APPENDIX B
MAINTENANCE AND INSPECTION MANUAL FOR HYDROMECHANICAL EQUIPMENT

APPENDIX B-1
MAINTENANCE OF HYDROMECHANICAL WORKS

1. MAINTENANCE OF STEEL PENSTOCK

(1) Prevention of Leakage

A leak from a riveted joint, bolt, packing or any other portions of the penstock shall immediately be repaired.

(2) Maintenance of Expansion Joint

An expansion joint shall always be well maintained so that a steel penstock can smoothly be expanded and contracted.

It is desirable to make an inspection at least once a year to check the actual condition of each joint concerning leakage, tightening conditions, etc., so that a steel penstock can smoothly be expanded and contracted.

The packing is generally replaced at intervals of 5 to 10 years depending on the material, shape etc. of the packing. They are at times replaced at longer intervals of 20 to 25 years, for an example on record.

(3) Maintenance of Air Pipes and Air Valves

Prior to draining the water inside the steel penstock, the functions of the air pipes and air valves shall be checked and the water should not be drained unless the functions are perfect.

A malfunction of the air pipes and air valves during draining may lead to backing up of the steel penstock, therefore, the water discharge should not be done without ensuring the perfect operation of these parts. When checking these parts and. discharging the water, the following should be noted:

1) Special attention shall be paid when inspecting and cleaning the inside of the air pipe. A thorough understanding of its operation is required to check that the air valve work properly.

2) In winter, special attention should be paid and the air valves should be checked for freezing, when draining a steel penstock that has not been in operation for a considerable period with water in it.

3) When draining, the drain valve should be gradually opened only after the normal function of the air pipe or air valve is confirmed through a trial draining using the drain valve installed at the bottom of the lower portion of the steel penstock..

4) Even if the soundness of the air pipe or air valve is ensured, a pressure regulator should never be used for discharging the water.

(4) Maintenance of Movable Part of Support

The movable part of the support shall always be well maintained so that a steel penstock can move smoothly .

(5) Prevention of Vibration

When a steel penstock vibrates excessively during the operation of the power station, this may affect the operation and some measures to decrease the vibration must be taken.

Vibration of a steel penstock consists of a bending vibration of the pipe wall, and a transverse vibration as a beam. When a momentary pressure vibration takes place at a turbine and a draft tube, and its frequency coincides with the characteristic frequency of the steel penstock, resonance occurs resulting in a noticeable vibration.

When the flatness of a pipe section fully filled with water is excessive, a noticeable section vibration takes place corresponding to the pressure oscillation. With the excessive vibration of a steel penstock, fatigue and stress corrosion etc. are likely to take place, and thus reduction of the vibration is required.

In order to take measures to prevent vibration, first of all, it is necessary to examine what sort of vibration is occurring in the steel penstock, and to study the relation between the cause of the pressure change and the steel penstock as a source of vibration. The causes of the pressure change are as follows:

1) Rotating speed of the turbine
2) Number of vanes of the runner
3) Water vortex in the draft tube.

In order to prevent the vibration, the best way is to e1iminate the pressure fluctuation as a source of vibration by supplying air into the draft tube. But this is a difficult method. Therefore, if resonance is a main cause, it is better to change the characteristic frequency of the steel penstock by increasing the stiffeners, or by increasing the anchor block and by other means. If section occurs variation in an oval pipe, section rigidity should be increased by providing or increasing the number of stiffeners.

To attach stiffeners to an existing pipe, it is sufficient to tighten with bolts stiffeners having the appropriate cross section .

(6) Consideration of Water Quality after Completion of the Penstock

When the pH value of the water inside the pipe has decreased to less than four after completion of a steel penstock because of the diversion of water, changes in water quality at source, or for other reasons , some measures to decrease corrosion shall be provided.

Some corrosion preventive measures should be taken if the pH of the water inside the pipe falls below four due to changes in water quality due to the intake of water from a river with low pH, volcanic activity around the water source area, or for other reasons.

(7) Check of Pipe Interior

Water inside the pipe of a steel penstock shall be drained as required, and a check necessary for the maintenance of the steel penstock shall be carried out.

(8) Measurement of Shell Thickness

The shell thickness of a steel penstock decreases over the years, therefore it shall be measured as required.

If shell thickness of a steel penstock gradually decreases due to corrosion and wear, and the decrease exceeds the corrosion allowance, the thickness cannot meet the designed condition and thus the penstock will be subjected to critical conditions. Therefore, the safety of the penstock should be secured or the modification of critical portions shall be implemented.

There are various methods to measure the shell thickness of a steel penstock, and those commonly used today are:

1) by an ultrasonic shell thickness measurement device
2) by modeling
3) by drill boring
4) by cutting off a test piece

1) For method 1), two techniques are available, i.e. reflection and resonance; reflection has become more popular in recent years. In either technique, no de-watering from the whole pipeline is required and the operation of the device is easy, but sampling measurements can cause some problems by overlooking local corrosion, and the measurement of the portion where a wavy corrosion is generated may become inaccurate.

   When using measuring devices, it is necessary to calibrate them using a plate with the same thickness as the object to be measured.

2) As for method 2), plaster, resin-molding material, etc. are used to make the model concerned.

3) Method 3) and 4) are the most accurate, but a comprehensive study is required for the base metal materials and residual stress, to repair the portions where a boring was made or a test piece was taken out.

   As for method 4), the piece cut off from the pipe itself is measured, and seldom the pipe is cut only for the thickness measurement. In many cases, the piece cut off for material test is used for this purpose.

   Usually, the shell thickness is measured as a primary check with an ultrasonic plate thickness measurement device, which requires no de-watering and is executed easily, and then the portion of interest is examined by boring or sampling as a detailed check..

(9) Repair or Replacement

Immediate repair or replacement shall be made if the decrease in shell thickness, deterioration of material, decrease in joint efficiency, etc. of a steel penstock are recognized as excessive.

It has been reported that the amount of annual corrosion is approximately 0.02 mm/year. This report is based on the results of measurements of shell thickness of steel penstocks at 47 places by the gravimetric method. The measured penstocks were constructed between 1910 and 1953, and were not constructed in places having highly acid water and much flowing sand.

As for the above penstocks that were investigated, there are some differences and uncertainties in the circumstances, materials, coatings and repair histories. These figures cannot be directly applied to the present penstocks from the point of view of the recent improvement in quality of materials, qualities and methods of coating, but can be of possible reference as to the amount of corrosion.

In order to establish preventive maintenance, the defective portions of a steel penstock as stated below should immediately be repaired or replaced:

1) As a result of measurement of the shell thickness, an excessive decrease in thickness due to corrosion or wear is recognized.

2) As a result of a material test of a cut-off test piece, it is shown that the elongation is below the specification of steel material and the impact value is especially low.

3) As a result of a tension test of a cut-off-piece, it is recognized that a joint (by forging, riveting or welding) efficiency is very low because of the decrease of the shell thickness, deterioration of materials and other reasons.

It is recommended to implement repair or replacement in the event of an excessive decrease in shell thickness based on the following:

1) When the maximum stress at a local area of the pipe shell or the average stress of a pipe shell (circumferential tensile stress by internal pressure) exceeds 90% or 65%, respectively, of the yield strength of the material used and thus a probable fracture is recognized.

2) The above maximum stress is calculated from the following formula which determines the maximum tensile stress concentrated around the edge of a concave portion when tension acts on a steel plate having a cylindrical concave portion, or from a formula having the same or higher precision: :

$$\sigma_{max} = \overline{\sigma} \times \frac{3}{1 + 2d} d \qquad d = \frac{t'}{t}$$

Where σ_{max} : Maximum stress at the edge of concave portion

σ : Mean stress with no concave portion

t' : Minimum shell thickness of concave portion

t : Mean shell thickness of a steel plate

(10) Recoating

When the coat on a steel penstock peels, immediate recoating shall be required.

2. MAINTENANCE OF HYDRAULIC GATES

(1) Maintenance, Inspection and Control

Maintenance, inspection and control for a hydraulic gate shall be conducted properly to well maintain each function.

The hydraulic gate should be inspected regularly and the functions of the gate should be appropriately maintained to prevent accidents . The historical records, specifications, design drawings, test records, and operation manuals for the hydraulic gate should be kept as well as the inspection records, operating records and repair records, etc.

The interval of the regular inspection should be set in the control standard taking into account the use conditions, functions, and importance of the gate.

After flooding, the gate leaf, gate guide, and auxiliary facilities should be inspected temporarily and immediately.

(2) Leak Prevention

In case of excessive water leakage from the seals, the seals should be immediately replaced or repaired. If the leakage increases due to deteriorated or damaged rubber seals, they should be replaced with new ones.

In addition, if a leak occurs at the intersection point between a bottom guide and an expansion joint for a dam, it should be stopped by the injection of asphalt or other fillers.

(3) Freeze Prevention

A hydraulic gate requiring operation during the winter season shall be maintained so as to avoid problems due to freezing.

For a hydraulic gate which may be required to operate even in cold season, the gate leaf, guide and hoist should be prevented from freezing, thus making the gate always operable.

(4) Maintenance of Support

Gate supports shall always be well maintained so as to operate smoothly.

Because the support for a gate leaf is a point where the hydraulic pressure working on the leaf is concentrated, all the supports should be in completely good conditions so that they operate smoothly under hydraulic pressure. In other words, the main wheel pins of a fixed wheel gate and trunnion pins of a radial gate should always be filled with appropriate lubrication. In particular, the wheel pins of a fixed wheel gate are numerous and the foothold for maintenance is generally poor, thus leading to insufficient maintenance.

The hinged supports of a hydraulic gate are generally subject to large water pressure and revolve at a low speed, and so extreme care should be taken to ensure that the lubrication is always applied throughout the entire surface. With insufficient lubrication, bearings are likely seize, and the wheel pin tends to rotate with the wheels, thus leading to problems in operating the gate leaf.

(5) Maintenance of Gate Hoist

A gate hoist shall always be well maintained so as to secure the operation of the gate leaf.
A gate hoist should be in maintained condition so that the gate leaf is operable at any time.

Attention should be paid during the inspection of lubrication points to the presence of rust and of slackness in the tightened bolts at each part of the gate hoist, to temperature increases in the bearings, to the limit switches and brakes, as well as to greasing the wire ropes. Tree leaves or wood chips at the rubber seals and rollers should be cleaned up before operation.

(6) Maintenance of Auxiliary Power

Auxiliary power equipment shall always be well maintained so as to afford rapid and secure operation.

Engines for the auxiliary power equipment should always be under good maintenance conditions so as to start at any time, and the operator is required to master how to start them. For the starting measures, batteries, compressed air, manpower, etc. are available. If batteries are used, they should be kept well charged and warm to ensure starting even in extremely cold weather. If compressed air is used, it should be kept at the required pressure.

(7) Repair and Replacement

Repair or replacement shall be made soon after there is fear of malfunction of a hydraulic gate due to decrease in material thickness, deterioration and corrosion of materials, etc. A hydraulic gate should be repaired or replaced based on the following:

1) When there is fear that the stress of each member exceeds the allowable stress for each material used, thus leading to a breakdown.

2) When the gate is estimated to be in danger because of structural instability due to vibrations.

3) When there is some trouble in operating the gate because of a deterioration in performance.

Attention should be paid to the deterioration of the hydraulic operating fluids, to the presence of foreign matter, to the volume of oil, and to the oil hydraulic device, if installed. If oil pressure drops or increases, the filter should be replaced or the oil should be replenished.

A wire rope should be replaced when more than 10% a of the strands re broken or when the diameter of the wire rope decrease by more than 7% of the nominal diameter.

(8) Maintenance Gate

A stop-log or floating gate shall be provided for the purpose of repairing the hydraulic gates, etc. This shall not be applicable if the gate leaf, etc., can be repaired without the maintenance gate.

A stop-log or floating gate is generally provided upstream of the hydraulic gate and is temporarily used as a substitute for the gate during repairs without lowering the water level in a reservoir.

However, the above device can be omitted if the water level in the reservoir can easily be lowered below the gate sill. Careful attention should be paid to storing or mooring of the above stop-log or floating gate.

(9) Recoating

Recoating shall be carried out immediately when the coating of the hydraulic gate deteriorates or becomes damaged.

The hydraulic gate should be recoated at certain intervals. The paints used previously should be carefully studied and checked, and the same or similar ones should be used again for recoating.

(10) Hoist Room

A hoist room shall be provided for the hydraulic gate, as appropriate. It is desirable to provide a hoist for the gate, to allow operating the gate without failure even when it is heavy rain.

(11) Access Bridge and Access Facilities

An access bridge and other appropriate access facilities shall be provided for the hydraulic gate, as appropriate.

An access bridge, stairway, etc., should be provided for the hydraulic gate to facilitate the necessary inspections for maintaining each function.

APPENDIX B-2
INSPECTION MANUAL
FOR HYDROMECHANICAL WORKS

1. INSPECTION

(1) Patrol

Patrol means going around an area or a building to check clearances between other structures, external conditions of equipment and indicators of equipment by visual inspection etc.

(2) Inspection

1) Visual Inspection

Visual inspection means the regular inspection and maintenance such as checking for abnormalities in structure or function, in order to determine the condition of the structure.

2) Internal Inspection

Internal inspection means the regular inspection and maintenance inside the waterway such as checking for abnormalities or incorrect function during the dewatering period, in order to determine the condition of the interior of the waterway.

3) Emergency Inspection

Emergency inspection means the immediate inspection and maintenance after an earthquake, flood, heavy rainfall, and when necessary.

4) Emergency Detailed Inspection

Emergency detailed inspection means the inspection and maintenance when further detailed inspection is required in addition to the patrol, regular inspection, and emergency inspection.

5) Operating Inspection

Operating inspection means the inspection and maintenance at the time the facility is operating.

2. CONTROL OPERATION

Control operation is to be carried out at the time of the regular inspection of the gate and valves, and the closing and opening movement should be confirmed.

(1) Spillway Gate

In the case of a gate without discharge experience during flooding , a control operation should be carried out during a non-flood period, in principle.

(2) Intake Gate, Tailrace Gate, Draft Gate

In the case of equipment which has not being operated for a long time (more than three years), a control operation should be carried out in principle.

(3) Outlet Works

In the case of equipment which has not being operated for a long time (more than five years), a control operation should be carried out in principle.

3. FREQUENCY OF PATROL AND INSPECTION

Table Frequency of Patrol and Inspection

Inspection Frequency / Equipment	Patrol	Visual Inspection		Internal Inspection	Emergency Inspection	Emergency Detailed Inspection	Operating Inspection Control Inspection
	Once/month A	Twice/year B	Once/year C	Once/3 years D	When necessary E	When necessary F	At operation G
Gate, valve	○	○	○	○	○	○	○
Penstock	○		○	○	○	○	
Trashrack	○	○	○	○	○	○	
Raking Machine	○	○	○		○	○	○
Auxiliary Power	○	○	○		○	○	○
Pump	○		○		○	○	○
Floating Net	○		○		○	○	
Bridge	○		○		○	○	

4. CHECK SHEET

The check sheets for the inspection of the steel penstock and spillway radial gate are attached as a reference.

Penstock

Penstock (outside) Inspection Item

Classification	Inspection portion	Kind of inspection, frequency	Inspection item	Inspection method	Inspection point and criterion for judgment	Note
outside	(pressure lining) general		cleaning condition	visual	Confirming there are not a lot of sand, rubbish and dirty mark inside the pipe section.	
	pressure lining		damage	visual	Confirming there is no dirty mark, cracks, scratch, subsidence, displacement and deformation by visual inspection.	
			deformation	visual.measurement	Confirming there is no deformation (dimple) by visual inspection. When recognizing some deformations, measurement of the deformations using scale should be done.	
			corrosion	visual.measurement	Confirming there is no corrosion by visual inspection.	
			leakage	visual	Confirming there is no leakage.	
			vibration	visual	Confirming there is no vibration.	
			unusual sound	acoustic	Confirming there is no unusual sound.	
			decrease of thickness	visual.measurement	Confirming there is no remarkable rust and wear. Decrease of thickness can be allowed within the permitted range or less.	
			sink・movement	visual.measurement	Confirming there is no sink and movement by visual inspection.	
	welding section		crack	visual	Not only visual inspection but also the Penetrate Test, the magnetic particle examination, and the ultra sonic test are to be executed. Evaluation criteria is shown in attached paper.	
			damage	visual	Confirming there is no rust, dirty mark and crack by visual inspection.	
			deformation	visual.measurement	Confirming there in no deformation. When recognizing some deformations, measurement of the deformations using scale should be done. Evaluation criteria is shown in attached paper.	
			leakage	visual	Confirming there is no leakage.	
	rivet		falling off	visual	Confirming there is no falling off.	
			looseness	visual・test hammer	Confirming there is no looseness using test hammer and visual inspection.	
			damage	visual	Confirming there is no rust, dirty mark and crack by visual inspection.	
			abrasion	visual	Confirming there is no remarkable rust and wear.	
			leakage	visual	Confirming there is no leakage.	

Penstock

Penstock (outside) Inspection Item

Classification	Inspection portion	Kind of inspection, frequency	Inspection item	Inspection method	Inspection point and criterion for judgment	Note
outside	(supporting portion) general		cleaning condition	visual	Confirming there is no remarkable dirty mark, rubbish around support structure such as fixed section, support and ring girder.	
	fixed portion		damage	visual	Confirming there is no rust and dirt mark by visual inspection.	
			deformation	visual.measurement	Confirming there is no deformation (dimple) by visual inspection. When recognizing some deformations, measurement of the deformations.	
			deterioration of concrete	visual	Confirming there is no deterioration such as crack and flaking off by visual inspection.	
			sink • movement	visual.measurement	Confirming there is no remarkable sink and movement by visual inspection.	
	ring support		damage	visual	Confirming there is no damage such as remarkable rust and dirty mark by visual inspection.	
			deformation	visual.measurement	Confirming there is no deformation (dimple) by visual inspection. When recognizing some deformations, measurement of the deformations.	
			vibration	visual	Confirming there is no vibration under operation.	
			unusual sound	acoustic	Confirming there is no unusual sound.	
			deterioration of concrete	visual	Confirming there is no deterioration such as crack and flaking off by visual inspection.	
			sink • movement	visual.measurement	There is no remarkable sink and movement around rink support by visual inspection.	
	saddle support		damage	visual	Confirming there is no damage such as remarkable rust and dirty mark by visual inspection.	
			deformation	visual.measurement	Confirming there is no deformation (dimple) by visual inspection. When recognizing some deformations, measurement of the deformations	
			vibration	visual	Confirming there is no vibration under operation.	
			unusual sound	acoustic	Confirming there is no unusual sound.	
			deterioration of concrete	visual	Confirming there is no deterioration such as crack and flaking off.	
			sink · movement	visual.measurement	There is no remarkable sink and movement around saddle support by visual inspection.	

Penstock

Penstock (outside) Inspection Item

Classification	Inspection portion	Kind of inspection, frequency	Inspection item	Inspection method	Inspection point and criterion for judgment	Note
general	(accessories)					
	manhole		leakage	visual	Confirming there is no leakage.	
expansion joint	general		cleaning condition	visual	Confirming there is not a lot of sand, weeds, rubbish and dirty mark around expansion joint, stiffener air pipe (valve) and manhole.	
			deformation • corrosion	visual	Confirming there is no vibration under operation.	
			leakage	visual	Confirming there is no leakage from packing.	
	oring・packing		deterioration · damage	visual	Leakage only has to stop by closing the valve more.	
	packing・set plate		deformation · corrosion	visual	Confirming packing keeps sound good without deformation and corrosion.	
stiffener	general		damage	visual	Confirming there is no damage such as dirty mark by visual inspection.	
			deformation	visual.measurement	Confirming there is no deformation (dimple) by visual inspection. When recognizing some deformations, measurement of the deformations. Amount of deformation can be allowed to be within the permitted range or less.	
air valve	valve・cover		leakage	visual	Confirming there is no leakage.	
	receiver of fountain		deformation · damage	visual	Confirming there is no water dispersion due to deformation and damage.	
	open speed control valve		operation	confirmation of operation	Confirming the air valve is opening correctly.	
			damage	visual	Confirming the nozzle keeping clear.	
	closing speed control valve		operation	confirmation of operation	Confirming the air valve is closing correctly.	
			damage	visual	Confirming the nozzle keeping clear.	
	oring・packing		deterioration · damage	visual	Confirming the air valve is opening correctly.	
	set plate of packing		deformation · corrosion	visual	Confirming the packing keeps sound good without deformation and corrosion.	
drain	pipe		deformation · damage	visual	Confirming the pipe keeps drainage fuction without deformation.	
			leakage	visual	Confirming there is no leakage from joint or damaged section.	
	stop valve		operation	confirmation of operation	Confirming the portion is not fixed.	
			damage	visual	Confirming there is no crack on the body.Confirming the rod is not bending.	
			leakage	visual	Confirming there is no leakage from the rod section and joint section.	
	set plate of packing		deformation • corrosion	visual	Confirming the packing keeps sound good without deformation and corrosion.	

