniently along with those for the civil structures and generating equipment.

5.3.2 Basic Design of Urgent Rehabilitation Plan

Referring to Table 5.8, the basic design was carried out to the following facilities.

(1) Renewal of seal rubber and seal clamps for gates and valves
(2) Repair painting work of gates and penstock
(3) Replacement of control panel of gates and valves
(4) Renewal of mechanical and electrical parts of gates and valves
(5) Repairing of damaged ring girders
(6) Renewal of irrigation valves
(7) Renewal of water supply pump
(8) Renewal of movable trash rack panel
(9) Renovation of rope haulage of penstock
(10) Provision of spare parts and maintenance equipment

The basic design on each facility categorized under the urgent rehabilitation plan was carried out in accordance with the latest Japanese Standards and Technical Standards.

(1) Renewal of seal rubbers and seal clamps

The renewal of seal rubber with seal clamps is required for the spillway radial gates, intake caterpillar gate, penstock butterfly valves with air valves and penstock expansion joints and manholes. The general design condition of seal rubbers and clamps are shown in Figures 5.8 to 5.11.

(2) Repair painting work of gates and penstock

The repair painting works are recommended to be carried out on the basis of the paint procedure shown in Table 5.9.

(3) Renewal of control panel for gates and valves

The existing control panels to be renewed are summarized as follows:

Facility	Local panel	Remote panel
Spillway radial gates	1 set	1 set
Intake caterpillar gate	1 set	-
Intake movable trash rack	1 set	-
Butterfly valves	1 set	-

At the moment, four (4) numbers of spillway radial gates are operated locally with one (1) local control panel located on the hoist deck of No.1 gate. It was considered from the field investigation that the gate operator may not observe overall operation condition of four (4) gates from the present location of local control panel during local control. Under the circumstances, it is recommended that two (2) local control panels for the respective gate operation are to be provided on the hoist deck to ensure safety of the spillway radial gates operation.

The control panels for all the facilities are required to be newly provided with the following digital transducers and indicators, and terminal units to accommodate to a new central control system for the flood forecasting system to be applied to the Da Nhim dam and power station in the future.

1) Telemetering items
   - Digital type gate or valve position indications

2) Supervisory items

The " on-off contacts" (free potential, normally opened and/or closed mechanical contacts) shall be provided to send signal of all alarms and indications to the remote terminal units in the power station.

For gates

- Gate fully raised indication
- Gates fully lowered indication
- Gates intermediate position indication
- Fault indications (shortage of incoming source voltage and overload condition for gate)

For penstock butterfly valves

- Valve fully opened indication
- Valve fully closed indication
- Fault indications (shortage of incoming source voltage and overload condition for gate)

Except for the above design requirement, the new control panels for the gates are designed in accordance with the as-built drawings for the electrical sequence of the facilities. Besides, the design of new control panels for butterfly valves are also based on the as-built drawings for hydraulic oil control and electrical sequence of the facilities.

(4) Renewal of mechanical and electrical parts of gates and valves

The mechanical and electrical parts to be renewed for the facilitiy are summarized as follows:

Facility	Mechanical parts	Electrical parts
(i) Spillway radial gates	Wire rope hangers Oil level gauge of gear reducers	Auxiliary parts such as limit switches, contacts, terminals, cable/wiring

(ii) Movable trash racks	Gear reducer	Auxiliary parts such as limit switches, contacts, terminals, cable/wiring
(iii) Intake caterpillar gate	-	Auxiliary parts such as limit switches, contacts, terminals, cable/wiring
(iv) Butterfly valves	Hydraulic piping Over velocity tripping device	Auxiliary parts such as limit switches, contacts, terminals, cable/wiring

The basic design on each mechanical and electrical part was carried out as follows:

Mechanical parts

(i) The wire rope hangers are recommendable to newly manufacture in accordance with Figure 5.12.

(ii) The stainless steel materials are recommended to apply for the hydraulic piping system of the butterfly valves.

(iii) Other parts are designed and provided on the basis of the existing as-built design drawings as long as possible.

Electrical parts

(i) All external cable/wiring between the electric terminal points and various points of the facilities will be multi-core copper, cross-linked polyethylene insulated PVC sheathed 600/1000 V grade cable.

(ii) All the external cable/wiring will be installed in the existing cable conduit and ducts.

(iii) The other parts are designed and provided on the basis of the existing as-built design drawings.

(5) Repairing of damaged ring girders

As described in the foregoing subsection 5.1.4 (2), the ring girders damaged are recommended to be repaired. The recommendable repairing method is shown in Table 5.10.

(6) Renewal of spillway irrigation valve facilities

The rehabilitation of irrigation valve facilities consists of the renewal of irrigation valves and the provision of the watertight manholes for the operation shaft.

The basic design of the facilities are as follows:

1) Renewal of spillway irrigation valve facilities

The following equipment will be renewed totally.

- One (1) set of 600 mm diameter butterfly valves
- One (1) set of 600 mm diameter sluice valve
- One (1) unit of pipe No.2
- Seal rubber and packing material of expansion joint

The portions and conditions to be totally renewed are shown in Figures 5.13 and 5.14. The above equipment are obliged to be designed and installed without any alteration of the existing civil structures.

Besides, new valves will be operated by the electric motor through the local control cabinet which will be located on the hoist deck of spillway radial gates. Therefore, all the necessary electrical equipment such as control panel, distribution panel, electric cables for carrying out the electric motor operation are required to be newly installed in the valve chamber and on the hoist deck of spillway radial gates.

All necessary controls for the operation of the new water supply pumps which will be installed in the pump chamber, will be provided into a new control panel for the irrigation valves, in view of economical design of the panel.

2) Provision of watertight manhole for operation shaft

The existing manhole is required to be changed to the watertight type to avoid the invasion of the rain water from the entrance of the operation shaft. For the

provision of the watertight manhole, the existing air supply pipe for the irrigation valve is rerouted at the entrance of operation shaft.

The recommendable rehabilitation design of the watertight manhole and the air supply pipe are shown in Figure 5.14.

(7) Renewal of water supply pump

The design data of the existing pump unit are as follows:

- Design discharge	: 2.0 m^3/min
- Type of pump	: Horizontal shaft three (3) stage volute pump
- Required motor capacity	: 37 kW
- Rated design head	: 60 m
- Diameter of suction pipe	: 150 mm
- Diameter of delivery pipe	: 150 mm
- Diameter of main delivery pipe	: 150 mm
- Length of main delivery pipe	: approx. 600 m
- Pump unit	: Two (2) sets
- Layout of piping system in pump chamber	: Refer to Figure 5.15

The design condition on the pump unit to be renewed is required to be complied with the above data as long as possible. In order to facilitate the renewal works in the pump chamber, a boundary for the works is set at the stop valves on each suction and delivery pipes in the pump chamber. It is noted that the works is obliged to be carried out without any alteration of civil structural condition except for the pump foundation.

A new control panel of pump unit will be located at the hoist deck of the spillway radial gates. All necessary instrument and control devises to suit the pump operation will be contained in the local control panel for the spillway irrigation valves.

The general layout of the pump chamber is shown in Figure 5.15.

(8) Renewal of movable upstream trash rack panel

As identified by the analysis of vibration effect to the trash rack discussed in the foregoing subsection 5.1.4 (2) 3), there is a possibility that the trash rack panel at the upstream is damaged with resonance of the trash rack bars which might be induced from flow of water into the intake tunnel. From the fact, the bolt connection type trash

rack panel of the screen bars is changed to the welded construction type in order to increase the natural frequency of the trash rack bars and to secure the safety factor of more than 2.5.

The recommendable design of the upstream trash rack panel is shown in Figure 5.16.

(9) Renovation of rope haulage for penstock

The rope haulage is provided at the penstock trench to facilitate the maintenance work of the penstock.

The basic design of the rope haulage was carried out as follows:

1) Design concept

The design condition of the rope haulage is established on the basis of the following concept.

a) The rope haulage will be installed at the difficult maintenance portion of the penstock line between the valve house and BL. No.8.

b) Design load of the rope haulage is considered as maximum 1 ton to achieve the following maintenance work of the penstock.

- Transportation of paint material and machine for repair paint of the penstock
- Transportation of concrete bags and minor construction equipment for repair of penstock trench
- Transportation of two (2) persons along with the above materials and equipment

c) Selection of the equipment type having simple construction and operating system in view of the easy maintenance work.

d) Achievement of the safety transportation under the condition of steep inclined penstock line at maximum 48 degree.

2) Type of rope haulage

From the field investigation on the topographical condition of the penstock trench, many eroded positions of ground surface were identified at the penstock inclined portion between BL. No.4 and BL. No.7, which were measured in visually as maximum 8 m depth. The optimum type of the haulage was selected from the following three (3) types in view of topographical condition:

- Cable crane type
- Monorail hoist type
- Wire rope winch type

These types were examined on the availability on the basis of the design concept discussed in the foregoing chapter (a) of this Clause and the past record of the manufacturing performance of the rope haulage. As a result of the examination, the wire rope winch type is recommended from the following comparison with other types :

a) The cable crane type is not suitable for the transportation of human in view of safety.

b) The monorail hoist type has no experience of manufacturing and installing under steeply inclined portion as more than 45 degrees. This type is mostly applied for the many experience slopes of less than 40 degrees. Thus, in view of the steep penstock line on 48 degrees at the Da Nhim power station, the monorail hoist type is not recommendable.

c) The wire rope winch type has a simple structural and mechanical systems compared with the monorail hoist type and the cable crane type. In view of the easy maintenance on the rope haulage, the wire rope winch type is recommendable.

