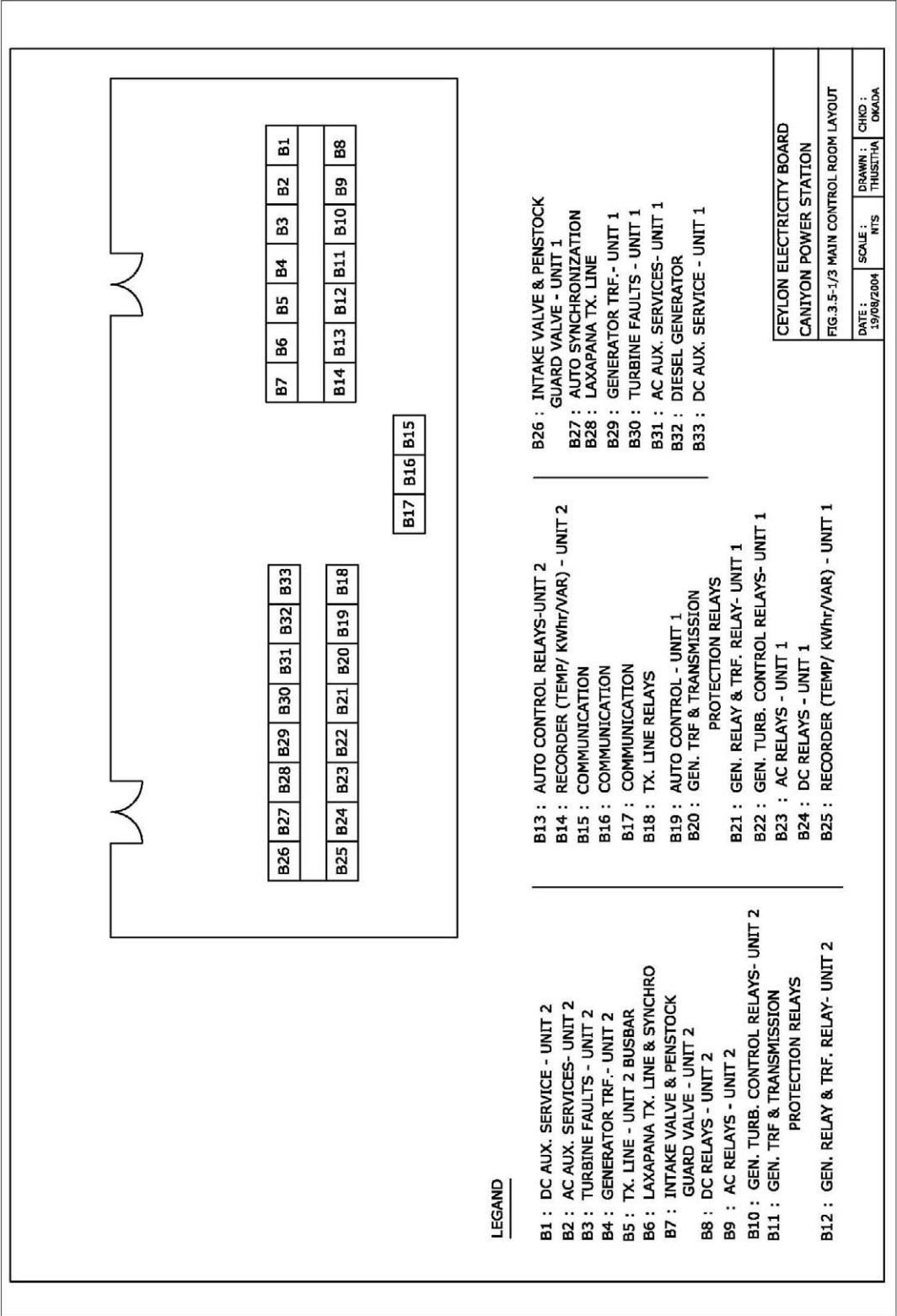


### ***3. Canyon Power Station***



**LEGEND**

- B1 : DC AUX. SERVICE - UNIT 2
- B2 : AC AUX. SERVICES- UNIT 2
- B3 : TURBINE FAULTS - UNIT 2
- B4 : GENERATOR TRF.- UNIT 2
- B5 : TX. LINE - UNIT 2 BUSBAR
- B6 : LAXAPANA TX. LINE & SYNCHRO
- B7 : INTAKE VALVE & PENSTOCK  
GUARD VALVE - UNIT 2
- B8 : DC RELAYS - UNIT 2
- B9 : AC RELAYS - UNIT 2
- B10 : GEN. TURB. CONTROL RELAYS- UNIT 2
- B11 : GEN. TRF & TRANSMISSION  
PROTECTION RELAYS
- B12 : GEN. RELAY & TRF. RELAY- UNIT 2

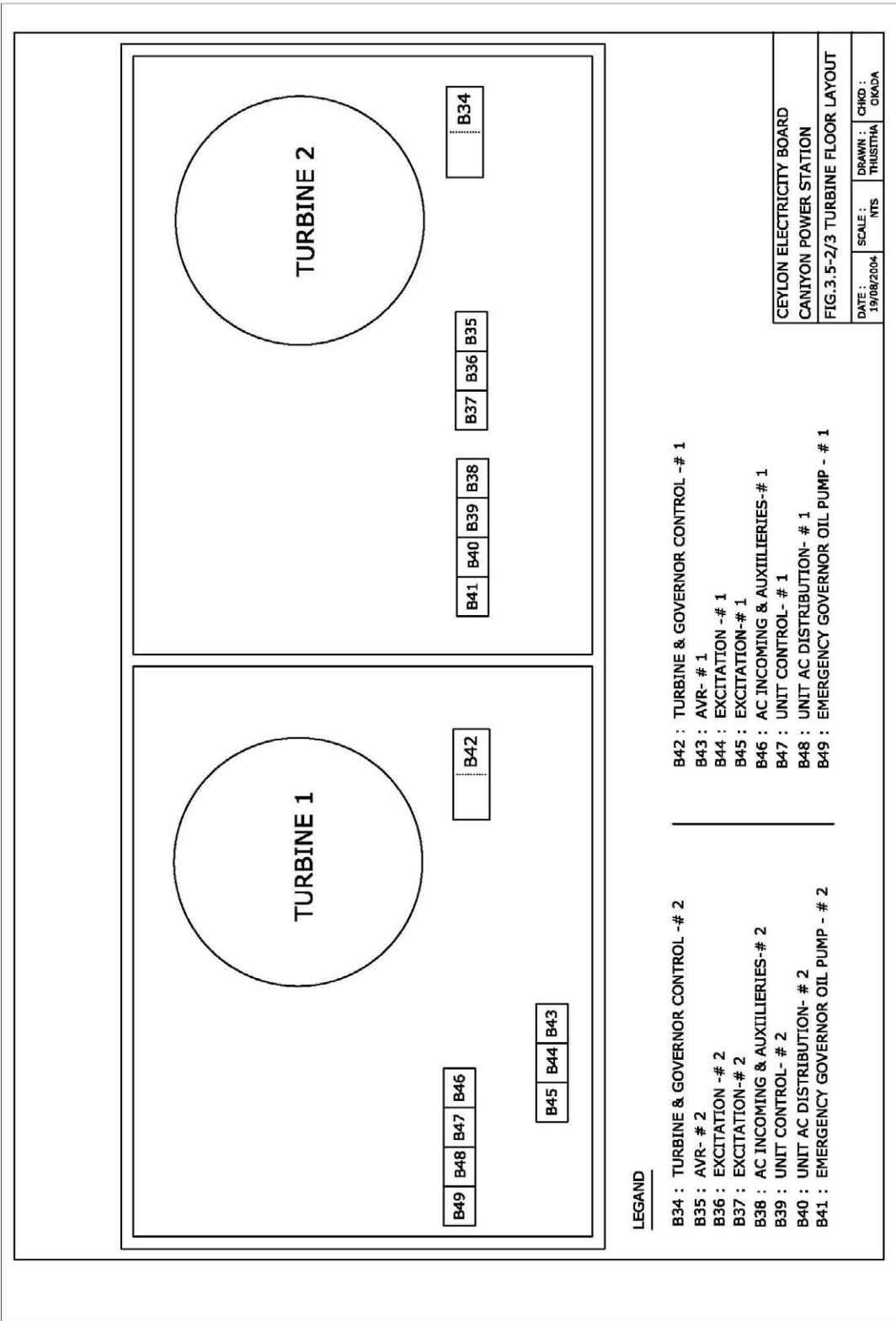
- B13 : AUTO CONTROL RELAYS-UNIT 2
- B14 : RECORDER (TEMP/ KWhr/VAR) - UNIT 2
- B15 : COMMUNICATION
- B16 : COMMUNICATION
- B17 : COMMUNICATION
- B18 : TX. LINE RELAYS
- B19 : AUTO CONTROL - UNIT 1
- B20 : GEN. TRF & TRANSMISSION  
PROTECTION RELAYS
- B21 : GEN. RELAY & TRF. RELAY- UNIT 1
- B22 : GEN. TURB. CONTROL RELAYS- UNIT 1
- B23 : AC RELAYS - UNIT 1
- B24 : DC RELAYS - UNIT 1
- B25 : RECORDER (TEMP/ KWhr/VAR) - UNIT 1

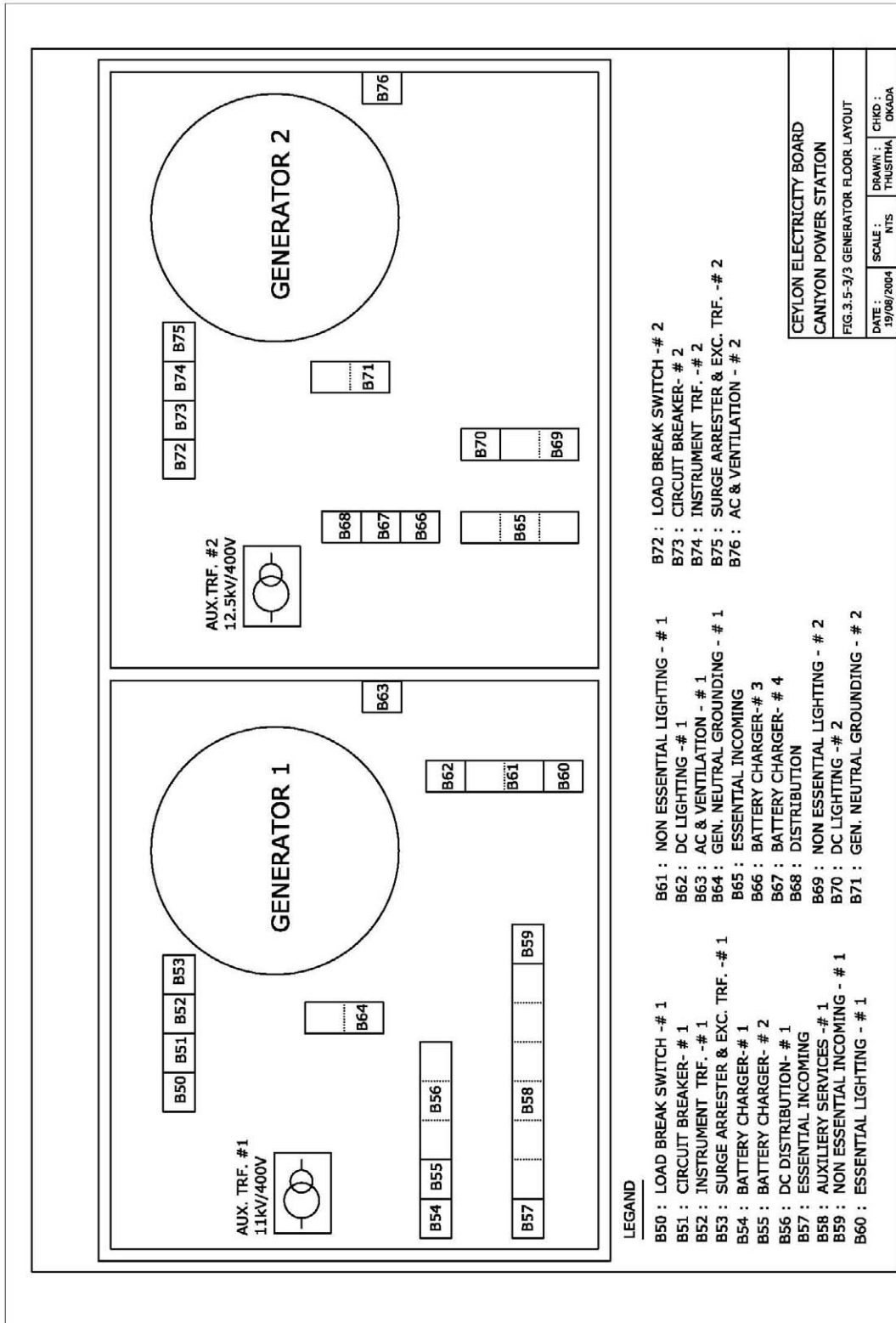
- B26 : INTAKE VALVE & PENSTOCK  
GUARD VALVE - UNIT 1
- B27 : AUTO SYNCHRONIZATION
- B28 : LAXAPANA TX. LINE
- B29 : GENERATOR TRF.- UNIT 1
- B30 : TURBINE FAULTS - UNIT 1
- B31 : AC AUX. SERVICES- UNIT 1
- B32 : DIESEL GENERATOR
- B33 : DC AUX. SERVICE - UNIT 1

CEYLON ELECTRICITY BOARD  
CANYON POWER STATION

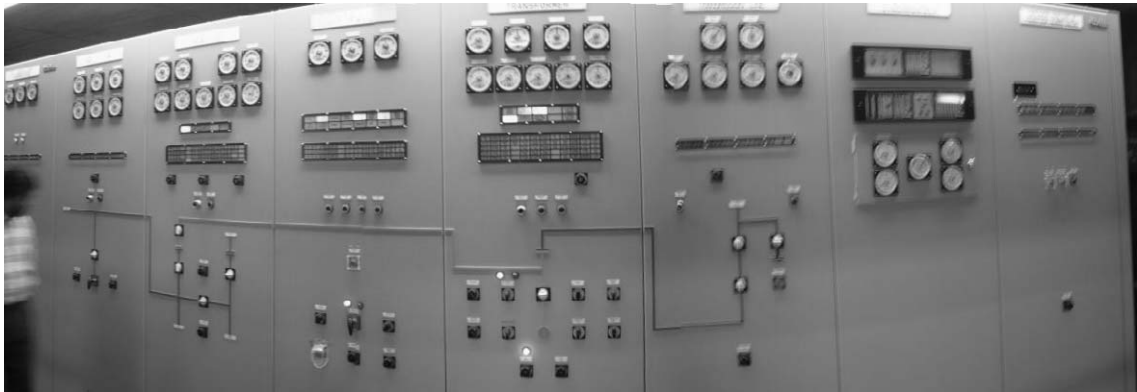
FIG.3.5-1/3 MAIN CONTROL ROOM LAYOUT

DATE :	SCALE :	DRAWN :	CHKD :
19/08/2004	NTS	THUSITHA	DMADA





**Picture-3.6 Control / Protection Equipment Board**



Unit 1 main & station service control board



Unit 2 main & station service control board and operator desk



Protection relay boards



Inside of both control & protection boards



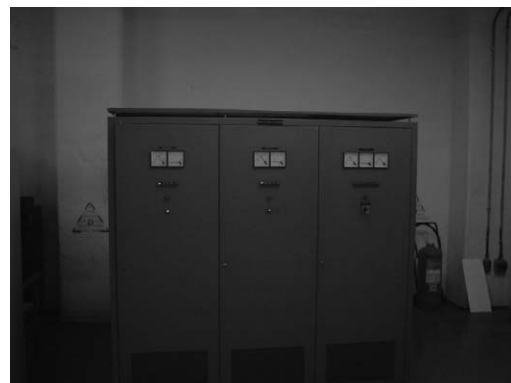
Turbine control & actuator cubicles



Excitation cubicle



DC distribution board



Battery charger cubicle



Battery of control system



Motor control center (MCC)

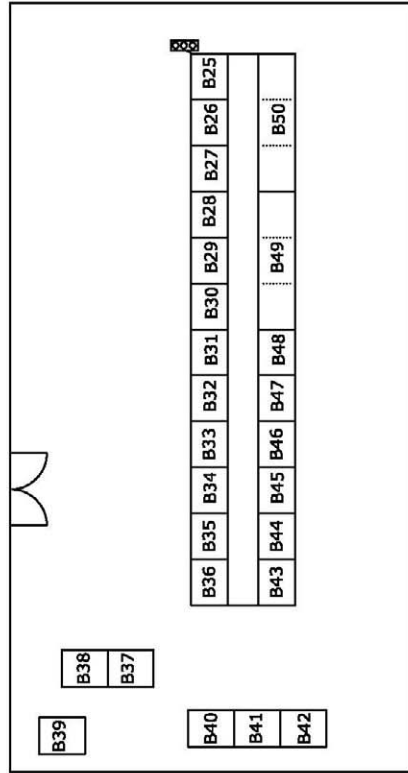


Telecommunication system



Indicator of GOV SD (5%)