Penstock

Penstock (inside) Inspection Item

Classi-fication	Inspection portion	Kind of inspection, frequency	Inspection item	Inspection method	Inspection points and criterion for judgment	Note
inside	（main pressure parts） general		cleaning condition	visual	Confirming there is not a lot of sand, rubbish and dirty marks inside the pipe section.	
	pressure pipe		damage	visual	Confirming there are no dirty marks, cracks, scratches, subsidence, displacement and deformation by visual inspection.	
			deformation	visual.measurement	Confirming there is no deformation (dimple) by visual inspection. When a deformation is detected, the deformation should be measured using a scale.	
			corrosion	visual.measurement	Confirming there is no corrosion by visual inspection.	
			decrease of thickness	visual.measurement	Confirming there is no remarkable corrosion and wear. Decrease of thickness can be allowed within the permitted range or less.	
	welded portion		crack	visual	Not only visual inspection but also the Penetrate Test, the magnetic particle examination, and the ultrasonic test are to be executed. Evaluation criteria are shown in the attached paper.	
			damage	visual	Confirming there is no rust, dirty marks and cracks by visual inspection.	
			deformation	visual.measurement	Confirming there in no deformation. When a deformation is detected, the deformation should bemeasured using a scale. Evaluation criteria are shown in the attached paper.	
			decrease of thickness	visual.measurement	Confirming there is no remarkable rust and wear. Decrease of thickness can be allowed within the permitted range or less.	
	riveted portion		falling off	visual	Confirming there is no falling off.	
			looseness	visual･test hammer	Confirming there is no looseness using a test hammer and visual inspection.	
			damage	visual	Confirming there is no rust, dirty marks and cracks by visual inspection.	
			abrasion	visual	Confirming there is no remarkable wear.	

Gate

Gate－Radial Gate Inspection Item

classifi-cation	Inspection portion	Kind of inspection, frequency	Inspection item	Inspection method	Inspection point and criterion for judgment	Note
gate leaf	general		cleaning condition	visual	There is no drift wood, rubbish and sand around crest, seal section inside a gate leaf, roller section and hinge section. Confirming there is no remarkable dirty mark and adhesion of rope oil.	
	welding		crack	visual and nondestructive testing	Confirming there is no damage causing any obstacle to the function. When visual inspection is not satisfying enough for the judgement,ondestructive test such as penetrate test and magnetic parcel test should be done.	
	general structure		vibration	visual･manipulation	Confirming there is no vibration under operation.	
			unusual sound	acoustic	Confirming there is no unusual sound under operation.	
			hang in one side	visual･measurement	The example allowance of the left-right difference of the top of gate leaf are follows gate span:gate height 1:1, 2:1. 10:1. 20:1 difference (mm) 20 40 100 100	
	bolt･nut･rivet		looseness･falling off	visual and test hammer	Confirming there is no looseness using test hammer and visual inspection.	
	skinplate		deformation	visual and scale	In addition to visual inspection, measuring the deformation using scale.	
			leakage from joint	visual	Confirming there is little leakage by visual inspection.	
			decrease of thickness	visual･measurement	Confirming there is no remarkable corrosion and wear. Decrease of thickness can be allowed within the permitted range or less.	
	main beam and arm		drain hole and air vent	visual	Confirming the nozzle keeps clear.	
			defection･deformation	visual･measurement	In addition to visual inspection, measuring the deformation using scale.	
			decrease of thickness (more than15years)	visual･measurement	Confirming there is no remarkable corrosion and wear. Decrease of thickness can be allowed within the permitted range or less.	
	relative dimension (gate leaf-guide frame)		relative dimension	visual	Confirming that gate leaf open and close without friction.	
	auxiliary beam		defection･deformation	visual ･ measurement	In addition to visual inspection, measuring the deformation and bending using scale.	
	flow regulating plate		deformation	visual and scale	In addition to visual inspection, measuring the deformation and bending using scale.	

Gate

Gate－Radial Gate Inspection Item

classifi-cation	Inspection portion	Kind of inspection, frequency	Inspection item	Inspection method	Inspection point and criterion for judgment	Note
	bearing of side roller		grease	visual	Confirming that grease supply system is working correctly. Relevant grease should be used. The amount of grease should be within permitted range or less. There is no grease leakage. (In the case of oil free bearing, grease supply is not necessary.)	
	side roller roller shaft bearing rocker beam		abrasion･damage	visual	Confirming there is no damage and wear. Confirming there is no obstacle to opening and closing operation.	
			operation	operation	Confirming that rollers move smoothly at gate operation or manually operation Confirming that all of rollers keep contacting rail. Confirming that rollers locate around the center of rail.	
			unusual sound	acoustic	Confirming there is no unusual sound under operation.	
	sheave sheave shaft bearing		abrasion･damage	visual	Confirming there is no damage and wear. Confirming there is no obstacle to opening and closing operation.	
			grease	visual	Confirming that grease supply system is working correctly. (In the case of oil free bearing, grease supply is not necessary.)	
			operation	operation	Confirming that rollers move smoothly at gate operation or manually operation Confirming that all of rollers keep contacting rail. Confirming that rollers locate around the center of rail.	
	bearing metal		abrasion	measurement	Confirming there is no gap more than allowance allowance（mm）	
					Axis diameter（mm） Allowance	
					25~40 1.2	
					41~60 1.6	
					61~100 2.0	
					101~160 2.5	
					161~250 3.0	
					251~400 4.0	
					401~600 5.0	
	cover		deformation	visual	Confirming that the pulley and wire rope are working without contacting the cover. Confirming that no rubbish gets into sheave box.	

Gate

Gate－Radial Gate Inspection Item

classifi-cation	Inspection portion	Kind of inspection, frequency	Inspection item	Inspection method	Inspection point and criterion for judgment	Note
	rubber seal		leakage	visual	Confirming there is no leakage by visual inspection.	
			deterioration	visual	Confirming there is no deterioration of rubber by visual inspection.	
			damage	visual	Confirming there is no damage of rubber by visual inspection.	
			deformation	visual and scale	Confirming there is no deformation by visual inspection. When a deformation is detected, it should be measured using a scale.	
			abrasion	visual	Confirming there is no wear by visual inspection	
gate leaf	clamp bolt ･nut		looseness	visual and test hammer	Confirming there is no looseness using test hammer and visual inspection.	
			damage	visual	Confirming there is no scratch, deformation and corrosion by visual inspection.	
			falling off	visual	Confirming there is no falling off.	
			leakage	visual	Confirming there is no leakage from bolt section.	
	clamp bar		deformation	visual and scale	Confirming there in no deformation. When a deformation is detected, it should be measured using a scale.	
	(lubricating device) grease bag		grease volume	visual	Confirming that grease volume is appropriate.	
	grease		properly greased	visual	Confirming that proper grease is used.	
	grease pump		operation	visual	Confirming that pressure occurs when operating pump handle a few times. (In the case of manual type)	
	piping		damage	visual and test hammer	Confirming there is no deformation, damage,defect of pipe or grease leakage using a test hammer and by visual inspection.	
	distribution valve		damage	visual and test hammer	Confirming there is no deformation, damage, defect of pipe or grease leakage using a test hammer and by visual inspection.	

Gate－Radial Gate Inspection Item

Classifi-cation	Inspection portion	Kind of inspection, frequency	Inspection item	Inspection method	Inspection point and criterion for judgment	Note
guide frame	general		cleaning condition	visual	Confirming there is no draft wood, rubbish and sand. Confirming there is no remarkable dirty mark and adhesion of rope oil.	
			leakage	visual	Confirming there is no leakage.	
	guide frame of side roller		damage	visual	Confirming there is no corrosion, dirty mark and crack by visual inspection.	
			deformation	visual・measurement	Confirming there is no obstacle to gate operation. Confirming the rollers support the load uniformly. When recognizing some deformations, measurement of the deformations using scale should be done.	
			abrasion	visual・scale	Confirming there is no remarkable wear by visual inspection.	
			leakage	visual	Confirming there is no leakage by visual inspection.	
	rail support		damage	visual	Confirming there is no corrosion, dirty mark and crack by visual inspection.	
			deformation	visual・measurement	Confirming there is no obstacle to gate operation. Confirming the rollers support the load uniformly. When recognizing some deformations, measurement of the deformations using scale should be done.	
			abrasion	visua • scale	Confirming there is no remarkable wear by visual inspection.	
ancho-rage	bottom seal plate		damage	visual	Confirming there is no corrosion, dirty mark and crack by visual inspection.	
			deformation	visual・measurement	Confirming there is no obstacle to gate operation. When recognizing some deformations, measurement of the deformations using scale should be done.	
			abrasion	visual・scale	Confirming there is no remarkable wear by visual inspection.	
			leakage	visual	Confirming there is no leakage by visual inspection.	
	side seal plate		damage	visual	Confirming there is no corrosion, dirty mark and crack by visual inspection.	
			deformation	visual・measurement	Confirming there is no obstacle to gate operation. When recognizing some deformations, measurement of the deformations using scale should be done.	
			abrasion	visual・scale	Confirming there is no remarkable wear by visual inspection.	
			leakage	visual	Confirming there is no leakage by visual inspection.	
	trunnion girder trunnion pin trunnion hub trunnion pedestal		damage	visual	Confirming there is no corrosion, dirty mark and crack by visual inspection.	
			deformation	visual • measurement	Confirming there is no obstacle to gate operation When recognizing some deformations, measurement of the deformations using scale should be done.	
			abrasion	visual・scale	Confirming there is no remarkable wear by visual inspection.	
	trunnion shaft		abrasion	measurement	Confirming that the shaft axis keeps the design diameter or more.	
			plating	visual	Confirming there is no corrosion and falling off.	

APPENDIX B-3
DETERIORATION MONITORING MANUAL
FOR HYDROMECHANICAL WORKS

1. PENSTOCK

1.1 Objective

The purpose of deterioration monitoring is to determine the soundness of the penstocks and to ensure proper operation and. maintenance of facilities.

Description

Deterioration monitoring is to be implemented for checking and analyzing the degree of deterioration and safety of the penstocks. Based upon the results of the monitoring, a study is to be made to evaluate the soundness of function and strength, and for establishing countermeasures (including repair and replacement). The results of the evaluation are to be shown in ranking order, in order to provide an easy understanding of the degree of soundness of the penstock.

Additionally, by executing a planned monitoring, the function of the penstock will be maintained to prevent accidents and their consequences, and to put in place as many safety measures as possible for the operation and maintenance of the hydropower station.

1.2 Scope of Application

The present manual applies to the exposed penstock of a hydropower station.

Description

This manual applies to the exposed penstock equipped with a concrete saddle or ring girder, and the applicable equipment are the pressure lining parts, the supporting parts, and accessories (expansion joints, valves, manholes). Embedded penstocks and bifurcation are not included in the scope of this manual.

The manual can be substantially applied to a discharge pipe and siphon, taking into account the structure, frequency of use, and importance. However, if the manual is applied to a penstock with a supporting structure not specified above, it is necessary to consider the importance of the materials etc.

Figure 1 shows the general drawing of the penstock. Figure 2 shows an example of the structure of the support.

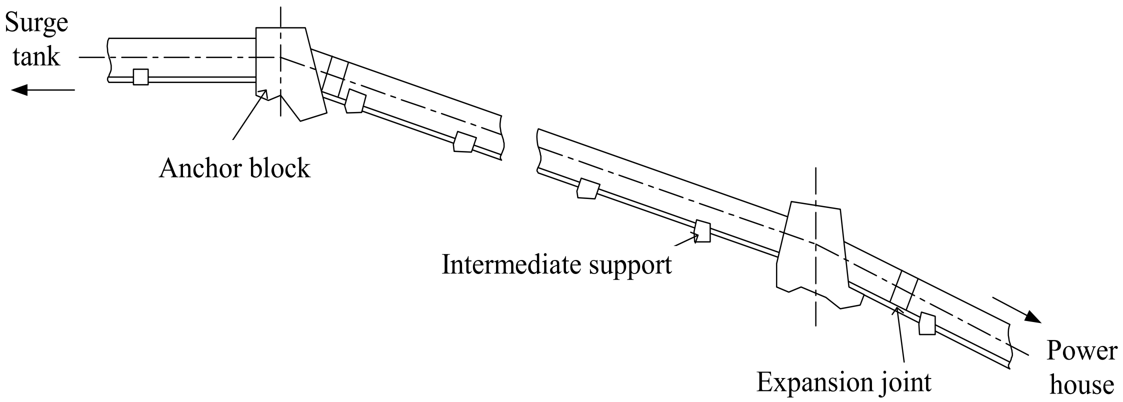


Figure 1 General Drawings of Penstock

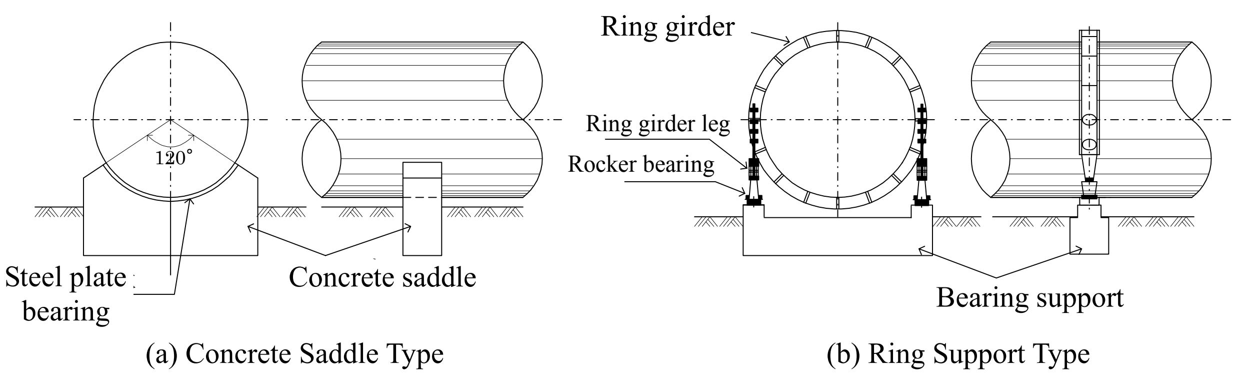


Figure 2 Example of Support

(Quoted from the “Technical Criteria of Dam and Weir” of the Dam and Weir Technical Corporation)

1.3 Definition

(1) Penstock

In principle, penstock refers to an exposed penstock, which includes the pressure lining portion, the supporting portion and accessories.

(2) Deterioration Monitoring

Deterioration monitoring consists of a series of investigations, evaluations and studies that include "functional check", "functional evaluation", "strength evaluation", "joint evaluation", "detailed monitoring", "detailed evaluation", and “study on countermeasures” based upon the results of the previous check and evaluation, and "decision on the date of the next monitoring".

(3) Soundness

Soundness is to show the degree of deterioration in strength and safety , and is expressed in the evaluation ranking order.

(4) Evaluation Ranking

The evaluation ranking is classified into four categories to show the soundness of the objects and is defined as follows:

A: No deterioration and high reliability (Apply to normal level of maintenance)

B: Some deterioration and low reliability (Inspection focusing mainly on low reliability)

C: Deteriorated and low reliability (Repair and replacement to be made as programmed)

D: Extremely deteriorated and lowest reliability (Urgent repair and replacement of the materials and parts required)

(5) Function

Function means the following characteristics that the penstock is supposed to have:

- To hold its structure reliably and be able to bear the projected loading.
- To maintain the proper structure to ensure adequate water tightness.
- To maintain the proper structure to prevent damaging vibration at the open and close operation .
- To possess durability against the surrounding environment.
- To maintain the proper structure that doesn’t cause harmful vibration at the operation of the power station.

(6) Abnormality

Abnormality means conditional change such as rusting and deformation, which obstruct the function of the penstock when in operation.

(7) Functional Monitoring

Functional monitoring is for determining the range and degree of the abnormality, to find the cause, and to understand the operating conditions based upon the data, the documents and hearings. This functional monitoring is to be planned and implemented in accordance with the deterioration monitoring and analysis results.

(8) Functional Evaluation

Functional evaluation is for evaluating the soundness of the operational function, based upon the classified degree of abnormality and operating conditions. The evaluation is classified in the ranking order of safety .

(9) Strength Evaluation

Strength evaluation is used to estimate the tensile stress by the internal pressure of the penstock, and to evaluate the structural soundness. This evaluation is described in an evaluation ranking reflecting the degree of safety.

(10) Joint Evaluation

Joint evaluation is to evaluate the soundness of the welding portion from the standpoint of fracture mechanics. This evaluation is described in an evaluation ranking reflecting the degree of safety.

(11) Integrated Evaluation

Integrated evaluation is used to select the lowest evaluation ranking from among the functional evaluation ranking, strength evaluation ranking and joint evaluation ranking orders.

(12) Detailed Monitoring

Detailed monitoring is to be executed for the low-soundness portions, when the an evaluation rank of C or D is given for strength evaluation and joint evaluation.

(13) Detailed Evaluation

Detailed evaluation is intended to evaluate the unsound parts based upon the results of detailed monitoring. This evaluation is a reevaluation of the strength evaluation and joint evaluation.

(14) Countermeasures

Countermeasures are the actions taken to implement the repairs and replacements required to restore the correct function of the water gate, judging from the monitoring and evaluation.