The arrangement of the rope haulage is shown in Figure 5.17.

(10) Provision of spare parts and testing equipment

As described in the foregoing subsection 5.2.3, PC-2 is recommended to carry out the strict periodical check on the facilities in the future. PC-2 is also recommended to procure the spare parts and the testing equipment of the facilities to achieve

satisfactorily the future maintenance work. The recommendable spare parts and testing equipment are listed in Table 5.11.

5.4 Implementation Programme of Urgent Rehabilitation Plan

5.4.1 Basic Concept for Implementation of Rehabilitation Plan

In view of the performance of the maintenance work on the existing facilities, PC-2 have an ample capability of proceeding the rehabilitation works such as the painting work of the facilities, the manufacturing of the movable trash rack panels, minor repairing work of the equipment, by themselves.

As seen in the work contents of the urgent rehabilitation plan listed in Table 5.3, the works are minor and the application of foreign high - technology on the face of the installation work will not be considered. From the consideration, the urgent rehabilitation work will be implemented in such a manner that all the equipment and materials will be procured from a reputable foreign contractor who will be selected by the Internationa Competitive Bid and installed by PC-2 under the supervision of the contractor. However, the following works out of those listed in Table 5.8 will be performed fully by PC-2 at PC-2's own fund.

	Works	Item Nos.in Table 5.8
(i)	Painting works of facilities	1.1 (3), 5.1 (2), 6.1, 7.1, 8.1, 8.3 (1), and 8.4
(ii)	Replacement of movable trash rack panel	4.1
(iii)	Repair of penstock ring girders	8.2 (2) and 8.3 (3)

On the basis of the above concept, the implementation schedule is worked out and the necessary cost of the urgent rehabilitation plan is estimated.

5.4.2 Implementation Schedule

The implementation schedule is drafted by the Study Team for the periods of the design, the procurement of material, the manufacturing, the transportation and the installation for the completion of the rehabilitation works.

The implementation schedule is shown in Figure 5.18.

On the other hand, it is recommended in view of economical project implementation that the rehabilitation work on the facilities will be carried out along with those of the other works such as civil work, turbine and generating equipment, as these works are closely related with the waterway and ancillary facilities.

5.5 Long Term Rehabilitation Plan

In view of the foregoing subsection 5.2.1, the following rehabilitation works which will be categorized as the long - term rehabilitation plan , are recommended.

(1) Modification of Intake Fixed Trash Racks

As stated in the foregoing subsection 5.1.3 (4), the accumulation of the trash/floating logs in front of the movable trash rack panels was observed. From the present condition, there is a possibility that many trash/floating logs, etc. are permitted to pass the intake fixed trash racks, against expectations of the original design concept. The counter - measure to the defects due to the vibration of the panels of the movable trash rack is proposed under the urgent rehabilitation plan, while it is important to prevent the entering the trash / floating logs into the intake tunnel as much as possible. Therefore, it is recommended that the bar pitch of the intake fixed trash racks should be changed from 100 mm in the original to 60 mm and a trash rake machine should be provided at the intake portal to remove the trash/floating logs accumulated in the front of the fixed trash racks, after the height of trash racks or other steel structure were extended up to higher than H.W.L 1,042 m.

The recommendable modification of the intake portal is shown in Figure 5.19.

(2) Removal of Intake Movable Trash Rack

It is noted that the present movable trash rack could be removed entirely after the modification of the intake fixed trash racks mentioned in the above item (1) of this Clause would have been completed.

(3) Renewal of Hoist of Intake Movable Trash Rack

In consideration of high frequency of the hoist operation as reported by PC-2 staff and importance of the intake movable trash rack at the moment, the renewal of hoist is

beneficial to ensure the reliable operation of generating equipment provided that the implementation of the modification of intake fixed trash racks recommended in the above item (1) of this clause will not be made.

(4) Penstock Portion Between BL.No.2 and BL. No.3 of Penstock No.2 line and No.82 Unit Pipe of Penstock No.2 Line

These portions of the penstocks are recommendable to examine the replacement with those fabricated from a suitable materials in adequate structures to ensure the safety of the penstock, subject to strict periodical check on the behavior of facilities and equipment.

(5) Replacement of Cooling Water Pipes

During the field investigation, the deteriorated cooling pipes were observed, although the urgent replacement is not required. However, the replacement of the cooling pipes is recommendable in the future.

(6) Replacement of trash rack for spillway irrigation outlet facilities

During the field investigation, the deteriorated trash rack were observed, although the urgent replacement is not required. However, the replacement of the trash rack is recommendable in the future.

5.6 Recommendation of Operation and Maintenance

As stated in the foregoing subsection 5.2.1, it was confirmed through the field investigation that there are no signs of serious damages on the facilities due to the proper maintenance works of PC-2 despite the facilities constructed over thirty (30) years ago. From the fact, the Study Team considers that PC-2 staffs of the Da Nhim power station have enough capability of maintaining the existing facilities properly. On the other hand, in view of the facilities constructed over thirty (30) years ago, PC-2 is recommended to establish their inspection plan soon in order to periodically record the behavior of all the facilities. Especially, the periodical inspection of the penstock is required to be strictly carried out by PC-2 at the same level of investigation method applied by the Study Team, as the penstocks have history that have been burst and restored two (2) time during the civil war.

Table 5.1 Main Design Data of Facilities (1/2)

The waterway and ancillary facilities in the Da Nhim dam and power station are as follows:

(1)	Spillway		
	(i) Radial type crest gates, guide frames, anchorages, stationary type cable-lift hoists and controls	:	11.0 m wide by 13.7 m high, 4 sets
	(ii) Irrigation outlet	:	Sluice valve in 0.6 m diameters with butterfly type guard valve in 0.6 m diameters : each one(1) set to be operated by manual
	(iii) Steel conduit	:	0.6 m diameter by approx.26.0 m long: 1 lane
	(iv) Fixed screen	:	4.777 m wide by 7.7 m heigh : 1 set
	(v) Water supply pump	:	2-15 HP, 75 mm diameters, 3 step volute pump
(2)	Intake		
	(i) Intake fixed trash racks	:	8.0 m wide by 11.25 m slant length : 2 sets
	(ii) Movable trash rack,guide frames, stationary type cable-lift hoist and control	:	3.6 m wide by 3.6 m heigh : 2 sets (trash rack panel : 2 sets, hoist : 1set)
	(iii) Intake caterpiller gate, guide frame, stationary type cable-lift hoist and control	:	3.6 m wide by 3.6 m heigh : 1 set

Table 5.1 Main Design Data of Facilities (2/2)

(3) Surge tank and penstock tunnel drain facilities		
(i) Drain facilities	:	Sluice valve in 0.6 m diameters with butterfly type guard valve in 0.6 m diameters : each two(2) sets to be operated by manual
(ii) Steel conduit	:	A diameter varying from 0.6 m to 1.2 m by approx.160 m long including one (1) Y type confluence pipe : 1 lane
(4) Butterfly valves	:	2.0 m diameters; 2 - sets to be operated by a hydraulic oil unit
(5) Surface type steel penstock	:	A diameter varying from 2.0 m to 1.05 m by approx.2,257 m long including one (1) Y type bifurcation for upper horizontal portion and one (1) spherical type bifurcations for lower branch portion, and max. design head 920 m (Static head: 800 m , water hammer: 15 %), 2 lanes
(6) Cooling water pipes	:	A diameter of 304.7 mm by approx.143 m long and max. design head 30.5 m, 4 lanes

Table 5.2 Defects and Issues Identified By Field Investigation (1/8)

Item No.	Facilities/Equipment	Present Defect Conditions	Request / Intention of PC - 2
1	Spillway Radial Gates and Hoists		
1.1	Gate leaves		
(1)	Seal rubbers	Leakage from gate leaf induced due to aging and deterioration of seal rubber quality	Renewal of seal portion to be carried out.
		Leakage from gate leaf induced due to damage of seal rubber	
		Serious corrosion of seal clamps	
(2)	Wire rope hangers	Occurrences of unbalanced wire rope tension of gate leaf due to serious corrosion of hanger shafts.	Renewal of wire rope hangers to be carried.
(3)	Paint of skin plate, main beams and arms	Occurrences of corrosion due to removal of paint material	Repair paint to be carried out.
1.2	Hoists and controls		
(1)	Hoists	Occurrences of aging and deterioration of auxiliary electrical and mechanical parts such as limit switches, oil level gauge of gear reducers, electrical cable/wiring system	PC-2 reported that a new central control system associated with flood forecasting system will be applied for the Da Nhim dam and power station in recent years. Therefore, it is noted that the present control panels and auxiliary electrical parts are required to renew inevitably to satisfy the requirement of such new control system when the application can be made.