#### ***4. New Laxapana Power Station***



**LEGAND**

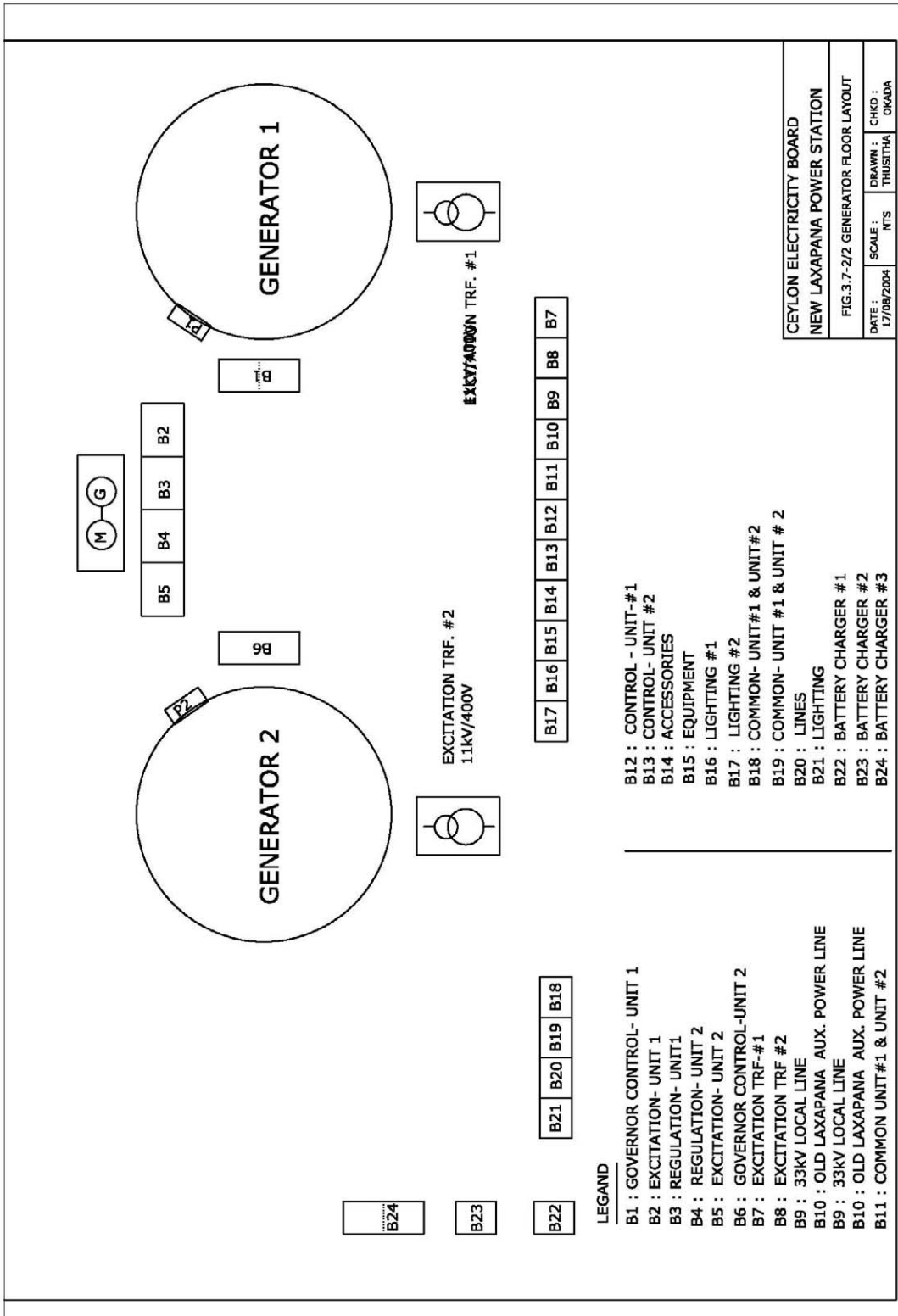
B25 : GEN-TRF # 1 OPERATION  
 B26 : GEN-TRF # 1 INDICATION  
 B27 : GEN-TRF # 1 INDICATION  
 B28 : GEN-TRF # 2 OPERATION  
 B29 : GEN-TRF # 2 INDICATION  
 B30 : GEN-TRF # 2 INDICATION  
 B31 : STATION TOTALIZING  
 B32 : BALANGODA 132KV LINE # 2  
 B33 : BALANGODA 132KV LINE # 1

B34 : POLPITTIYA 132KV LINE # 1  
 B35 : POLPITTIYA 132KV LINE # 2  
 B36 : CANIYON 132KV LINE  
 B37 : SUPERVISORY PANEL # 1  
 B38 : SUPERVISORY PANEL # 2  
 B39 : COMMUNICATION  
 B40 : BUS BAR PROTECTION  
 B41 : BUS BAR PROTECTION  
 B42 : BUS BAR PROTECTION

B43 : PROT.RELAYS - CANIYON LINE  
 B44 : PROT. RELAYS POLPITTIYA LINE 2  
 B45 : PROT.RELAYS POLPITTIYA LINE 1  
 B46 : PROT.RELAYS BALANGODA LINE1  
 B47 : PROT.RELAYS BALANGODA LINE2  
 B48 : RELAYS- TOTALIZING PANEL  
 B49 : PROT.RELAYS GEN.TRF # 2  
 B50 : PROT.RELAYS GEN.TRF # 1

CEYLON ELECTRICITY BOARD			
NEW LAXAPANA POWER STATION			
FIG.3.7-1/2 MAIN CONTROL ROOM LAYOUT			
DATE :	SCALE :	DRAWN :	CHKD :
17/08/2004	NTS	THUSITHA	OKADA





CEYLON ELECTRICITY BOARD			
NEW LAXAPANA POWER STATION			
FIG.3.7-2/2 GENERATOR FLOOR LAYOUT			
DATE :	SCALE :	DRAWN :	CHKD :
17/08/2004	NTS	THUSTHA	OKADA

- LEGEND**
- B1 : GOVERNOR CONTROL- UNIT 1
  - B2 : EXCITATION- UNIT 1
  - B3 : REGULATION- UNIT1
  - B4 : REGULATION- UNIT 2
  - B5 : EXCITATION- UNIT 2
  - B6 : GOVERNOR CONTROL-UNIT 2
  - B7 : EXCITATION TRF-#1
  - B8 : EXCITATION TRF #2
  - B9 : 33KV LOCAL LINE
  - B10 : OLD LAXAPANA AUX. POWER LINE
  - B10 : 33KV LOCAL LINE
  - B10 : OLD LAXAPANA AUX. POWER LINE
  - B11 : COMMON UNIT#1 & UNIT #2
  - B12 : CONTROL - UNIT-#1
  - B13 : CONTROL- UNIT #2
  - B14 : ACCESSORIES
  - B15 : EQUIPMENT
  - B16 : LIGHTING #1
  - B17 : LIGHTING #2
  - B18 : COMMON- UNIT#1 & UNIT# 2
  - B19 : COMMON- UNIT #1 & UNIT # 2
  - B20 : LINES
  - B21 : LIGHTING
  - B22 : BATTERY CHARGER #1
  - B23 : BATTERY CHARGER #2
  - B24 : BATTERY CHARGER #3

Picture 3.8 Control / Protection Equipment Board



Control boards of turbine- generator and transmission line



Control boards of transmission line



Protection relay boards



Protection relay boards and renewed lockout relay # 86



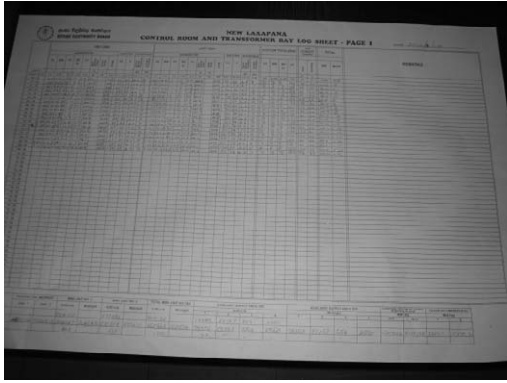
Auxiliary control board (NFB and ACB)



Governor & Actuators cubicle



Excitation regulator board



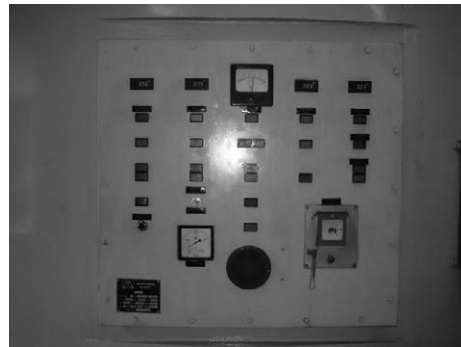
Operating record sheet



Supervisory CRT  
(for Old Laxapana ps of remote station)



Compressor control panel



Auxiliary panel of Generator



Battery charger of control & communication

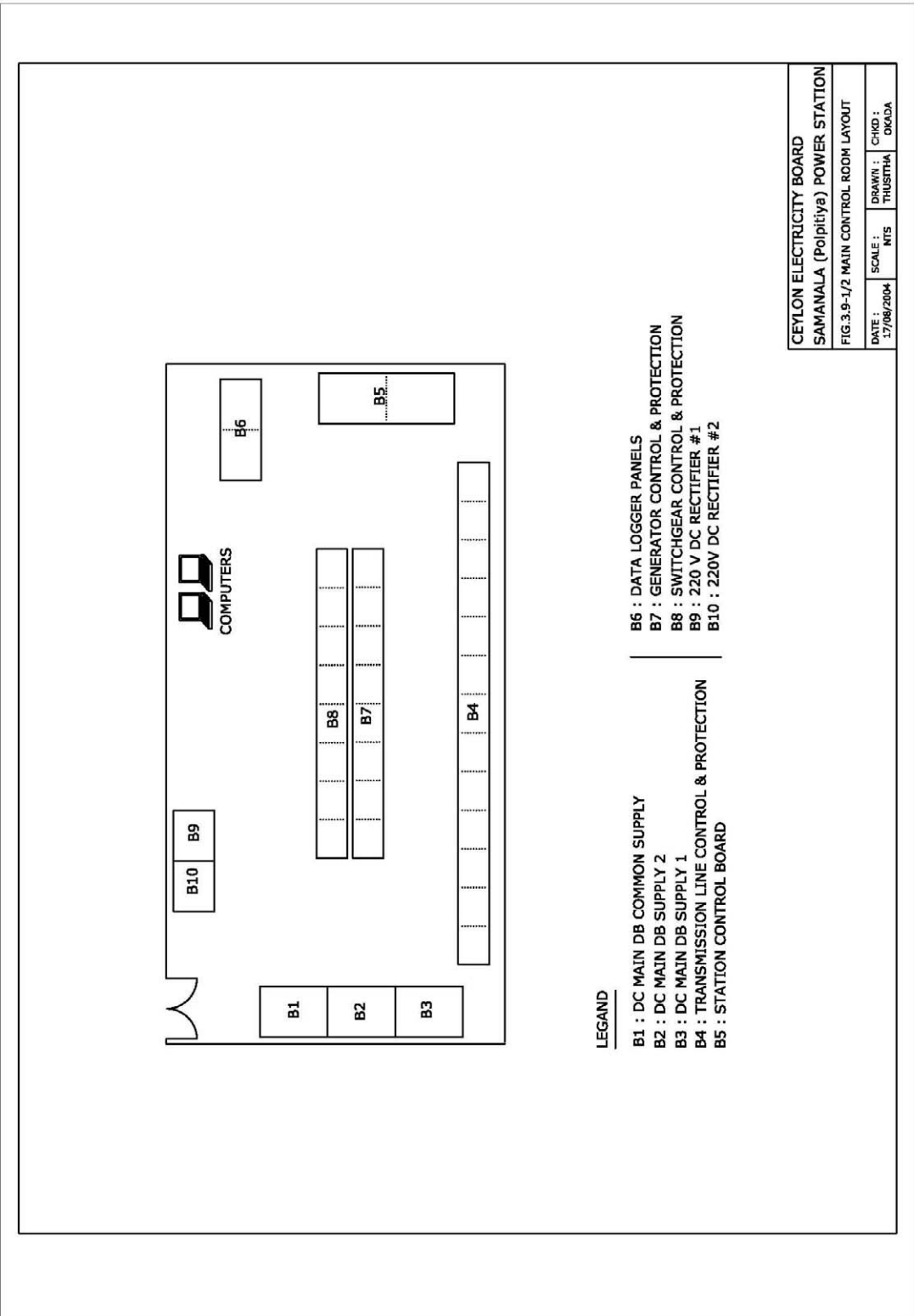


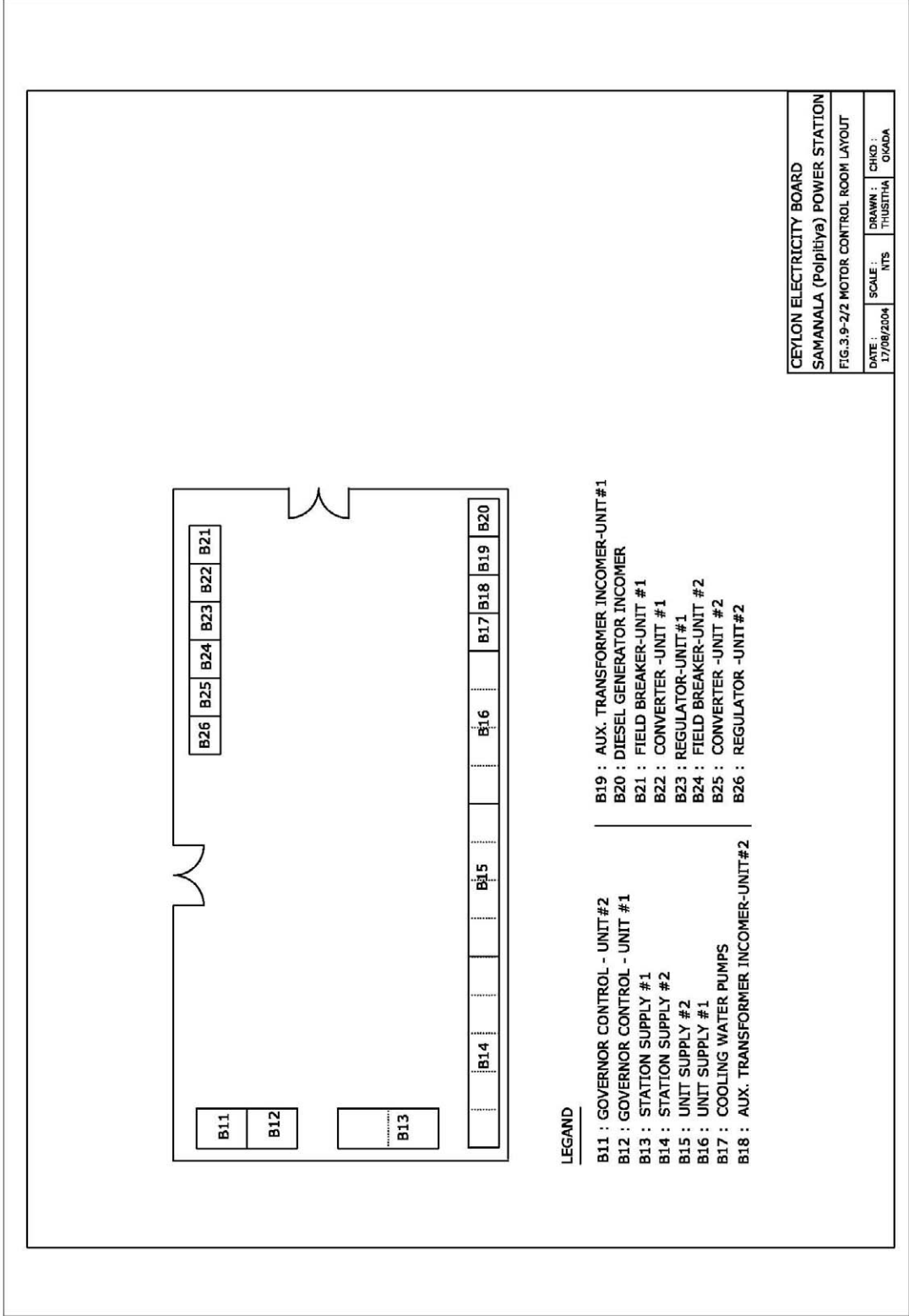
Battery of communication system



Battery of control system

## ***5. Polpitiya Power Station***





CEYLON ELECTRICITY BOARD			
SAMANALA (Poipitiya) POWER STATION			
FIG.3.9-2/2 MOTOR CONTROL ROOM LAYOUT			
DATE :	SCALE :	DRAWN :	CHKD :
17/08/2004	NTS	TRUSTITHA	ODDA



**Picture 3.10 Control / Protection Equipment Board**



Control Boards of Generator / Transformer (left site) and Transmission Line (right side)

Control Desk with CRT (below)



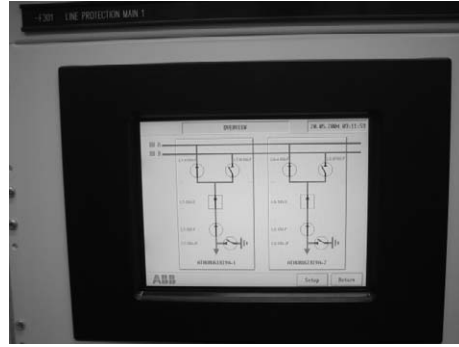
Control Board of Transmission/Line



Control Board of Gen & Tr.



Station Service Boards



Show Display on Control Board



Excitation Boards



Governor Control Board



Battery Charger of Control

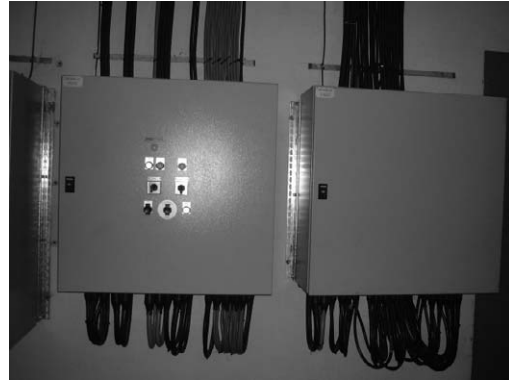


DC Distribution Boards



Station Service Cub. & Unit 1 & 2 Motor Control Center (MCC)





Contr

Control Panel of Turbine (left ) and Generator Auxiliary Equipment (right)



Battery Charger Cubicles of Communication



Communication Boards



Battery of Control and Communication Equipment



Cabling Layout

## ***6. Summary***

**Table 3.11 Control / Protection Equipment Summary for Investigation**

<i>Item</i>	<i>Wimalasurendra P.S</i>	<i>Canyon P.S</i>	<i>Old Laxapana P.S</i>	<i>New Laxapana P.S</i>	<i>Polpitiya P.S</i>
Commissioning year of hydropower station	Jan.'64	Mar.'83 and '88	Dec.'50 and Dec.'58	Feb.'74 and Mar.'74	Apr.'69
Replaced year of control and protection equipment	-	-	Stage I : 1995 Stage II : 2003	-	2003
1. Control equipment	Manual control system (Governor, Exciter, Parallel in, etc.) AVR is out of order	One man control system	One control system	One man control system (Remote control from Old Laxapana P.S)	One man control system
Measures	Need replacement	OK	OK	Need r Replacement needed	OK
2. Protection equipment	Electro magnetic relays	Electro magnetic relays	Numerical relay	Old system with electromagnetic relays	Numerical relay
Measures	Need replacement.	OK	OK	Need Replacement needed	OK
3. Control power source equipment	220V battery control and uninterruptible power source	220V battery control	220V battery control	220V battery control and uninterruptible power source	220V battery control
Measures	Need replacement and installation	OK	OK	Need Replacement and installation needed	OK
4. Communication equipment	PLC limited capacity	PLC limited capacity	Communication equipment –	Communication Equipment at Old Laxapana	
Measures	Telephone system: OK Communication line OPGW : needs installation for SCADA system	Telephone system: OK Communication line OPGW : needs installation for SCADA system	Telephone system: OK Communication line OPGW : needs installation for SCADA system	Telephone system: OK Communication line OPGW : needs installation for SCADA system	Telephone system: OK Communication line OPGW : needs installation for SCADA system
5. Dam distribution equipment	Dam control at Castlereigh	Poor operation	Power taken from the grid	Power taken from the grid	Dam distribution feeder cable from Old Laxapana
Measures	Need future replacement needed	Need future replacement needed	Need future replacement needed	Need future replacement needed	Need future replacement needed