1.4 Order of Deterioration Monitoring

The deterioration monitoring of the penstock is executed in the order shown below:

Description

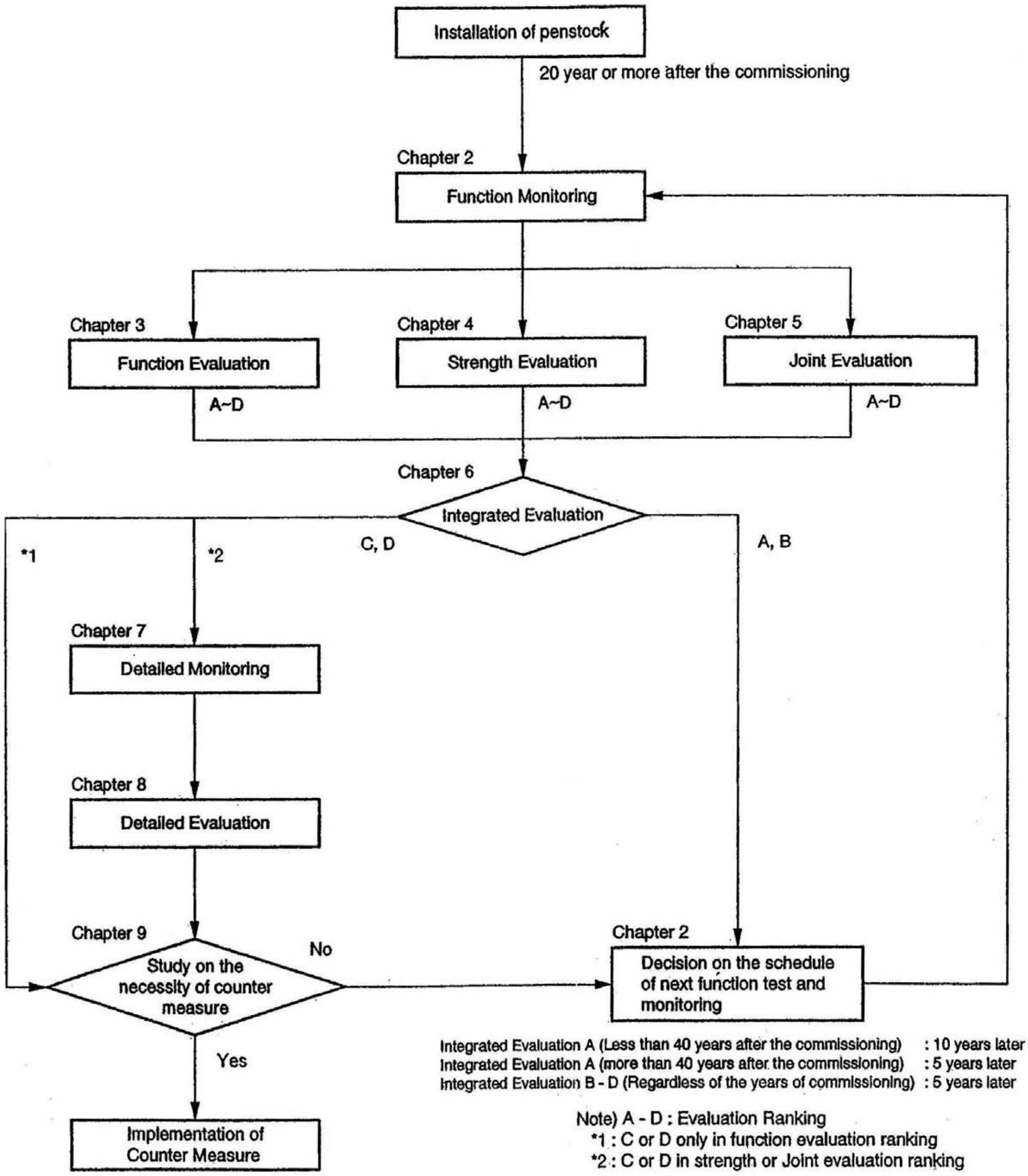


Figure 3 Penstock Deterioration Diagnosis Sequence

2. GATE

2.1 Objective

Deterioration monitoring is carried out to determine the soundness of the water gates and to ensure the proper operation and. maintenance of facilities.

Description

The purpose of deterioration monitoring is to check and analyze the degree of deterioration and safety of a water gate. Based upon the results of the monitoring, a study is implemented to evaluate the soundness of function and strength, and to establish countermeasures (including repair and replacement). The results of the evaluation are to be expressed in ranking order, in order to provide easy understanding of the degree of soundness of the water gate.

Additionally, by implementing planned monitoring the function of the water gate will be maintained to prevent accidents and their consequences, and to put in place as many safety measures as possible for the operation and maintenance of the hydropower station.

2.2 Scope of Application

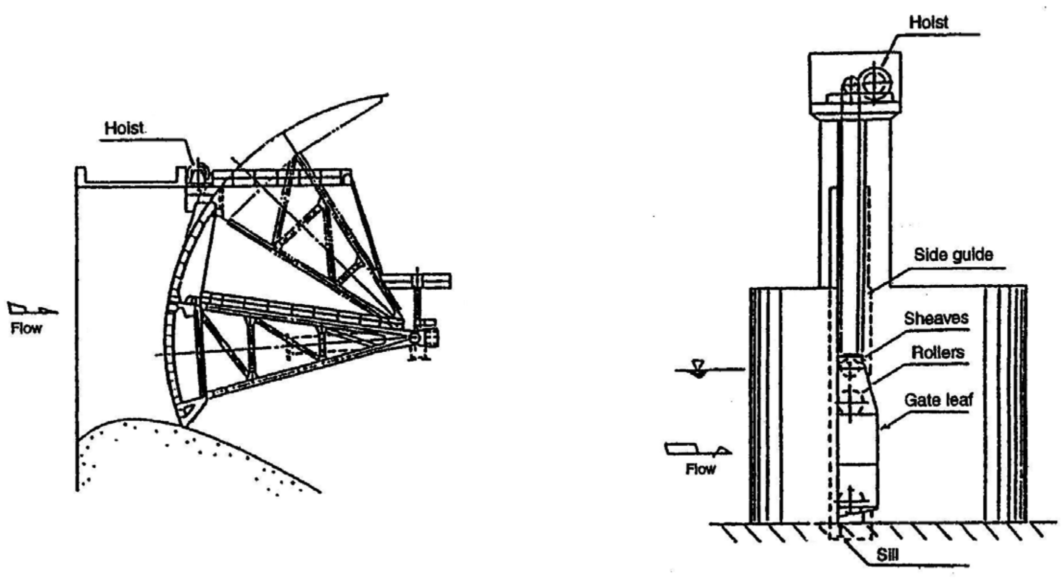
The present manual is applies to the spillway gate of a hydropower station.

Description

This manual is applicable to the Crest-Radial-Gate type, (hereinafter called " Radial Gate") which is equipped with the driving unit of a wire-rope winch, being water tight in three dimensions, and the Roller-Gate with a Plate Girder Structure (hereinafter called, "Roller Gate"). The particular equipment to which the manual applies are the door unit, the driving unit, the door contact, the fixed portion, and the equipment control unit.

Taking into account the structure, frequency of use, and importance, the manual can be substantially applied to a flow control gate. However, if the manual is applied to a gate with a structure or driving unit not specified above, it is necessary to consider the importance of materials etc.

Figure 4 shows the general drawing of the gate. Figure 5 shows a sample of the structure of the wire-rope-winch type (one motor and two drum winches).



(a) Radical Gate (b) Roller Gate

Figure 4 General Drawing of Gate

(Quoted from the “Technical Criteria of Dam and Weir” of the Dam and Weir Technical Corporation)

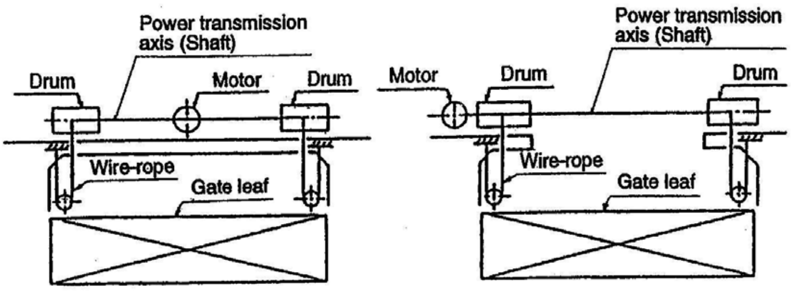


Figure 5 Structural Drawing with One Motor and Two Winches

(Quoted from the “Technical Criteria of Dam and Weir” of the Dam and Weir Technical Corporation)

2.3 Definition

(1) Water Gate

in principle, water gate refers to a spillway gate, which includes gate leaf with the fixed portion, the guide portion, and the hoist.

(2) Deterioration Monitoring

Deterioration monitoring consists of a series of investigations, evaluations and studies that include "functional check", "functional evaluation", "design stress evaluation", "stress check", "actual stress evaluation", and "study on countermeasures" based upon the results of the previous check and evaluation, and a "decision on the date of the next monitoring".

(3) Soundness

Soundness is to show the degree of deterioration in strength and safety and is expressed in the evaluation ranking order.

(4) Evaluation Ranking

The evaluation ranking is classified into four categories to show the soundness of the objects and is defined as follows:

A: No deterioration and high reliability (Apply to ordinal level of maintenance)

B: Some deterioration and low reliability (Inspect focusing mainly on low reliability)

C: Deteriorated and low reliability (Repair and replacement to be made as programmed)

D: Extremely deteriorated and lowest reliability (Urgent repair and replacement of the materials and parts is required)

(5) Function

Function means the following characteristics that the gate is supposed to have:

- To hold its structure reliably to bear the projected loading.
- To hold a proper structure to maintain adequate water tightness.
- To hold a proper structure to prevent damaging vibration at the open and close operation.
- To be durable against the installation environment.
- To hold a proper structure that doesn’t cause harmful vibration at the open and close operation .

(6) Abnormality

Abnormality means a conditional change such as rusting and deformation, which obstruct the function of the water gate during operation.

(7) Functional Monitoring

Functional monitoring is to determine the scope and degree of abnormality, to find the cause, and to understand the operating conditions based upon the data, documents and hearings. This functional monitoring is to be planned and implemented in accordance with the deterioration monitoring and analysis results.

(8) Functional Evaluation

Functional evaluation is to evaluate the soundness of operational function, based upon the classified degree of abnormality and operational conditions. The evaluation is classified into ranking of safety order.

(9) Designed Stress Evaluation

Designed stress evaluation is to estimate the designed stress of the water gate for the evaluation of its structural soundness. This evaluation is described in the evaluation ranking reflecting the degree of safety.

(10) Stress Monitoring

Stress Monitoring is to measure the actual stress.

(11) Actual Stress Evaluation

Actual stress evaluation is to evaluate the strength soundness based upon the above mentioned actual stress. The evaluation is described in the safety ranking order.

(12) Integrated Evaluation

Integrated evaluation is to select the lowest evaluation ranking from among the function evaluation, design stress evaluation and actual stress evaluation ranking orders.

(13) Countermeasures

Countermeasures the actions of repair and replacement which are required for restoring the due function of the water gate, judging from the monitoring and evaluation.

2.4 Order of Deterioration Monitoring

The deterioration monitoring of the water gate is executed in the order shown below:

Description

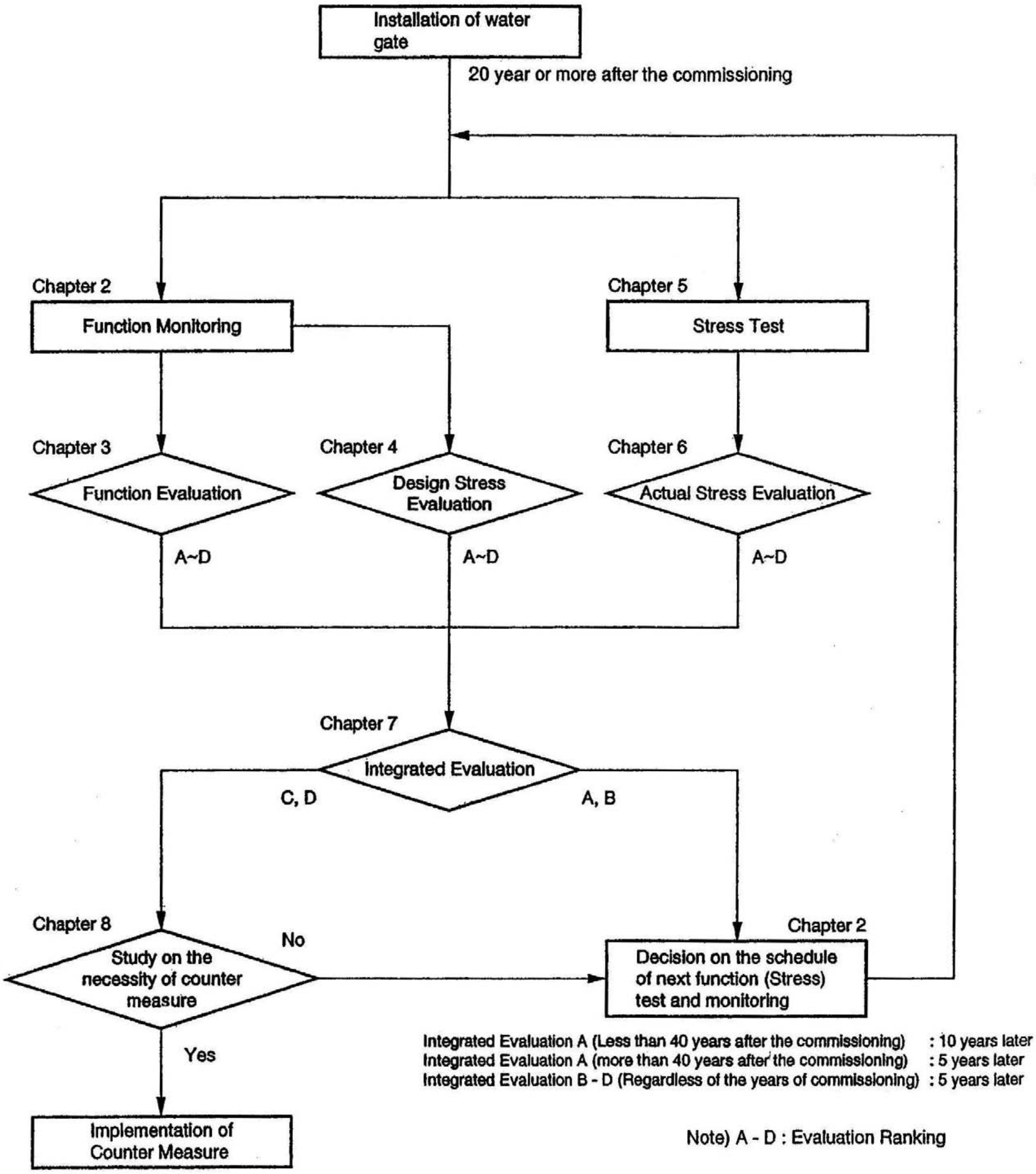


Figure 6 Order of Water Gate Deterioration diagnosis

APPENDIX B-4
REPAINTING MANUAL FOR HYDROMECHANICAL WORKS

1. OBJECTIVE AND SCOPE OF APPLICATION

This manual is provided for the purpose of describing the basic repair method for the gates and penstocks etc., and to prolong the life of the equipment.

2. PAINTING SURVEY

2.1 The Corrosive Environment of Penstock and Gate

When surveying the painting of the penstock and the gate leaf, the surveyor should understand the corrosive environment around each structure in order to conduct a suitable survey.

2.2 Frequency of survey

Survey frequency is as follows.

(1) Regular survey: once /year

(2) Detailed survey: Every five (5) years, in principle.

However, a detailed survey should be planned according to the results of the regular survey.

2.3 Surveyors

The surveyors are as follows:

(1) Regular survey: Two or more company staff members.

(2) Detailed survey: In principle, a professional engineer

2.4 Scope and Area of Survey Location

The survey is classified as follows:

(1) Regular survey: Specific scope and area are not limited.

(2) Detailed survey:

1) Penstock

a) For the exterior survey, four points (top-bottom, left-right) should be surveyed at one cross-section of each anchor block.

b) For the interior survey, it is to be carried out at each manhole, in principle.

2) Gate

a) The upstream side is divided into three parts such as the part above water, the water level fluctuating part, and the part under water.

b) The downstream side is divided into three parts: the top part, the middle part, and the bottom part.

2.5 Survey Method

The method and items of the survey are as follows:

(1) Regular survey

Visual inspection should be done in accordance with the patrol and inspection manual.

(2) Detailed survey

1) Visual Inspection

The following items should be confirmed by visual inspection:

(a) rust	(b) swelling	(c) peeling
(d) cracks	(e) discoloration	

2) Measuring inspection

The following items should be confirmed by a measuring inspection:

(a) adhesion

(b) embitterment (impedance measurement)

(c) painting thickness

2.6 Survey Record

(1) The survey record should be used for determining the age deterioration, estimating future requirements and making a long-term maintenance plan for the equipment. A change in condition should be recorded in addition to the record of the survey items as much as possible.

(2) The survey record should be prepared in accordance with the patrol and inspection manual.

(3) Picture- taking should be done together with the survey. (Electronic media is included)

Table 1 Painting Survey Rating Schedules

2.6(1)a. Rust

1) Rating of Rust

Corroded area	Appearance condition	rating
0 ~ 0.03%	Looks good. No one can detect any rust on surface.	3
0.03 ~ .3%	Except for some rusted areas, the anti-rust performance of the paint is nearly maintained.	2
0.3 ~ 5.0%	There are many rusted areas, some treatment should be done.	1
> 5.0%	Totally deteriorated painting surface Immediate treatment is required.	0

2) Area conversion table of rust standard sample

Corroded area	Corroded area per 1 m2
0.03%	3 cm^2 (Approx.1.7 cm x 1.7 cm)
0.3%	30 cm^2 (Approx. 5.5 cm x 5.5 cm)
3%	300 cm^2 (Approx.17.3 cm x 17.3 cm)
5%	500 cm^2 (Approx.22.4 cm x 22.4 cm)

2.6(1)b. Swelling

Swollen area		Rating
swelling area	0 ~ 0.03%	3
- ditto -	0.03 ~ 0.3%	2
- ditto -	0.3 ~ 5.0%	1
- ditto -	>5.0%	0

Refer to 2.6 (1)a for visual condition and area conversion

2.6(1)c. Peeling

Concurrent condition		Rating
Occurrence area	0 ~ 0.03%	3
- ditto -	0.01 ~ 0.5%	2
- ditto -	0.5 ~ 2.0%	1

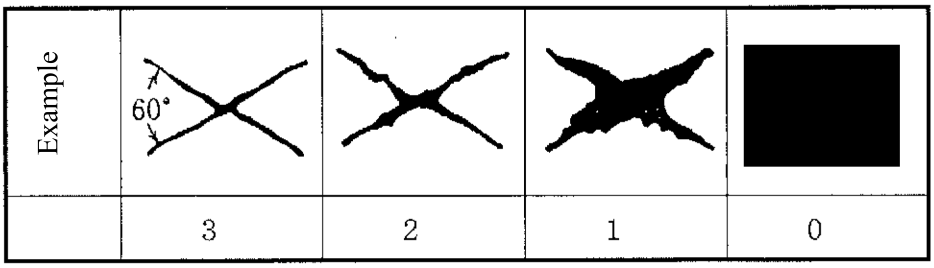
2.6(1)d. Cracks

Concurrent condition		Rating
Occurrence area	0 %	3
- ditto -	0.01 ~ 0.5%	2
- ditto -	0.5 ~ 2.0%	1

2.6(1)e. Discoloration

Degree of discoloration	Rating
Almost no change	3
Changed	2
Changed remarkably	1

2.6(2)a. Adhesion

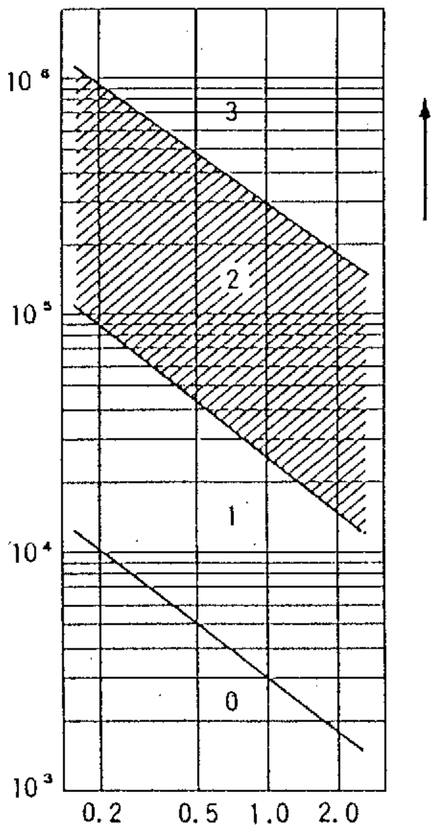


2.6(2)b. Embitterment（impedance measurement）

1) Evaluation curve of resistance value of paint film
   Refer to Evaluation curve -1

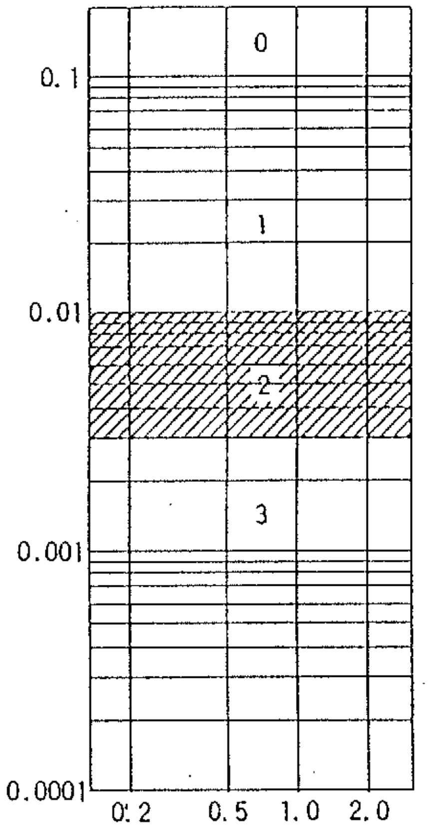
2) Evaluation curve of electrostatic capacity of paint film
   Refer to Evaluation curve -2

(note) Resistance value decrease, and electrostatic capacity increase in the impedance of paint film with deterioration's progress



F KHz

Evaluation Curve-1



F KHz

Evaluation Curve-2

Sample Check Sheet for Paint Film (Penstock)

Survey Item			top	bottom	left	right	Rating
Visual inspection	rust						
	bubbles						
	cracking						
	peeling						
	discoloration						
60° cross cut tape test							
Impedance measurement	Resistance (Ω)	0.2KHz					
		0.5KHz					
		1.0KHz					
	Capacity (μF)	0.2KHz					
		0.5KHz					
		1.0KHz					
	Rating						
	Temperature (°C)						
Film thickness (μ)							
Maximum • Minimum (μ)							
Average							
Standard deviation							
Total rating score							
Deterioration index (degree of deterioration)							
Note	(e.g.) depth of rust						
Remark	(outside) (inside)						

2.7 Evaluation Criteria of Deterioration Grade

Evaluation of deterioration grade for paint should be done as follows

(1) Regular Inspection

When unusual conditions are detected as the result of visual observation, a detailed inspection should be planned based on the result.