Table 5.2 Defects and Issues Identified By Field Investigation (2/8)

Item No.	Facilities/Equipment	Present Defect Conditions	Request / Intention of PC - 2
(2)	Control panels and cabling system	Occurrences of aging and deterioration of electrical parts contained in the remote and local panels Occurrences of aging and deterioration of electrical cable / wiring between control panels and hoists	Renewal of control panels and electrical parts to be carried out.
2	Spillway Irrigation Outlet		
2.1	Outlet valves	The valve chamber for the outlet valves was completely submerged over thirty (30) years ago and thus no water supply to dam downstream area was possible. The inspection on the valves was impossible. According to the present condition of valve chamber, it was appeared that the valve chamber with the blockage of drainage pipes was submerged due to entering of rain water	PC-2 expressed their intention to renovate and recover the function of the outlet facilities urgently. PC-2 has also their intention that new valve will be operated by electric motor to achieve the remote control operation system when outlet facilities is renovated.
2.2	Water supply pump	Out of two (2) water supply pump units, one pump unit was already out of order and other pump can not satisfy the specified water supply capacity due to the aging of pump unit. Aging of control panel and electrical wiring	Renewal of water supply pump and electrical parts to be carried out.
2.3	Trash rack panel	Same corrosion degree of trash rack bars as those of the intake fixed trashracks was observed.	

Table 5.2 Defects and Issues Identified By Field Investigation (3/8)

Item No.	Facilities/Equipment	Present Defect Conditions	Request / Intention of PC - 2
3	Intake Fixed Trash Racks		
		Corrosion of trash rack panel was extended seriously. Approx. 3 mm deduction of trash rack bar thickness was measured.	PC-2 has their schedule to replace the upper trash rack panel above EL. 1,020.8 m with new panel in 1995 by themselves.
4	Movable Trash Racks		
4.1	Upstream trash rack	Deformation of trash rack bars and loosing of distance pieces due to vibration of panels which might occurred with a high flow velocity of tunnel.	PC-2 has their shedule replace the upstream trash rack panel with new panel .
		Occurrences of corrosion of trash rack bars and frames due to removal of paint material	
4.2	Guide frames	The large concrete breakage (approx. 3.1 m high x 15 cm depth) of secondary concrete was observed at left side of a front guide frame of trash rack panel.	PC-2 has their intention to pour the filling material into the breakage portion when the water level reached at EL. 1,019 m.
4.3	Hoist and control		
(1)	Hoist	Occurrences of aging and deterioration of auxiliary electrical and mechanical parts such as limit switches and electrical cable/wiring system	Renewal of electrical and mechanical parts to be carried out.
		Oil leakage from gear reducer	

Table 5.2 Defects and Issues Identified By Field Investigation (4/8)

Item No.	Facilities/Equipment	Present Defect Conditions	Request / Intention of PC - 2
	(2) Control panel and cabling system	Occurrences of aging and deterioration of electrical parts contained in the local panel	Renewal of control panel and electrical parts to be carried out.
		Occurrences of aging and deterioration of electrical cable / wiring between control panels and hoists	
5	Intake Caterpillar Gate and Hoist		
	5.1 Gate leaf		
	(1) Seal rubbers	Leakage from gate leaf induced due to aging and deterioration of seal rubber quality	Renewal of seal portion to be carried out.
		Leakage from gate leaf to be induced damage of seal rubbers	
	(2) Paint of skin plate and main beam	Occurrences of corrosion due to removal of paint material	Repair paint to be carried out.

Table 5.2 Defects and Issues Identified By Field Investigation (5/8)

Item No.	Facilities/Equipment	Present Defect Conditions	Request / Intention of PC - 2
5.2	Hoist		
(1)	Hoist	Occurrences of aging and deterioration of auxiliary electrical and mechanical parts such as limit switches and electric cable/wiring system.	PC-2 reported that a new central control system associated with flood forecasting system will be applied for the Da Nhim dam and power station in recent years. (It is noted that the present control panels and auxiliary electrical parts are required to renew inevitably to satisfy the requirement of such new control system when the application can be made.)
(2)	Control panel and cabling system	Occurrences of aging and deterioration of electric parts contained in the local panel	
		Occurrences of aging and deterioration of electrical cable / wiring between control panels and hoists	
6	Surge Tank Drain Facilities		
		Minor corrosion on the outer surface of facilities	Repair paint to be carried out.
7	Butterfly Valves		
7.1	Butterfly valves	Aging of seat rubbers	Renewal of seal portion to be carried out.
		Minor leakage (4.5 l/min) from No.2 valve	
		Corrosion on the outer surface of valve due to removal of paint material.	Repair paint to be carried out.

Table 5.2 Defects and Issues Identified By Field Investigation (6/8)

Item No.	Facilities/Equipment	Present Defect Conditions	Request / Intention of PC - 2
		The difficulty of smooth operation of No.2 butterfly valve closure by the counter - weight due to increased friction load of seal rubber.	Detailed check to be carried out by the specialist of butter fly valves.
7.2	Auxiliary equipment (air valves, bypass pipes and valves)	Aging of seat rubbers of air valve	Renewal of seal to be carried out.
		Aging of over velocity tripping device	Renewal of the damaged and aged equipment to be carried out.
		Damage of pressure gauge and its transmitter	
7.3	Control panel and cabling system		
		Aging of hydraulic oil unit	Renewal of hydraulic oil unit with piping and all electrical parts to be carried.
		Occurrences of aging and deterioration of auxiliary electric and mechanical parts such as limit switches and electrical cable/wiring system	
		Occurrences of aging and deterioration of electric parts contained in the control panel	
		Occurrences of aging and deterioration of electrical cable / wiring between control panel and hydraulic oil unit.	
8	Penstoks		
8.1	Penstock at upstream of butterfly valves	The corrosion on the exposed outer surface was observed due to removal of paint material.	Repair paint to be carried out.

Table 5.2 Defects and Issues Identified By Field Investigation (7/8)

Item No.	Facilities/Equipment	Present Defect Conditions	Request / Intention of PC - 2
8.2	Penstock rope haulage	10 ton capacity rope haulage which has been provided orginally, is impossible to utilize for the maintenance of penstock due to the destruction of the penstock in 1967.	PC-2 requested to provide a new penstock maintenance equipment as they have difficult maintenance work on the penstock line between the valve house and the upper crossing.
8.3	Penstock No.1 line		
(1)	Paint condition	As a result of the various inspections, it was considered that the penstock line is maintained in a good condition.	
(2)	Ring girders	Due to the fallen stones from side slop wall of penstock trench, ring girder No. 28 of penstock No.1 line was damaged.	Repair of the damaged ring girders to be carried out.
(3)	Expansion joints	Aging of seal rubber and seal material of expansion joints.	Renewal of seal portion to be carried out.
(4)	Manholes	Aging of gaskets of manholes	PC-2 is requesting to supply new gaskets of 32 sets for the manholes.
8.4	No.2 penstock		
(1)	Paint condition	It was confirmed through the visual inspections that the repaint of the inner surface is required to carry out urgently, as the corrosion is seriously observed compared with penstock No.1 line.	Repair paint to be carried out.

Table 5.2 Defects and Issues Identified By Field Investigation (8/8)

Item No.	Facilities/Equipment	Present Defect Conditions	Request / Intention of PC - 2
	(2) Ring girders	Due to the fallen stones from side slop wall of penstock trench, ring girder Nos. 40 and 54 of penstock No.2 line were damaged. As a results of dye penetrant inspection, ring girder No. 54 is required to rectify urgently as the ring girder was damaged seriously on the fillet welding line of girder.	Repair of the damaged ring girders to be carried out.
	(3) Expansion joints	Aging of seal rubber and sealing material of expansion joints	Renewal of seal rubber and material to be carried out.
	(4) Manholes	Aging of gaskets of manholes	PC-2 is requesting to supply new gaskets of 32 sets for the manholes.
	(5) Penstock repaired by Viet Nam	The safety of penstock portion repaired by Viet Nam was discussed on the basis of the detailed analysis of material and stress analysis of penstock.	
9	Others		
	9.1 Spare parts and tools	No stock of spare parts High quality of spare parts to be provided. (Minor spare parts are mainly procured in Viet Nam.) Minor maintenance tools are stocked by PC-2.	Provision of the necessary spare parts and testing equipment to be intended.
	9.2 Testing equipment	Insufficient provision of testing equipment	

Table 5.3 Stress Analysis of Trash Racks

(I) Design data

	Trash rack for irrigation outlet		Intake fixed trash racks	
Design head (P1)	0.5	m	0.5	m
Clear span (B)	-		8	m
Clear height (H)	-		10.575	m
Bar pitch (B0)	10	cm	10	cm
Supporting span (B1)	2	m	3.866	m
Allowable stress (So)	1,150	kgf/cm²	1,150	kgf/cm²
Corrosion ratio	3	mm	3	mm

(II) Strength of screen bars

$M = Pw \times B1^2 / 8$

$S1 = M / Z$

Where,

M : bending moment of bar
Pw : Distributed load per unit length
B1 : Supporting distance of bar
I : Moment of inertia of bar
Z : Sectional modulus of bar
A : sectional area
S1 : Stress