***APPENDIX C-4  
CEB's CHECK LIST FOR  
CANYON HYDROPOWER STATION***

# 1. INSPECTION ITEMS FOR ELECTRICAL EQUIPMENT IN CANYON HYDROPOWER STATION

## 1.1 Electrical Equipment

Equipment	No.	Inspection Items	Interval
Moussakelle Dam	1	Replace fused bulbs	1 Week
	2	Inspection of the electrical wiring and accessories of the radial gates.	1 Week
	3	Inspection of the electrical wiring and accessories of the Intake gates.	1 Week
	4	Inspection of the electrical wiring and accessories of the Needle Valve.	1 Week
	5	Operational tests of the diesel generator with lighting load, record diesel generator data.	1 Week
	6	Cleaning of all accessories and cubicles	1 Month
	7	Insulation resistance	3 Months
	8	Operational check of radial gates using a standby diesel generator	3 Months
T.I.V.H.	1	Replace fused bulbs	1 Month
	2	Clean the meters' cubicle and the accessories	1 Month
	3	General inspection of limit switches wiring etc.	2 Weeks
M/K Diesel Engine and Generator 28 kVA	1	Operation test of the diesel generator with the lighting load. Record diesel generator data	1 Week
	2	Cleaning of all accessories and cubicles	1 Month
	3	Measure and record generator insulation resistance	3 Months
	4	Check transfer switch	6 Months
Battery Bank P.G.V.H.	1	Measure and record total Voltage on battery	2 Weeks
	2	Check acid level	2 Weeks
	3	Check for dust and clean the battery cubicle	2 Weeks
	4	Check and record individual cell Voltage	1 Month
	5	Check for discharge at terminals	1 Month
	6	Measure and record specific gravity of all cells	1 Month
	7	Check for abnormalities	1 Month
	8	Tighten connections	6 Months
	9	Equalizing charges	3 Months
Neutral Grounding Transformer	1	Check winding core and leads	1 Month
	2	Check and clean wedge supports	1 Month
	3	Clean external surfaces	1 Month
	4	Check for corrosion in damped device	1 Year
	5	Check for loose bolts	1 Year
	6	Check insulation resistance	1 Year
Battery Charger P.G.V.H.	1	Measure A.C. input voltage	1 Month
	2	Check the lamps	1 Month
	3	Check floating and equalizing voltages	1 Month
	4	Check for abnormalities	3 Months
	5	Clean and tighten the contacts	6 Months
	6	Check the manual operation	3 Months
	7	Calibrate CTs and the meters	3 Months

<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
33 kV Stand by Auxiliary Transformer	1	Check temperature and oil level	Every day
	2	Check for abnormalities	1 Month
	3	Check for oil leakage	1 Month
	4	Check breather oil level	1 Month
	5	Change silica gel	when colors change
	6	Bolt tightening and cleaning	6 Months
	7	Check thermometers	1 Year
	8	Inspect and clean the bushing	1 Year
	9	Inspect and clean the tap changer	1 Year
132 kV Main Transformer	1	Check temperature and oil level	Everyday
	2	Check for abnormalities	1 Month
	3	Check for oil leakage	1 Month
	4	Check breather oil level	1 Month
	5	Change cover silica gel	When color change
	6	Check radiators for oil leakage	1 Month
	7	Check bushing for oil leakage	1 Month
	8	Check fan bearings for oil leakage	1 Month
	9	Bolt tightening and cleaning	6 Months
	10	Measure insulation resistance of winding	1 Year
	11	Measure dielectric strength of oil	1 Year
	12	Measure acid volume of oil	1 Year
	13	Operate tap changer through its full range	1 Year
	14	Check for oil leakage of the tap changer and lubricate gears	1 Year
	15	Check radiators	1 Year
	16	Check bushings for local heating damage or pollution of porcelain and oil leads	1 Year
	17	Check and clean pressure relief device	1 Year
	18	Check and clean indicators	1 Year
	19	Clean and retighten terminal box of relays	1 Year
	20	Check for operation of alarm switches	1 Year
	21	Measure insulation resistance, inspect the wiring of protection and control circuit	1 Year
	22	Measurement of "Tan $\Delta$ " of the transformer	3 Years
	23	Measure insulation resistance of bushing and arrester	2 Years
	24	Filter insulation oil if abnormality found on test 11,12,22	Abnormality found
	25	Check and clean inside contents	5 Years
132 kV Line Transformer	1	Clean the contacts and accessories	1 Year
	2	Inspect the contacts	1 Year
	3	Lubricate levers	2 Years
	4	Lubricate the operating device	2 Years
132 kV O.C.B.	1	Inspect the O.C.B. for any abnormalities	1 Month
	2	Clean O.C.B. and all insulators	1 Month
	3	Check the oil level and pressure in the breaking unit	1 Month
	4	Lubrication of bearings	1 Year
	5	Do the sample test check of oil	3 Years
	6	Remove inspection covers and clean, anti-rust treatment, lubricate and check oil in the dashpot	6 Years
	7	Complete overhaul	12 Years



<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
12.5 kV Auxiliary Transformer	1	Check temperature and oil level	Everyday
	2	Check for abnormalities	1 Month
	3	Check for oil leakage	1 Month
	4	Check breather oil level	1 Month
	5	Change silica gel when color changes to pink	Acc. to requirement
	6	Bolt tightening and cleaning	6 Months
	7	Check thermometers	1 Year
	8	Inspect and the tap changer	1 Year
	9	Inspect and clean the bushings	1 Year
	10	Check pressure relief device	1 Year
	12	Measure wedge and bushing insulation resistance	1 Year
	13	Measure dielectric strength of insulation oil	1 Year
	14	Measure " Tan $\Delta$ " of the transformer	1 Year
	15	Check for operation of alarm switches	3 Years
	16	Measure insulation resistance and inspect the wiring of protection and control circuits	1 Year
	17	Filter insulation oil if abnormality found on tests 12,13,and 14	1 Year
	132 kV Line Earthing Switch	1	Inspect the contacts and accessories
2		Clean the contacts and accessories	1 Year
3		Lubricate levers	2 Years
4		Lubricate the operating device,	2 Years
Main T/F Fire Protection System	1	Testing of main T/F fire protection using emergency fire protection button at the switch yard	1 Year
	2	Testing of main T/F fire protection using fire detector	1 Year
	3	Testing of main T/F fire protection using emergency fire protection button at the cubicle on the power house	1 Year
Excitation Transformer	1	Inspect the winding, core, connection lead for any damage discoloration and dust deposit	1 Month
	2	Check the wedge supporting structure for any damage	1 Month
	3	Check for contamination in the air filter	1 Month
	4	Clean the winding support, core and winding	1 Month
	5	Check for corrosion	3 Months
	6	Measure the insulation resistance	6 Months
	7	Check the conductive parts for any loosing over heating and corrosion	6 Months
	8	Check the cooling fans	6 Months
	9	Check for loosing in any of the parts	6 Months
Generator	1	Check the operation condition from log sheets	Everyday
	2	Check for the rated amount of cooling water flow in the air cooler	1 Week
	3	Check for unusual smell of the winding	Everyday
	4	Check insulators for discoloration	1 Year
	5	Check for wedges	1 Year
	6	Check for loose or broken binding strands	1 Year
	7	Check the lead wires	1 Year
	8	Check the station winding temperature for abnormalities	1 Week
	9	Check for anything unusual	1 Week
	10	Check for water leakage from cooling water pipes	1 Month
	11	Check for oil leakage	1 Month

<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
	12	Check all the joints for any sign of discoloration and overheating	1 Month
	13	Check the field winding temperature for abnormalities	1 Week
	14	Check tightness of all the bolts and flexibility of the leads	2 Weeks
	15	Inspect the bus bar	1 Year
	16	Clean inside the generator housing	1 Month
	17	Generator air cooler cleaning	1 Month
	Instrument Transformer	1	Check for loose contacts
2		Check for any abnormalities	1 Month
3		Clean inside the cubicles	1 Month
4		Check for deformation of insulation	1 Year
Brushless Exciter	1	Measure A.C. exciter pole coil insulation resistance	1 Year
	2	Measure exiting current pickup coil insulation resistance	1 Year
	3	Measure rotor insulation resistance	1 Year
	4	Inspect the rotary rectifier for abnormalities of connection parts	1 Year
	5	Inspect the fuse indicator of silicon rectifier	1 Year
	6	Measure reverse resistance of silicon rectifier	1 Year
12.5 kV O.C.B.	1	Cleaning inside the cubicle	1 Month
	2	Check oil level	1 Year
	3	Check the dielectric strength	2 Years
	4	Check Insulation oil	5 Years
	5	Check weaker contacts ( 5000 operations )	5 Years
	6	Check parts of arc quenching chamber ( 5000 operations )	5 Years
	7	Lubrication ( 5000 operations )	5 Years
	8	Clean gas purge hole ( 5000 operations )	5 Years
	9	Replace gas purge plug ( 5000 operations )	5 Years
	10	Clean completely ( 5000 operations )	5 Years
Load Break Switch	1	Clean inside the cubicle	1 Month
	2	Check for loose contacts and abnormalities	1 Month
	3	Cleaning and greasing completely	1 Year
	4	Check for any burnt parts	1 Month
	5	Check the arc chamber	5 Years
	6	Check the arching ring	5 Years
	7	Check the quenching device	5 Years
	8	Check auxiliary main contacts and damping plate	5 Years
	9	Check fixed contact support insulation	5 Years
	10	Check that the auxiliary moving contact runs into auxiliary mating contact	5 Years
Governors	1	Check the system motor	1 Year
	2	Check the minimum operating voltage of solenoid valve	3-5 years
	3	Check the limit switches for operation	1 Year
	4	Cleaning the cubicle and instrument	1 Month
	5	Check oil pump motor AC and DC	1 Month
	6	Check insulation resistance of the oil pump motors	6 Months
14.5 kV current Transformer	1	Check for oil leakage	1 Week
	2	Check for paint coating damage	1 Month
	3	Check for insulators	1 Month
	4	Clean the insulators and supporting parts	3 Months
	5	Measure the insulation resistance	1 Year

<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
Battery Changer No. 01	1	Measure A.C. input voltage	1 Month
	2	Clean the cubicle	1 Month
	3	Tighten the contacts	3 Months
	4	Check temperature rise in thyristor	3 Months
	5	Check contacts of variable resistor in gate control	6 Months
	6	Check temperature in transformer coil	6 Months
	7	Check for control switches	6 Months
	8	Check relays and magnetic switches	6 Months
	9	Check meters for correct indicators	1 Year
	10	Check terminal of terminal boards	1 Year
Battery Changer No. 02	1	Measure A.C. input voltage	1 Month
	2	Clean the cubicle	1 Month
	3	Tighten the contacts	3 Months
	4	Check temperature rise in thyristor	3 Months
	5	Check contacts of variable resistor in gate control	6 Months
	6	Check temperature in transformer coil	6 Months
	7	Check for control switches	6 Months
	8	Check relays and magnetic switches	6 Months
	9	Check meters for correct indicators	1 Year
Main Battery Bank	1	Measure and record total voltage on floating	1 Week
	2	Check acid valve	1 Week
	3	Check for dirt and clean	1 Week
	4	Clean battery charger room	1 Week
	5	Check and record individual cell voltage	1 Week
	6	Check for discharger of terminal	1 Week
	7	Measure and record specific gravity of all cells	1 Week
	8	Check for abnormalities	1 Week
	9	Confirm there is no obstruction of ventilation apparatus	1 Month
	10	Tightening connections	6 Months
	11	Equalizing charge	3 Months
A.C. and D.C. Distribution Board	1	Clean all cubicles	1 Month
	2	Check auto breakers	1 Month
	3	Check magnetic conductor	1 Month
	4	Check auxiliary relays	1 Month
	5	Check D.C. electromagnetic conductor	1 Month
	6	Check thermal overload relays	1 Month
Relays and Control Boards	1	Clean main control board relays, meters at out side control room	1 Week
	2	Clean the governor cubicle, meters and switches	1 Week
	3	Clean AVR cubicle and excitation	1 Week
	4	Check the contacts of relays	1 Week
	5	Test the relays	1 Week
Wide Scale Self Balancing Recorder	1	Replace the recording chart at appropriate time	Appropriate time
	2	Replace the recording pen when the color becomes too light	When color changes
	3	Replace the printing pad, when the color of print becomes too light	When color changes
	4	Lubricate the necessary parts	1 Year
	5	Retighten external terminal and interior mechanism	1 Year
	6	Effect calibration if required	1 Year
	7	Replace the component parts according to manufacturer recommendations	1 Year

<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
Cooling Water Pump 1 and 11	1	Check the motors for sound operation	1 Week
	2	Check the motor insulation	1 Week
48 V Battery Charger	1	Measure A.C. input voltage	1 Month
	2	Clean the cubicle	1 Month
	3	Tighten the contacts	3 Months
	4	Check temperature rise in rectifier elements	3 Months
	5	Check meters for correct indications	1 Year
48 V Battery Bank	1	Measure and record total voltage on floating	1 Week
	2	Check acid value	1 Week
	3	Check for dirt and clean as needed	1 Week
	4	Check and record individual cell voltage	1 Week
	5	Check for discharge at terminals	1 Week
	6	Measure and record specific gravity of all cells	1 Week
	7	Check for abnormalities	1 Week
	8	Tighten connections	6 Months
	9	Equalizing charge	1 Month
Canyon Dam	1	Replace fused bulbs	1 Week
	2	Inspection of the electrical wiring and accessories of the radial gates	1 Week
	3	Inspection of the electrical wiring and accessories of the Intake gates	1 Week
	4	Inspection of the electrical wiring and accessories of the vent	1 Week
	5	Operation test of the diesel generator with the lighting load	1 Week
	6	Clean all the accessories and cubicles	1 Month
	7	Insulation resistance measurement	3 Months
	8	Operational check of the radial gates using standby diesel generator	3 Months

## 1.2 Mechanical Equipment

Equipment	No.	Inspection Items	Interval
Moussakelle Dam	1	Greasing of all points	1 Week
	2	Clean the accessories and dam site	1 Week
	3	Inspection of gear wheels and lubrication	1 Month
	4	Operational check of the radial gates	1 Month
	5	Operational check of the needle valve	1 Month
	6	Inspection of the wire ropes	1 Month
	7	Routine maintenance of diesel engine	1 Month
	8	Compound the wire ropes	3 Months
	9	Gallery inspection	3 Months
Tunnel Inlet Valve House	1	Service the monorail hoist	1 Month
	2	Clean the accessories	1 Month
	3	Clean the floor, roof, walls, windows, doors and drains	1 Month
	4	Weed and clean the site	1 Month
Tunnel Inlet Valve	1	Check for water leakage at dismantling joints	2 Weeks
	2	Check for water leakage from clamped joints	2 Weeks
	3	Check for oil leakage from servomotor	2 Weeks
	4	Check for rust and damage if red parts are uncovered	2 Weeks
	5	Look for foreign matter on floor	2 Weeks
	6	Observation of vibration and noise	2 Weeks
	7	Check for peeling of paint	2 Weeks
	8	Check for water leakage from valve seat	1 Year
	9	Check for damage of valve body, seat casting, shaft etc.	1 Year
	10	Observe and record cavitation and pitting	1 Year
	11	Check for tightening[??] of rod and pin of servomotor	1 Year
	12	Check for discoloration and corrosion of shaft	3 Years
	13	Check for wear and damage to bearing bushes	3 Years
	14	Confirm the bush interior lubrication is satisfactory	3 Years
	15	Check for wear and damage of cylinder piston and packing	3 Years
By Pass Valve for Tunnel Inlet Valve	1	Check for vibration and noise	2 Weeks
	2	Check for water leakage from valve seat	1 Year
	3	Check and record cavitation and pitting	1 Year
	4	Check for damage to valve seat, casing, shaft etc.	1 Year
	5	Check for discoloration and corrosion of shaft	3 Years
	6	Check for wear damage and lubrication in bearing bushes	3 Years
	7	Check servomotor for oil leakage, tight pin	1 Year
	8	Check cylinder, piston and packing for wear damage	3 Years
Pressure Oil Supply System For Tunnel Inlet Valve	1	Check temperature of pumps and motors	2 Weeks
	2	Check for abnormal noise or vibration	2 Weeks
	3	Confirm that the sump oil level is normal	2 Weeks
	4	Check operation of oil pumps and driving motors	1 Month
	5	Check for oil leakage	1 Month
	6	Confirm oil level switches operates correctly	6 Months
	7	Check the oil and filter if necessary	1 Year
	8	Check discharged oil volume of pumps	1 Year
	9	Clean strainers	1 Year
Penstock Guard Valve	1	Check for water leakage at dismantling joints	2 Weeks
	2	Check for water leakage from clamped joints	2 Weeks
	3	Check for oil leakage from servomotor	2 Weeks

<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>	
	4	Check for rust and damage in uncovered parts	2 Weeks	
	5	Inspect for foreign matter on floor	2 Weeks	
	6	Observation of vibration and noise	2 Weeks	
	7	Check for peeling paints	2 Weeks	
	8	Check for water leakage from valve seat	1 Year	
	9	Check for damage and valve body, seat casing, shaft etc.	1 Year	
	10	Observe and record cavitation and pitting	1 Year	
	11	Check tightness of rod and pin of servomotor	1 Year	
	12	Inspect for shaft discoloration and corrosion	3 Years	
	13	Check bearing bushes for wear and damage	3 Years	
	14	Confirm the bush interior lubrication	3 Years	
	15	Check cylinder piston and packing for wear and damage	3 Years	
	Penstock Guard Valve House	1	Service the monorail hoist	1 Month
		2	Clean the accessories	1 Month
		3	Clean the floor, roof, walls, windows, doors and drains	1 Month
4		Weed and clean the site	1 Month	
Bypass Valve For Penstock Guard Valve	1	Check for vibration and noise	2 Weeks	
	2	Check for water leakage from valve seat	1 Year	
	3	Check and record cavitation and pitting	1 Year	
	4	Check for damage to valve seat, casing, shaft etc.	1 Year	
	5	Check shaft for discoloration	3 Years	
	6	Check for wear damage and lubrication in bearing bushes	3 Years	
	7	Check servomotor for oil leakage, tightness of rod and pin	1 Year	
	8	Check cylinder, piston and packing for wear damage	3 Years	
Penstock	1	Cleaning of the sliding parts of the penstock	2 Weeks	
	2	Tightening the sliding parts	2 Weeks	
	3	Check the penstock for corrosion	2 Weeks	
	4	Check for the leakage at the manhole	2 Weeks	
	5	Check for leakage at the expansion joints	2 Weeks	
	6	Tighten them if necessary	2 Weeks	
	7	Replace the braid packing if necessary	10 Weeks	
	8	Paint the penstock line	10 Weeks	
Pressure Oil Supply System For P.G.V.	1	Check temperature of pumps and motors	2 Weeks	
	2	Check for abnormal noise or vibration	2 Weeks	
	3	Confirm the sump oil level	2 Weeks	
	4	Check operation of oil pumps and driving motors	1 Month	
	5	Check for oil leakage	1 Month	
	6	Confirm oil level switches operate correctly	6 Months	
	7	Check the oil and filter if necessary	1 Year	
	8	Check discharge oil volume pumps	1 Year	
	9	Clean strainers	1 Year	
Turbine Inlet Valve	1	Check for water leakage at dismantling joints	2 Weeks	
	2	Check for water leakage from clamped joints	2 Weeks	
	3	Check for oil leakage from servomotor	2 Weeks	
	4	Check for rust and damage in uncovered parts	2 Weeks	
	5	Inspect for foreign matter on floor	2 Weeks	
	6	Observation of vibration and noise	2 Weeks	
	7	Check for peeling paints	2 Weeks	
	8	Check for water leakage from valve seat	1 Year	
	9	Check for damage in valve body, seat casing, shaft etc.	1 Year	
	10	Observe and record cavitation and pitting	1 Year	
	11	Check for tightening of rod and pin of servomotor	1 Year	