(2) Detailed Inspection

The deterioration is to be evaluated based on the deterioration index and the following table.

The deterioration index is to be calculated according to the following formula.

$$Deterioration\ index = 1 - \left(\frac{Total\ point\ of\ all\ evaluation\ items}{The\ number\ of\ evaluation\ items \times 3} \right) \times 100$$

When most of the paint faults are of the same type, that type of paint fault can be regarded as a single evaluation item, and the deterioration index can be calculated based on the single item.

Deterioration Evaluation Table

Condition Rank	Deterioration Index	Condition
A	0 to 10	No unusual appearance or extremely minor faults are observed
B	More than 10 to 20	Minor faults are observed. However, the other parts are good.
C	More than 20 to 40	Small faults such as rust, swelling and peeling off are observed as a whole. Relatively larger faults are observed and deterioration is getting partially worse .
D	More than 40 to 100	Faults such as rust, swelling and peeling off are observed as a whole. Deterioration is getting worse.

3. STANDARD OF REPAINTING (REPAIR) WORK

The repainting and repair painting should be done according to the following classification:

A: Repair painting is unnecessary
B: Though it is a slight defect, repainting (repair) should be done as soon as possible
C: Repainting (repair) should be done soon.
D: Immediate repainting (repair) is required

(1) Deterioration condition A

Paint still in sound condition. Small spots of rust are seen occasionally. Slight discoloration has occurred .

Basically, repair is not necessary, but it is recommended that even small and minor faults should be repaired soon.

(2) Deterioration condition B

Faults are small, but these faults might accelerate deterioration. Repainting (repair) should be done. However, because the area of the faults is small, it is recommended that several repair works should be done at the same time with the near gates and penstock belonging to the same river basin.

(3) Deterioration condition C

Because the deterioration is considerably worse and relatively larger faults are observed, the remarkably deteriorated parts should be repaired and the time of repainting should be determined.

(4) Deterioration condition D

Because rust and faults are seen around the whole section, and some sections are extremely deteriorated, immediate repainting is required.

APPENDIX C
MAINTENANCE AND INSPECTION MANUAL
ELECTRO-MACHINE EQUIPMENT

APPENDIX C-1
SIMPLIFIED EFFICIENCY TEST USING A PORTABLE ULTRASONIC FLOW METER

1. OVERVIEW

The inspection conducted by disassembling turbines and auxiliaries is normally implemented at the beginning stage of the rehabilitation plan to determine the scope of replacement and repairs. However, it was impossible to shut down the power stations and to carry out the inspection in the Study due to an electric power shortage.

The main purpose of the simplified efficiency test using a portable ultrasonic flow meter is to identify the performance deterioration of a machine when it is impossible to disassemble and inspect it. The level of measured performance suggests latent deterioration resulting from invisible erosion, corrosion and other damage, as well as improper alignment of the needle and diffuser.

Flow measurements were implemented at Units 1 and 4 of Old Laxapana H.P.S., Unit 2 of Polpitiya H.P.S. and Unit 2 of New Laxapana H.P.S., taking into consideration the priority of prospective deterioration.

It is concluded that the results of the simplified efficiency tests are very useful to enable implementing the rehabilitation plan without shutting down of the power station under the circumstances mentioned above.

2. FLOW MEASUREMENT

2.1 Portable Ultrasonic Flow Meter

The portable ultrasonic flow meter is used mainly for small or medium size pipes, while it is not applicable for penstock. However, it is small and convenient to handle at the outside penstock with a steep slope. The specifications are described below.

Table 1 Specifications of Ultrasonic Flow Meter

Subject	Specifications
Type	UFP-10
Manufacturer	TOKIMEC in Japan
Measured fluid	Homogeneous and sonically conductive liquid (river water)
Measurable pipe	300 to 5000 mm diameter for large sensor / Material: steel
	Lining: Tar epoxy resin
Straight length of pipe	Upstream: ≧ 10 pipe diameter, Downstream: ≧5 pipe diameter.
Pipe thickness	1.5 to 100 mm for steel pipe
Measuring Principle	Ultrasonic pulse technique, transit time method
Measuring accuracy	±1.0 % RD
Measuring range	Equivalent to velocity: -20 m/s to +20 m/s
Measuring method	Z method, V method (Variation of detector mounting)
Power supply	11 to 30V DC (AC adapter or Battery: standard operation time 7.5 Hr)
Power consumption	Approx. 3W
Applicable temperature	-10 to 50℃
Applicable humidity	Less than 90%
Weight	1.3 kg

The Z method with single path and large sensors is adopted for this measurement, while small sensors are used for smaller pipes.

2.2 Flow Measurement Procedure

Picture 1 shows the fitting arrangement of ultrasonic sensors on the penstock.

Table 2 shows the dimension check of each penstock and the input data for the Ultrasonic Flow Meter. Sensor locations were selected on the outside straight penstock while the following criteria were observed.

1) Straight pipe length upstream of upper sensor: Larger than 10 times the pipe inner diameter

2) Straight pipe length downstream of lower sensor: Larger than 5 times the pipe inner diameter

Picture 1 Sensor installation state

Table 2 Dimension Check of Measured Penstock and Applied Input Data for Ultrasonic Flow Meter

Item	Unit	Old Laxapana Unit 1	Old Laxapana Unit 4	Polpitiya Unit	New Laxapana Unit	Remarks
Test date		2004.8.4	2004.8.6	2004.8.12	2004.8.18	
Pipe type		Steel pipe	Steel pipe	Steel pipe	Steel pipe	
Outer diameter: D	mm	989.3	963.5	2062.9	1565.4	
Pipe material		Mild steel	Mild steel	Mild steel	Mild steel	
Pipe thickness	mm	32.6	21.7	26.3	29	
Lining of pipe interior		Tar epoxy	Tar epoxy	Tar epoxy	Tar epoxy	
Lining thickness	mm	0.5	0.5	0.5	0.5	
Measured liquid		water	water	water	water	
Sensor type		Large sensor	Large sensor	Large sensor	Large sensor	
Measuring method		Z	Z	Z	Z	
Distance between 2 sensors (upstream side and downstream side)	mm	504.7	466.2	947.1	741.5	
Cable length between sensor and flow meter	m	10	10	10	10	
Measurement unit		m^3/s	m^3/s	m^3/s	m^3/s	
Straight pipe length upstream of upper sensor	m	Larger than 50m (larger than 10 times the pipe diameter)	Larger than 50m (larger than 10 times the pipe diameter)	Larger than 50m (larger than 10 times the pipe diameter)	29m (29/1.507=19.24, larger than 10 times the pipe diameter)	Straight pipe length satisfies test conditions of Ultrasonic flow measurement
Straight pipe length downstream of lower sensor	m	27.61 (27.61/0.9893=27.9, larger than 5 times the pipe diameter)	5.81 (5.81/0.9635=6.03, larger than 5 times the pipe diameter)	21.43 (21.43/2.01=10.66, larger than 5 times the pipe diameter)	9.458 (9.458/1.507=6.27, larger than 5 times the pipe diameter)	Straight pipe length satisfies test conditions of Ultrasonic flow measurement

3. SIMPLIFIED EFFICIENCY TEST

Due to the lack of information on penstock, layout and pressure gauge tap locations as well as performance data at the installation stages, it was very difficult to prepare the instruments necessary for the usual turbine efficiency test.

Consequently the simplified efficiency test was implemented under the following conditions.

1) The portable ultrasonic flow meter (UFP-10, TOKIMEC in Japan) with single path was used.

2) Large ultrasonic sensors usually used for penstock were adopted.

3) Effective head was calculated from measured water levels of upper reservoir, surge chamber and tailrace, considering the measured head loss of the headrace tunnel and the calculated penstock .

In the case of Pelton turbines, the level of the turbine runner center was substituted for the tailrace water level. Figure 1 indicates the measurement benchmarks for each unit.

Friction head loss of penstock is expressed by the following formula.

$$Hf = f * L / D * V^2 / 2g$$

$$F = 124.5 * n^2 / D^{0.3333}$$

Where,

Hf : Friction head loss of penstock (m)

L : Length of penstock (m)

D : Inner diameter of penstock (m)

V : Velocity (m / s)

N : Manning's roughness coefficient, n = 0.012 for penstock

4) Electrical manometer (pressure transducer) was used for the calibration of the effective head, if applicable. It was used for Unit 2 of Polpitiya H.P.S.

5) Flow data of ultrasonic flow meter was calibrated by another flow measurement method such as weir, if applicable. It was used for Unit 4 of Old Laxapana H.P.S.

6) Generator output was calculated by the watt hour meter of the power station in lieu of the precision class digital watt hour meter usually used for the efficiency test.

7) There were no generator efficiency data at the installation stage with respect to the four (4) tested units. Consequently, the generator efficiencies of the existing similar machines in J-POWER were applied for the calculation.

8) Generator reactive power was kept to zero during the test as much as practically possible.

9) Generator outputs selected were 100 %, 80 %, 60 %, 40 % and 20 %, and additional outputs were selected if necessary.

10) Prior to each measurement, one trial measurement was conducted confirming the preparation of deployed personnel by transceiver.

11) Measurement interval was 10 minutes.

12) The necessary access route to penstock, tent cover, ladder and scaffold were determined to protect personnel and instruments from frequent rain and danger at the outside penstock.

13) A test data sheet form similar to the usual efficiency test was used and modified in consideration of the above conditions.

Tables 3 to 6 indicate test results relevant to Unit 1 and Unit 4 of Old Laxapana H.P.S., Unit 2 of Polpitiya H.P.S. and Unit 2 of New Laxapana H.P.S., respectively.

Figures 2 to 5 indicate calculated turbine efficiencies for each unit.

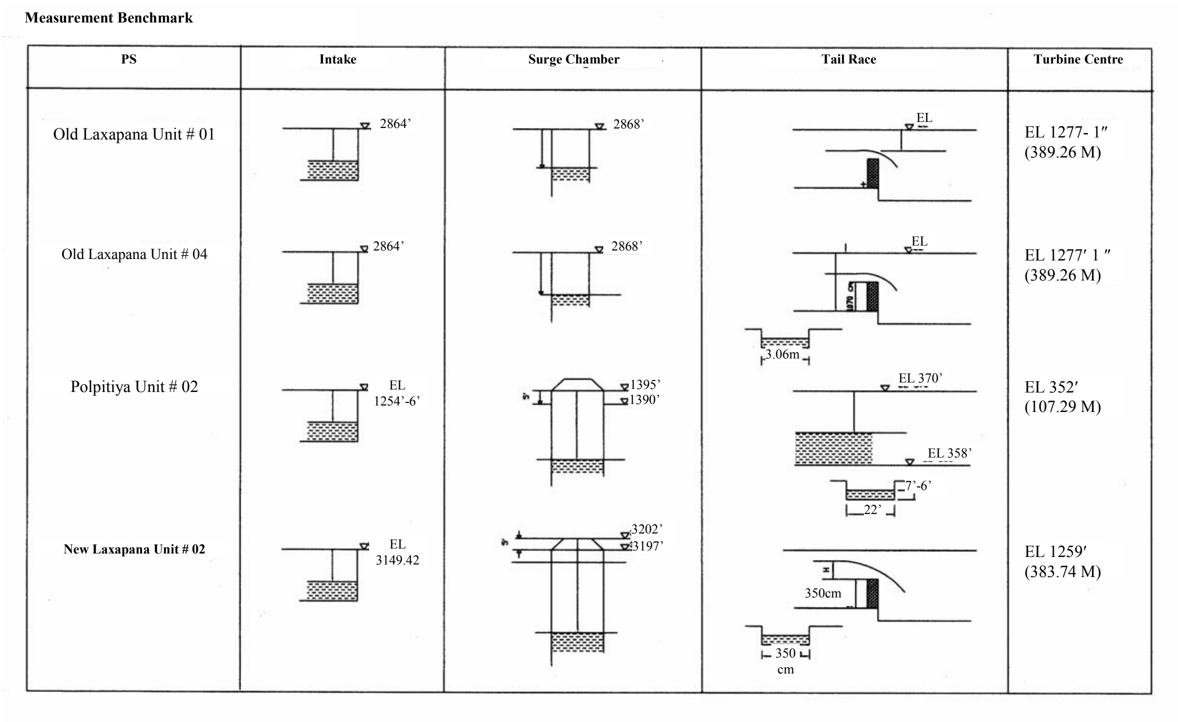


Figure 1 Measurement Benchmark

Table 3 Discharge Measurement and Efficiency Evaluation

PS Name:	Old Laxapana	Survey date:	4th August 2004
Unit Number:	Unit No.1	Weather:	Rain and Clouds
Flow coefficient:		Room temperature:	28 degree Celsius
Water temperature:		Outside temperature:	31 degree Celsius

Item		Unit	Practice	10:05	10:15	10:25	10:35	10:45	Remarks
Generator	Generator output	MW	1.9	8.0	6.6	5.0	3.3	1.6	Control room
	Generator reactive power	MVar	-1.3	-1.5	-1.6	-1.3	-1.5	-1.2	Control room
	Time of 100 kWh or 200 kWh	min sec	2 51	1 28	1 48	2 24	3 32	3 40	Cubicle room, Blue letter 100 kWh
	Calculated G. output	MW	2.11	8.18	6.67	5.00	3.40	1.64	
	Generator voltage	kV	10.7	10.7	10.8	10.8	10.7	10.7	Control room
	Generator current	A	119	428	360	272	192	102	Control room
	Field winding voltage	V	38	57	50	47	41	38	Control room
	Field winding current	A	167	255	226	205	177	169	Control room
	Power factor (p.f.)	%	82.5%	98.3%	97.2%	96.8%	91.0%	80.0%	
	Frequency	Hz	-	49.98	49.96	49.81	49.89	49.85	Control room
	Coil temperature	℃	-	56	56	56	54	51	
Turbine	Rotational speed	mim^{-1}	600	600	600	600	600	600	Control room
	Wicket gate opening	mm	-	-	-	-	-	-	
	Needle opening #1	mm	46.0	85.0	73.0	64.0	54.5	46.0	Servomotor stroke (0MW, 31mm)
	Needle opening #2	mm	49.0	86.0	76.0	64.5	57.0	48.0	Servomotor stroke (0MW, 34mm)
	Needle opening #3	mm	-	-	-	-	-	-	
	Needle opening #4	mm	-	-	-	-	-	-	
	Deflector Opening	%	16.0%	53.5%	42.5%	32.0%	24.0%	15.0%	Servomotor stroke
Discharge	Used flow (discharge)	m^3/s	0.829	2.511	2.116	1.649	1.194	0.744	Penstock A
Head	Water level of Intake	ft inch	23 9	24 1	24 1.5	24 2	24 2.5	24 3	Headrace
	Water level of surge chamber	m	9.08	9.71	9.65	9.51	9.41	9.28	Surge Chamber
	Water level of tailrace (weir)	m	0.29	0.56	0.51	0.43	0.35	0.26	Tailrace
	Penstock pressure gauge (in)	ft	1590	1550	1560	1570	1580	1590	Penstock pressure
	Penstock pressure gauge (out)	ft	1590	1550	1560	1570	1580	1590	Penstock pressure
Calculated	Water level of intake	EL..m	865.71	865.61	865.59	865.58	865.57	865.56	2864 ft
Head	Water level of surge chamber	EL..m	865.09	864.46	864.52	864.66	864.76	864.89	2868 ft
	Turbine center	EL..m	389.26	389.26	389.26	389.26	389.26	389.26	1277' 1" ft
	Pipe loss	m	1.91	17.50	12.43	7.55	3.96	1.54	
	Pressure head	m	-	-	-	-	-	-	-
	Gross head	m	475.83	475.20	475.26	475.40	475.50	475.63	Surge chamber El.- Tailrace El.
	Effective head	m	473.92	457.70	462.83	467.85	471.54	474.09	-
Efficiency	Generator efficiency	%	92.5%	96.3%	95.9%	95.2%	94.4%	92.1%	Calculated Value based on commissioning test. Think of less than 1% from above value below pf 90%
	Turbine output	MW	2.28	8.5	6.95	5.25	3.6	1.78	-
	Turbine input	MW	3.85	11.26	9.60	7.56	5.52	3.46	-
	Turbine efficiency	%	59.2%	75.5%	72.4%	69.4%	65.2%	51.4%	-
	G-T efficiency	%	54.8%	72.6%	69.5%	66.1%	61.6%	47.4%	-
Converted value to the specification	Effective head	m	-	-	-	-	-	-	-
	Discharge	m^3/s	-	-	-	-	-	-	-
	Turbine output	kW	-	-	-	-	-	-	-

Reliability	Flow meter	1.0%
	PT	0.5%
	CT	0.5%
	Wh meter	0.5%
	Safety factor	2.0%
Total reliability		4.6%

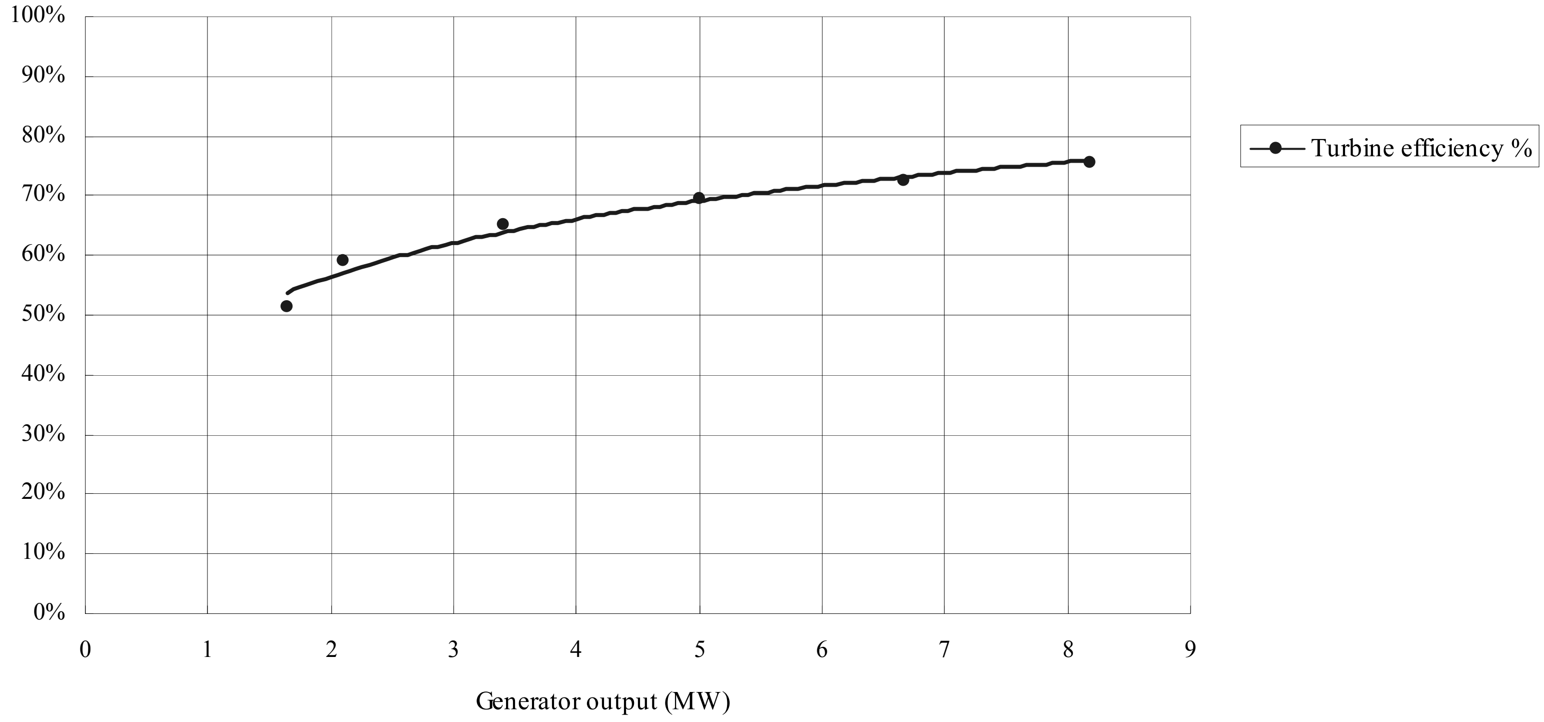


Figure 2 Turbine Efficiency of Old Laxapana Unit 1
Date of the measurement: 4th Aug.2004