Place	Bar size ax b (cm)	I (cm⁴)	Z (cm³)	A (cm²)	Pw (kgf/cm)	B1 (cm)	M (kg - cm)	Sa (kgf / cm²)
Irrigation outlet	7.2 x 0.6	17.7	4.9	4.2	0.5	200	2,500	510
Intake	9.7 x 0.9	64.5	13.3	8.6	0.5	386.6	9,341	702

(III) Strength of horizontal beam

$W1 = P1 \times L$

$M = W1 \times B / 8 \times (2 \times B1^2 - B)$

$S2 = M / Z$

Where,

P1 : Design head
L : Length of pressure (= H/3)
B : Clear span
B1 : Supporting span
I : Moment of inertia of beam
Z : Sectional modulus of beam
A : Area of beam

Place	Beam size	P1 (kgf/cm²)	L (cm)	W1 (kgf/cm)	B (cm)	B1 (cm)	M (tf -m)
Intake	H447x172 x 8 x 17	0.05	358	17.92	800	830	1.541

Place	I (cm⁴)	Z (cm³)	S2 (kgf/cm²)
Intake	H447x172 x 8 x 17	0.05	1,085

Table 5.4 Vibration Effect To Movable Trash Racks

(I) Frequency due to Karman Vortex

$f = (S \times V / d)$

Where, S : Strouhal number
V: Velocity
d : Thickness of screen bar or horizontal beam at flow direction

Case	S	V (m/sec)	d (cm)	f (Hz)
Case 1	0.2	1.92	0.9	42.9
Case 2	0.2	1.92	16	2.4
Case 3 . i)	0.2	1.92	0.9	42.9
ii)	0.2	1.92	0.9	42.9
iii)	0.2	1.92	0.9	42.9

(II) Natural frequency of screen bars or horizontal beam

$fn = (a / 2\pi) \times \sqrt{(E \times I \times g)/(W \times L^3)}$ $\quad W = Vo \times (q + b/d \times at)$

Where, fn : Natural frequency of screen bar or horizontal beam
a : Coefficient of support condition
E : Elastic modulus of steel
I : Moment of inertia
g : Acceleration of gravity
L : Distance of support
W : See above formular

Where, Vo : Volume between screen bars
V=b x d x L
q : Specific gravity of steel
at : Specific gravity of water
b : Clear span of screen bar or beam
d : Thickness of screen bar or beam

Safety factor =fn / f > 2.5

Case	a	E (kgf/cm^2)	I (cm^4)	g (cm/sec^2)	L (cm)	Vo (cm^3)	q (kgf/cm^3)
Case 1	22.7	2,100,000	0.547	9.8	52.2	423	0.00785
Case 2	22.7	2,100,000	830.9	9.8	362.2	26,658	0.00785
Case 3 . i)	9.87	2,100,000	0.547	9.8	52.2	423	0.00785
ii)	9.87	2,100,000	0.547	9.8	104.3	845	0.00785
iii)	9.87	2,100,000	0.547	9.8	156.5	1,268	0.00785

Case	at (kgf/cm^3)	b (cm)	d (cm)	W (kgf)	fn (Hz)	f (Hz)	Safety factor fn / f
Case 1	0.001	5.1	0.9	5.7	134.6	42.9	3.1
Case 2	0.001	176.5	16	503	30.6	2.4	12.8
Case 3 . i)	0.001	0.9	9	5.7	58.5	42.9	1.4
ii)	0.001	0.9	9	11.4	14.7	42.9	0.3
iii)	0.001	0.9	9	17.1	6.5	42.9	0.2

Table 5.5 Stress Analysis of Ring Girder No.54 (1/3)

The stress analyses are carried out on the basis of the assumption that the distance of stiffeners of the ring girder was reduced to 150 mm from 180 mm due to the damage.

(I) Design data

Pipe No.	:	208-1
Design head	:	651.80 m
Diameter	:	1,650 mm
Thickness	:	30 mm
Material	:	JIS-SM 590 class
Corrosion allowance	:	0 mm

(II) Estimate of Allowable Stress

$$Sca = Sy \times 0.7 / 1.65$$

Where,
Sca : Allowable stress : 1,951 kgf/cm²
Sy : Yield stress : 4,600 kgf/cm²

(III) Strength of pipe shell

$$Sc = P \times Do / (2 \times t\,1)$$

Where,
Sc : Circumferential stress : 1,792 kgf/ cm² < 1,951 x 0.95 = 1,853 kgf/cm²
P: Design stress : 65.18 kgf/cm²
Do: Diameter of pipe : 165 cm
t 1 : Thickness : 3.0 cm

(IV) Axial stress

(1) Bending moment of pipe shell

$$Sb = \pm M/Z \times 10^3$$

Where,
M : Bending moment
Sb: Bending stress
Z : Sectional modulus of pipe
t : Thickness of pipe shell

Do (cm)	t (cm)	M (tf - cm)	Z (cm³)	Sb (kgf/cm²)
165	3	10,800	65,355	165

Table 5.5 Stress Analysis of Ring Girder No.54 (2/3)

(2) Local bending moment of shell plate due to fix of stiffener

$$Sf = \pm 1.82 \times A1/A \times P \times rm/t$$

Where,
Sf : Locall bending moment
A1 : Sectional area of ring stiffener
A : Sectional area of shell plate and ring stiffener
P : Design pressure
t : Shell thickness of shell plate

Do (cm)	t (cm)	P (kgf/cm²)	2A1 (cm²)	2A (cm²)	rm (cm)	Sf (kgf/cm²)
165	3	65.18	46.8	176.9	84	879

(3) Axial force

i) Force induced from the friction of pipe shell and ring girder support due to axial force (P1)
ii) Force due to inclined pipe (P2)
iii) Force due to the friction of the expansion joint (P3)
iv) Force due to the internal pressure of the expansion joint (P4)
v) Force due to the internal pressure of reducer pipe (P5)
vi) Axial stress

$$Sp = (P1 + P2 + P3 + P4 + P5)/A \times 10^3$$

P1 (ton)	P2 (ton)	P3 (ton)	P4 (ton)	P5 (ton)	A (cm²)	Sp (kgf/cm²)
56.75	42.27	151.15	105.46	-	1,583	224

* The values of P1 to P5 were obtained from as - built calculation sheet of the penstocks.

(4) Axial stress

$$Sc = Sb + Sf + Sp$$

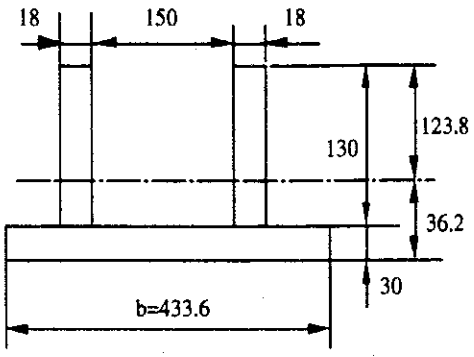
Sb (kgf/cm²)	Sf (kgf/cm²)	Sp (kgf/cm²)	Sc (kgf/cm²)	Material	Allowable stress (kgf/cm²)
165	879	224	1,268	JIS-SM590 class	1,951

The values of the axial stress are within allowable stress.

(V) Calculation of ring girder No.54

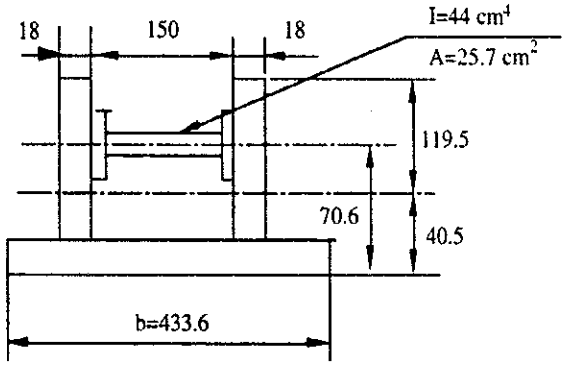
D= 1,650 mm
t = 30 mm
Q = 64.8 ton
P = 65.18 ton
Material JIS-SM 590 class

Table 5.5 Stress Analysis of Ring Girder No.54 (3/3)



except vicinity of 90o

I = 2,959 cm⁴
Zi= 817 cm³
Zo= 239 cm³
A= 176.9 cm²



vicinity of 90o

I = 3,270 cm⁴
Zi= 807 cm³
Zo=273 cm³
A= 202 cm²

(1) Normal condition

B = 0.733
R = 86.12 cm
X = 3.44 cm
N = 239.04 ton

	T	M	T/A	M/Zi	- M/Zo	N/A	Si	So
	ton	t -cm	(kgf/cm²)	(kgf/cm²)	(kgf/cm²)	(kgf/cm²)	(kgf/cm²)	(kgf/cm²)
0	- 0.35	47.65	- 2	58	-	1,352	1,408	-
60	- 9.35	- 57.23	- 54	-	235	1,351	-	1,533
90	16.2	- 55.73	80	-	204	1,180	-	1,464
120	9.53	56.23	54	69	-	1,351	1,474	-
180	0.35	- 47.65	2	-	199	1,351	-	1,553