<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
	12	Inspect shaft for discoloration and corrosion	3 Years
	13	Check bearing bushes for wear and damage	3 Years
	14	Confirm the bush interior lubrication	3 Years
	15	Check cylinder piston and packing for wear and damage	3 Years
By Pass Valve for I.V.	1	Check for vibration and noise	2 Weeks
	2	Check for water leakage from valve seat	1 Year
	3	Check and record cavitation and pitting	1 Year
	4	Check for damage to valve seat, casing, shaft etc.	1 Year
	5	Check shaft for discoloration and corrosion	3 Years
	6	Check for wear, damage and lubrication in bearing bushes	3 Years
	7	Check servomotor for oil leakage, tightness of rod and pin	1 Year
	8	Check cylinder, piston and packing for wear, damage	3 Years
Wicket Gates	1	Check for damage to wicket gate bodies	1 Year
	2	Record cavitation on mating surface	1 Year
	3	Check clearance of mating surface	1 Year
	4	Look for obstructions to movement of gates	1 Year
	5	Measure and record top and bottom clearances	1 Year
	6	Check for discoloration and corrosion	3-5Years
	7	Check for adequate greasing	3-5Years
	8	Inspect guide bearing and bush for wear	3 Years
	9	Inspect thrust bearing and lines for damages	3-5Years
	10	Replace damaged packing	3-5 Years
Wicket Gate Operating Mechanism	1	Check the grease lubricating condition for wicket gate upper stem guide and thrust bearings	1 Week
	2	Check for water leakage at gate stem	1 Week
	3	Check for grease leakage	1 Week
	4	Inspect for broken shear pin	1 Week
	5	Check rust in wicket gate lever shear pin and link	1 Year
	6	Inspect the locking of nuts	1 Year
	7	Check for damage of external surface	3 Years
	8	Check wicket gate stem and bushes for wear and damage	
	9	Check damage to rubber packing	3 Years
	10	Observe differences in accumulated grease at each bushes and clean them	3 Years
	11	Inspect bearing for wear damage and lubrication	3 Years
	12	Check tightness of rod and pin of the servomotor	1 Year
	13	Check the squeeze of rod and pin of the servomotor	1 Year
	14	Check cylinder for wear and damage	1 Year
	15	Check piston and piston ring for damage	3 Years
	16	Check for damage to packing	3 Years
Shaft Seal	1	Check for water leakage from seal	1 Week
	2	Observe the wear of carbon ring	1 Week
	3	Check housing, cover and carbon ring holder for corrosion	1 Year
	4	Check for quantity of cooling water	1 Year
	5	Check the amount of wear of carbon ring	3 Years
	6	Check for damage to rubber packing and spring	3 Years

<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
Runner	1	Note vibration and sound	1 Week
	2	Observe and record cavitation pitting	1 Year
	3	Measure clearance	1 Year
	4	Repair cavitation pitting if necessary	3 Years
	5	Check for cracks in runner	3 Years
	6	Measure clearance of wearing ring	5 Years
Turbine Internal Surface	1	Inspect for wear damage in spiral casing	1 Year
	2	Inspect for wear and damage to stay vanes	1 Year
	3	Observe and record cavitation pitting in the draft tube	1 Year
	4	Check for damage to negative pressure side of the jet pump	1 Year
	5	Check facing plate for wear and damage	1 Year
	6	Inspect the bottom ring	1 Year
	7	Remove rust, mud and sand from piping	1 Year
	8	Check the hinge and lock bolt of the manhole cover for rust, corrosion	1 Year
	9	Repaint inner surface if necessary	3-5Years
Turbine External Surface	1	Check for water leakage at dismantling joints of turbine inlet valve	1 Week
	2	Check leakage of spiral casing manhole	1 Week
	3	Confirm the tightness of head cover bolts	1 Week
	4	Check for leakage at the cover	1 Week
	5	Check for leakage at flanges of pit liners and check for foreign matter on platform	1 Week
	6	Inspect rusting at gate ring	1 Week
	7	Observe if there is abnormal noise in draft tube	1 Week
	8	Inspect for oil leakage from servomotor	1 Week
	9	Inspect servomotor for rust and damage	1 Week
Turbine Guide Bearing	1	Check for temperature abnormality	1 Week
	2	Check oil level in lubrication oil tank	1 Week
	3	Check for oil discoloration	1 Week
	4	Check for oil leakage	1 Week
	5	Check for adequate cooling water flow	1 Week
	6	Filter oil if necessary	1 Year
	7	Replace oil if necessary	1 Year
	8	Measure bearing clearances	3-5Years
	9	Clean inside and outside of oil reservoir	3-5Years
Generator Lower Guide Bearing	1	Check for temperature abnormality	1 Week
	2	Check oil level	1 Week
	3	Check for oil discoloration	1 Week
	4	Check for oil leakage	1 Week
	5	Check for adequate cooling water flow	1 Week
	6	Filter oil if necessary	1 Year
	7	Measuring clearance of the bearing	3-5Years
	8	Clean inside and outside of oil reservoirs	3-5Years
Brake Shoes and Brake Ring	1	Check and record the amount of wear of brake shoes	1 Month
	2	Inspect the relationship between the wear and the operating frequency	1 Month
	3	Check the brake ring for any sign of wear and damage	1 Month
	4	Check the brake piston movement	1 Month



<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
Generator Upper Guide Bearing	1	Check for temperature abnormality	1 Week
	2	Check oil level	1 Week
	3	Check for oil discoloration	1 Week
	4	Check for oil leakage	1 Week
	5	Check for adequate cooling water flow	1 Week
	6	Filter oil if necessary	1 Year
	7	Measure bearing clearances	3-5Years
	8	Clean inside and outside of oil reservoir	3-5Years
Generator	1	Check for the rated amount of cooling water flow in the air cooler	1 Week
	2	Check for water leak from cooling water pipes	1 Month
	3	Check for oil leakage	1 Month
	4	Cleaning of generator air coolers	1 Month
Governor	1	Oil quantity in dash pot	1 Week
	2	Lubricate link and sliding parts	6 Months
	3	Clean oil filters	6 Months
	4	Measure opening and closing time of wicket gate	6 Months
	5	Measure operating time of 77 m and 66 m	1 Year
	6	Check opening position indicator	1 Year
	7	Check for oil leakage at valves and piping	1 Year
	8	Check oil pressure switches for operation	1 Year
	9	Check distributing valves and control valves for operation and oil leakage	3-5Years
Pressure oil Supply System	1	Confirm that pressure and oil level of the pressure tank are within normal range	1 Week
	2	Check for any oil or air leakage from pressure tank	1 Week
	3	Check oil cooler for any leakage	1 Week
	4	Check operation of pumps etc.	1 Week
	5	Check the temperature of oil pumps and motors	1 Week
	6	Check for abnormal noise or vibration	1 Week
	7	Confirm the oil level and temperature of sump tank	1 Week
	8	Check the operation of unloader valve and control valves	1 Week
	9	Check the oil for abnormality, and filter if necessary	6 Months
	10	Confirm the oil pressure level switches operate correctly	6 Months
	11	Clean the filter element	6 Months
	12	Clean strainers	1 Year
	13	Calibrate the pressure gauge	1 Year
	14	Confirm the pressure switches operate correctly	1 Year
	15	Check the operation of safety valves	1 Year
	16	Check the discharge volume of oil pumps	1 Year
Governor Air Compressor	1	Check crank case oil level	Everyday
	2	Check drain valve	Everyday
	3	Cleaning external surface	1 Week
	4	Check for any abnormality of vibration, sound, temperature and current	1 Week
	5	Check for oil leakage	1 Week
	6	Check for belt tightness	1 Month
	7	Check unloaded starting device and crank case oil	3 Months
	8	Clean suction and delivery valves	6 Months
	9	Replacement of lubricating oil	1 Year

<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
Brake Air Compressor	1	Check the crank case oil level	Everyday
	2	Check drain valve	Everyday
	3	Clean external surface	1 Week
	4	Check for absorbability of vibration, sound, temperature and current	1 Week
	5	Check for oil leakage	1 Week
	6	Check for belt tightness	1 Month
	7	Check unloaded starting device and crank case oil	3 Months
	8	Clean suction and delivery valves	6 Months
	9	Replacement of lubricating oil	1 Year
Cooling Water Pump No.01	1	Check for excessive vibration and noise	1 Week
	2	Check for adequate amount of lubricating oil	1 Week
	3	Measure bearing temperature	1 Week
	4	Clean the outer surface	1 Week
	5	Check packing	1 Week
	6	Change bearing oil	6 Months
	7	Check the oil seal	1 Year
	8	Check the shaft sleeve and impeller	1 Year
Cooling Water Pump No.02	1	Check for excessive vibration and noise	1 Week
	2	Check for adequate amount of lubricating oil	1 Week
	3	Measure bearing temperature	1 Week
	4	Clean the outer surface	1 Week
	5	Check packing	1 Week
	6	Change bearing oil	6 Months
	7	Check the oil seal	1 Year
	8	Check the shaft sleeve and impeller	1 Year
Centralized Grease Lubrication System	1	Check the operating time of distributor	1 Week
	2	Check the operation of hydraulically operated reversing valve	1 Week
	3	Inspect the operation of distributor	1 Week
	4	Check for grease leakage from pipes	1 Week
	5	Check for damage of respective equipment	1 Week
	6	Check the amount of grease in reservoir and stroke can	1 Week
	7	Check the lubricating oil for contamination	1 Week
	8	Check the motor driver grease pump for operation	1 Week
	9	Confirm the lubrication condition of every part	1 Month
	10	Check the operation of the manual lubricating pump	1 Month
	11	Check the operation of the motor driver barrel pump	1 Month
	12	Clean filling part strainer	1 Month
	13	Clean Y-type strainer	1 Month
	14	Charge the lubricating oil in the pump casing	1 Year
Draft Tube Gates	1	Check all the lubricating points for adequate lubrication	1 Month
	2	Check all the bolts and nuts of monorail hoist, gate leaf and lifting beam	1 Month
	3	Check each portion for cracks and deformation	1 Month
	4	Check the wire ropes for broken strands	1 Month
	5	Inspect abnormal noise and vibration during operation	1 Month
	6	Clean the seal rubber portion of gate leaf	1 Month
	7	Check the seal rubber packing for ablation breaking or wear	1 Month
	8	Clean and check for corrosion	1 Month
	9	Lubricate wire ropes	1 Year

<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
	10	Check for water leakage at full closed position of gate leaf	1 Year
Fire Protection System	1	Confirm the availability of the water in the fire protection tank	Everyday
	2	Measuring and recording of fire extinguisher weights	6 Months
	3	Inspection of fire protection system valves and water tank tubes	6 Months
Drainage Pump No.01	1	Check for excessive vibration and noise	1 Week
	2	Check for adequate amount of lubrication oil	1 Week
	3	Measure thrust bearing temperature	1 Week
	4	Adjust tightness of the gland	1 Week
	5	Clean the outer surface	1 Week
	6	Change ball and roller bearing oil	3 Months
	7	Check inner and outer race surface	3 Months
	8	Inspect gland packing for water leakage	3 Months
	9	Check under water sliding bearing	1 Year
	10	Check the sliding surfaces of mechanical seal	1 Year
	11	Check the shaft sleeve	1 Year
	12	Check the O – ring	1 Year
	13	Check the casing wear ring	1 Year
	14	Check the entire impeller	1 Year
	15	Check the coupling bolts and rubber rings	1 Year
	16	Check the shaft sleeve	2 Years
	17	Replace the O - ring	2 Years
	18	Measure the sliding surface between the impeller and casing wear ring	2 Years
Drainage Pump No.02	1	Check for excessive vibration and noise	1 Week
	2	Check for adequate amount of lubrication oil	1 Week
	3	Measure thrust bearing temperature	1 Week
	4	Adjust tightness of gland packing	1 Week
	5	Clean the outer surface	1 Week
	6	Change ball and roller bearing oil	3 Months
	7	Check inner and outer race surface	3 Months
	8	Inspect gland packing for water leakage	3 Months
	9	Check underwater sliding bearing	1 Year
	10	Check the sliding surfaces of mechanical seal	1 Year
	11	Check the shaft sleeve	1 Year
	12	Check the O - ring	1 Year
	13	Check the casing wear ring	1 Year
	14	Check the entire impeller	1 Year
	15	Check the coupling bolts and rubber rings	1 Year
	16	Check the shaft sleeve	2 Years
	17	Replace the O - ring	2 Years
	18	Measure the sliding surface between the impeller and casing wear ring	2 Years
Station Service Air Compressor	1	Check oil level and pressure	Everyday
	2	Check drain valve	Everyday
	3	Check for leakage of air and oil	1 Week
	4	Check for abnormal noise and vibrations	1 Week
	5	Clean external surface	1 Week
	6	Check the safety valve	1 Week
	7	Check the bolts and nuts for tightness	1 Month

<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
	8	Check the belts for tightness	1 Month
	9	Clean the air filters	3 Months
	10	Change lubricating oil	3 Months
	11	Clean oil strainer	3 Months
	12	Check and adjust the oil pressure adjustment valve if necessary	6 Months
	13	Clean suction and delivery valves	6 Months
	14	Check for wear of valve springs and plates	6 Months
	15	Change element of air filter	6 Months
Hoisting Mechanical	1	Coupling bolts, motor, break bolts and operation	1 Month
	2	Unusual noise and vibration	1 Month
	3	Wear of break lining and slack of bolts for gear box and bearings	1 Month
	4	Wear of drum groove (24% of the wire rope diameter)	1 Month
	5	Condition of oil and damage of drum	1 Month
	6	Reduction of wire rope diameter (7%)	1 Month
	7	Cut lines and joints of the wire rope, and setting condition of the wire rope clamps.	1 Month
	8	Bush, key plate, pin of the hook block and rotation of the hook	1 Month
	9	Damage to the hook, hook screw and hook nut	1 Month
Over Head Travel Crane	1	The condition of the runway	1 Week
	2	The rail supports of the trolley	1 Week
	3	The condition of the wire rope passing places	1 Week
	4	Unusual noise, temperature rise and vibration	1 Week
	5	Performance of the brake	1 Week
	6	Performance of the overwinding protectors	1 Week
	7	Meander of trolley and saddles	1 Week
	8	Performance of the controls	1 Week
	9	Hook, rope sheave, drum, cracks and deformation in girders, and welded parts	1 Week
Runway and Traveling Mechanical Equipment of O.H.T.C.	1	Set bolt, sole plate, stoppers and rail clip of the runway	1 Week
	2	Compiling bolts, motor bolts and operation	1 Week
	3	Oil leakage, unusual noise of gear box	1 Week
	4	Slack of brake lining wheels and bearing case	1 Week
	5	Wear of brake lining wheels and bearing case	1 Week
	6	Condition of oiling	1 Week
Traversing Mechanical Equipment for O.H.T.C.	1	Wear of wheel lubrication of the bearing and deformation and slack of the end plates	1 Month
	2	Wear of the lining, torque adjustment device	1 Month
	3	Operation of the brake lever and brake oil	1 Month
	4	Deformation of the brake lever and pin, and brake oil	1 Month
	5	At motor and brake bolts, unusual noise and vibration of the gear box	1 Month
Structure of O.H.T.C.	1	Bending of the structure of girder and saddle	1 Month
	2	Check tightness of girder and saddle joining bolts	1 Month
	3	Check tightness of joining bolts of the trolley	1 Month
Electrical and Mechanical Equipment O.H.T.C.	1	Runway	1 Year
	2	Traversing rail	1 Year
	3	Hook	1 Year
	4	Rust and painting	1 Year

<b>Equipment</b>	<b>No.</b>	<b>Inspection Items</b>	<b>Interval</b>
Diesel Engine and Generator	1	Check for lubrication oil leakage	1 Month
	2	Check for operation of oil heater	1 Month
	3	Check engine oil level	1 Month
	4	Check hydraulic governor oil level	1 Month
	5	Check for cooling air leakage	1 Month
	6	Check for radiator air restriction	1 Month
	7	Check for operation of coolant heater	1 Month
	8	Check hose and connections	1 Month
	9	Check coolant level	1 Month
	10	Check Antfreeze and DCA connection	1 Month
	11	Check belt condition and tension	1 Month
	12	Check air intake for leakage	1 Month
	13	Check for air cleaner restrictions	1 Month
	14	Check fuel oil leakage	1 Month
	15	Check fuel level	1 Month
	16	Check fuel transfer pump	1 Month
	17	Check exhaust restriction	1 Month
	18	Drain condensate trap	1 Month
	19	Change fuel flow filter	6 Months
	20	Change bypass filter	250 hours
	21	Change engine oil	250 hours
	22	Change hydraulic governor oil	250 hours
	23	Check heat exchanger	250 hours
	24	Change DCA water filter	250 hours
	25	Check piping and connection	250 hours
	26	Clean crank case breather	250 hours
	27	Clean or change air cleaner element	250 hours
	28	Check governor linkage	250 hours
	29	Check fuel lines and connections	250 hours
	30	Drain sediment from tank	250 hours
	31	Change fuel filters	250 hours
	32	Check fan hub, drive pulley, Water pump	250 hours
	33	Clean cooling system	1 Year
	34	Change float tank breather	1 Year
	35	Tighten exhaust manifold and turbo charger cap screw	1 Year
	36	Check for tightness of mounting hardware	1 Year
	37	Clean engine	1 Year
Air Conditioner and Ventilation System	1	Check belt and bearing for wear	1 Month
	2	Check belt tension	1 Month
	3	Check pulley alignment	1 Month
	4	Check wheel balance condition	1 Month
	5	Check for air leakage from panels	1 Month
	6	Check for proper refrigeration charge	1 Month
	7	Inspect refrigeration charge	1 Month
	8	Inspect the filters	1 Month
	9	Clean the units	1 Month
	10	Inspect the ventilation fan for abnormalities	1 Month
	11	Check for obstructions of the ventilation	1 Month
	12	Clean the filters	1 Month
	13	Inspect bearing, relubricate or replace if necessary	1 Year

## **2. MAJOR OVERHAUL ITEMS IN CANYON HYDROPOWER STATION**

### **2.1 Hydro turbine**

- Dewatering the hydro turbine
- Visual inspection of cavitation damage of the runner
- Visual inspection of the wicket gate and the upper facing plate
- Cleaning and lubricating mechanism of the wicket gate
- Inspection of the wicket gate clearance
- Disassembling the shaft seal
- Changing all the O-rings, the corroded nuts and bolts in the shaft seal
- Visual inspection of the draft tube and the spiral case
- Polishing the damaged air admission pipes
- Welding the inlet valve and the bypass valve
- Measuring the clearance between the main shaft and the turbine guide bearing
- Filtering oil in the bearing
- Oil inspection for the bearing oil (about flash point, viscosity and acid)
- Cleaning oil filter in the governor
- Filtering oil in the governor
- Oil inspection for the governor oil (flash point, viscosity and acidity)

### **2.2 Generator**

- Cleaning the stator and the rotor with cloths and wooden sticks
- Visual inspection of the end winding in the stator
- Measuring insulation resistance of the stator and the rotor
- Disassembling and cleaning the PGM and the exciter
- Measuring insulation resistance of the PGM and the exciter
- Filtering the upper and lower guide bearing oils
- Oil inspection for the upper and lower bearing oils (flash point, viscosity and acidity)

### **2.3 Transformer**

- Filtering the transformer oil
- Oil inspection for the upper and lower bearing oils (water content, sludge and acidity)

### **2.4 12.5kV OCB**

- Visual inspection
- Check of the oil level

### **2.5 Instrument transformers (CT and VT)**

- Cleaning the transformers
- Measuring insulation resistance of the instrument transformers

## **2.6 132kV OCB**

- Cleaning the OCB
- Check of oil level

## **2.7 132kV line isolator and 132kV line earth switch**

- Visual inspection of the contact and mechanisms
- Lubricating the mechanism

## **2.8 Cooling water system**

- Disassembling the cooling water pumps
- Visual inspect of the cooling water pipe lines
- Cleaning the pipe line with compressed air and high pressure water
- Cleaning strainers of the system

***APPENDIX C-5  
INSPECTION ITEMS AND  
EXAMPLE OF MAINTENANCE  
MANUAL FOR  
ELECTRO-MECHANICAL EQUIPMENT***



# 1. INSPECTION ITEMS AND INSPECTION FREQUENCY

The items and frequencies of the periodic inspection and overhaul to be carried out for Laxapana Complex are introduced here. If the equipment is operated under hard conditions, it is desirable to shorten the interval between inspections by one year. Bold-faced inspections are important and the related manuals are provided in Section 2 “Inspection Manual”.