Table 4 Discharge Measurement and Efficiency Evaluation

PS Name:	Old Laxapana	Survey date:	6th August 2004
Unit Number:	Unit No.4	Weather:	Rain and Clouds
Flow coefficient:		Room temperature:	27 degree Celsius
Water temperature:		Outside temperature:	27 degree Celsius

Item		Unit	Practice	10:05	10:15	10:25	10:35	10:45	Remarks
Generator	Generator output	MW	12.3	12.1	9.9	7.3	5.1	2.6	Control room
	Generator reactive power	MVar	1.0	0.0	0.1	0.0	0.1	0.1	Control room
	Time of 250 kWh or 500 kWh	min sec	1 13	2 23	3 1	4 6	2 57	5 38	Cubicle room, Blue letter 100 kWh
	Calculated G. output	MW	12.33	12.59	9.94	7.32	5.08	2.66	
	Generator voltage	kV	11.3	11.2	11.2	11.2	11.2	11.2	Control room
	Generator current	A	625	622	509	374	264	137	Control room
	Field winding voltage	V	78	73	69	64	60	58	Control room
	Field winding current	A	359	335	317	292	278	266	Control room
	Power factor (p.f.)	%	99.7%	100.0%	100.0%	100.0%	100.0%	99.9%	
	Frequency	Hz	49.98	50.08	49.87	49.99	49.88	49.88	Control room
	Coil temperature	℃	104	104	103	99	94	88	Max
Turbine	Rotational speed	mim^{-1}	499	500	498	498	498	498	Control room
	Wicket gate opening	mm	-	-	-	-	-	-	
	Needle opening #1	%	63.0%	62.0%	42.0%	30.0%	21.0%	12.0%	Servomotor stroke
	Needle opening #2	mm	-	-	-	-	-	-	Servomotor stroke
	Needle opening #3	mm	-	-	-	-	-	-	
	Needle opening #4	mm	-	-	-	-	-	-	
	Needle opening at Governor	mm	184	188	219	240	255	273	Servomotor stroke(0MW, 296 mm)
	Deflector Opening	%	68.0%	66.0%	54.0%	46.0%	40.0%	30.0%	Servomotor stroke
Discharge	Used flow (discharge)	m^3/s	3.65	3.628	2.705	1.981	1.395	0.794	Penstock A
Head	Water level of Intake	ft inch	22 5	22 7	22 7.5	22 7.5	22 8	22 8	Headrace
	Water level of surge chamber	m	14.20	14.20	13.41	12.86	12.46	12.06	Surge Chamber
	Water level of tailrace (weir)	m	1.77	1.77	1.66	1.55	1.46	1.33	Tailrace (The wide is 3.06m)
	Penstock pressure gauge (in)	ft	1450	1450	1500	1520	1540	1550	Penstock pressure
	Penstock pressure gauge (out)	ft	1460	1460	1460	1460	1460	1460	Penstock pressure
Calculated Head	Water level of intake	EL..m	866.11	866.06	866.05	866.05	866.04	866.04	2864 ft
	Water level of surge chamber	EL..m	859.97	859.97	860.76	861.31	861.71	862.11	2868 ft
	Turbine center	EL..m	389.26	389.26	389.26	389.26	389.26	389.26	1277' 1" ft
	Pipe loss	m	16.38	16.19	9.00	4.83	2.39	0.78	
	Pressure head	m	-	-	-	-	-	-	-
	Velocity head	m	-	-	-	-	-	-	-
	Gross head	m	470.71	470.71	471.50	472.05	472.45	472.85	Surge chamber El.- Tailrace El.
	Effective head	m	454.33	454.52	462.50	467.22	470.06	472.07	-
Efficiency	Generator efficiency	%	97.2%	98.2%	97.5%	96.6%	95.6%	94.2%	Calculated Value based on commissioning test. Think of less than 1% from above value below pf 90%
	Turbine output	MW	12.69	12.82	10.19	7.58	5.32	2.82	-
	Turbine input	MW	16.25	16.16	12.26	9.07	6.43	3.67	-
	Turbine efficiency	%	78.1%	79.3%	83.1%	83.6%	82.7%	76.8%	-
	G-T efficiency	%	75.9%	77.9%	81.1%	80.7%	79.1%	72.4%	-
Converted value to the specification	Effective head	m	-	-	-	-	-	-	-
	Discharge	m^3/s	-	-	-	-	-	-	-
	Turbine output	kW	-	-	-	-	-	-	-

Reliability	Flow meter	1.0%	Other unit operation	U1	7.6	MW
	PT	0.5%	at 10:00	U2	8.0	MW
	CT	0.5%		U3	8.0	MW
	Wh meter	0.5%		U5	12.6	MW
	Safety factor	2.0%				
Total tolerance		4.6%				

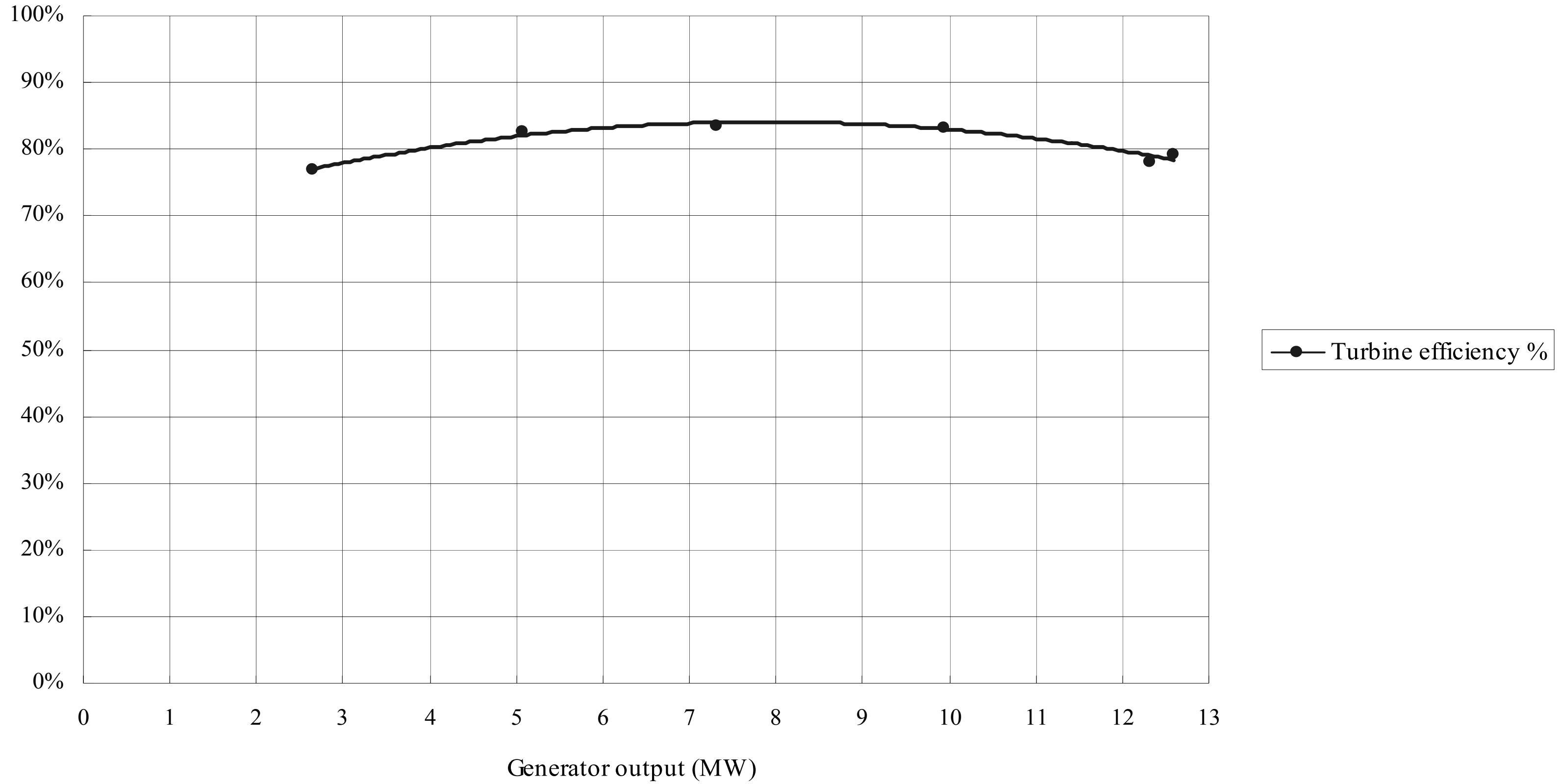


Figure 3 Turbine efficiency of Old Laxapana Unit 4
Date of the Measurement: 6th Aug. 2004

Table 5 Discharge Measurement and Efficiency Evaluation

PS Name:	Polpitiya				Weather:					Cloudy								
Unit Number:	2				Room temperature:					36	degree Celsius							
Survey date:	12th August 2004				Outside temperature:					32	degree Celsius							
Item		Unit	Practice		10:05		10:20		10:35		10:50		11:05		11:20		Remarks	
Generator	Generator output	MW	32.5		37.0		29.7		22.1		15.5		6.9		4.8		Control room	
	Generator reactive power	MVar	10.5		0.0		-0.2		0.4		-0.3		0.3		0.4		Control room	
	Time of 500 kWh or 1 MWh	min sec	1	55	1	40	2	5	2	49	4	1	8	27	6	10	Cubicle room, Blue letter 100 kWh	
	Calculated G. output	MW	31.30		36.00		28.80		21.30		14.94		7.10		4.86			
	Generator voltage	kV	12.4		12.1		12.1		12.0		12.1		12.1		12.1		Control room	
	Generator current	A	1579		1779		1424		1051		744		333		220		Control room	
	Field winding voltage	V	76		68		60		57		53		51		49		Control room	
	Field winding current	A	809		705		643		601		557		542		529		Control room	
	Power factor (p.f.)	%	95.2%		100.0%		100.0%		100.0%		100.0%		99.9%		99.7%			
	Frequency	Hz	49.95		49.96		50.11		49.79		50.03		49.88		50.08		Control room	
	Coil temperature	℃	65		65		64		61		59		59		53		Max	
Unit1	Generator output	MW	37.5		37.5		37.5		37.5		37.5		37.5		37.5			
Turbine	Rotational speed	mim^{-1}	499		499		499		498		500		498		500		Control room	
	Wicket gate opening at Meter	%	64%		77%		60%		47%		35%		18%		14%		Servomotor stroke	
	Wicket gate opening at Gov.	mm	206		224		200		180		160		130		125		Servomotor stroke(0MW, 102 mm)	
	Shaft run-out	1/100mm	5		5		5		5		5		4		3		Vibration	
Discharge	Used flow (discharge)	m^3/s	14.85		17.09		13.78		10.72		7.96		4.46		3.54		Penstock	
Head	Water level of Intake	ft inch	20	9.5	21	2.5	20	8.0	20	6.0	19	10	18	10	17	9.5	Headrace	
	Water level of surge chamber	ft inch	194	5.5	200	9	193	0.5	188	0	182	10	177	10	176	0.5	Surge chamber, The Elevation is confirmed on 8/17	
	Water level of tailrace (weir)	m	1.09		1.06		1.17		1.30		1.40		1.52		1.54		Tailrace (The width is 22 ft)	
	Penstock pressure gauge	Bar	25		24.8		25.5		26.0		26.2		26.5		26.6		Penstock pressure	
Calculated	Water level of intake	EL..m	376.03		375.91		376.07		376.12		376.33		376.63		376.95		1254.5	ft
Head	Water level of surge chamber	EL..m	365.93		364.01		366.36		367.89		369.47		370.99		371.54		1395	ft
	Water level of discharge	EL..m	111.69		111.72		111.61		111.48		111.38		111.26		111.24		370	ft
	Pipe loss	m	2.82		3.74		2.43		1.47		0.81		0.25		0.16			
	Pressure head	m	-		-		-		-		-		-		-		-	
	Velocity head	m	-		-		-		-		-		-		-		-	
	Gross head	m	254.24		252.29		254.75		256.41		258.09		259.73		260.30		Surge Chamber El.- Tailrace El.	
	Effective head	m	251.42		248.55		252.32		254.94		257.28		259.48		260.14		-	
	Discharge based on 12th data	m^3/s																
Efficiency	Generator efficiency	%	96.5%		96.8%		96.0%		95.0%		93.9%		92.4%		91.9%		Calculated Value.	
	Turbine output	MW	32.43		37.18		29.99		22.42		15.91		7.69		5.29		-	
	Turbine input	MW	36.59		41.63		34.07		26.78		20.07		11.34		9.02		-	
	Turbine efficiency	%	88.6%		89.3%		88.0%		83.7%		79.3%		67.8%		58.6%		-	
	G-T efficiency	%	85.5%		86.5%		84.5%		79.5%		74.4%		62.6%		53.9%		-	
Converted value to the specification	Effective head	m	-		-		-		-		-		-		-		-	
	Discharge	m^3/s	-		-		-		-		-		-		-		-	
	Turbine output	kW	-		-		-		-		-		-		-		-	
Reliability	Flow meter	1.0%		Other unit operation				U1	37.5	MW								
	PT	0.5%	temporary															
	CT	0.5%	temporary															
	Wh meter	0.5%																
	Safety factor	2.0%																
Total tolerance		4.6%																

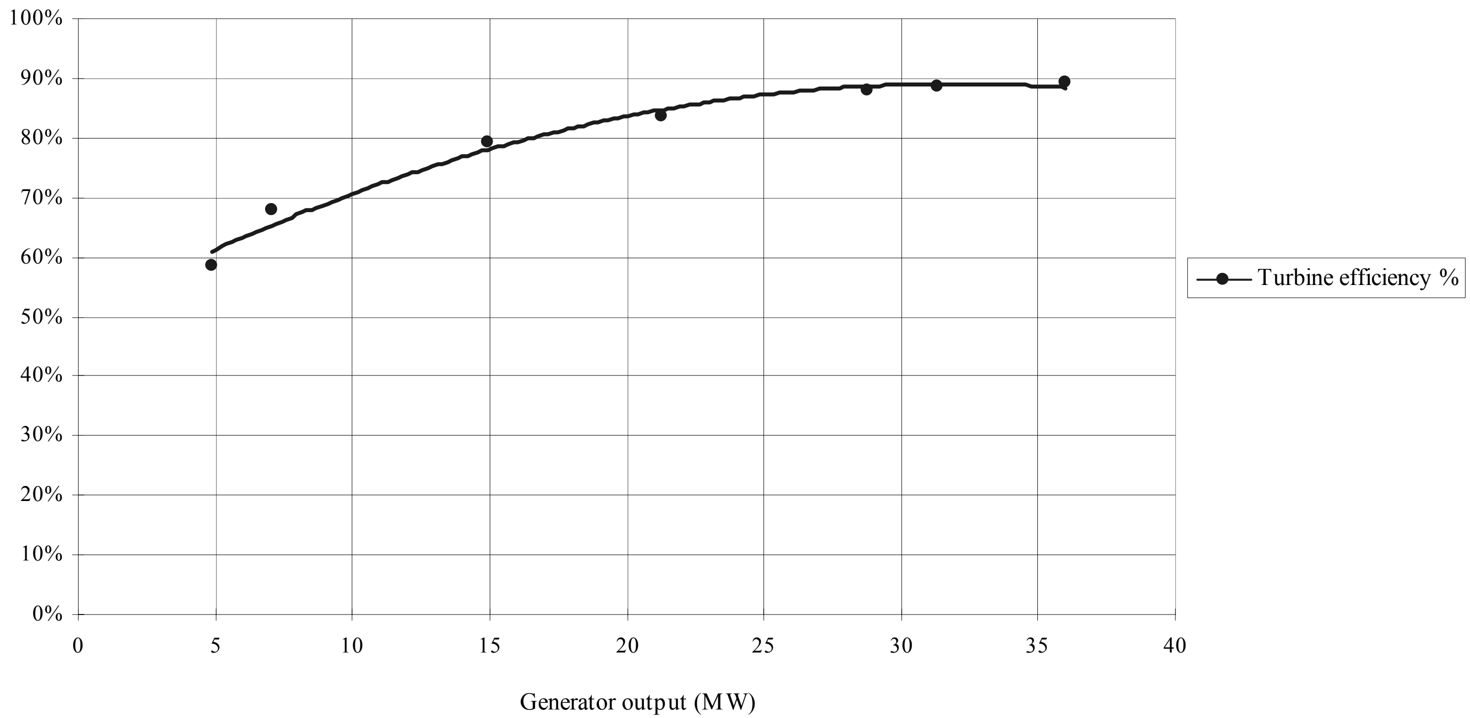


Figure 4 Turbine efficiency of Polpitiya Unit 2
Date of the measurement: 12th Aug. 2004

Table 6 Discharge Measurement and Efficiency Evaluation

PS Name:	New Laxapana	Survey date:	18th August 2004
Unit Number:	Unit No.2	Weather:	
Flow coefficient:		Room temperature:	degree Celsius
Water temperature:		Outside temperature:	degree Celsius