All stresses are within allowable stress (Sca=1,951 kgf/cm²)

(2) Resulutant stress

Hs = 3.44 ton
Hw = 3.42 ton
S = 63 cm
B = 1.348

	T	M	T/A	- M/Zo	N/A	Si	So	Allowable stress
	ton	t -cm	(kgf/cm²)	(kgf/cm²)	(kgf/cm²)	(kgf/cm²)	(kgf/cm²)	(kgf/cm²)
60	- 1.33	- 51.19	- 8	214	207	1,533	1,739	2,610
270	1.2	- 77.75	6	285	291	1,464	1,755	2,610

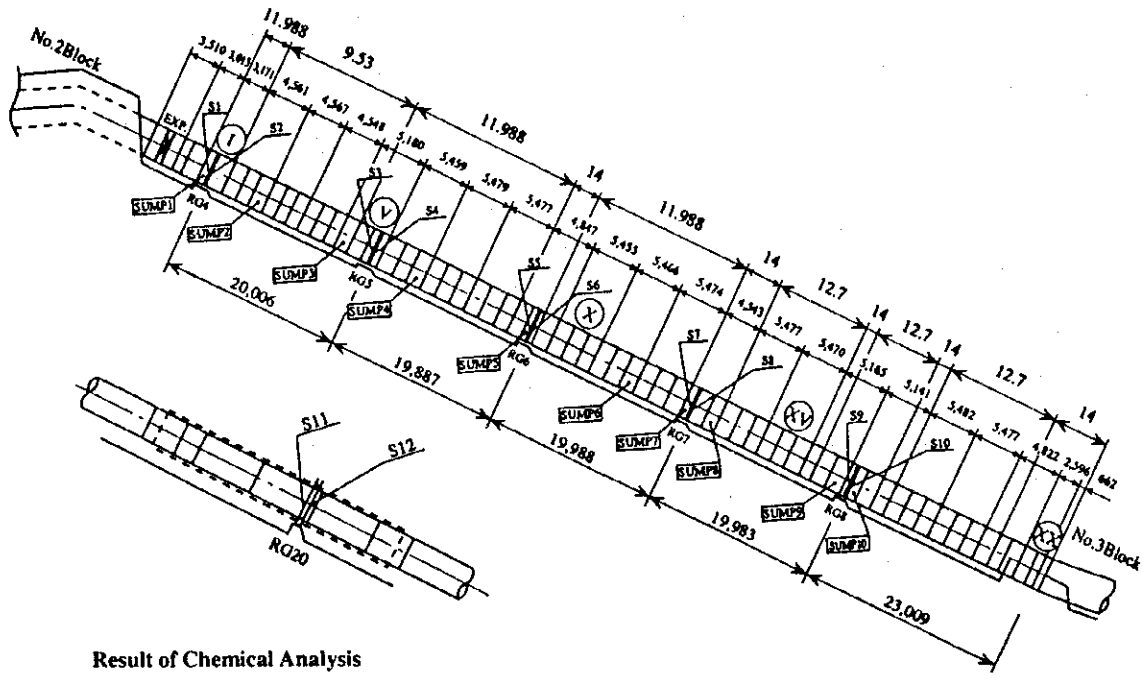
Allowable stress

Sca=0.45 x Ts = 2,610 kgf/cm²

Ts : ultimate tesile strength of inside pip : 5,800 kgf/cm²

All stress are within allowable stress.

Table 5.6 Material Analysis of Penstocks



Result of Chemical Analysis

Unit: wt %

Sample	C	Si	Mn	P	S	Ni	Cr	Mo	V	Equi. C
No.1	0.32	0.03	0.55	0.006	0.022	0.04	0.02	< 0.01	< 0.01	0.42
No.2	0.30	0.04	0.58	0.005	0.022	0.04	0.03	< 0.01	< 0.01	0.41
No.3	0.32	0.04	0.56	0.007	0.022	0.04	0.03	< 0.01	< 0.01	0.42
No.4	0.29	0.04	0.58	0.005	0.023	0.04	0.03	< 0.01	< 0.01	0.40
No.5	0.28	0.04	0.58	0.005	0.023	0.04	0.03	< 0.01	< 0.01	0.39
No.6	0.30	0.04	0.56	0.007	0.022	0.04	0.03	< 0.01	< 0.01	0.40
No.7	0.16	0.07	0.41	0.006	0.033	0.02	0.02	< 0.01	< 0.01	0.24
No.8	0.15	0.07	0.42	0.006	0.033	0.02	0.02	< 0.01	< 0.01	0.23
No.9	0.16	0.07	0.42	0.006	0.033	0.02	0.02	< 0.01	< 0.01	0.24
No.10	0.16	0.07	0.41	0.006	0.033	0.02	0.02	< 0.01	< 0.01	0.24
No.11	0.22	0.02	1.10	0.008	0.027	0.03	0.03	< 0.01	< 0.01	0.41
							Cu	0.08	Nb	< 0.01
No.12	0.21	0.02	1.08	0.007	0.025	0.04	0.02	< 0.01	< 0.01	0.40

Calculation formula of equiv. C

Equiv. C (%)= C+ Mn/6 + Si/24 + Ni/40 + Cr/5 + Mo/4 + V/14

(Judgement)

In view of value of high equiv. C % and microstructure condition obtained from SUMP test, the materials of the above sample are judged as follows:

1. Materials of sample No. 1 to No.6 : JIS - SS 490 class
2. Materials of sample No.7 to No.10 : JIS - SS 400 class
3. Materials of sample No.11 to No.12 : JIS - SS 490 class

Table 5.7 Stress Analysis of Penstocks

The stress analyses are carried out at pipe No. V 20 - 3 which will be functioned with maximum pressure at the portion between anchore block N0.2 ar The method of stress analysis is based on the PC-2 report of " Report of Restoration 1976".

(I) Design data

Pipe No.	:	V20-3
Design head	:	119.84 m
Diameter	:	2,000 mm
Thickness	:	13.88 mm *
Material	:	JIS-SS400 class
Corrosion allowance	:	0 mm

* : Thickness of shell plate was estimated from the result of field investigation.

(II) Estimate of Allowable Stress

$$Sca = Sy \times 0.7 / 1.65$$

Where,
Sca : Allowable stress : 975 kgf/cm²
Sy : Yield stress : 2,300 kgf/cm²

(III) Strength of pipe shell

$$Sc = P \times Do / (2 \times t\,1)$$

Where,
Sc : Circumferential stress : 863 kgf/ cm² < 975 x 0.95 = 926 kgf/cm²
P: Design stress : 11.984 kgf/cm²
Do: Diameter of pipe : 200 cm
t 1 : Thickness : 1.388 cm

Table 5.8 Urgent Rehabilitation Plan On Defects (1/8)

Item No.	Facilities/Equipment	Present defect conditions	Method of Analysis	Results of Analysis	Rehabilitation Works to be required
I	Spillway Radial Gates and Hoists				
1.1	Gate leaves				
(1)	Seal rubbers	Leakage from gate leaf to be induced due to aging and deterioration of seal rubber quality.			Early renewal of seal rubbers to be required.
		Leakage from gate leaf to be induced due to damage of seal rubber.			Early renewal of seal rubbers to be required.
		Serious corrosion of seal clamps.			Early renewal of seal clamps to be required.
(2)	Wire rope hangers	Occurrences of unbalanced wire rope tension of gate leaf due to serious corrosion of hanger shaft.			Early replacement of hanger shaft with unti-corrosive materials to be required.
(3)	Paint of skin plate, main beams and arms	Occurrences of corrosion due to removal of paint material.			Early repainting work to be required.
1.2	Hoists and controls				
(1)	Hoists	Occurrences of aging and deterioration of auxiliary electrical and mechanical parts such as limit switches, oil level gauge of gear reducers, electrical cable/wiring system.			Early replacement of defective electrical and mechanical parts to be required. It is noted that the design of additional provision of electrical parts may be required to be considered after confirmation of the design concepts of a new central control system.
(2)	Control panels and cabling system	Occurrences of aging and deterioration of electrical parts contained in the remote and local panels			It is noted that the additional provision of electrical parts may be required after confirmation of the design concepts of a new central contro; system and that early provision of new control panel to be required.