## 1.1 Periodic Inspection

### (1) Hydraulic turbine

1) Frequency of inspection: Once / 3 years

2) Inspection items:

- Dewatering of spiral case and draft tube
- Visual check of each component part in hydraulic turbines
- Check for looseness, discoloration, smell, cracks, erosion, peeling paint, wear, scuffing, rust, water leakage, oil leakage, clogged piping and gaps
- Cleaning
- Check for vibration and unusual sound
- Packing check (groove check and replacement)
- Valve check (operation test and disassembly inspection)
- Oil check
  - Oil filtering
  - Oil quality diagnosis (viscosity, flash point, acidity and color)
- Non-destructive inspection of shear pin and runner (liquid penetrant test or magnetic particle test)
- Check of setting values and secular change
  - Servomotor stroke versus wicket gate opening (Francis turbine)**
  - Servomotor stroke versus needle and deflector openings (Pelton turbine)**
  - Deflector servomotor stroke versus needle servomotor stroke (Pelton turbine)**
  - Squeeze
  - Gap
  - Oil level
  - Leakage water quantity
- Characteristics test of hydraulic turbine
  - Opening and closing test of wicket gates
  - Automatic start and stop test
  - Measurement of shaft run-out and vibration
- Relay test (confirmation of setting value and operation test)
- Calibration of instrument

### (2) Inlet valve

1) Frequency of inspection: Once / 3 years

2) Inspection items:

- Visual check of each component part of inlet valve
- Check for looseness, discoloration, cracks, erosion, peeling paint, wear, scuffing, rust, water leakage, oil leakage, clogged piping and gaps
- Cleaning
- Check of associated valve (operation test and disassembly inspection)

- Opening and closing test for inlet valve
- Measurement of leakage water quantity
- Relay test (confirmation of setting value and operation test)

(3) Speed governor

1) Frequency of inspection: Once / 3 years

2) Inspection items:

- Visual check of each component part of speed governor
- Check for looseness, peeling paint and oil leakage
- Cleaning
- **Measurement of insulation resistance of cubicle heater, permanent magnetic generator, wiring, transformer and governor**
- Calibration of balance meter, gate position meter, speed setting meter, speed meter and pressure gauge
- Characteristic test of permanent magnetic generator, speed signal generator, amplifier, potentiometer (value confirmation between output and input)
- Operation test of limit switch, control motor for speed setting and gate position
- Characteristic test of governor
  - Opening and closing test of wicket gate
  - Characteristic test of main distributing valve**
  - Characteristic test of frequency detecting circuit**
  - Characteristic test of converter**
  - Characteristic test of rigid and flexible returns**
  - Characteristic test of speed adjusting device (abbreviated as 65F) and load limiting device (abbreviated as 65P)**
  - Characteristic test of dead band**
  - Indicial response test**
    - Damping characteristic
    - Step control test
    - Automatic start and stop test

(4) Generator

1) Frequency of inspection: Once / 3 years

2) Inspection items:

- Visual check of air housing, stator, rotor, air cooler, bearings, bracket, brake, NGR and so on.
- Check for looseness, discoloration, smell, cracks, peeling paint, wear, scuffing, rust, water leakage, oil leakage, clogged piping and gaps
- Replacement of consumables such as gaskets
- Cleaning
- Valve check (operation test and disassembly inspection)
- Oil check
  - Oil filtering
  - Oil quality diagnosis (viscosity, flash point, acidity and color)
- Characteristic test of generator
  - Measurement of insulation resistance**
    - Confirmation of polarization index
    - Measurement of shaft voltage
    - Measurement of vibration under operation

- Sequence and operation test
- Automatic start and stop test
- **Relay test (confirmation of setting value and operation test)**

(5) Excitation equipment

- 1) Frequency of inspection: Once / 3 years
- 2) Inspection items:
  - Visual check of excitation equipment
  - Check for looseness, discoloration, smell, cracks, peeling paint, wear, scuffing, rust and gaps
  - Replacement of consumables such as gaskets
  - Cleaning
  - Check size of brush and brush holder
  - Characteristic test of excitation system
  - Measurement of insulation resistance**
  - Characteristic test of voltage detecting circuit**
  - Indicial response test**
  - Manual and remote operation and sequence test
  - Individual test for automatic voltage regulator (AVR)
  - Relay test (confirmation of setting value and operation test)

(6) Generator transformer

- 1) Frequency of inspection: Once / 6 years
- 2) Inspection items:
  - Visual check of tank, bushing, tap changer, conservator and so on
  - Check for looseness, discoloration, smell, cracks, rust, water leakage, oil leakage and clogged piping
  - Lubrication of operation linkage of on-load tap changer
  - Replacement of consumables such as contact of on-load tap changer
  - Cleaning
  - Calibration of dial thermometer
  - Oil check
  - Oil filtering
  - Oil quality diagnosis (viscosity, flash point, acidity, color and gas diagnosis of H<sub>2</sub>, N<sub>2</sub>, HC, C<sub>2</sub>H<sub>2</sub>, CO, CO<sub>2</sub>)
  - Characteristic test of generator transformer
  - Measurement of insulation resistance**
  - Measurement of current of auxiliary equipment
  - Sequence and operation test
  - Relay test (confirmation of setting value and operation test)

(7) Switchgear

- 1) Frequency of inspection:
  - Once / 3 years for oil circuit breaker, air circuit breaker, magnetic circuit breaker and vacuum circuit breaker
  - Once / 6 years for gas circuit breaker

- 2) Inspection items:
  - Visual check of main conductor and operation structure
  - Check for looseness, discoloration, smell, cracks, rust, oil leakage and gas leakage
  - Lubrication of operation linkage
  - Adjustment of moving parts
  - Replacement of consumables such as gaskets
  - Cleaning
  - Calibration of safety valve
  - Characteristic test of switchgear
  - Measurement of insulation resistance**
  - Manual and remote operation test
  - Sequence and operation test
  - Relay test (confirmation of setting value and operation test)

(8) Control and protection equipment

- 1) Frequency of the inspection for the whole equipment: As needed
- 2) Frequency of inspection of component parts is shown for reference.
  - Control equipment
    - Once / 3 years for analogue measurement part
    - Once / year for power source
    - Once / 12 years for instrument
    - Once / 6 years for other parts
  - Protection equipment
    - Once / 6 years for digital type (numerical type)
    - Once / 4 years for non-digital type with automatic monitoring system
    - Once / 2 years for non-digital type without automatic monitoring system
- 3) Inspection items:
  - Visual check and cleaning (indicators, meters and relays on main control equipment, auxiliary and protection equipment)
  - Characteristic tests
    - Measurement of insulation resistance (meters, relays, current & voltage circuits)**
    - Burden check (indicators, meters, relays, current & voltage circuits)**
    - Sequence test of direct current (protection system)
    - Overall sequence and operation test (turbine, generator with auxiliary equipment)**

## 1.2 Overhaul

(1) Hydraulic turbine

- 1) Overhaul frequency for Francis and Pelton turbines is shown below.
  - Once / 16 - 19 years for turbine less than 20MW
  - Once / 15 – 18 years for turbine from 20MW to less than 40MW
  - Once / 14 – 16 years for turbine over 40MW

2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Full dewatering and full disassembly
- Non-destructive inspection (liquid penetrant inspection or magnetic particle inspection: coupling flange, bearing metal surface, liner, shear pin and wicket gate root)
- Characteristic test with the whole equipment
  - Wicket gate operation with and without water
  - Main bearing heat test
  - Output versus gate (or needle) opening test**
- Report on assembly (records of gap, level value, and leveling and adjusting method)

(2) Inlet valve

1) Overhaul frequency: Twice the above-indicated frequency for hydraulic turbines

2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Full dewatering and full disassembly
- Replacement of packing
- Characteristic test (opening and closing test with and without water)

(3) Speed governor

1) Overhaul frequency: half of the above-indicated frequency for hydraulic turbines

2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Measurement of resistance, voltage and waveform
- Operation test of load limiting device, locking device and distributing valve
- Inspection of servomotor
  - Disassembly inspection
  - Replacement of packing
  - Measurement of relation between auxiliary and main servomotor strokes
  - Measurement of opening and closing force of main servomotor
  - Measurement of opening and closing time
- Total characteristic test of hydraulic turbine and governor
  - Measurement of speed droop
  - Measurement of dead band
  - Indicial response test
  - Measurement of frequency control range
  - Characteristic test of amplifier and feedback system
  - Load rejection test**

(4) Generator

- 1) Overhaul frequency: Same as the frequency for hydraulic turbines
- 2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Disassembly of generator including removal of rotor
- Visual check of all wedges and coils in stator
- Disassembly inspection of air cooler and bearing
- Liquid penetrant test for bearing
- Characteristic test of generator
  - Voltage sharing test on rotor (coil impedance test on rotor)
  - Bump test after assembly
  - Balance adjustment
  - Load test**
- Report on assembly (records of gap, level value, and leveling and adjusting method)

(5) Excitation equipment

- 1) Overhaul frequency:

Same as the frequency for the generator for excitation equipment  
Half of the frequency for the generator for AVR

- 2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Disassembly of exciter
- Visual check of exciter, field circuit breaker, cubicle (controller and exciter transformer) and AVR
- Characteristic test (recommended by manufacturer)

(6) Generator transformer

- 1) Overhaul frequency: As needed

Transformer should be overhauled, whenever an abnormal component value of inflammable gas in tank oil is observed by oil gas diagnosis.

- Once / 6 years or 50,000 operations for on-load tap changer

Same as the frequency of generator

- 2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- Drainage of oil from tank
- Visual check of transformer interior (coil, insulating paper and so on)
- Degassing of oil and oil-filling to tank

(7) Switchgear

1) Overhaul frequency:

- Once / 6 years or frequency recommended by manufacturer for oil circuit breaker and magnetic circuit breaker
- Once / 12 years or frequency recommended by manufacturer for air circuit breaker, gas circuit breaker and vacuum circuit breaker

2) Inspection items::

The following inspections are carried out in addition to the periodic inspection items.

- Disassembly of safety valve, main contact and operation linkage
- Replacement of operation oil

(8) Control and protection equipment

1) Overhaul frequency: As needed

2) Inspection items:

The following inspections are carried out in addition to the periodic inspection items.

- **Load rejection test**

## 2. INSPECTION MANUAL

### 2.1 Inspection manual of periodic inspection

(1) Servomotor stroke versus wicket gate opening (Francis)

- 1) Purpose:
  - a) To measure correlation between servomotor stroke and wicket gate opening.
  - b) To check the difference between the measured value and original setting value.
  - c) To confirm the secular change.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Servomotor stroke			
4. Wicket gate opening			
5. Operator			

5) Measurement conditions:

- a) This measurement is performed in the periodic inspection
- b) This measurement is a dry test
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - No electrical lock
    - Mechanical lock for inlet valve
  - Other conditions:
    - None

6) Measurement procedure:

- a) Wicket gate servomotor is operated from governor.
- b) The servomotor is opened from closing position to 100% opening position. The wicket gate opening should be measured every 10% of the servomotor stroke.
- c) Same procedure is applied to the opening measurement from 100% opening to closing.
- d) The wicket gate opening is measured at the center of the gate.
- e) Operation direction (opening or closing) of the servomotor should not be changed during the measurement.
- f) For safety, the main oil supply valve should be fully closed when the wicket gate opening is measured. Also, it should be confirmed that there is no residual pressure at the governor distribution valve. The servomotor stopper should be used during the measurement, if possible.



7) Measurement schedule:

The following time is shown for reference.

- 8:00 Meeting before the measurement  
Prepare for the measurement and lock the equipment shown in item 5)-c)
- 9:00 Operator operates the servomotor  
Set the servomotor stroke to 10% opening  
Close the oil supply valve and set the servomotor stopper  
Measure the wicket gate opening
- 9:15 Next measurement is repeated. ·····

8) Table for measurement:

Refer to the table “Servomotor stroke vs wicket gate opening”

9) Judgment criteria:

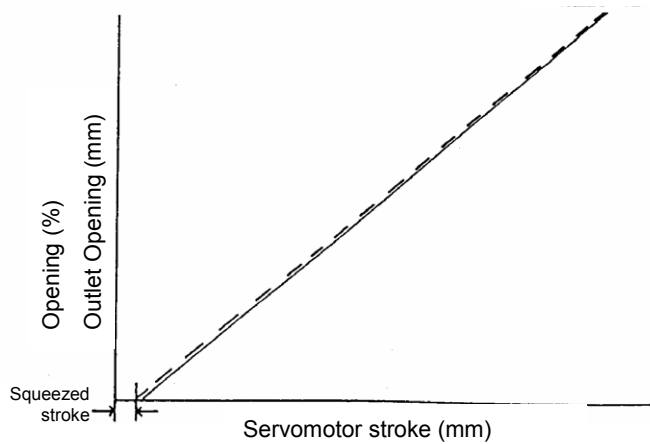
Less than  $\pm 1.5\%$  of average stroke at 100% wicket gate opening (for reference)

# Servomotor Stroke VS Wicket Gate Opening

Record

Servomotor Stroke (mm)	No. of Wicket Gate (mm)	Wicket Gate Opening (mm)					Average
		~	~	~	~	~	
Open Direction							
Close Direction							

Remarks:  
 a. Design Valve of 100% of Gate Opening (Outlet Opening) \_\_\_\_\_ mm Servomotor Stroke \_\_\_\_\_ mm  
 b. Squeezed Stroke \_\_\_\_\_ mm  
 c. Oil temperature \_\_\_\_\_ °C



(2) Servomotor stroke versus needle and deflector openings (Pelton)

1) Purpose:

- a) To measure correlation between the needle servomotor stroke and needle opening.
- b) To measure correlation between the deflector servomotor stroke and deflector opening.
- c) To check the difference between the measured value and the original setting value.
- d) To confirm the secular change.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Deflector servomotor stroke			
4. Deflector opening			
5. Needle servomotor stroke			
6. Needle opening			
7. Operator			

5) Measurement conditions:

- a) This measurement is performed in the periodic inspection
- b) This measurement is a dry test
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - No electrical lock
    - Mechanical lock for inlet valve
  - Other conditions:
    - None

6) Measurement procedure:

- a) Needle servomotor is operated from governor.
- b) The needle servomotor is opened from closing position to 100% opening position. The needle gate opening should be measured every 10% of the needle servomotor stroke.
- c) Same procedure is applied to the opening measurement from 100% opening to closing.
- d) The above-mentioned procedure is applied to measurement of “deflector servomotor stroke and deflector opening”.
- c) Operation (opening or closing) direction of the servomotors should not be changed during the measurement.
- d) For safety, the main oil supply valve should be fully closed when the needle opening is measured. Also, it should be confirmed that there is no residual pressure at the governor distribution valve. The servomotor stopper should be used during the measurement, if possible.

7) Measurement schedule:

Refer to the measurement schedule of “(1) Servomotor stroke versus wicket gate opening”

8) Table for measurement:

Refer to the table “Servomotor stroke and needle opening” and “Servomotor stroke and deflector opening”.

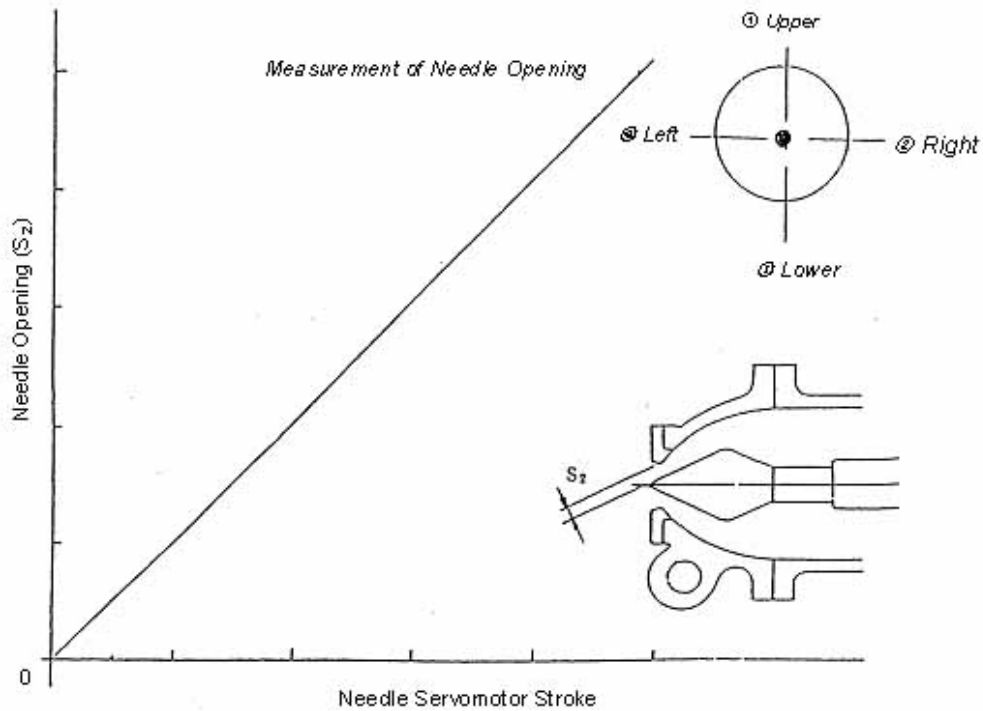
9) Judgment criteria:

The difference of each servomotor stroke is less than  $\pm 2$  mm of mean values for needle opening and deflector opening (for reference).