Item		Unit	Practice	10:05	10:15	10:25	10:35	10:45	Remarks
Generator	Generator output	MW	40.0	50.0	38.0	30.0	20.0	10.0	Control room
	Generator reactive power	MVar	8	0	0	0	3	0	Control room
	Time of 250 kWh or 500 kWh	min sec	1 27	1 10	1 30	1 57	3 0	6 4	Cubicle
	Calculated G. output	MW	41.38	51.43	40.00	30.77	20.00	9.89	
	Generator voltage	kV	12.1	11.9	11.9	11.9	12	11.9	Control room
	Generator current	A	2050	2500	2000	1200	(962)	(485)	Control room, Calculated value is shown in ().
	Field winding voltage	V	77	80	76	72	71	60	Control room
	Field winding current	A	830	840	800	770	760	710	Control room
	Power factor (p.f.)	%	98.1%	100.0%	100.0%	100.0%	98.9%	100.0%	
	Frequency	Hz	49.89	49.92	50.13	49.96	47.2	44.8	Control room
	Coil temperature	℃	52.6	55.3	53.1	50.3	50.1	50	Max
Unit1	Generator output	MW	40	45	45	45	45	45	
Turbine	Rotational speed	mim^{-1}	438	439	439	439	439	440	Control room (old meter, no calibration)
	Needle opening #1	mm	104	157	101	72	47	30	Servomotor stroke
	Needle opening #2	mm	110	157	104	76	50	30	Servomotor stroke
	Needle opening #3	mm	106	158	101	71	46	26	Servomotor stroke
	Needle opening #4	mm	110	164	108	77	51	31	Servomotor stroke
	Needle opening at Governor	%	82.5%	92.0%	80.0%	70.0%	57.5%	46.0%	Servomotor stroke(0MW, mm)
	Deflector Opening	%							Servomotor stroke
Discharge	Used flow (discharge)	m^3/s	8.55	10.83	8.30	6.34	4.18	2.24	Penstock
Head	Water level of Intake (EL)	ft inch	3147	3145 10	3146 10	3147 1	3147 10	3148 4	Headrace
	Water level of surge chamber	ft inch	77 8	88 10	80 8	75 9	70 0	65 11	Surge Chamber
	Water level of tailrace (weir)	cm	112	127	119	106	96	86	Tailrace (The width is 3.5 m)
	Penstock pressure gauge (in)	bar	53	52	53	54	55	56	Penstock pressure
	Penstock pressure gauge (out)	bar	57	57	57	57	57	57	Penstock pressure
Calculated	Water level of intake	EL..m	959.21	958.85	959.15	959.23	959.46	959.61	3149.42 ft
Head	Water level of surge chamber	EL..m	952.30	948.89	951.38	952.88	954.63	955.88	3202 ft
	Turbine center	EL..m	384	384	384	384	384	384	384 m
	Pipe loss	m	11.33	18.18	10.68	6.23	2.71	0.78	
	Pressure head	m	-	-	-	-	-	-	-
	Velocity head	m	-	-	-	-	-	-	-
	Gross head	m	568.30	564.89	567.38	568.88	570.63	571.88	Surge chamber El.- Tailrace El.
	Effective head	m	556.97	546.71	556.70	562.65	567.92	571.10	-
Efficiency	Generator efficiency	%	96.0%	96.5%	95.9%	95.1%	94.1%	92.9%	Calculated Value.
	Turbine output	MW	43.09	53.27	41.72	32.34	21.25	10.65	-
	Turbine input	MW	46.67	58.02	45.28	34.96	23.26	12.54	-
	Turbine efficiency	%	92.3%	91.8%	92.1%	92.5%	91.4%	84.9%	-
	G-T efficiency	%	88.7%	88.6%	88.3%	88.0%	86.0%	78.9%	-
Turbine Efficiency in Commissioning test		%							
Converted value to the specification	Effective head	m	-	-	-	-	-	-	-
	Discharge	m^3/s	-	-	-	-	-	-	-
	Turbine output	kW	-	-	-	-	-	-	-

Reliability	Flow meter	1.0%	Other unit operation				
	PT	0.3%		at 9:20	U1	50	MW
	CT	0.3%		after 10:00	U1	50	MW
	Wh meter	0.5% Temporary					
	Safety factor	2.0%					
Total tolerance		4.2%					

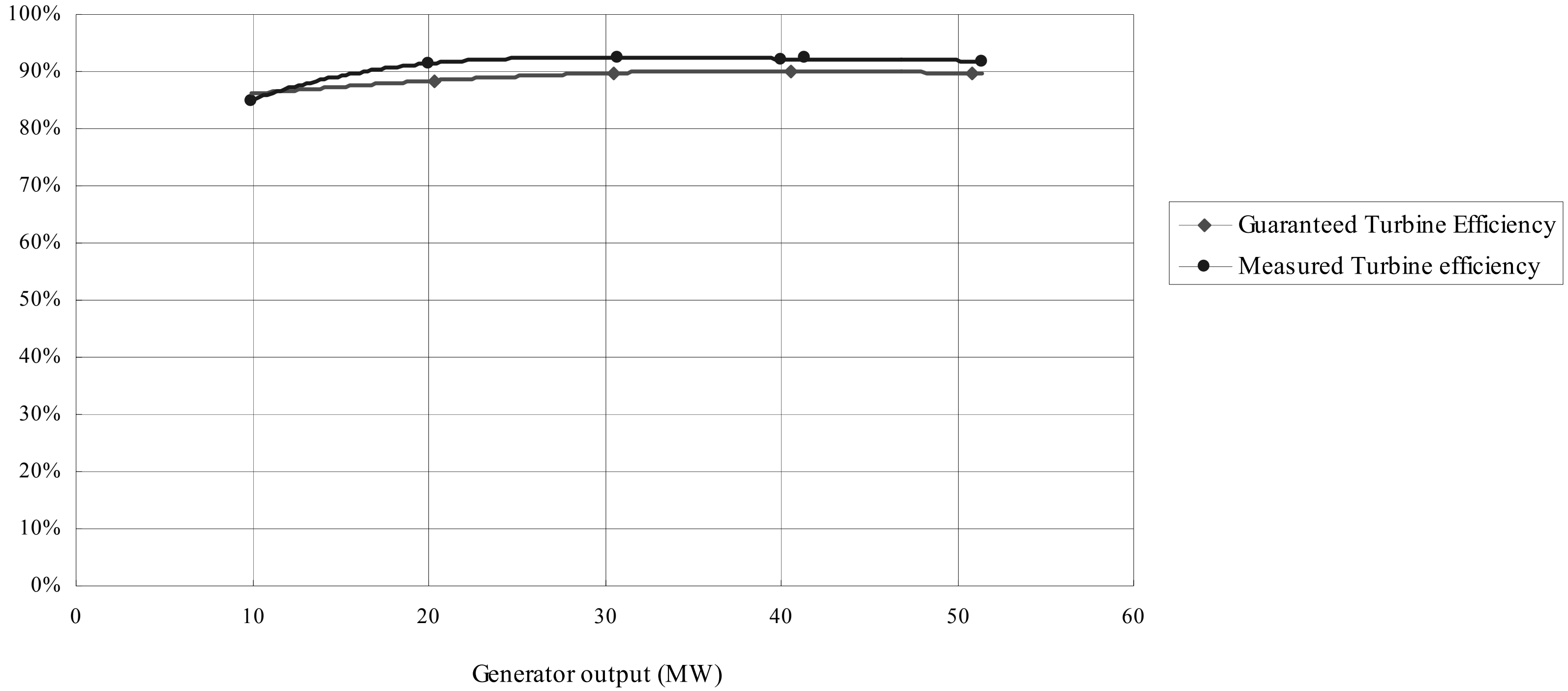


Figure 5 Turbine efficiency of New Laxapana Unit 2
Date of the measurement: 18th Aug. 2004

4. ACCURACY OF TEST RESULT

4.1 Accuracy of Measuring Instrument

Ultrasonic Flow Meter	:	± 1.0 %
PT	:	± 0.5 %
CT	:	± 0.5 %
Watt-hour meter	:	± 0.5 %

If a safety factor of ± 2.0 % is assumed, the total measurement error may be ± 4.6 %.

Fortunately the calibration of flow measurement by the weir was implemented at the tailrace of Unit 4 of Old Laxapana H.P.S. The calibration of the effective head by a pressure transducer (HAENNI) was performed at the inlet of the spiral case for Unit 2 of Polpitiya H.P.S.

Correlations between servomotor stroke, generator output and turbine discharge were compared in Unit 2 of New Laxapana H.P.S. relevant to ones of the present test result and the installation data.
Very good coincidence is identified.

4.2 Calibration of Flow Measurement by Weir

Table 7 and Figure 6 indicate the comparison between turbine discharges measured by the Ultrasonic Flow Meter and the weir at the tailrace of Unit 4 of Old Laxapana H.P.S. The weir appeared to have not been used for a long time, and the existing measurement instrument was missing. Therefore, a scale was used to measure the distance from the benchmark shown in Figure 1 to the tailrace channel water level. Good coincidence is observed on both measured discharges, while a manual measurement by a scale is not appropriate against the fluctuating water level at the tailrace channel.

It is confirmed the accuracy of the portable ultrasonic flow meter is satisfactory for penstock flow measurement.

Table 7 Calibration of flow measurement by weir

Old Laxapana Unit 4
Date 6th Aug. 04

No.	Time	Unit	Practice	10.05	10.15	10.25	10.35	10.45
1	Water level of weir	(m)	1.77	1.77	1.66	1.55	1.46	1.33
2	Calculated discharge: Qweir	(Cubic m/s)	3.490	3.490	2.670	1.940	1.400	0.753
3	Discharge measured by Ultrasonic flow meter: Qflow	(Cubic m/s)	3.650	3.628	2.705	1.981	1.395	0.794
4	Fluctuation of Qflow	Cubic m/s	less than 0.03	less than 0.03	less than 0.03	less than 0.03	less than 0.04	less than 0.04
5	No.2/ No.3		0.956	0.962	0.987	0.979	1.004	0.948

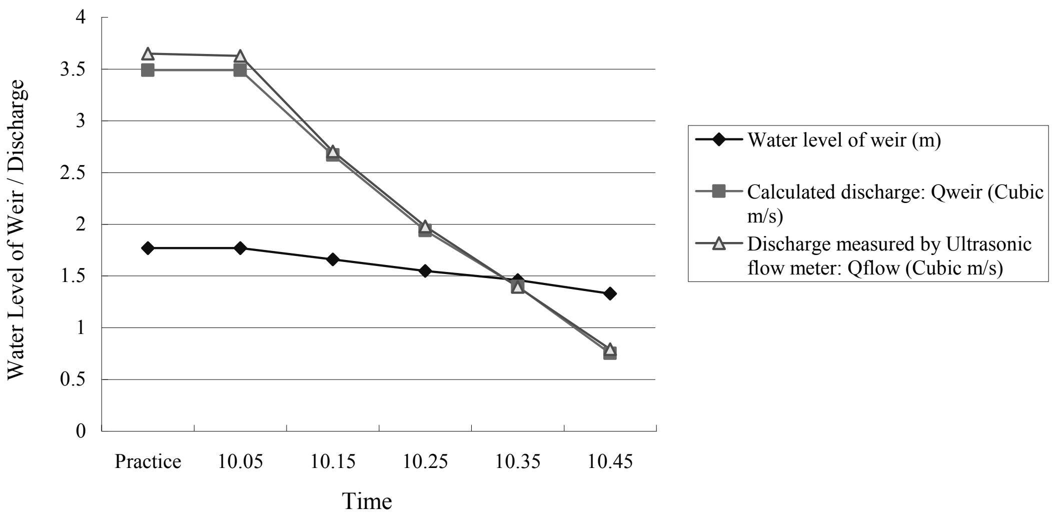


Figure 6 Calibration of Flow Measurement by Weir

4.3 Calibration of the Effective Head by a Pressure Transducer (HAENNI) provided by CEB

This was conducted at Unit 2 of Polpitiya H.P.S. 14 days after the efficiency test. Mahaweli Hydro Complex of CEB provided a calibrated pressure transducer.

The effective head, which is calculated from the measured water level, was compared with the values measured by the transducer

Measured effective head is expressed as follows.

Measured effective head = Htr +correction of head due to transducer location + (tailrace water level – turbine center level) + V^2 / 2 * g

Where,

Htr : Measured pressure by transducer (m)

Correction of head due to transducer location: 2.05 m (measured by a scale)

V : Velocity at the pressure tap location for transducer

g : Gravitational acceleration (m/s^2)

Tables 8 and 9 indicate the calibration results.

Tables 8 Outline of Discharge Measurement and Efficiency Evaluation (Head Calibration)

Item	Unit / Time	14.50	15.20	Remarks
Calculated Generator Output	MW	37.50	29.51	Watt hour meter
Effective Head	m	257.2	260.4	By water level
Measured Effective Head	m	258.4	261.3	By transducer

This comparison suggests that the simplified calculation by water level provides the effective head with a small error using the measured water levels and the calculated head loss of penstock.

Table 9 Discharge Measurement and Efficiency Evaluation (Head Calibration)

PS Name: Polpitiya　　　　Weather: Fair
Unit Number: 2
Survey date: 26th August 2004

Item		Unit	14:50	15:20	Remarks
Generator	Generator output	MW	37.7	30.3	Control room
	Generator reactive power	MVar	0.2	-0.1	Control room, 0MVar
	Time of 500 kWh	min sec	48	1 1	Cubicle
	Time of 1,000 kWh	min sec	1 38	2 2	Cubicle
	Calculated G. output	MW	37.50	29.51	
	Generator voltage	kV	12.0	12.0	Control room
	Generator current	A	1811	1448	Control room
	Field winding voltage	V	67	61	Control room
	Field winding current	A	699	642	Control room
	Power factor (p.f.)	%	100.0%	100.0%	
	Frequency	Hz	50.05	50.05	Control room
	Coil temperature	℃	66	66	Control room, Max
Unit1	Generator output	MW	5.4	5.6	
Turbine	Rotational speed	min^{-1}	499	499	Control room
	Wicket gate opening at Meter	%	72%	58%	Servomotor stroke
	Wicket gate opening at Gov.	mm	217	197	Servomotor stroke(0MW, 102 mm)
	Vibration	1/100mm	5	5	
Head	Water level of Intake	ft inch	9 9	8 6	Headrace
	Water level of surge chamber	ft inch	173 8	168 0	Surge chamber
	Water level of tailrace (weir)	m	1.51	1.64	Tailrace (The width is 22ft)
	Penstock pressure gauge	Bar	25.5	26.0	Penstock pressure
	Pressure head	Bar	24.96	25.44	Transducer
Calculated Head	Water level of intake	EL..m	379.4	379.78	1254.5 ft
	Water level of surge chamber	EL..m	372.26	373.99	1395 ft
	Water level of discharge	EL..m	111.268	111.138	370 ft
	Pipe loss	m	3.78	2.39	
	Velocity head	m	-	-	-
	Goss head	m	260.99	262.85	Surge Chamber El.- Tailrace El.
	Temporary effective head	m	257.25	260.42	Value of Pipe loss based on 12th data
	Discharge based on 12th data	m^3/s	17.20	13.68	
	Effective head	m	257.21	260.46	
	Measured head	m	258.47	261.30	By transducer measurement
Difference between E. head and M. head					
	Difference head	m	-1.26	-0.84	
	Difference rate	%	-0.5%	-0.3%	

4.4 Correlations between Servomotor Stroke, Generator Output and Turbine Discharge

Figure 7 shows the generator output versus needle servomotor stroke relevant to Unit 2 test results for New Laxapana H.P.S. on 18th Aug. 2004, and Unit 1 data indicated in the installation report on 20th Mar. 1974. Figure 8 indicates the discharge versus generator output.

A good coincidence is observed, suggesting the following:

1) Turbine performance and generator performance of Unit 2 of New Laxapana H.P.S. maintain their original level. This substantiates the good runner condition without harmful cavitation erosion.

2) Discharge measurement in 1974 appears to have been implemented by the weir installed at the tailrace channel. The good coincidence means that the function and performance of the needle and nozzle are maintained in the original conditions.

In addition, the measurement by the Portable ultrasonic flow meter is sufficiently accurate.

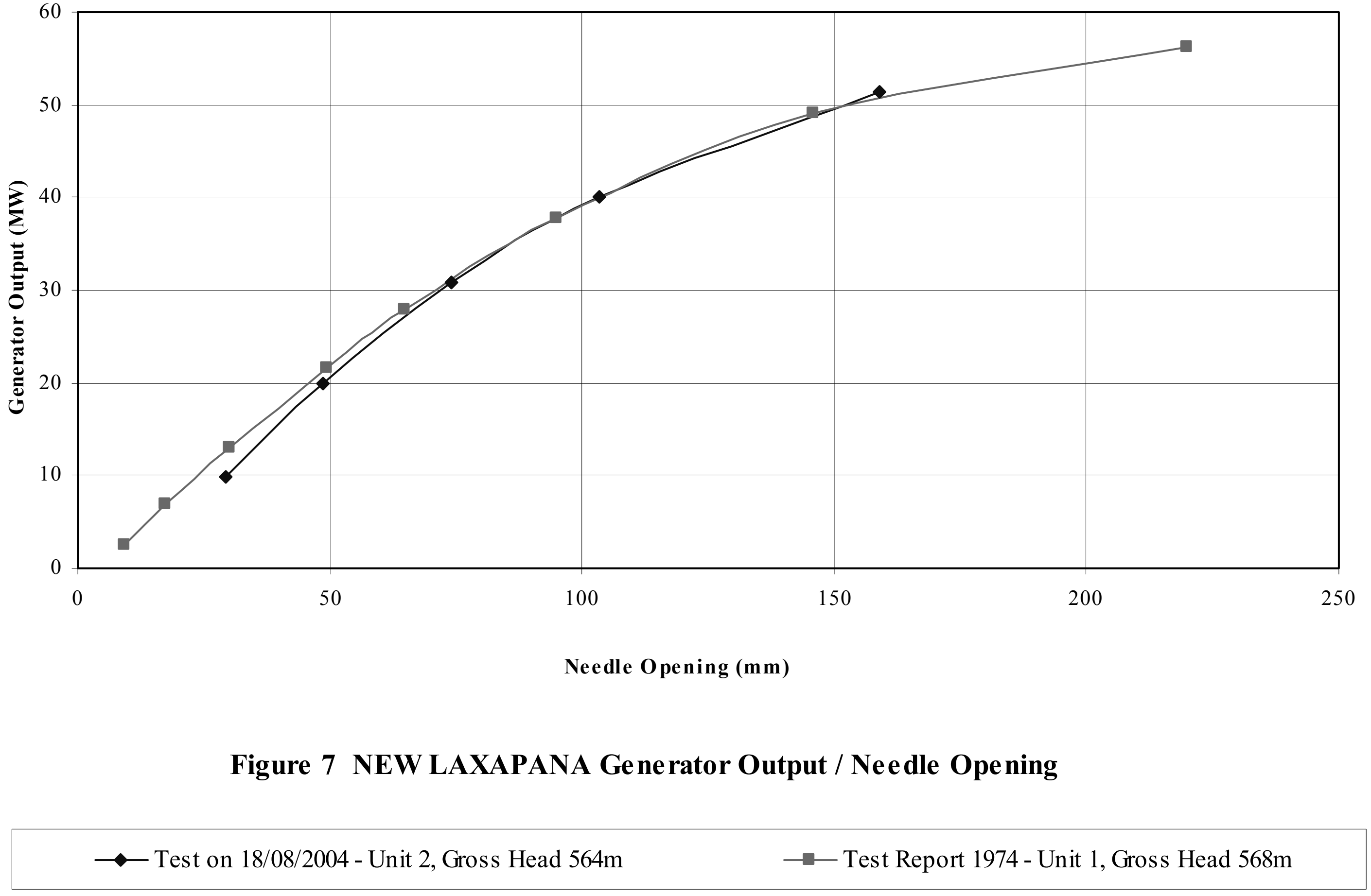


Figure 7 NEW LAXAPANA Generator Output / Needle Opening

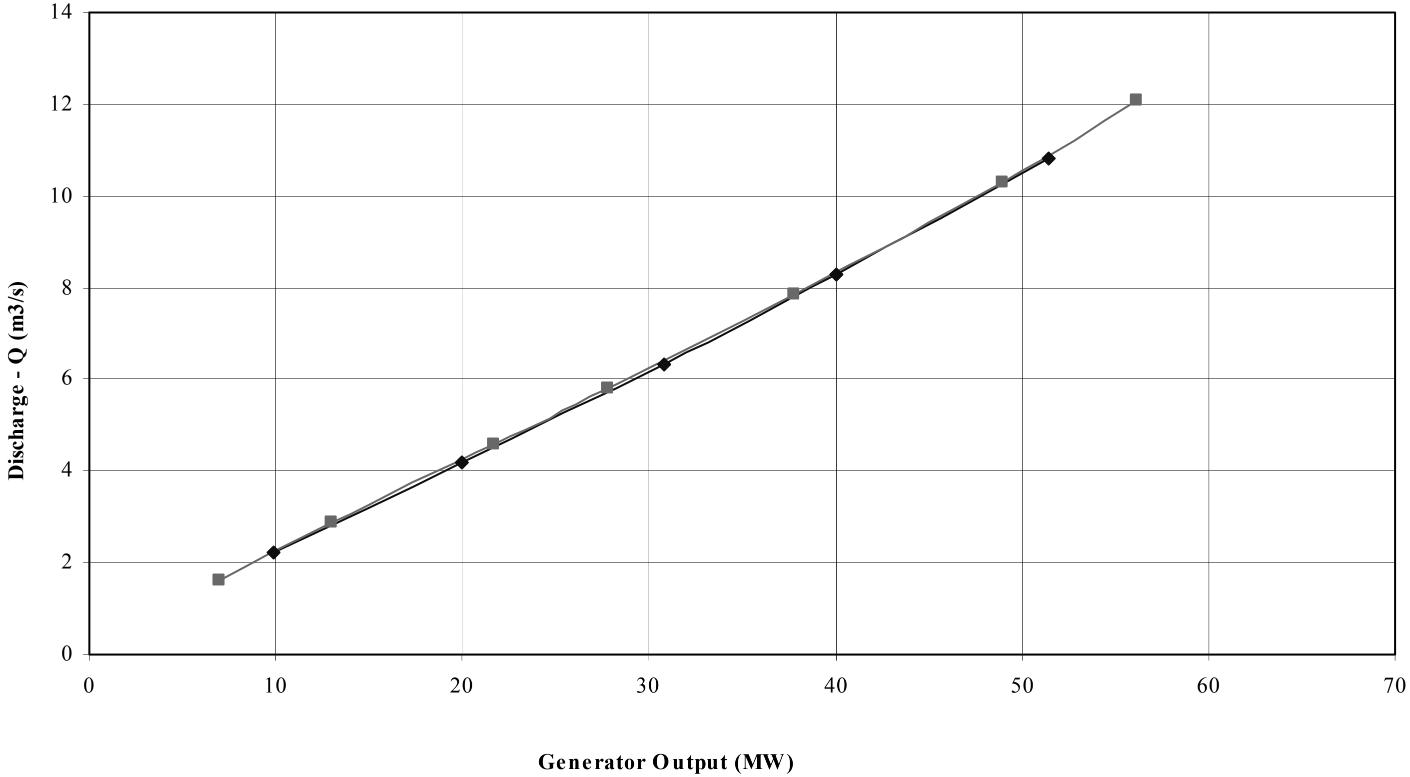


Figure 8 NEW LAXAPANA Discharge / Generator Output

5. CONCLUSION

5.1 Based on the calibrations described above, the simplified efficiency test using a Portable ultrasonic flow meter is a reliable method to estimate turbine performance at Old Laxapana H.P.S., Polpitiya H.P.S. and New Laxapana H.P.S.