Table 5.8 Urgent Rehabilitation Plan On Defects (2/8)

Item No.	Facilities/Equipment	Present defect conditions	Method of Analysis	Results of Analysis	Rehabilitation Works to be required
		Occurrences of aging and deterioration of electrical cable / wiring between control panels and hoists			Early renewal of electric cable/wiring system to be required along with the provision of new control cabinet.
2	Spillway Irrigation Outlet				
2.1	Outlet valves	The valve chamber for the outlet valves was completely submerged over thirty (30) years ago and thus no water supply to dam downstream area was possible. The inspection on the valves was impossible. However, according to the present condition of valve chamber, it was appeared that the valve chamber was submerged due to entering rain water into under the blockage of drainage pipes in the chamber.			Early renewal of all irrigation valves to be required after reliable drainage system was provided in the valve chamber. In addition , it is noted that a new valve will be operated by electric motor in view of convenient operation for irrigation valves.
2.2	Water supply pump	Out of two (2) water supply pump units, one pump unit was already out of order and other pump can not satisfy the specified water supply capacity due to the aging of pump unit. Aging of control panel and electrical wiring			Early renewal of two (2) water supply pump with all electric parts and control panel to be required.
2.3	Trash rack panel	Same corrosion degree of trash rack panel as those of the intake fixed trashracks was observed.	Stress analysis of trash rack bars	As a result of the stress calculation of trash rack panel, the stress was within allowable stress. (refer to Table 5.3)	No urgent rehabilitation plan was required at the moment. It is recommended to replace the trash rack panel under the long term rehabilitation plan.

Table 5.8 Urgent Rehabilitation Plan On Defects (3/8)

Item No.	Facilities/Equipment	Present defect conditions	Method of Analysis	Results of Analysis	Rehabilitation Works to be required
3	Intake Fixed Trash Racks				
		Corrosion of trash rack panel was extended seriously. Approx. 3 mm deduction of trash rack bar thickness was measured.	Stress analysis of trash rack bars	As a result of the stress calculation of trash racks, the stress was within allowable stress. (refer to Table 5.3)	No urgent rehabilitation plan was required at the moment. It is recommendable to replace the trash rack panel under the long term rehabilitation plan.
4	Movable Trash Rack				
4.1	Upstream trash rack panels	Deformation of trash rack bars and loosing of distance pieces due to vibration of panels which might be occurred with a high flow velocity of tunnel. Occurrences of corrosion of trash rack bars and frames due to removal of paint	(1) Vibration analysis on the trash rack bars using theoretical method. (2) Stress analysis of trash rack bars (3) Examination of operation procedure of trash rack panels	(1) The occurrences of damage due to vibration are considered. (refer to Table5.4) (2) The stress was within allowable stress. (3) The following operation procedure of movable trash rack is recommended to be established. i) The downstream trash rack be utilized for usual operation. ii) PC-2 is required to establish the operation system for remove the trash at least one (1) time per one (1) day during flood season.	The construction condition of trash rack will be required to modify for withstanding the vibration of trash rack.
4.2	Guide frames	The large concrete breakage (approx. 3.1 m high x 15 cm depth) of secondary concrete was observed at left side of a front guide frame of trash rack panel.			Concrete or other filling materials to be poured by civil work when the reservoir level reached below W.L 1,019 m. The proposed rehabilitation plan shows in clause 6.3.
4.3	Hoist and control				
(1)	Hoist	Occurrences of aging and deterioration of auxiliary electrical and mechanical parts such as limit switches and electrical cable/wiring system			Early replacement of defective electrical and mechanical parts to be required.

Table 5.8 Urgent Rehabilitation Plan On Defects (4/8)

Item No.	Facilities/Equipment	Present defect conditions	Method of Analysis	Results of Analysis	Rehabilitation Works to be required
		Oil leakage from gear reducer			Early renewal of gear reducer
(2)	Control panel and cabling system	Occurrences of aging and deterioration of electrical parts contained in the local panel			Early renewal of control panel to be required.
		Occurrences of aging and deterioration of electrical cable / wiring between control panels and hoists.			Along with the provision of new control cabinet, early renewal of electric cable/wiring system to be required.
5	Intake Caterpillar Gate and Hoist				
5.1	Gate leaf				
(1)	Seal rubbers	Leakage from gate leaf to be induced due to aging and deterioration of seal rubber quality.			Early renewal of seal rubbers to be required.
		Leakage from gate leaf to be induced due to damage of seal rubber.			Early renewal of seal rubbers to be required.
(2)	Paint of skin plate and main beam	Occurrences of corrosion due to removal paint.			Early repainting work to be required.
5.2	Hoist				
(1)	Hoist	Occurrences of aging and deterioration of auxiliary electric and mechanical parts such as limit switches and electric cable/wiring system.			Early replacement of defective electrical and mechanical parts to be required. Early repainting works to be required. It is noted that the procurement of paint material and painting work will be carried out by PC-2.

Table 5.8 Urgent Rehabilitation Plan On Defects (5/8)

Item No.	Facilities/Equipment	Present defect conditions	Method of Analysis	Results of Analysis	Rehabilitation Works to be required
(2)	Control panels and cabling system	Occurrences of aging and deterioration of electrical parts contained in the local panel.			After confirmation of the design concepts of a new central control system, the design of additional provision of electrical parts is required and that early provision of new control panel to be required.
		Occurrences of aging and deterioration of electric cable / wiring between control panels and hoist.			Along with the provision of new control cabinet, early renewal of electric cable/wiring system to be required.
6	Surge Tank Drain Facilities				
6.1	Drain facilities	Minor corrosion on the outer surface of facilities.			Early repainting works to be required. It is noted that the procurement of paint material and painting work will be carried out by PC-2.
7	Butterfly Valves				
7.1	Butterfly valves	Aging of seat rubbers			Early renewal of seal rubbers to be required.
		Minor leakage(approx. 4.5 l/min) from No.2 valve			Early renewal of seal rubbers to be required.
		Paint damage and corrosion on the outer surface of valve			Early repainting works to be required. It is noted that the procurement of paint material and painting work will be carried out by PC-2.
		The difficulty of smooth operation of valve closure by the counter - weight due to increased friction load of seal rubber.			Checking by a specialist when the seat rubbers are replaced.
7.2	Auxiliary facilities (air valves, bypass pipes and valves)	Aging of seat rubbers			Early renewal of seal rubbers to be required.
		Aging of over velocity tripping devices			Early renewal of over velocity tripping devices to be required.

Table 5.8 Urgent Rehabilitation Plan On Defects (6/8)

Item No.	Facilities/Equipment	Present defect conditions	Method of Analysis	Results of Analysis	Rehabilitation Works to be required
		Damage of pressure gauge and its transmitter			The rehabilitation plan is discussed in Chapter 8.
	7.3 Control panel and cabling system				
		Aging of hydraulic oil unit			Early renewal of hydraulic oil unit with piping system to be required.
		Occurrences of aging and deterioration of auxiliary electrical and mechanical parts such as limit switches electrical cable/wiring system			Early replacement of defective electrical and mechanical parts to be required.
		Occurrences of aging and deterioration of electrical parts contained in the control panel.			Early renewal of control panel to be required.
		Occurrences of aging and deterioration of electrical cable / wiring between control panels and hydraulic oil unit			Along with the provision of new control cabinet, early renewal of electric cable/wiring system to be required.
8	Penstocks				
	8.1 Penstock at upstream of butterfly valves	The corrosion on the exposed outer surface was observed due to removal of paint material.			Early painting works to be required.
	8.2 Penstock rope haulage	10 ton capacity rope haulage which has been provided originally, is impossible to utilize for the maintenance of the penstock due to the destuction of the penstock in 1967.			Early provision of penstock rope haulage equipment for the portion between the valve house and BL.No.8.

Table 5.8 Urgent Rehabilitation Plan On Defects (7/8)

Item No.	Facilities/Equipment	Present defect conditions	Method of Analysis	Results of Analysis	Rehabilitation Works to be required
8.3	No.1 penstock				
(1)	Painting condition	As a result of the various inspections, it was considered that the penstock line is maintained in a good condition.			No repainting works to be required.
(2)	Ring girders	Due to the fallen stones from side slope wall of penstock trench, ring girder No. 28 of penstock No.1 line was damaged.			Early repairing works of damaged ring girders to be required. Early wall slop protection to be required by civil works. The proposed rehabilitation plan shows in Clause 6.3.
(3)	Expansion joints	Aging of seal rubber and sealing material of expansion joints			Early renewal seal rubbers and sealing materials of all the expansion joints with high quality materials to be required.
(4)	Manholes	Aging of gaskets of manholes			Early provision of high quality gaskets of 32 sheets for the manholes.
8.4	No.2 penstock				
(1)	Paint condition	It was confirmed through the visual inspections that the repaint of the inner surface is required to carry out urgently, the many corrosions are observed compared with penstock No.1 line.			Early repainting works to be required. It is noted that the procurement of paint material and painting work will be carried out by PC-2.
(2)	Ring girders	Due to the fallen stones from side slop wall of penstock trench, ring girder Nos. 40 and 54 of penstock No.2 line were damaged. As a results of dye penetration inspection, ring girder No. 54 is required to rectify urgently as the ring girder was damaged seriously on the fillet welding line of girder.	Stress analysis of ring girder No.54	Max. stress of the ring girder No.54 was 1,755 kgf/cm2 and was less than 2,610 kgf/cm2 of the allowable stress. (refer to Table II-5.5)	Early repairing of damaged ring girders to be required. It is noted that the repairing methods of ring girder No.54 are recommended to be carried out in accordance with Table 5.10. Early wall slop protection to be required by civil works.