Servomotor stroke and needle opening

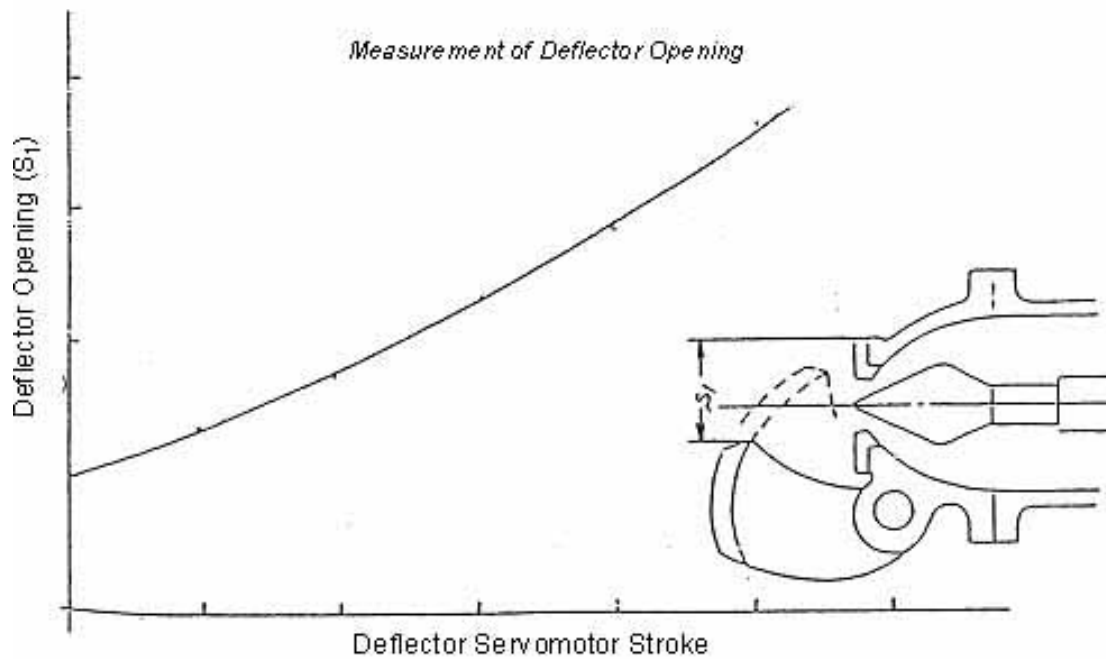
Needle Servomotor Stroke (mm)																	
Needle Opening (mm)	①																
	②																
	③																
	④																

Remarks: To be measured for all needles



Servomotor stroke and deflector opening

Deflector Servomotor Stroke (mm)													
Deflector Opening (mm)	No. 1												
	No. 2												
	No. 3												
	No. 4												



(3) Deflector servomotor stroke versus needle servomotor stroke (Pelton)

1) Purpose:

- a) To measure correlation between the deflector servomotor stroke and needle servomotor stroke.
- b) To check the difference between the measured value and the designed value.
- c) To confirm the secular change.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Deflector servomotor stroke			
4. Needle servomotor stroke			
5. Operator			

5) Measurement conditions:

- a) This measurement is performed in the periodic inspection
- b) This measurement is a dry test
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - No electrical lock
    - Mechanical lock for inlet valve
  - Other conditions:
    - None

6) Measurement procedure:

- a) Deflector and needle servomotors are operated from governor.
- b) The deflector servomotor is opened from closing position to 100% opening position. The needle servomotor stroke should be measured every 10% of the deflector servomotor stroke.
- c) Same procedure is applied to the opening measurement from 100% opening to closing.
- d) Operation direction (opening or closing) of the servomotor should not be changed during the measurement.

7) Measurement schedule:

Refer to the measurement schedule of “(1) Servomotor stroke versus wicket gate opening”

8) Table for measurement:

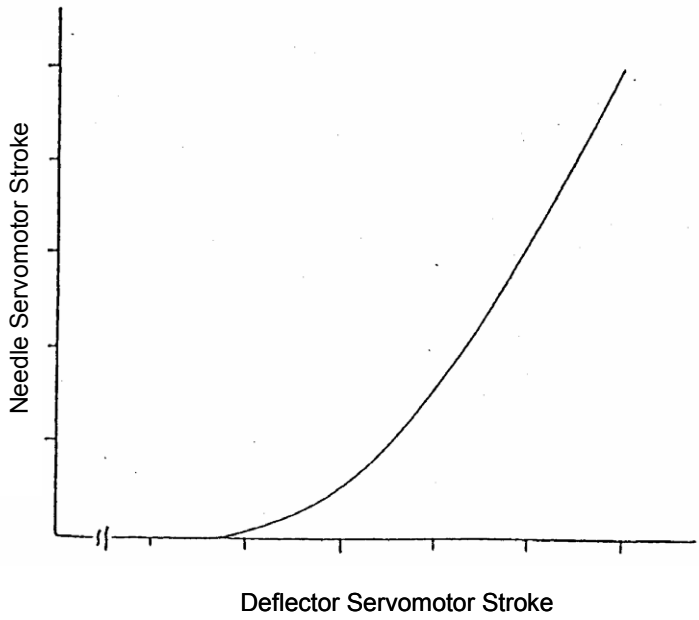
Refer to the table “Deflector stroke vs needle stroke”

9) Judgment criteria:

Less than  $\pm 1$  % of designed value (for reference)

## Deflector Stroke VS Needle Stroke

Deflector Servomotor Stroke (mm)	Design Values of Needle Servomotor Stroke (mm)	Measured Values of Needle Servomotor Stroke (mm)			
		No.1	No.2	No.3	No.4
<i>Remarks:</i> Oil pressure _____ °C					



(4) Characteristic test of main distributing valve in governor

1) Purpose:

To confirm the capacity of the main distributing valve and the oil pressure lap through the measurement of the distributing valve lift and the opening & closing velocities of the main servomotor.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Lift of distributing valve			
4. Main servomotor stroke			
5. Time			
6. Operator			

5) Measurement conditions:

- a) This measurement is performed in the periodic inspection.
- b) This measurement is a dry test or wet test.
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - No electrical lock
    - Mechanical lock for the inlet valve
  - Other conditions:
    - Oil temperature in the servomotor should be adjusted nearly equal to that in the oil pressure tank.
    - The oil pressure of pressure tank should be within the normal oil pressure range during measurement.
    - The safety director should prohibit any person from entering the spiral case and turbine pit during the operation of the wicket gates (or deflectors, needles, runner vanes).

6) Measurement procedure:

- a) The feedback mechanism should be disconnected from the main servomotor to prevent the transmission of a feedback signal to the main distributing valve.
- b) After confirming that the distributing valve is located at the neutral position, the opening and closing velocity of the main servomotor to each valve lift should be measured.
- c) Measurement should be performed after finishing the adjustment and setting of main servomotor stoppers corresponding to full closing and full opening positions.



7) Measurement schedule:

The following schedule is shown for reference.

- 8:00 Meeting before the measurement  
Prepare for the measurement and lock the equipment shown in item 5)-c)
- 9:00 Operator operates the distributing valve to measure the oil pressure lap.  
Set the lift of the distributing valve and measure the velocity of the main servomotor.
- 9:15 Next measurement is repeated. ....

8) Table for measurement: Refer to the table “Characteristic Test of Main Distributing Valve”

9) Judgment criteria:

- a) The proper oil pressure lap of main distributing valve should be confirmed.
- b) The main servomotor velocity should have a sufficient margin for the required servomotor velocity for load rejection.

Opening direction			
Lift of distributing valve (1/100 mm)			
Main servomotor stroke (mm)			
Time (s)			
Velocity of main servomotor (mm/s)			
Closing direction			
Lift of distributing valve (1/100 mm)			
Main servomotor stroke (mm)			
Time (s)			
Velocity of main servomotor (mm/s)			
Remarks:			
a) Full stroke of main servomotor			mm
b) Maximum lift of distributing valve			mm
c) Stroke of throttle valve	closing		mm
	opening		mm
d) Oil temperature			°C

The graph plots the velocity of the main servomotor (mm/s) on the vertical axis against the lift of the distributing valve (1/100 mm) on the horizontal axis. Two curves are shown: one for the opening direction and one for the closing direction. The opening curve starts at zero velocity and shows a horizontal segment labeled 'Oil pressure lap' before the velocity begins to rise. The closing curve shows a similar horizontal segment before the velocity drops to zero. The full range of valve lift is indicated by a horizontal double-headed arrow.

(5) Characteristic test of frequency detecting circuit

1) Purpose:

To confirm the linearity and the gain to frequency of the output of the frequency detecting circuit.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Frequency			
4. Output (V or R)			
5. Operator			

5) Measurement condition:

- a) This measurement is performed in the periodic inspection.
- b) This measurement is a dry test.
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - Mechanical lock for the inlet valve
    - The electrical system of the governor should be disconnected from the mechanical system before the measurement.
    - The control pressure oil system should be isolated from the servomotor by means of the stop or main valve.

6) Measurement procedure:

- a) The rated frequency should be input into the frequency detecting circuit through a test power generating set or a variable frequency generating set. The position of the speed adjustment device (abbreviated as 65F) should be confirmed when the output voltage or current of the frequency detecting circuit becomes zero.
- b) Holding the speed adjustment device (65F) at the above position, the output voltage or current of the frequency detecting circuit should be measured while changing the input frequency.
- c) The variation range of the frequency should be within the control range of the speed adjustment device (65F).

Note: An example of a test circuit for the characteristics test of the frequency detecting circuit is shown in the attached table.

7) Measurement schedule:

The following schedule is shown for reference.

- 8:00 Meeting before the measurement  
Prepare for the measurement and lock the equipment shown in item 5)-c)
- 9:00 Operator operates a test power generating set or a variable frequency generating set.  
Measure the output voltage or current.
- 9:15 Next measurement is repeated. ....

8) Table for measurement:

Refer to the table “Characteristic Test of Speed Detecting Device for Governor”

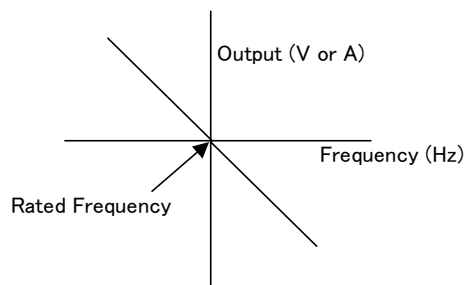
9) Judgment criteria:

- a) The output of the frequency detecting circuit should have linearity and a satisfactory gain to frequency .

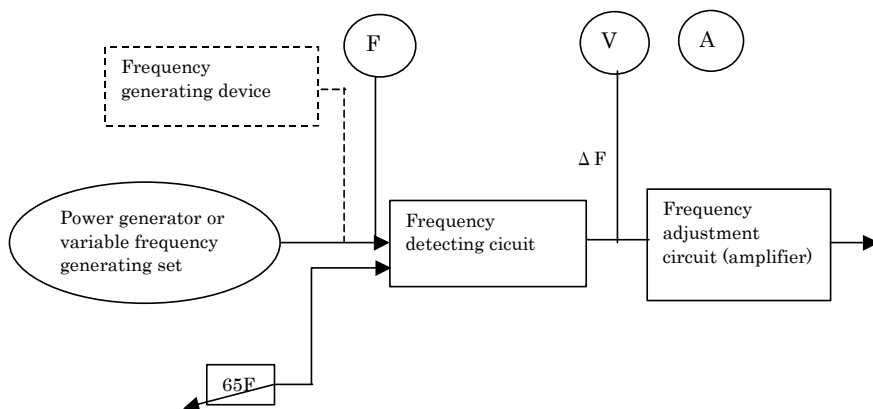
**Characteristic Test of Frequency Detecting Circuit for Governor**

Frequency (Hz)						
Output Voltage (V)						
or Output Current (A)						

Note: Setting of the speed adjustment device (abbreviated as 65F) \_\_\_\_\_



An example of a test circuit for characteristic test of frequency detecting circuit



(6) Characteristic test of converter in governor

1) Purpose:

To confirm the characteristics of the converter that converts the electrical signal into the oil pressure.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety director			
3. Converter input			
4. Converter movement			
5. Operator			

5) Measurement conditions:

- a) This measurement is performed in the periodic inspection.
- b) This measurement is a dry test.
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - No electrical lock
    - Mechanical lock for the inlet valve
    - The control pressure oil system should be isolated from the servomotor by means of the stop or main valve.

6) Measurement procedure:

- a) Opening and closing movement of the converter according to the input voltage or current should be measured.
- b) If it is difficult to directly measure the movement, the relation between converter input and opening / closing velocity of the auxiliary servomotor should be measured. In this case, the primary distributing valve should be held at its neutral position.

7) Measurement schedule:

The following schedule is shown for reference.

- 8:00 Meeting before the measurement  
Prepare for the measurement and lock the equipment shown in item 5)-c).
- 9:00 Operator operates a converter input.  
Measure the converter output.
- 9:15 Next measurement is repeated. ....

8) Table for measurement:

Refer to the table “Characteristic Test of Converter for Governor”

9) Judgment criteria:

- a) The characteristics of the converter should have linearity and fewer hysteresis.
- b) The primary distributing valve should have the proper oil pressure lap, and the auxiliary servomotor should have sufficient velocity within the specified input range of the converter.
- c) The auxiliary servomotor should have the closing tendency with the zero input of converter.

<b>Characteristic Test of Converter for Governor</b>				
<b>(1) Characteristic test when the converter movement can be directly measured.</b>				
Opening direction				
Converter input voltage (V) or current (A)				
Converter movement (mm)				
Closing direction				
Converter input voltage (V) or current (A)				
Converter movement (mm)				
Note: Oil pressure _____°C				
<b>(2) Characteristic test when the converter movement can not be directly measured.</b>				
Opening direction				
Converter input voltage (V) or current (A)				
Velocity of auxiliary servomotor (mm/s)				
Closing direction				
Converter input voltage (V) or current (A)				
Velocity of auxiliary servomotor (mm/s)				
Note: Oil pressure _____°C				
(closing direction)				

(7) Characteristic Test of Rigid and Flexible Returns

1) Purpose:

To confirm that the speed droop, temporary speed droop and time constant of the flexible return (damping) satisfy the specifications.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety operator			
3. Frequency			
4. Auxiliary servomotor stroke			
5. Setup scale of rigid return			
6. Setup scale of flexible return			
7. Voltage of flexible return			
8. Operator			

5) Measurement conditions:

- a) This measurement is performed in the periodic inspection.
- b) This measurement is a dry test.
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - No electrical locks
    - Mechanical lock for inlet valve

6) Measurement procedure:

6-1) Rigid return

- a) The flexible return should be removed from the closing loop including the auxiliary servomotor, i.e., the damping setting equals zero.  
The following adjustments should be implemented.  
The auxiliary servomotor opening is adjusted to 50% with the rated frequency. The load limiting device (abbreviated as 65P) should be set at the position where the converter input is zero.
- b) The set stroke of the auxiliary servomotor should be measured with the rigid return scale as a parameter, changing  $\pm \delta$  % of the rated frequency. The measured stroke of the auxiliary servomotor may be within 5 to 95 % of total stroke.  
 $\delta$  should be within 1/2 of the adjustment range of the specified speed droop.

6-2) Flexible return (damping)

a) Flexible return value:

The rigid return should be removed from the closing loop including the auxiliary servomotor. The time constant adjustment device of the flexible return should be locked, i.e., its capacitor should be shorted.

The output voltage of the flexible return should be measured in relation to the auxiliary servomotor stroke, with the flexible return scale as a parameter.

b) Time constant of flexible return:

A correct step input should be applied to the flexible return. The time when the output becomes 37 % of the peak value should be measured.

Note: An example of the test circuit is shown in the attached table.

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement

Prepare for the measurement and lock the equipment shown in item 5)-c).

9:00 Add the input frequency and measure the servomotor stroke in relation to each rigid return scale.

Calculate the speed droop.

9:15 Next measurement is repeated. ....

8) Table for measurement:

Refer to the tables “Characteristic Test of Rigid and Flexible Returns for Governor (1), (2), (3)”

9) Judgment criteria:

a) Each characteristic test result should satisfy the specified value.

**Characteristic Test of Rigid and Flexible Returns for Governor (1)**

**(I) Rigid return**

Input frequency (Hz)	Auxiliary servomotor stroke (mm)				
Setup scale of rigid return	2	4	6	8	10
Speed droop (%)					

Note:

a.) Setup scale of speed adjusting device (abbreviated as 65F) \_\_\_\_\_

b) Setup scale of load limiting device (abbreviated as 65P) \_\_\_\_\_

c) Calculation of speed droop

$$D = \{(F_0 - F_{100}) / F_n\} * 100 (\%)$$

Where; D: Speed droop (%)

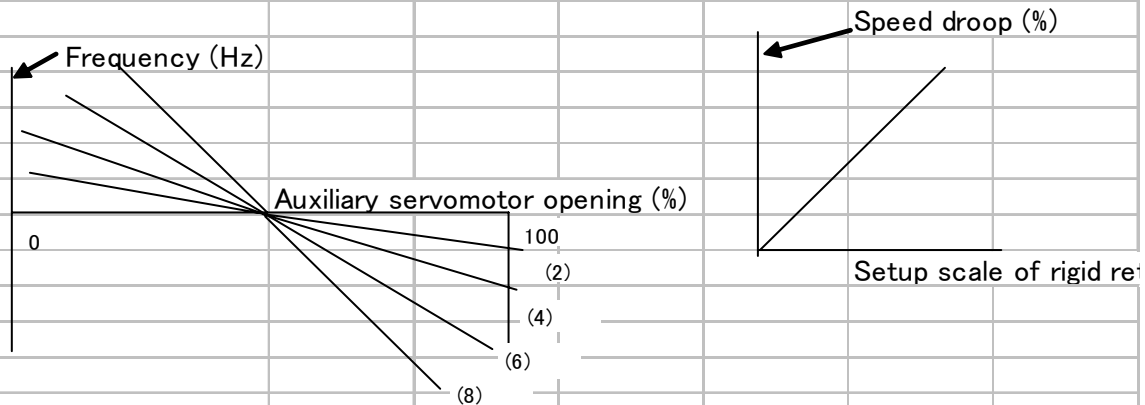
F<sub>n</sub>: Rated frequency (Hz)

F<sub>0</sub>: Frequency corresponding to 0 % of auxiliary servomotor opening

F<sub>100</sub>: Frequency corresponding to 100 % of auxiliary servomotor opening

d) Specification Speed droop 0 to \_\_\_\_\_ %

e) Oil temperature \_\_\_\_\_ °C



Note:

( ) indicates the setup target of rigid return



**Characteristic Test of Rigid and Flexible Returns for Governor (2)**

**(2) Flexible return**

	Voltage of flexible return (V)				
Setup scale of flexible return	2	4	6	8	10
Auxiliary servomotor stroke (mm)					
Temporary speed droop (%)					

Note:

a) Calculation of temporary speed droop

$$D_T = V_R / V_D$$

Where;

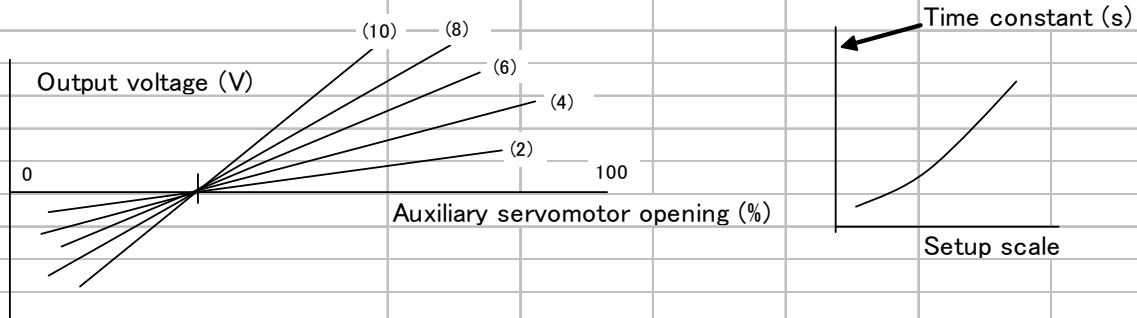
$D_T$ : Temporary speed droop (%)

$V_R$ : The voltage of flexible return per 100 % stroke of auxiliary servomotor (V)

$V_D$ : Detected voltage per 1 % of frequency (V)

b) Specification temporary speed droop \_\_\_\_\_ %

e) Oil temperature \_\_\_\_\_ °C



Note:

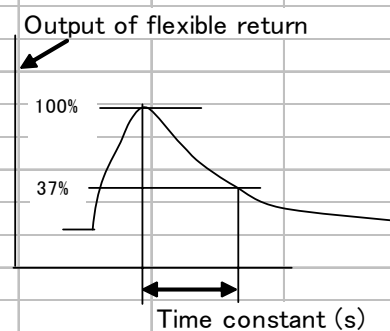
( ) indicates the setup target for time constant of flexible return

Setup target for time constant of flexible return

Setup target for time constant	Time constant (s)
1	
2	
3	
4	
5	

Note: Specification

Time constant of flexible return



(8) Characteristic Test of Speed Adjusting Device (abbreviated as 65F) and Load Limiting Device (abbreviated as 65P)

1) Purpose:

To confirm that the adjustment ranges satisfy the specifications, and each set value provides satisfactory linearity with respect to the speed adjusting device (65F) and load limiting device (65P).