5.2 The application of the simplified efficiency test using a Portable ultrasonic flow meter is very useful for estimation and planning of the rehabilitation.

5.3 The measured turbine efficiency includes a ±4.6% inaccuracy margin. However, it should be taken into consideration that the measured efficiency of Unit 2 at New Laxapana H.P.S. is slightly higher than the guaranteed value, while the turbine discharge is precisely measured.

Consequently, relevant to the economic analysis, it is appropriate to adopt the measured efficiency itself without applying the upper or lower limits of inaccuracy.

APPENDIX C-2
STUDIES ON THE UNIT SPECIFICATIONS
AND
EFFICIENCY IMPROVEMENTS

"Loss Heads, Water Levels of Surge Chamber, Net Heads, Unit Specifications and Efficiencies Relevant to Rehabilitation Plans on Old Laxapana Stage I (Unit Capacity of 9 MW for 3 units) and Polpitiya (Unit Capacity of 40 MW for 2 units) Power Stations "

1. SPECIFICATIONS FOR RESERVOIR (POND), HEADRACE TUNNEL, SURGE CHAMBER, PENSTOCK AND TAILRACE

Table 1 shows the major specifications for the reservoir (pond), headrace tunnel, surge chamber, penstock and tailrace for each power station.

Length and diameter are obtained from existing drawings. The diameter of the headrace tunnel is the equivalent diameter corresponding to each sectional area.

2. ANALYSIS OF LOSS HEAD OF OLD LAXAPANA H.P.S.

Figure 1 shows the schematic diagram of waterways for Old Laxapana H.P.S.

Table 2 shows the analysis of loss head of Old Laxapana H.P.S. The calculated loss head using the "Mott MacDonald Report" and the measured values subject to the Simplified Efficiency Test are compared relevant to the headrace tunnel.

Penstock loss head is calculated using the formula in "Mott MacDonald Report" issued on Nov. 1999.

Table 3 shows the calculated Manning's roughness coefficient corresponding to the measured loss head of the headrace tunnel.

3. ANALYSIS OF LOSS HEAD OF POLPITIYA H.P.S.

Table 4 shows the analysis of loss head of Polpitiya H.P.S. The measured loss head subject to the simplified efficiency test and the calculated values for smaller discharge are compared relevant to the headrace tunnel.

Table 5 shows the calculated Manning's roughness coefficient corresponding to the measured loss head of the headrace tunnel.

Table 6 shows the calculated loss head of penstock using Manning's roughness coefficient of 0.012.

4. WATER LEVEL OF SURGE CHAMBER AND CEILING LEVEL OF PENSTOCK INLET

Table 7 shows the relation between the water level of surge chamber and the ceiling level of the penstock inlet relevant to Old Laxapana and Polpitiya Power Stations.

The table suggests the possibility of air suction into the penstock in Old Laxapana Power Station under the lower water level of the intake.

It is informed that a bursting sound was heard when a unit was quickly stopped in the previous operation. CEB is interested in the surge chamber vortex and air suction.

Under this circumstance, it is recommended to investigate following subjects immediately.

1) To confirm the operation data when the bursting sound was heard. (Intake water level, generator output of each unit to estimate the total discharge)

2) To observe the vortex building in the surge chamber to confirm under what operating conditions it is occurred. It is important to verify the lowest water level of the intake to permit turbine operation without harmful air suction.

3) To confirm the design history of the headrace tunnel on the Stage II (Expansion Unit 4 and 5). The headrace tunnel capacity and the penstock inlet elevation seem to be the problem.

4) To plan the preferable operating conditions of Units 1 to 5.

The air suction into the penstock is not reported for Polpitiya Power Station.

5. STUDIES ON THE UNIT SPECIFICATIONS

5.1 Old Laxapana Stage I H.P.S. (Units 1 to 3)

5.1.1 Existing Surge Chamber Capacity and Total Discharge

Table 8 shows the outputs and discharges of the existing units at the design stage, which are assumed in the “Mott MacDonald Report”, as well as the values measured in the Simplified Efficiency Test on Aug. 6, 2004. The total discharge is assumed to be 13.4 m^3/s with a total output of 50.03 MW at the design stage. Currently, it has been measured at 14.54 m^3/s with 48.79 MW. If the output of Unit 1 is assumed to be 8.0 MW in lieu of measured 7.6 MW, the total discharge may be 14.64 m^3/s with 49.19 MW, which are assumed to be the maximum discharge and output of the power station. The turbine discharge is increased due to the turbine performance deterioration.

Meanwhile, the history and criteria on the detailed design of the surge chamber, headrace tunnel and penstocks are not clear at present. However, it is reported that a bursting sound was observed at the unit shutdown. Table 7 suggests the possibility of air suction into the penstock under the lower water level of the intake reservoir. Consequently, it is estimated that some discharge limitation may exist on the existing waterway configuration.

Under these circumstances, it is necessary that the turbine specifications will not influence the existing civil specifications such as surge chamber height and diameter. Therefore, the total discharge shall be less than 14.64 m^3/s.

5.1.2 Hydraulic Transients and Water Elevation of Surge Chamber: “Studies based on the Site Measurement and the Calculation Code of JPOWER”

(1) Hydraulic Transients and Water Elevation of Surge Chamber

The hydraulic transients of Old Laxapana Power Station were studied in “The Mott MacDonald Report” entitled “Old Laxapana Power Station Uprating Study” issued in November 1999. The report illustrates the calculated example relevant to the needle valve closure, water elevation of surge chamber and static pressure head after full load rejection, with the total discharge Q of 17.0 m^3/s. 17.0 m^3/s was studied aiming at the up-rating of existing units in lieu of the assumed design discharge of 13.4 m^3/s.

Meanwhile, JPOWER has its own calculation code for hydraulic transients. It is applied to many existing hydropower stations and its accuracy is verified.

Table 9 shows hydraulic transients in the following typical cases of operation.

1) Existing assumed design Q of 13.4 m^3/s and Uprating study Q of 17.0 m^3/s in the "Mott MacDonald Report" entitled "Old Laxapana Power Station Uprating Study".

2) Q of 6.51 m^3/s and Q of 14.54 m^3/s from the flow measurement implemented on August 4 and 6, 2004, respectively, with reference to the Simplified Efficiency Tests.

3) Q of 15.1 m^3/s when the total assumed capacity of the rehabilitated units is 30 MW, and the existing Units 4 to 5 are utilized without modification.

4) Q of 14.64 m^3/s corresponding to the maximum discharge at present, assuming the existing Unit 1 discharge to be 2.46 m^3/s with the generator output of 8.0 MW in lieu of 7.6 MW.

5) Q of 14.32 m^3/s when the total assumed capacity of the rehabilitated units is 27 MW, and the existing Units 4 and 5 are utilized without modification.

(2) Air Suction into the Penstock and its Countermeasure

There is the possibility of air suction into the penstock in the following operations.

1) Steady state operation with the total assumed capacity of the rehabilitated units of 30 MW and existing Unit 4 to 5 with Q of 15.1 m^3/s and full load, when the water level of Norton Pond is at a minimum of 860.75 m as shown in item 3 Hydraulic Transients on Table 9.

2) In addition, steady state operation of 5 existing units with Q of 14.54 m^3/s and full load, when the water level of Norton Pond is at a minimum of 860.75 m as shown in Table 7.

3) Rapid load increase of remaining units when some units are operated under the lower water level conditions of the upper reservoir.

Under these conditions, the operation restriction on full load is recommended to avoid air suction into the penstock under the lower water level of the upper reservoir.

Details on surging calculation are described in the study of civil structures (Refer to Chapter 5.7). It is reported that a flashboard 1.5 m in height may be installed at the Norton Pond dam in the future. If the operation region is shifted to the higher water level of Norton Pond avoiding its lower water level, air suction will be improved. However, it seems to take a long time to apply this countermeasure due to the difficulties posed by the Environmental Compliance Certificate.

5.1.3 Net Head and the Specifications of Rehabilitated Unit

(1) Net Head

Table 10 shows the net head of the rehabilitated unit of Old Laxapana Stage I H.P.S. (Units 1 to 3). The rated output of each turbine is assumed to be 9,250 kW.

According to the calculation results in Table 10, it seems the rated net head of 453 m can be obtained. However, these results are obtained from only one measurement of the headrace tunnel loss head as well as the calculated penstock loss head. Additional measurements are preferable. Consequently, the rated net head is assumed to be 499 m, similar to that of the existing units in consideration of a net head margin.

(2) Specifications of the Unit: Comparison between Plans for the 3 Units of 9 MW and 2 Units of 13.5 MW

1) Comparison of Plans with respect to Unit Capacity and Quantities

The maximum unit output of the existing turbines of Stage I (Unit 1 to 3) is 8.33 MW. It is desirable to increase the unit output to take charge of the peak power demand as practically as possible.

Three (3) units of 9 MW plan and two (2) units of 13.5 MW plan are studied with respect to a couple of evaluation factors. Table 11 shows the comparison of the plans as well as existing specifications.

Factors to be studied include the dimensions of the generation units (Turbine and Generator), the span distance between units, layouts, foundations, penstocks, branches, penstock gate valves, tailrace channels, hydraulic transients, construction procedure and outage time, as well as rehabilitation cost.

Table 12 shows the major dimensions of each plan.

Figure 2 shows the drawing (2 main bearings) with the dimensions corresponding to A to K in Table 12 with respect to the 9 MW Unit.

Figure 3 shows the drawing (3 main bearings) with the dimensions corresponding to A to K in Table 12 with respect to the 13.5 MW Unit.

2) Evaluation of Unit Capacity and Quantity

The 9 MW plan can utilize the existing foundations with less modification. Relocation of foundations and associated excavations for the 13.5 MW machine seems to be very difficult due to the lack of existing drawings regarding layout, foundation and reinforcement. Therefore, the 13.5 MW plan requires considerable modification for the foundations of the existing Unit 1 and 3 due to the larger axial machine dimensions than the existing span of 9,800 mm. According to the recent generator design, the total axial length (Dimension J in Table 12) is estimated to be 10,200 mm for the 13.5 MW plan.

With respect to each plan including the existing units, there remains the problem of air suction into penstocks under the lower water level of the upper reservoir due to the lack of surge chamber capacity and the improper elevation of the penstock inlet. It is necessary to avoid the full load operation under lower water level conditions of the upper reservoir.

Therefore, it is preferable not to utilize a discharge larger than that of the existing units, i.e. 14.64 m^3/s.

3) Conclusion

Consequently, it is recommended to adopt the 3-units plan with the unit capacity of 9 MW utilizing the existing foundations.

Tables 13 and 14 indicate the specifications for the rehabilitated turbine and generator, respectively.

Figure 4 shows the correlation between the generator output and turbine efficiency for the existing unit (8 MW) and the rehabilitated one (9 MW).

5.2 Polpitiya H.P.S.

5.2.1 Effective Head and Specifications of Rehabilitated Unit

(1) Net Head

Table 10 shows the net head of Polpitiya H.P.S. The rated capacity of the turbine is assumed to be 40,000 kW.

According to the calculation results in Table 10, it is difficult to adopt 269 m rated net head at the installation stage due to the large loss head of the headrace tunnel.

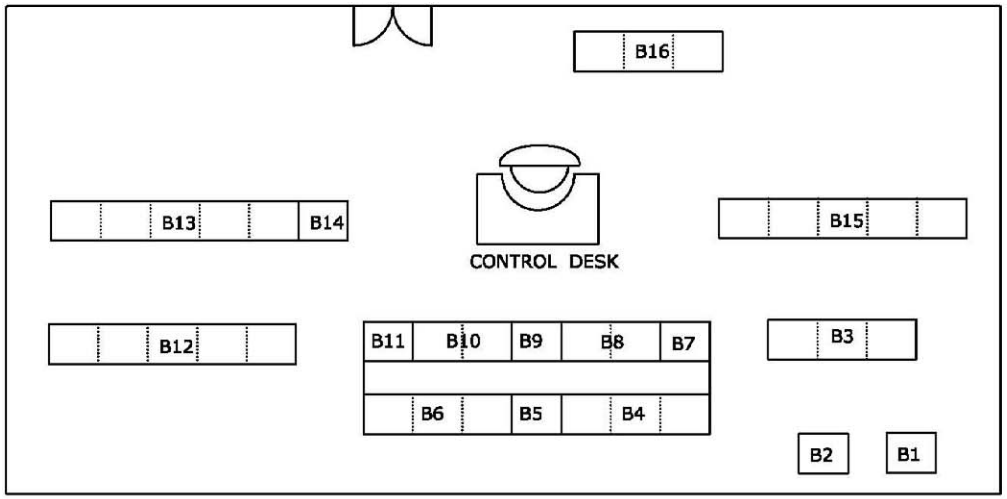
Therefore, the rated net head selected is 250 m.

(2) Specifications of the Rehabilitated Turbine

Table 15 indicates the rehabilitated turbine specifications. Figure 5 shows the correlation between the generator output and turbine efficiency for the existing unit and the rehabilitated one for Polpitiya H.P.S.

APPENDIX C-3
CONTROL / PROTECTION EQUIPMENT
LIST OF CONTROL ROOM LAYOUT
(with Picture)

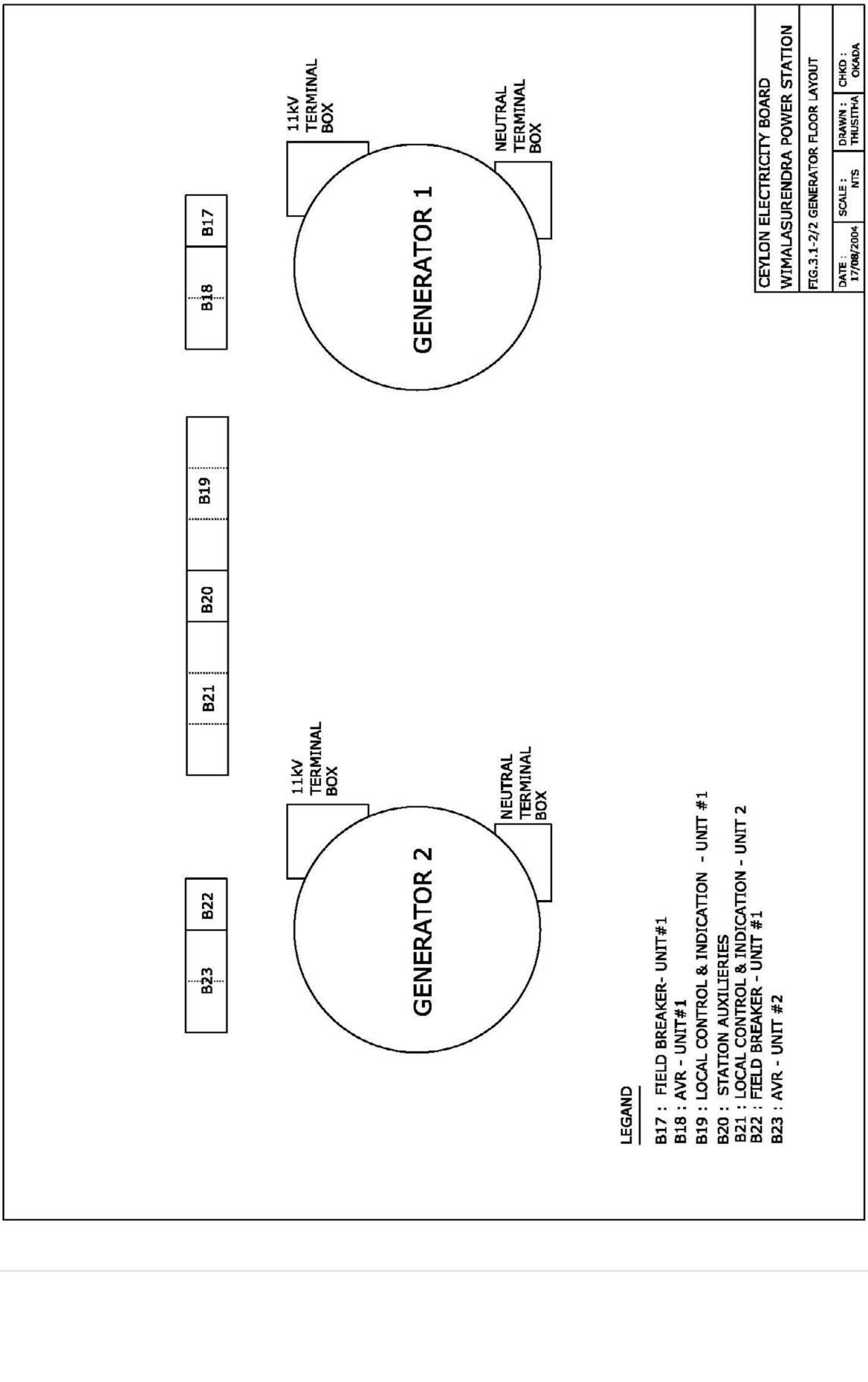
1. Wimalasurendra Power Station



LEGAND

B1 : RECTIFIER FOR CONTROL
B2 : RECTIFIER FOR POWER
B3 : DC AUXILERIES
B4 : GEN-TRF #1 CONTROL & PROTECTION
B5 : AUXILIERIES
B6 : GEN-TRF #2 CONTROL & PROTECTION
B7 : SYNCHRONIZATION
B8 : GEN -TRF #1 CONTROL
B9 : AC AUXILIERIES
B10 : GEN-TRF #2 CONTROL
B11 : DC AUXILIERIES
B12 : AUXILIERY BOARD #3
B13 : AUXILIERY BOARD #2
B14 : WPS-LAXAPANA TIE LINE
B15 : AUXILIERY BOARD #1
B16 : COMMUNICATION

CEYLON ELECTRICITY BOARD			
WIMALASURENDRA POWER STATION			
FIG. 3.1-1/2 MAIN CONTROL ROOM LAYOUT			
DATE : 17/08/2004	SCALE : NTS	DRAWN : THUSITHA	CHKD : OKADA