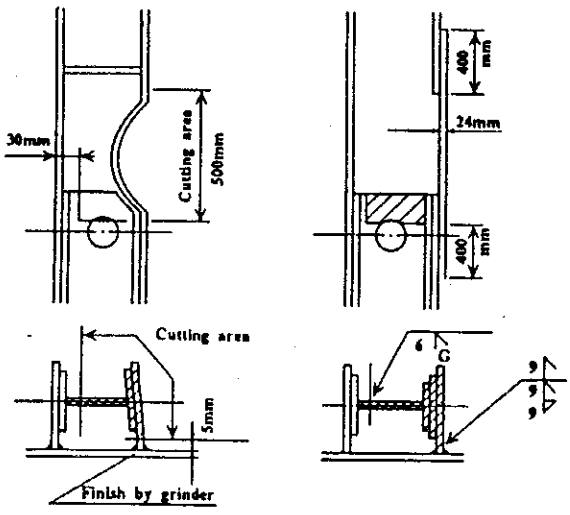
Table 5.8 Urgent Rehabilitation Plan On Defects (8/8)

Item No.	Facilities/Equipment	Present defect conditions	Method of Analysis	Results of Analysis	Rehabilitation Works to be required
(3)	Expansion joints	Aging of seal rubber and sealing material of expansion joints			Early renewal seal rubbers and sealing materials of all the expansion joints with high quality materials to be required.
(4)	Manholes	Aging of gaskets of manholes			Early provision of high quality gaskets of 32 sheets for the manholes.
(5)	Penstock repaired by Viet Nam	The safety of penstock portion repaired by Viet Nam was discussed on the basis of the detailed analysis of material and stress analysis of penstock.	(1) Clarification of material (2) Study of safety of penstock	(1) As a result of the material test, it was confirmed that the materials of the penstock between BL. No.2 and BL.No.3 were equivalent to JIS - SS 400 and SS 490. (refer to Table II-5.6) (2) Max. stress of the penstock 863 kgf/cm2 and was less than 926 kgf/cm2 of the allowable stress. (refer to Table II-5.7)	No urgent rehabilitation plan is required at the moment. It is recommended that the replacement of penstock be made under the long term rehabilitation plan, subject to the performance of the periodical check of penstock.
9	Others				
9.1	Spare parts and tools	No stock of spare parts Minor pare parts are mainly procured in Viet Nam. Minor maintenance tools are stocked by PC-2.			Early procurement of high quality spare parts to be required. The recommendable spare parts and testing equipment to be worked out by the Study Team.
9.2	Testing equipment	Insufficient provision of testing equipment			

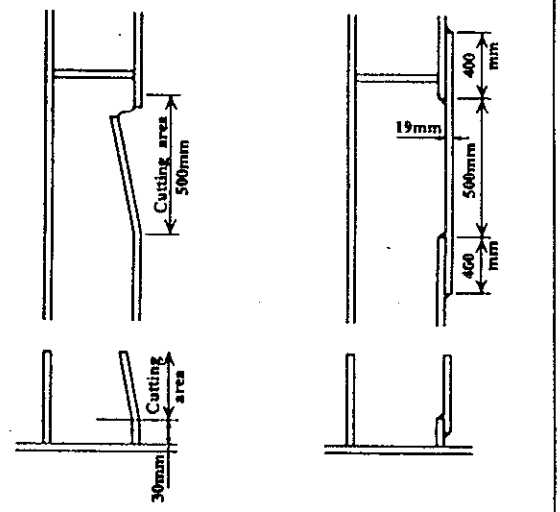
Table 5.9 Recommendable Paint Procedure of Facilities

Item No.	Facilitiy Name	Application surfaces	Process	Paint Procedure
1	Spillway radial gates	Skin plate	Surface preparation	Power tool or sweep blasting up to Grade SA 3.0 of Swedish standard SIS 05 59 00
			Primer coat	Zinc rich primer : more than 15 μ
			First coat	Tar epoxy resin paint : more than 100 μ
			Second coat	Tar epoxy resin paint : more than 100 μ
			Third coat	Tar epoxy resin paint : more than 100 μ
			Finish coat	Tar epoxy resin paint for finish coat : 40 μ x 2 times
				Total paint thickness : more than 395 μ
		Downstream side of leaf	Surface preparation	Power tool or sweep blasting up to Grade SA 3.0 of Swedish standard SIS 05 59 00
			Primer coat	Wash primer : more than 15 μ
			First coat	Red-lead paint , Class 1 : 35 μ x 1 time
			Second coat	Red-lead paint , Class 2 : 35 μ x 1 time
			Third coat	Phthalic resin paint : 25 μ x 2 time
				Total paint thickness : more than 120 μ
2	Movable trash rack	Trash rack	Surface preparation	Sand blasting up to Grade SA 2 of Swedish standard SIS 05 59 00
			Primer coat	Zinc rich primer : more than 15 μ
			First coat	Tar epoxy resin paint : more than 100 μ
			Second coat	Tar epoxy resin paint : more than 100 μ
			Third coat	Tar epoxy resin paint : more than 100 μ
			Finish coat	Tar epoxy resin paint for finish coat : 40 μ x 2 times
				Total paint thickness : more than 395 μ
3	Intake caterpillar gate	Gate leaf (except for caterpillar roller parts)	Surface preparation	Power tool or sweep blasting up to Grade SA 3.0 of Swedish standard SIS 05 59 00
			Primer coat	Zinc rich primer : more than 15 μ
			First coat	Tar epoxy resin paint : more than 100 μ
			Second coat	Tar epoxy resin paint : more than 100 μ
			Third coat	Tar epoxy resin paint : more than 100 μ
			Finish coat	Tar epoxy resin paint for finish coat : 40 μ x 2 times
				Total paint thickness : more than 395 μ
4	No.2 penstock, Penstock at upstream of butterfly valves and surge tank drain facilities	Internal surface	Surface preparation	Power tool or sweep blasting up to Grade SA 3.0 of Swedish standard SIS 05 59 00
			Primer coat	Zinc rich primer : more than 15 μ
			First coat	Tar epoxy resin paint : more than 100 μ
			Second coat	Tar epoxy resin paint : more than 100 μ
			Third coat	Tar epoxy resin paint : more than 100 μ
			Finish coat	Tar epoxy resin paint for finish coat : 40 μ x 2 times
				Total paint thickness : more than 395 μ
		Outer surface	Surface preparation	Power tool or sweep blasting up to Grade SA 3.0 of Swedish standard SIS 05 59 00
			Primer coat	Wash primer : more than 15 μ
			First coat	Red-lead paint , Class 1 : 35 μ x 1 time
			Second coat	Red-lead paint , Class 2 : 35 μ x 1 time
			Third coat	Aluminum paint : 10 μ x 1 time
		Repairing paint for damaged ring girders	Surface preparation	Power tool or sweep blasting up to Grade SA 3.0 of Swedish standard SIS 05 59 00
			Finish coat	Epoxy resin paint x 6 times : more than 400 μ
		External surface of penstock at upstream of butterfly valves and surge tank drain facilities	Surface preparation	Power tool or sweep blasting up to Grade SA 3.0 of Swedish standard SIS 05 59 00
			Primer coat	Zinc rich primer : more than 15 μ
			First coat	Tar epoxy resin paint : more than 100 μ
			Second coat	Tar epoxy resin paint : more than 100 μ
			Third coat	Tar epoxy resin paint : more than 100 μ
			Finish coat	Tar epoxy resin paint for finish coat : 40 μ x 2 times
				Total paint thickness : more than 395 μ

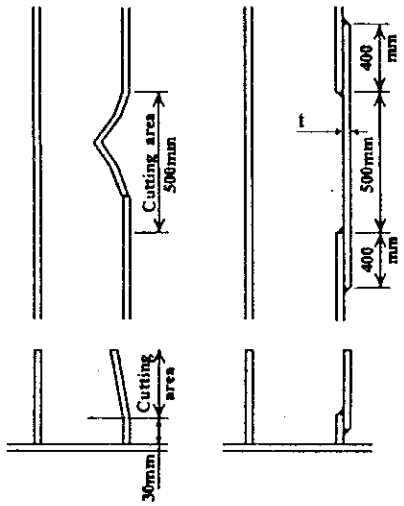
Table 5.10 Repair of Ring Girder



Ring Girder No.54 of No.2 Line



Ring Girder No.28 of No.1 Line



Other Ring Girder

Number of other ring girder

No.1 Line: Nos. 7, 8, 17, 19, 20, 24, 31, 33, 35, 48 & 55

No.2 Line: Nos. 6, 7, 8, 9 x 2, 18 x 2, 19 x 2, 20, 21, 25, 26, 28, 30, 31, 32, 33, 35, 40, 44, 45, 52, 57, 93 & 99

Thickness of plate :

Thickness of 19 mm (t=19 mm) shall be applied to the ring girder positioned above ring girder No.41.