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety director			
3. Frequency			
4. 65F scale			
5. 65P scale			
6. Auxiliary servomotor opening			
7. Operator			

5) Measurement conditions:

- a) This measurement is performed in the periodic inspection.
- b) This measurement is a dry test.
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - No electrical lock
    - Mechanical lock for inlet valve

6) Measurement procedure:

6-1) Characteristics of speed adjusting device (65F)

The following should be measured.

Input frequency, in which the output of the frequency detecting circuit becomes zero at each set value (position) of 65F  
 Operating time of control motor for 65F

6-2) Characteristics of load limiting device (65P)

The followings should be measured.

The auxiliary servomotor stroke at each set value (position)  
 Operating time of control motor for 65P

7) Measurement schedule:

The following schedule is shown for reference.

- 8:00 Meeting before the measurement  
Prepare for the measurement and lock the equipment shown in item 5)-c).
- 9:00 Set up the 65F scale  
Measure the frequency.
- 9:15 Next measurement is repeated. ·····

8) Table for measurement:

Refer to the table “Characteristic Test of Speed Adjusting Device (65F) and Load Limiting Device (65P)”

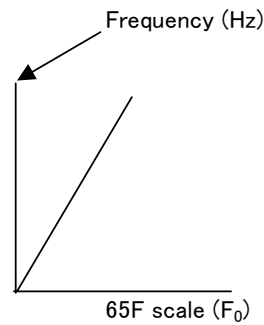
9) Judgment criteria:

- a) Each characteristic test result should satisfy the specification.

**Characteristic Test of Speed Adjusting Device (abbreviated as 65F) and Load Limiting Device (abbreviated as 65P)**

**(1) 65F**

65F scale	Frequency (Hz)
0	
2	
4	
6	
8	
10	
Operating time of the control motor for 65F (65FM)	(s)



Note:

- a) Specification:  
Frequency adjusting range \_\_\_\_\_ Hz
- b) Symbol of measurement terminal \_\_\_\_\_

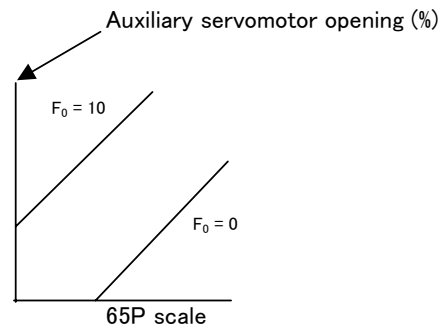
**(2) 65P**

Scale of 65P	Auxiliary servomotor opening (%)	
	$F_0 = 0$	$F_0 = 10$
0		
2		
4		
6		
8		
10		
Operating time of the control motor for 65P (65PM)	(s)	

Note:

- a) Oil temperature \_\_\_\_\_ °C

$F_0$ : 65F scale



(9) Characteristic Test of Dead Band

1) Purpose:

To confirm that the dead band satisfies the specification.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Control room as Commander			
2. Frequency			
3. Auxiliary servomotor movement			
4. Operator			

5) Measurement conditions:

- a) This measurement is performed in the periodic inspection.
- b) This measurement is a dry test.
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - No electrical lock
    - Mechanical lock for inlet valve

6) Measurement procedure:

- a) The auxiliary servomotor opening should be held at its middle position.
- b) Input frequency for the frequency detecting circuit should be adjusted slightly up and down.
- c) Then, the frequency at which the auxiliary servomotor starts should be measured.

Note: the following special measuring instrument is needed.

Precision frequency generator

/ Generated frequency: It should be possible to generate less than 0.01% of the rated frequency.

/ Generated voltage: It should be sufficient to supply the voltage to the frequency detecting circuit.

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement

Prepare for the measurement and lock the equipment shown in item 5)-c).

9:00 Adjust the frequency slightly above and below the rated one.

Measure the frequency for the auxiliary servomotor to begin closing or opening movement.

9:15 Next measurement is repeated. ....

8) Table for measurement:

Refer to the table “Characteristic Test of Dead Band”

9) Judgment criteria:

a) The dead band should meet the specification.

#### Characteristic Test of Dead Band

Frequency for the auxiliary servomotor to begin closing movement (Hz)	
Frequency for the auxiliary servomotor to begin opening movement (Hz)	
Dead band (%)	

Note:

a) Calculation of dead band

$$2 \Delta = (F_c - F_0) * 100 / F_n$$

Where;

$2 \Delta$ : Dead band (%)

$F_n$ : Rated frequency (Hz)

$F_c$ : Frequency for the auxiliary servomotor to begin closing movement (Hz)

$F_0$ : Frequency for the auxiliary servomotor to begin opening movement (Hz)

b) Specification: Dead band \_\_\_\_\_ %

c) Oil temperature \_\_\_\_\_ °C

(10) Indicial response test for governor

1) Purpose:

To confirm the dynamic characteristics of the speed control under no load operation

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety director			
3. Setup scale of rigid return			
4. Setup scale of flexible return			
5. Setup target on time constant			
6. Step input			
7. Rotational speed			
8. Time			
9. Operator			

5) Measurement conditions:

- a) This measurement is performed in the periodic inspection.
- b) This measurement is a wet test.
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - No electrical lock
    - No mechanical lock

6) Measurement procedure:

- a) A step input corresponding to approximately  $\pm 5\%$  of the rated speed should be applied to the output terminal of the frequency detecting circuit under the governor's free operation with no load.
- b) Under the above conditions, variations of rotational speed, auxiliary servomotor stroke, main servomotor stroke and step input should be recorded by an oscillograph.
- c) Rigid and flexible returns should be adjusted to achieve the optimum dynamic characteristics.
- d) No load damping should be comprehensively determined with the results of the governor dynamic characteristics and the load rejection.
- e) Preparatory test with small input should be implemented to avoid excessive speed rise and hydraulic pressure.

7) Measurement schedule:

The following schedule is shown for reference.

8:00 Meeting before the measurement

Prepare for the measurement

9:00 Set up the oscillograph

Add the step input.

Confirm the rotational speed and the time until the defined stable condition.

9:15 Next measurement is repeated. ·····

8) Table for measurement:

Refer to the table “Indicial Test for Governor”

9) Judgment criteria:

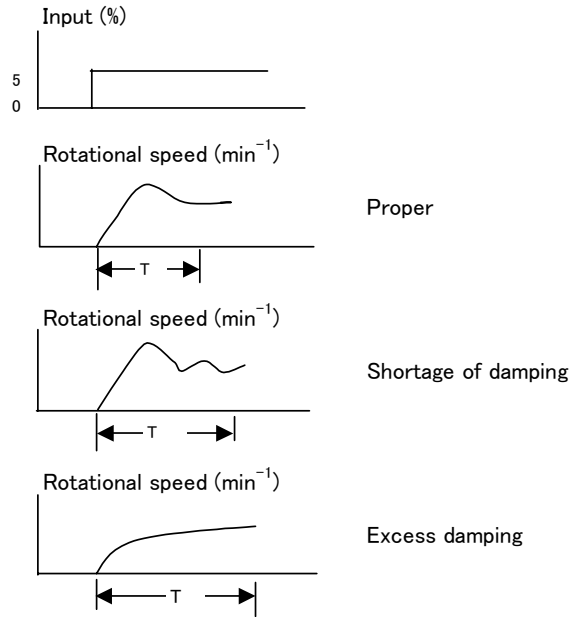
a) The time required for the rotational speed to be stabilized should be as short as possible.



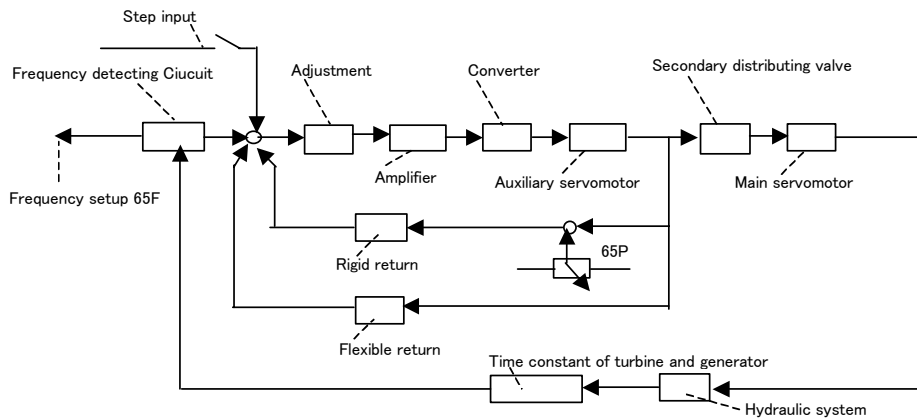
### Indicial Response Test for Governor

Test number				Setup
Setup scale of rigid return				
Setup scale of flexible return				
Setup target on the time constant for flexible return				
Step input (%)				
Rotational speed ( $\text{min}^{-1}$ )				
Before input				
Maximum (Minimum)				
After steadiness				
Time (s)				
Until maximum (minimum)				
Until steadiness				

Note: Oil temperature \_\_\_\_\_ °C



### Example of a test loop for indicial response



(11) Measurement of insulation resistance

1) Purpose:

- a) To measure the insulation resistance of AC and DC circuits.
- b) To confirm the secular change.

2) Date:

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Operator			
4. Staff No.1 who makes circuit to be measured			Refer to the note
5. Staff No.1 who makes circuit to be measured			Refer to the note

Note: The personnel who makes the circuit to be measured should make the circuit under observation of the safety director.

5) Measurement conditions

- a) This measurement is performed in the periodic inspection
- b) This measurement is a dry test
- c) All grounding wires are removed from the circuit to be measured before the measurement. The circuit breakers that are connected to the circuit are locked. The circuit should be isolated from other circuits.
- d) Operator should confirm there is no voltage on the circuit before the measurement.
- e) Safety director should prohibit any person from entering the measurement area during the measurement.
- f) The charged electricity on the circuit should be discharged after the measurement. Then the removed grounding wires should be reconnected immediately.

6) Measurement procedure

The main circuits to be measured are as follows:

- Between the PT (PD) circuit and earth
- Between the CT circuit and earth
- Between the DC circuit and earth
- Between the low voltage AC circuit and the DC circuit
- Between the stator coil and earth at the neutral grounding equipment
- Between the field coil and earth at the field circuit breaker
- Between each phase of the auxiliary circuit and earth

7) Measurement Schedule

- 8:00 Meeting before the measurement.  
Prepare for the measurement  
Safety director confirms the safety of the measurement area.  
Operator confirms there is no voltage on circuit to be measured, and charges voltage.
- 9:00 Operator starts the measurement
- 9:01 Resistance value of 1 minute is measured.
- 9:02 Resistance value of 2 minutes is measured.
- 9:03 Resistance value of 3 minutes is measured.
- 9:04 Resistance value of 4 minutes is measured.
- 9:05 Resistance value of 5 minutes is measured.
- 9:06 Resistance value of 6 minutes is measured.
- 9:07 Resistance value of 7 minutes is measured.
- 9:08 Resistance value of 8 minutes is measured.
- 9:09 Resistance value of 9 minutes is measured.
- 9:10 Resistance value of 10 minutes is measured.  
Operator discharges the electricity on the circuit.  
Removed grounding wires are reconnected.  
All locked equipment is unlocked.

8) Table for measurement:

Refer to the table "Measurement of insulation resistance"

9) Judgment criteria

Refer to the table "Measurement of insulation resistance"

Measurement of insulation resister

Weather:

Room temperature (°C):

Outside temperature (°C):

Time	At Start	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10min
MΩ											

Specification of measuring instrument: (500 V mega, 1000 V mega or 2000 V mega)

No. of Instrument	Name	Type	Rated	Manufacturing No.	Manufacturing Date	Manufacture

Judgment criteria (for reference)

Calculation of Polarization Index (PI)

PI = Measurement value of 10 min / Measurement value of 1 min should be more than 1.5

Minimum Insulation Resister 1 for transformer (MIR)

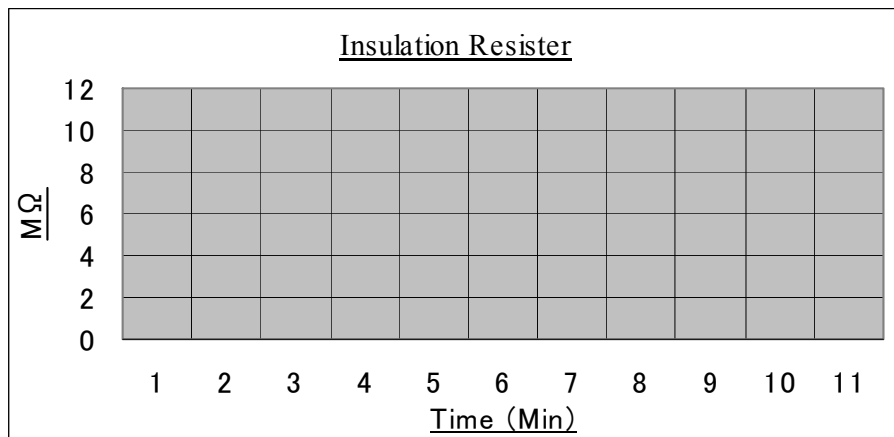
More than 2 M Ohm for each circuit at humidity less than 90 % for AC low voltage

More than 75 M Ohm for coil between 6.6 kV and less than 22 kV at 40degree-C

More than 90 M Ohm for coil between 22 kV and less than 66 kV at 40degree-C

More than 100 M Ohm for coil of more than 66 kV at 40degree-C

Characteristic Curve of Insulation Resister



(12) Characteristic Test of voltage detecting circuit

1) Purpose:

To confirm the linearity and the gain to generator voltage of the output of the voltage detecting circuit.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety director			
3. Voltage			
4. Output			
5. Operator			

5) Measurement conditions:

- a) This measurement is performed in the periodic inspection.
- b) This measurement is a dry test.
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:  
Mechanical lock for the inlet valve, parallel-in circuit breaker and field circuit breaker  
Dummy generator voltage is supplied from the test terminal circuit.

6) Measurement procedure:

- a) The rated generator voltage should be input into the voltage detecting circuit through a variable voltage supply set. The output of direct current to the voltage should be confirmed.
- b) Every signal to various input voltages should be measured. The gain to detected voltage should be confirmed.
- c) The detected voltage to the rated generator voltage should be determined.

7) Measurement schedule:

The following schedule is shown for reference.

- 8:00 Meeting before the measurement  
Prepare for the measurement and lock the equipment shown in item 5)-c)
- 9:00 Operator operates the variable voltage generating set.  
Measure the signal.
- 9:15 Next measurement is repeated. ....

8) Table for measurement:

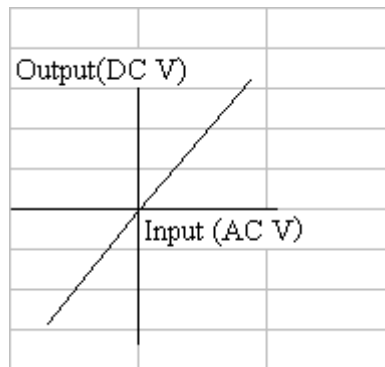
Refer to the table “Characteristic test of voltage detecting circuit in exciter system”

9) Judgment criteria:

- a) The output of the voltage detecting circuit should have linearity and a satisfactory gain to generator voltage .

Characteristic test of voltage detecting circuit in exciter system

Input AC voltage (V)	Output DC voltage (V)



(13) Indicial response test for exciter

1) Purpose:

To confirm the dynamic characteristics of the voltage control under no load operation.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement points	Communication	Name	Note
1. Commander			
2. Safety director			
3. Oscillograph			
4. Generator voltage			
5. Field current			
6. Time			
7. Operator			

5) Measurement conditions:

- a) This measurement is performed in the periodic inspection.
- b) This measurement is a wet test.
- c) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - No electrical lock
    - No mechanical lock

6) Measurement procedure:

- a) A step input corresponding to approximately  $\pm 10\%$  of the rated generator voltage should be applied to the output terminal of the voltage detecting circuit under normal operation with no load.
- b) Under the above conditions, variations of generator voltage, field current, and step input should be recorded by an oscillograph.
- c) Damping should be adjusted to achieve the optimum dynamic characteristics.
- d) Damping should be comprehensively determined with the static characteristics of the voltage controller and the result of the load rejection.

7) Measurement schedule:

The following schedule is shown for reference.

- 8:00 Meeting before the measurement  
Prepare for the measurement
- 9:00 Set up the oscillograph  
Add the step input  
Confirm the voltage and the time until the defined stable condition.
- 9:15 Next measurement is repeated. ....