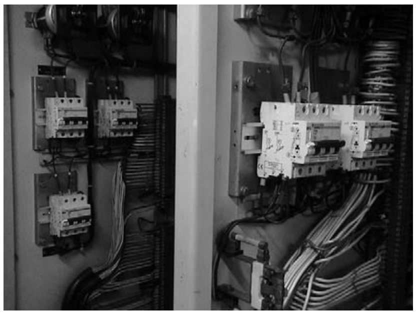

CEYLON ELECTRICITY BOARD
WIMALASURENDRA POWER STATION
FIG.3.1-2/2 GENERATOR FLOOR LAYOUT
DATE : 17/08/2004
SCALE : NTS
DRAWN : THUSITHA
CHKD : OKADA
GENERATOR 1
GENERATOR 2
11kV TERMINAL BOX
NEUTRAL TERMINAL BOX
11kV TERMINAL BOX
NEUTRAL TERMINAL BOX
B17
B18
B19
B20
B21
B22
B23
LEGAND
B17 : FIELD BREAKER- UNIT#1
B18 : AVR - UNIT#1
B19 : LOCAL CONTROL & INDICATION - UNIT #1
B20 : STATION AUXILIERIES
B21 : LOCAL CONTROL & INDICATION - UNIT 2
B22 : FIELD BREAKER - UNIT #1
B23 : AVR - UNIT #2

Picture 3.2 Control / Protection Equipment Board

Main Control Board and Control Desk

Inside of Main Control & Protection Relay Board

Protection Relay of Electromagnetic Type



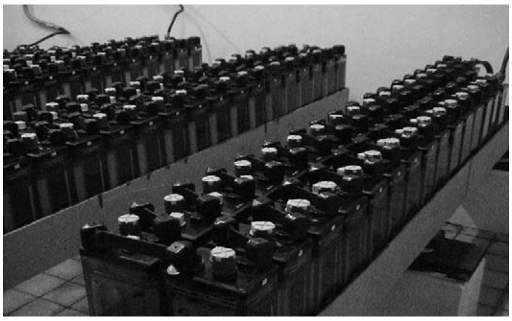
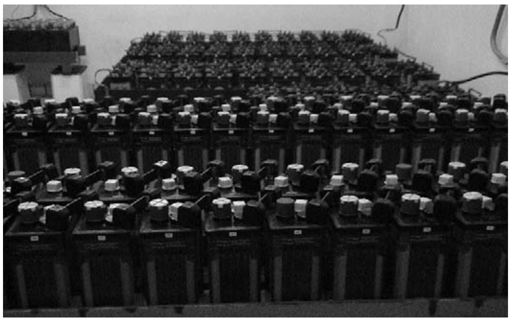
Auxiliary Relay in Board

Renewed No Fuse Switch

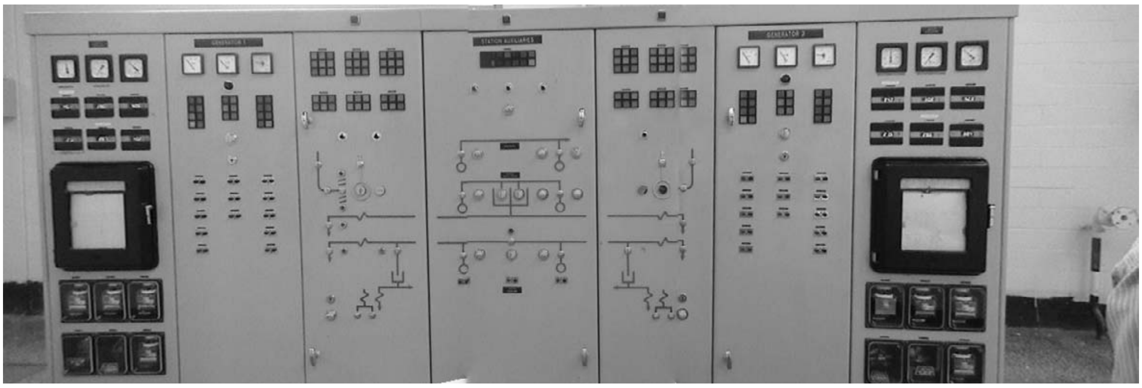
Motor Control Centers for Unit 1 & 2

Battery Charger

DC Auxiliary Board

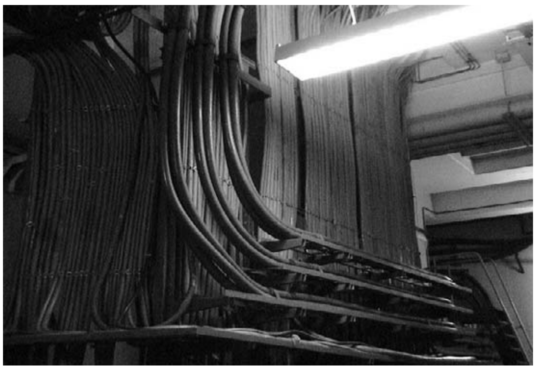
Battery of Control & Communication Systems



Local Control Board of Unit 1 (left) & 2 (right) and Station Auxiliary Board (center)

Excitation Equipment Board

Governor Control Board



Control and Power Cables

Generator and Excitation Cubicles (left side)

3.3 kV Switchgear & Distribution Line Control and Protection Relay Boards

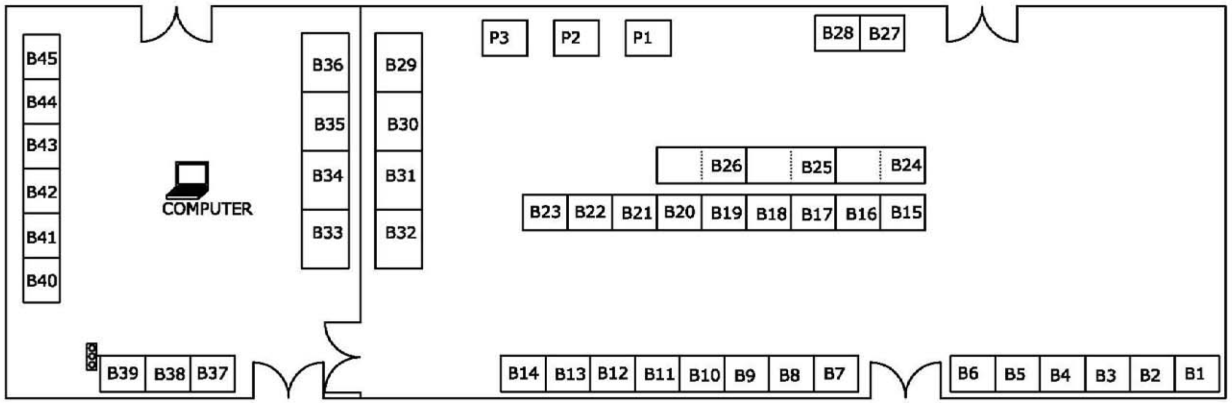
3.3 kV Switchgear & Distribution Line Control Boards

3.3 kV Switchgear & Distribution Line

Battery Charger Cubicle

DC Distribution Cubicle

2. Old Laxapana Power Station



LEGAND

B1 : OUTGOING TO AUX. TRF #2
B2 : OUTGOING TO MAIN. TRF #2
B3 : OUTGOING TO AUX. TRF #1
B4 : GENERATOR #1 INCOMING
B5 : GENERATOR #2 INCOMING
B6 : GENERATOR #3 INCOMING
B7 : INCOMING FROM AUX.TRF #1
B8 : INCOMING FROM AUX.TRF #2
B9 : UNIT#1
B10 : UNIT #2
B11 : UNIT #3
B12 : GENERAL

B13 : GENERAL
B14 : INCOMING FROM DIESEL GEN.
B15 : FIELD BREAKER - UNIT#1
B16 : CONVERTOR - UNIT #1
B17 : VOLTAGE REGULATOR- UNIT#1
B18 : FIELD BREAKER - UNIT#2
B19 : CONVERTOR - UNIT #2
B20 : VOLTAGE REGULATOR- UNIT#2
B21 : FIELD BREAKER - UNIT#3
B22 : CONVERTOR - UNIT #3
B23 : VOLTAGE REGULATOR- UNIT#3
B24 : DC MAIN DB#1

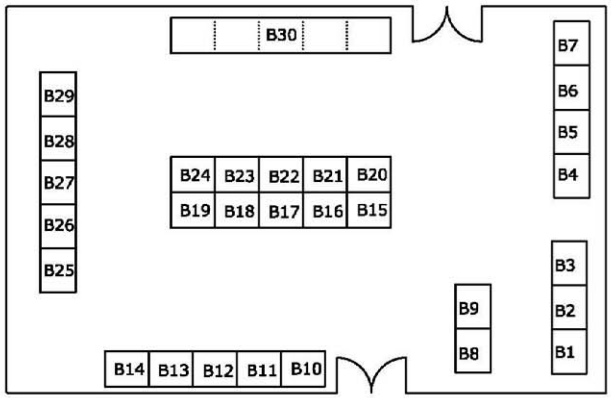
B25 : DC MAIN DB #2
B26 : DC COMMON
B27 : BATTERY CHARGER #1
B28 : BATTERY CHARGER #2
P1 : PANEL FOR MOTORS
P2 : DC/AC INVERTER PANEL
P3 : DISTR. PANEL FOR INVERTER
B29 : DC DISTRIBUTION
B30 : GOVERNOR - UNIT#3
B31 : GOVERNOR UNIT#2
B32 : GOVERNOR UNIT#1
B33 : STATION COMPUTER

B34 : GENERAL CONTROL
B35 : GENERAL CONTROL
B36 : 11/132 KV RELAY PROTECTION
B37 : RELAY PROTECTION -UNIT #3
B38 : AUX.RELAY-UNIT#3
B39 : CONTROL -UNIT #3
B40 : RELAY PROTECTION -UNIT #2
B41 : AUX.RELAY-UNIT#2
B42 : CONTROL -UNIT #2
B43 : RELAY PROTECTION -UNIT #1
B44 : AUX.RELAY-UNIT#1
B45 : CONTROL -UNIT #1

CEYLON ELECTRICITY BOARD
OLD LAXAPANA POWER STATION

FIG.3.3-1/2 CONTROL ROOM LAYOUT - STAGE 1

DATE :	SCALE :	DRAWN :	CHKD :
17/08/2004	NTS	THUSITHA	OKADA



LEGAND

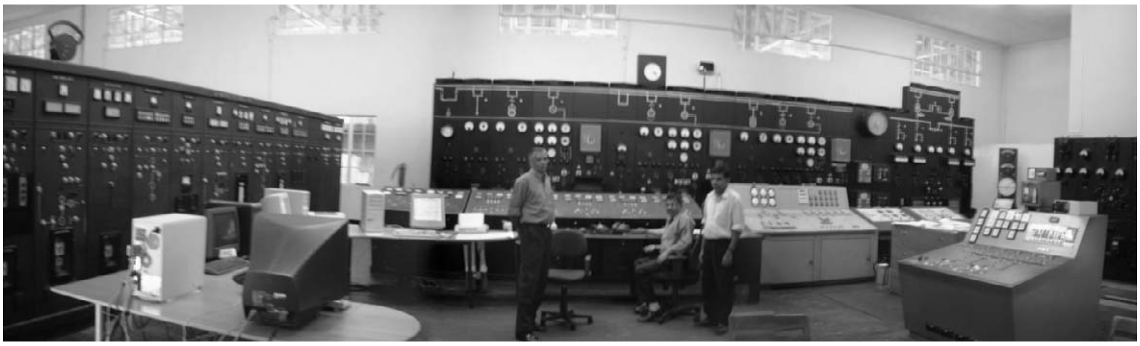
B1 : FIELD BREAKER- UNIT 5
B2 : CONVERTER- UNIT 5
B3 : REGULATOR- UNIT5
B4 : STEP-UP TRF.#2
B5 : GENERATOR BREAKER #2
B6 : STEP-UP TRF. #1
B7 : GENERATOR BREAKER #1
B8 : FAULT RECORDER
B9 : FAULT RECORDER
B10 : 230V INVERTER

B11 : DC FUSES FOR CONTROL & PROTECTION
B12 : REGULATOR- UNIT #4
B13 : CONVERTER- UNIT #4
B14 : FIELD BREAKER- UNIT #4
B15 : TURBINE GOVERNOR- UNIT#5
B16 : CONTROL- UNIT #5
B17 : AUX. RELAYS- UNIT#5
B18 : GEN. & GEN.TRF PROTECTION- UNIT #5
B19 : GEN. & GEN.TRF PROTECTION- UNIT #5
B20 : GEN. & GEN.TRF PROTECTION- UNIT #4

B21 : GEN. & GEN.TRF PROTECTION- UNIT #4
B22 : AUX. RELAYS - UNIT#4
B23 : CONTROL- UNIT#4
B24 : TURBINE GOVERNOR- UNIT#4
B25 : NUWARAELIYA LINE 1 & 2
B26 : NEW LAXAPANA LINE 1 & 2
B27 : POLPITIYA LINE 1 & 2
B28 : WIMALASURENDRA LINE 1& 2
B29 : BUS COUPLER FOR STATION TRF.
B30 : 132 kV SWITCHGEAR CONTROL

CEYLON ELECTRICITY BOARD			
OLD LAXAPANA POWER STATION			
FIG.3.3-2/2 CONTROL ROOM LAYOUT - STAGE 2			
DATE : 17/08/2004	SCALE : NTS	DRAWN : THUSITHA	CHKD : OKADA

Picture 3.4 Control / Protection Equipment Board



Computer control with CRT shown on left side and
Remote control desk for New-Laxapana PS (right side)
(Old control boards <black color>)

Computer control with CRT
(Old boards <black color>)

New Control Boards of Units 1 & 2 renewed by 2003

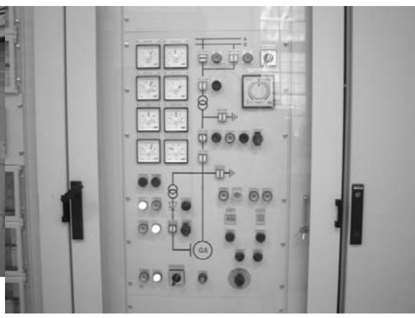
Control & protection relay boards of transmission line

CB of GEN & Tr.

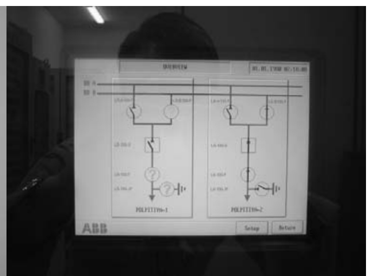
Aux. relay boards

Ex. Cub

Line flout locator

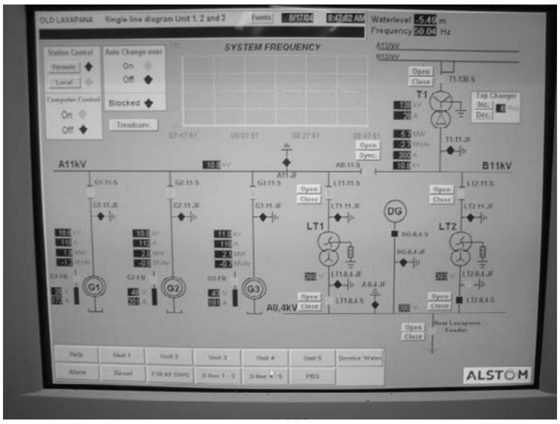


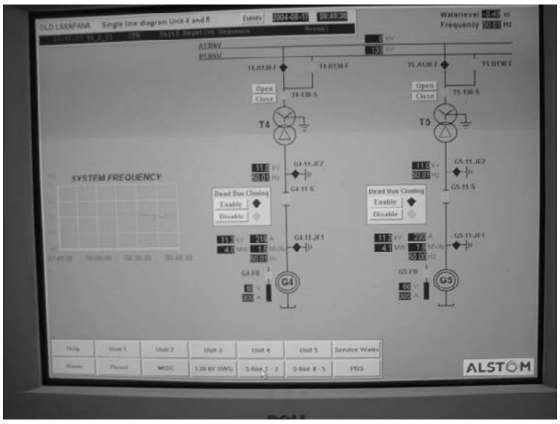
Local control board



Local touch panel of T/L

CRT





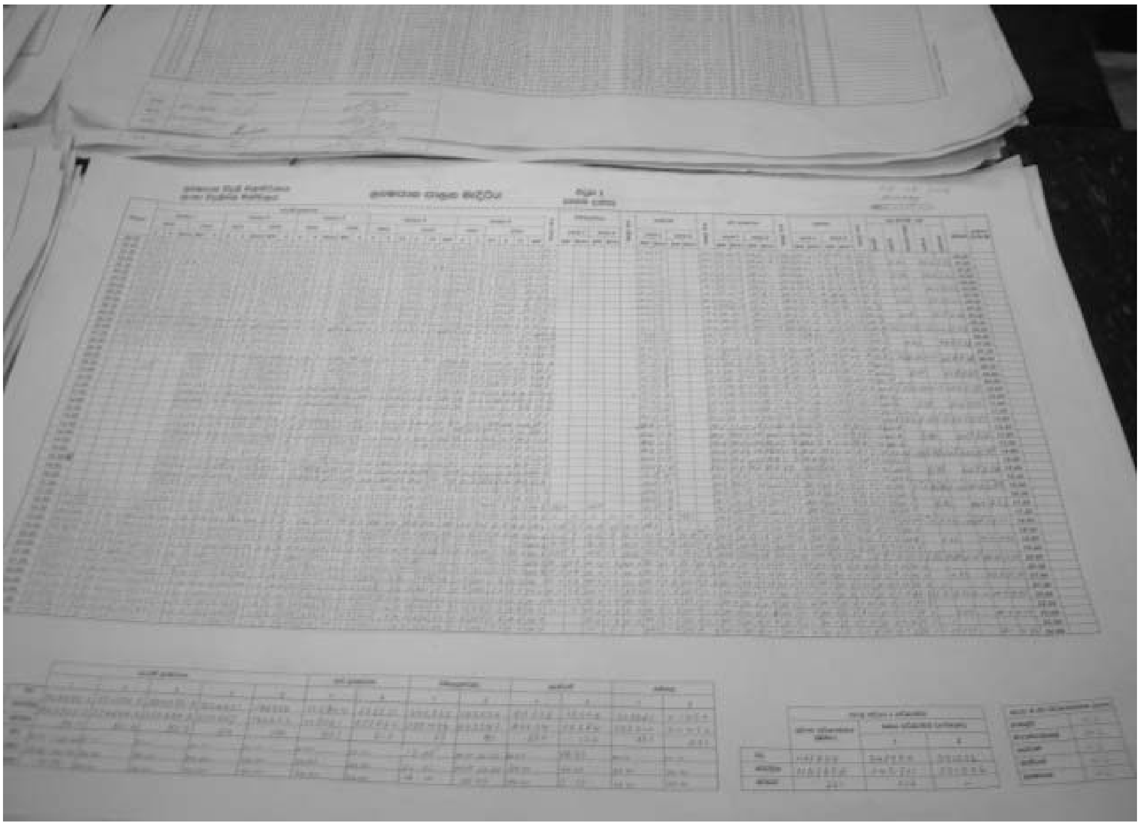
(diagram shown on units 1 to 3 & station service circuit and units 4 & 5)

Battery (48VDC) of communication system

Battery (110VDC) of control system

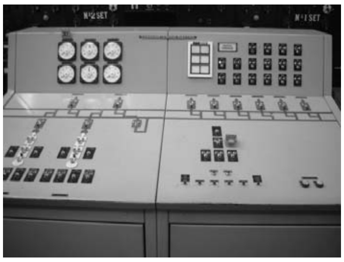
Control cables in cable treating room

Control cable arrangement under floor of turbine-generator



Operating record of Turbine-generator and Aux. Equipment

Communication Boards and it’s its battery charger



Old remote control desks installed in Old Laxapana control room

for Wimalasurendra PS for Polpitiya PS for Canyon PS