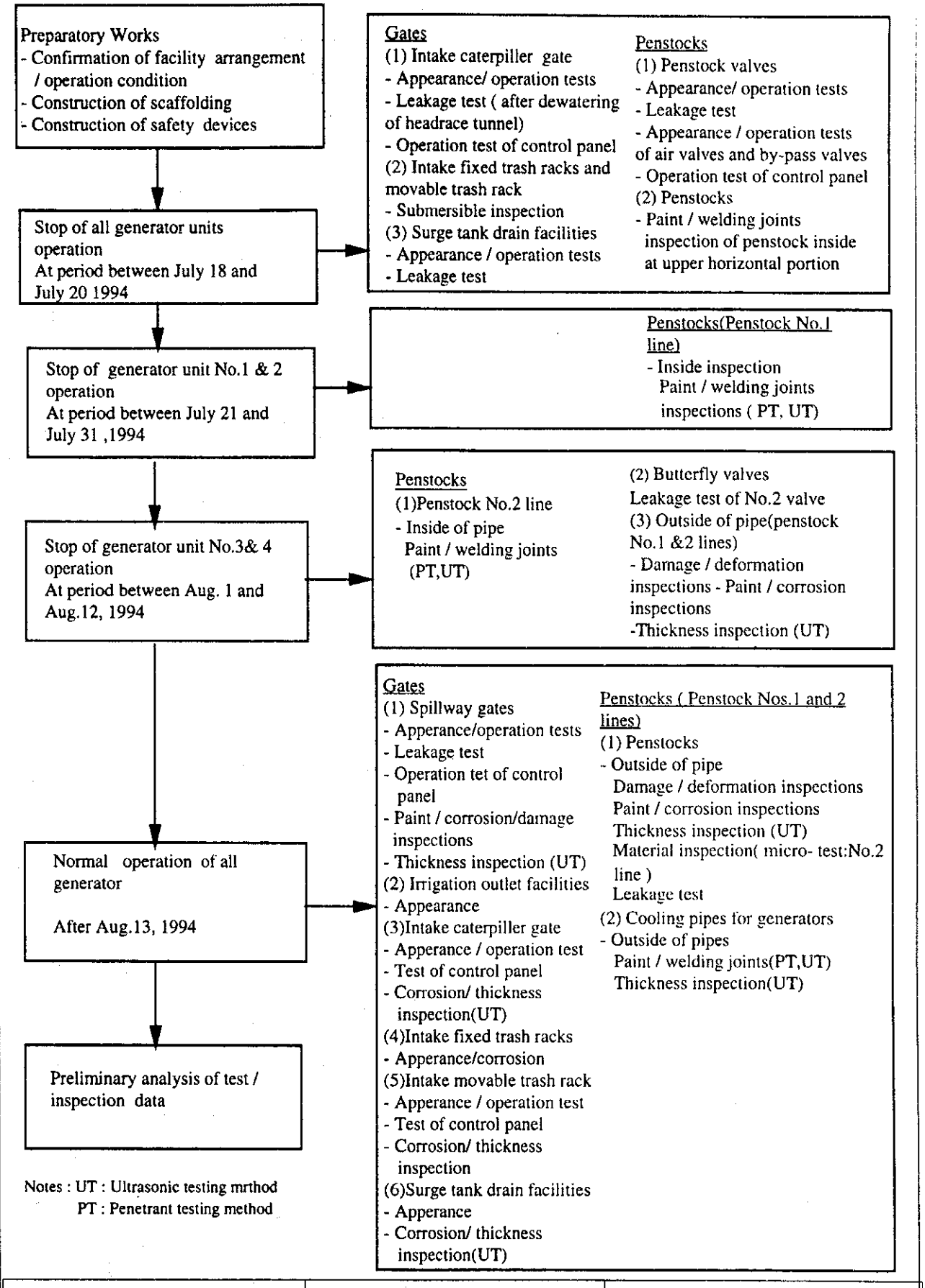
Thickness of 24 mm (t=24 mm) shall be applied to the ring girder positioned below ring girder No.41.

Standard welding procedure

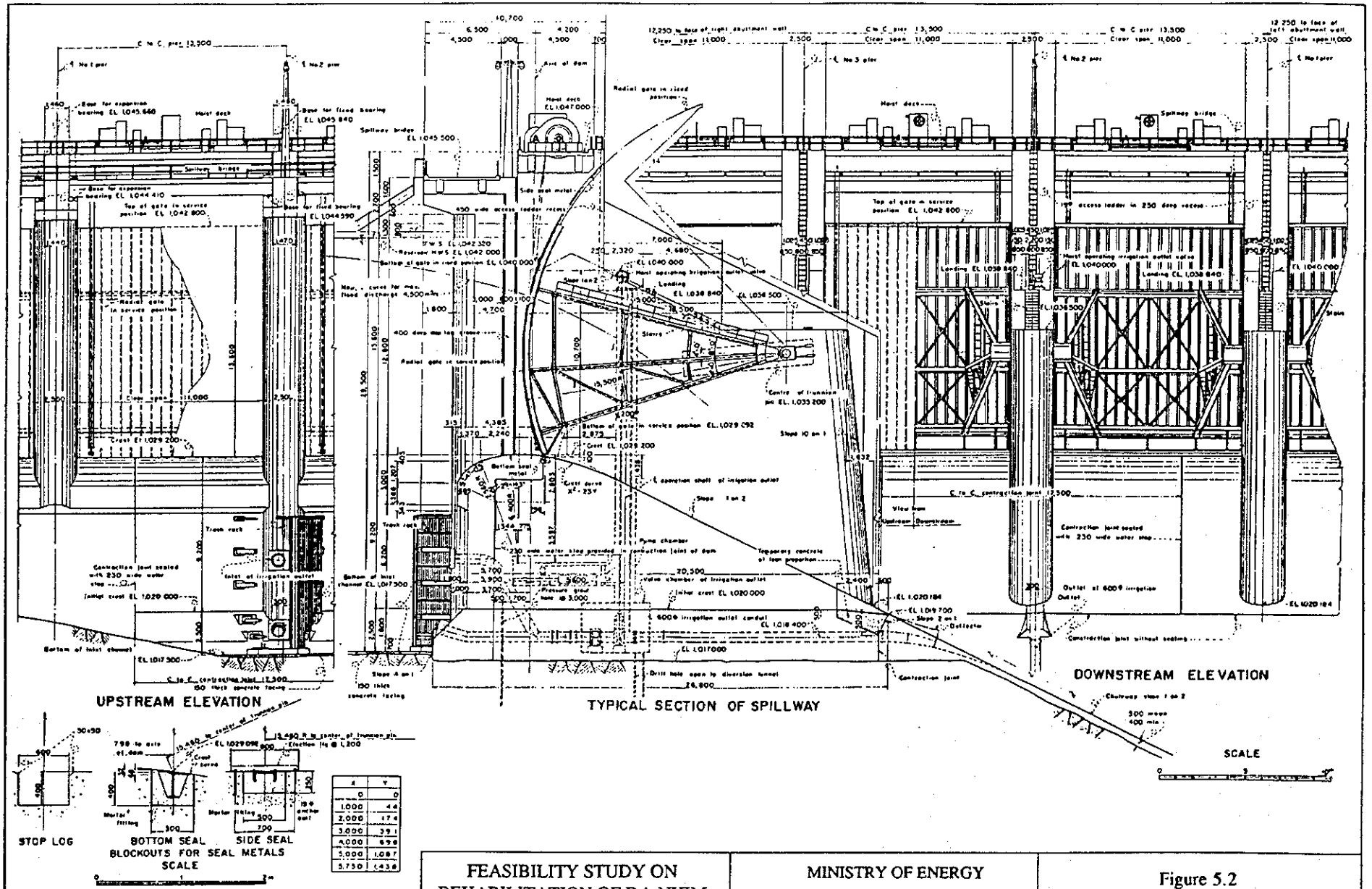
Ring girder No. (Material)	Electrode			Currennt (A)	Voltage (V)	Speed (cm/min)	Welding process	Heat Input (kJ/cm)
	Standard	Type of rode	Dia. (mm)					
JIS SM400 class	D5826	Low hydrogen	3.2&4.0	100 - 250	Less than 28	4 - 25	Manual	-
JIS SM490 class	D5016	Low hydrogen	3.2 & 4.0	100 - 250	Less than 28	4 - 25	Manual	Less than 80
JIS SM590 class	D5816	Low hydrogen	3.2 & 4.0	100 - 250	Less than 28	4 - 25	Manual	Less than 60

Table 5.11 Recommendable Spare Parts and Testing Equipment

Description	Quantity
1. Thickness inspetion of pipe shell	
Ultrasonic test equipment	2 sets
2. Paint inspection	
Pinhole detector	2 sets
Magnetic thickness meter	
3. Vibration inspection of pipe shell	
Sound level meter	1 set
Vibrometer	1 set
4. Inspection of hoist	
Thermometer (0 - 200 °C)	10 sets
Ampere - volt meter	4 sets
Insulation tester (500 V, 1000 meg. ohm)	2 sets
5. Gaskets of penstock manhole	
Gaskets for No.1 penstock (each 2 sets)	64 sheets
Gaskets for No.2 penstock (each 2 sets)	64 sheets
6. Communication system at site	
Transceiver	3 sets



FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 5.1 General Work Flow for Field Investigation



FEASIBILITY STUDY ON REHABILITATION OF DA NHIM POWER SYSTEM	MINISTRY OF ENERGY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 5.2 Spillway Gates and Hoists