8) Table for measurement:

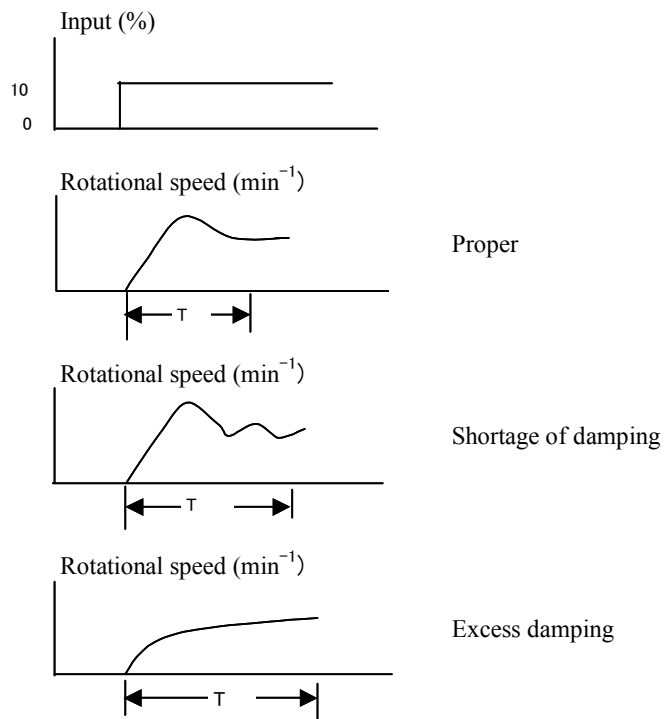
Refer to the table “Indicial Test for Exciter”

9) Judgment criteria:

a) The time required for the rotational speed to be stabilized should be as short as possible (J-POWER’s criterion: 2 Hz and below).

**Indicial Response Test for Exciter**

Test number				Setup
Step input (%)				
Generator voltage (V)				
Before input				
Maximum (Minimum)				
After steadiness				
Field current (A)				
Before input				
Maximum (Minimum)				
After steadiness				
Time (s)				
Until maximum (minimum)				
Until steadiness				
Field current (A)				
Set value of damping				





(14) Relay test (function test of thermal relay, level switch and pressure switch)

- 1) Purpose:
  - a) To ensure that the function of the thermal relay, level and pressure switch is correct.
- 2) Date: \_\_\_\_\_
- 3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station
- 4) Assigned persons:

Measurement point	Name	Note
1. Commander		
2. Safety director		
2. Relay checker		
3. Main operator for oil heater and dead weight gauge tester		
4. Sub-operator for oil heater and dead weight gauge tester		

- 5) Measurement conditions:
  - a) This measurement is performed in the periodic inspection
  - b) This measurement is a dry test
  - c) The relays to be measured should be removed from the turbine and generator. These relays should be inspected individually.
  - d) Equipment to be locked and other conditions are as follows:
    - Equipment to be locked:
      - No electrical lock
      - No mechanical lock
    - Other conditions:

The following items should be prepared before the measurement:

Standard thermometer  
Oil basin  
Oil heater  
Dead weight gauge tester

- 6) Measurement procedure
  - a) Thermal relay
    - The thermal relay probe and standard thermometer are placed into the basin filled with oil (or water).
    - The oil (or water) temperature is raised up to the setting value by the oil heater (water heater).
    - The actual temperature at the relay's opening and closing time is measured.
  - b) Level switch
    - The level switch is placed into the basin filled with oil (or water).
    - The actual range of the oil (or water) level at the relay's opening and closing time is measured

c) Pressure switch

- The pressure switch is placed into the dead weight gauge tester.
- The actual pressure value at the relay's closing and opening time is measured.

7) Measurement schedule

The following schedule is shown for reference.

8:00 Meeting before measurement  
Preparation for measurement

10:00 Start of "Measurement"

- Measurement of thermal relay
- Measurement of level switch
- Measurement of pressure switch

8) Table for measurement

a) Thermal relay for alarm

Date: \_\_\_\_\_

Room Temperature: \_\_\_\_\_

Measurement point	Device No.	Setting value (°C)	Measured value (°C)
Alarm of turbine guide bearing			
Alarm of generator lower bearing			
Alarm of generator upper bearing			
Alarm of thrust bearing			

b) Thermal relay for shutdown

Date: \_\_\_\_\_

Room Temperature: \_\_\_\_\_

Measurement point	Device No.	Setting value (°C)	Measured value (°C)
Shutdown of turbine guide bearing			
Shutdown of generator lower bearing			
Shutdown of generator upper bearing			
Shutdown of thrust bearing			

c) Level switch

Date: \_\_\_\_\_  
 Room Temperature: \_\_\_\_\_

Measurement point	Device No.	Setting value (mm)		Measured value (mm)	
		Closing value	Opening value	Closing value	Opening value
Turbine guide bearing			-		-
Generator lower bearing			-		-
Thrust bearing			-		-
Oil tank					
Leakage oil tank					
Pressured oil tank					

d) Pressure switch

Date: \_\_\_\_\_  
 Room Temperature: \_\_\_\_\_

Measurement point	Device No.	Setting value (Pa)		Measured value (Pa)	
		Closing value	Opening value	Closing value	Opening value
Oil pressure in pressured oil tank					

9) Judgment criteria:

The measurement result should be judged by the criteria in the manufacturer's instructions.

(15) Burden check

1) Purpose:

a) To measure the burden of the circuit in control and protection relay boards.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Commander			
2. Safety director			
3. Current meter			
4. Voltage meter			
5. Operator			
6. Staff member No. 1 who makes circuit to be measured			
7. Staff member No. 2 who makes circuit to be measured			

Note: The staff members who make the circuit to be measured should make the circuit under the observation of the safety director.

5) Measurement conditions:

a) This measurement is performed in the periodic inspection

b) This measurement is a dry test

c) The circuit to be measured should be isolated from other circuits.

d) The safety director should prohibit any person from entering the measurement area during the measurement.

e) Equipment to be locked and other conditions are as follows:

- Equipment to be locked:

Electrical lock for the control, protection board and related equipment

No mechanical lock

- Other conditions:

An accurate power source should be prepared to supply the correct voltage and current to the circuit to be measured.

6) Measurement procedure

Current of the circuit is measured under rated voltage.

7) Measurement Schedule

Refer to the measurement schedule of “(5) Relay test”

8) Table for measurement:

Weather:

Room temperature (°C):

Outside temperature (°C):

Name of Circuit	Applied Voltage (V)	Applied Current (A)	Burden (VA)	Designed Burden (VA)

Specification of Measuring Instrument:

No. of Instrument	Name	Type	Rated	Manufacturing No.	Manufacturing Date	Manufacturer
	Test device for single-phase voltage and current					

9) Judgment criteria

There should be no significant difference between the measured values and the designed value.

(16) Overall sequence and operation test

1) Purpose:

- a) To measure the sequence time of the start and stop of the generator with the turbine and auxiliary equipment.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Control room as commander			
2. Safety director			
2. Inlet valve			
3. Turbine pit			
4. Turbine control board			
5. Excitation board			
6. Surge tank			
7. Tailrace			
8. Operator			

5) Measurement conditions

- a) This measurement is performed in the periodic inspection
- b) This is a wet test.
- c) The generator should be operated normally.
- d) Equipment to be locked for the test and other conditions are as follows:
  - Equipment to be locked:
    - No electrical lock
    - No mechanical lock
  - Other conditions:
    - None

6) Measurement procedure

- a) Operator starts the generator normally.
- b) Sequence time at each step during start sequence is measured.
- b) Sequence time at each step during stop sequence is measured.

7) Measurement schedule

- 8:00 Meeting before the measurement  
Prepare for the measurement
- 9:00 Operator starts the generator in normal procedure.  
Start the measurement until the generator parallels in the system
- 9:20 The measurement from parallel-in to complete stop is performed.

8) Table for measurement

Weather:

Room temperature (°C):

Outside temperature (°C):

		Operation Indicator on control board	Unit	Time	30S	Note
Start sequence (Time from start operation)	Inlet valve	Opening of bypass valve	min-s	-		
		Opening of main inlet valve	min-s	-		
	Start	Rated speed	min-s	-		
		Servomotor stroke at turbine start	mm			
		Closing of field circuit breaker	min-s	-		
	Parallel in	Operated automatic synchronize equipment	min-s	-		
		Parallel in from start control	min-s	-		
		Servomotor stroke at parallel in	mm	-		
		Penstock pressure at parallel in	mAq			
	Load	Achievement of load required	min-s	-		
		Generator output at the load	kW			
		Servomotor stroke at the load	mm			
Stopping sequence (Time from stop operation)	Stopping	Generator output before stop operation	kW			
		Servomotor stroke at before stop operation	mm	-		
		Parallel off	min-s	-		
		Brake start	min-s	-		
		Rotating speed at brake start	min <sup>-1</sup>			
	Complete stop of generator	min-s	-			
	Inlet valve	Completion of main inlet valve closing	min-s	-		
		Completion of bypass valve closing	min-s	-		

Note: a) Water level of reservoir El. \_\_\_\_\_ m, Water level of tailrace El. \_\_\_\_\_ m,

b) Temperature of cooling water \_\_\_\_\_ °C

c) Temperature of oil sump tank \_\_\_\_\_ °C

9) Judgment criteria

- To operate the generator without any delay or problem in each step in the sequence
- There should be no significant difference between the measured values and the designed values.

## 2.2 Inspection manual of overhaul

### (1) Output versus gate (or needle) opening test

#### 1) Purpose:

- a) To measure correlation between generator output and wicket gate opening (or needle opening).
- b) To confirm the stable operation range and output restriction range as well as the looseness of the wicket gate (or needle) operating mechanism.
- c) To check the difference between the measured value and the original setting value
- d) To confirm the secular change

#### 2) Date: \_\_\_\_\_

#### 3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

#### 4) Assigned persons:

Measurement point	Communication	Name	Note
1. Control room as Commander			
2. Safety director			
3. Generator output			
4. Generator voltage, current, power factor			
5. Field voltage, current			
6. Wicket gate (or needle, deflector) servomotor stroke			
7. Pressure			Refer to table
8. Vibration			Refer to table
9. Noise			Refer to table
10. Shaft run out			Refer to table
11. Water level			Refer to table
12. Pressure fluctuation			Refer to table
13. Operator			

#### 5) Measurement conditions:

- a) This measurement is performed during overhaul.
- b) This measurement is a wet test.
- c) The generator should be operated normally.
- d) Equipment to be locked for the test and other conditions are as follows.
  - Equipment to be locked:
    - No electrical lock
    - No mechanical lock
  - Other conditions:
    - None

#### 6) Measurement procedure:

- a) After the generator is paralleled, the generator is operated from no load to the maximum load.
- b) The servomotor stroke is measured every 10% of the generator output. Similar measurements should be implemented in the closing direction.



- c) The field voltage and field current should be measured. The rated power factor should be maintained.
- d) The same procedure is applied to the stroke measurement from maximum output to no load.
- e) The vibration, noise, shaft runout and pressure fluctuation should be measured to confirm the stable operation range.
- f) The output restriction range should be determined in view of the net head, output and discharge.
- g) Output should be measured by a precision class Wattmeter.
- h) Pressure fluctuation should be measured with an oscillograph.
- i) Operation direction (increasing or decreasing) of the output should not be changed during the measurement.
- h) Each measurement should be performed after the output becomes stable.

7) Measurement schedule:

- 8:00 Meeting before the measurement  
Prepare for the measurement
- 9:00 Operator starts the generator.  
Set the generator output to 10% opening  
Close the oil supply valve and set the servomotor stopper  
Measure the wicket gate opening
- 9:15 Next measurement is repeated. ....

8) Table for measurement:

Refer to the table "Output versus gate opening test (Francis)"

9) Judgment criteria:

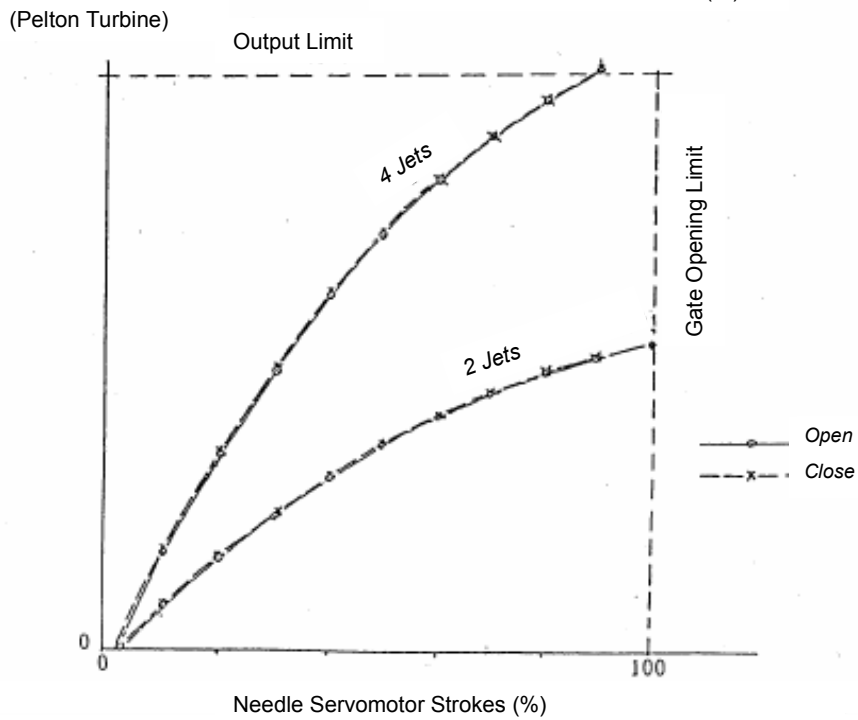
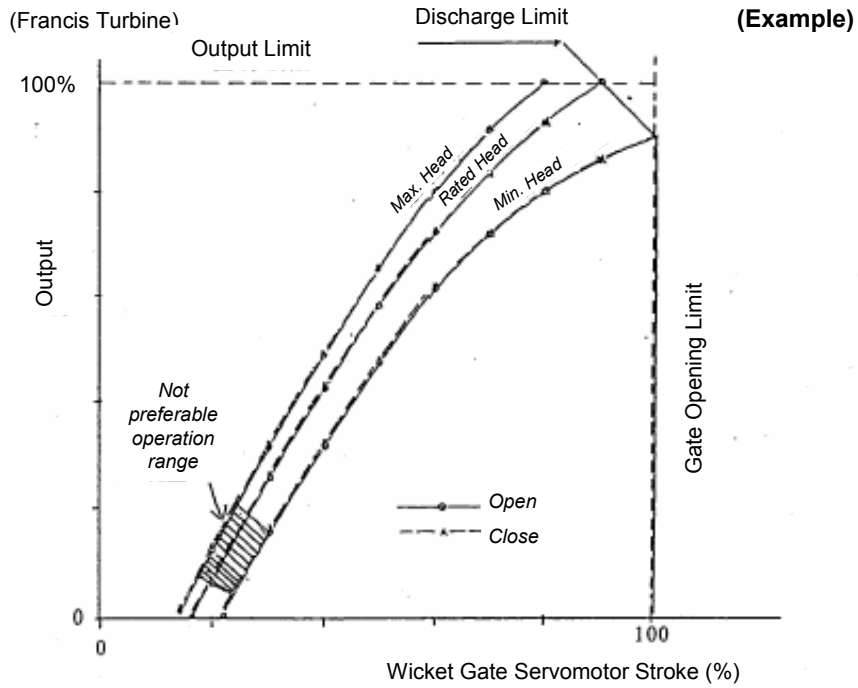
The proper correlation should be confirmed with respect to generator output and wicket gate (needle) servomotor stroke.

J-POWER's criteria of vibration and shaft runout are shown below as reference.

- Vibration in operation: 50  $\mu$  m P-P and below
- Shaft runout in operation: 70% and below of between shaft and bearing metal
- Shaft runout in assembly: 50  $\mu$  m P-P and below (for domestic power station)  
L/D \* 0.05mm (for foreign power station)  
L: distance of shaft direction from sliding surface of thrust bearing to measuring point  
D: diameter of thrust bearing metal



## Output Versus Gate Opening Test

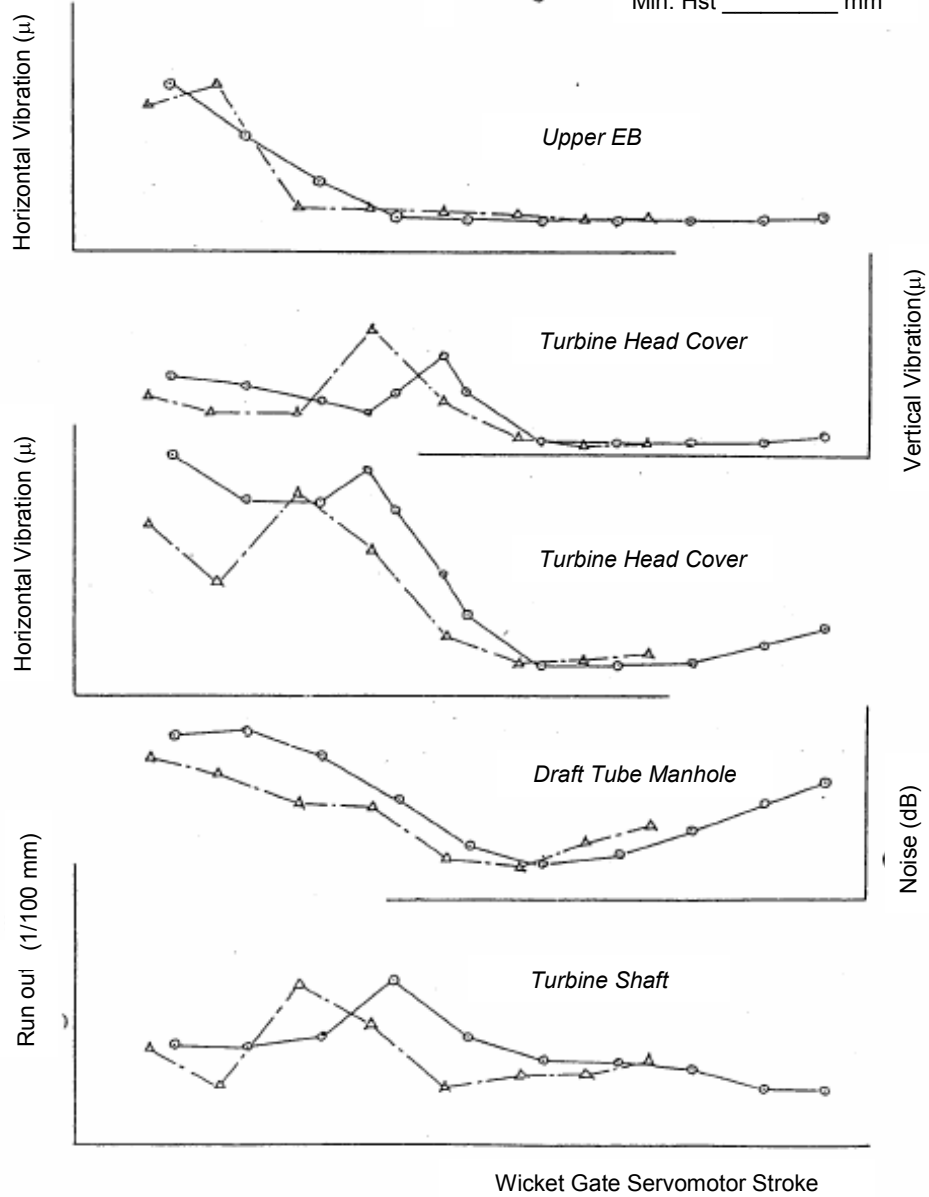


# Output Versus Gate Opening Test

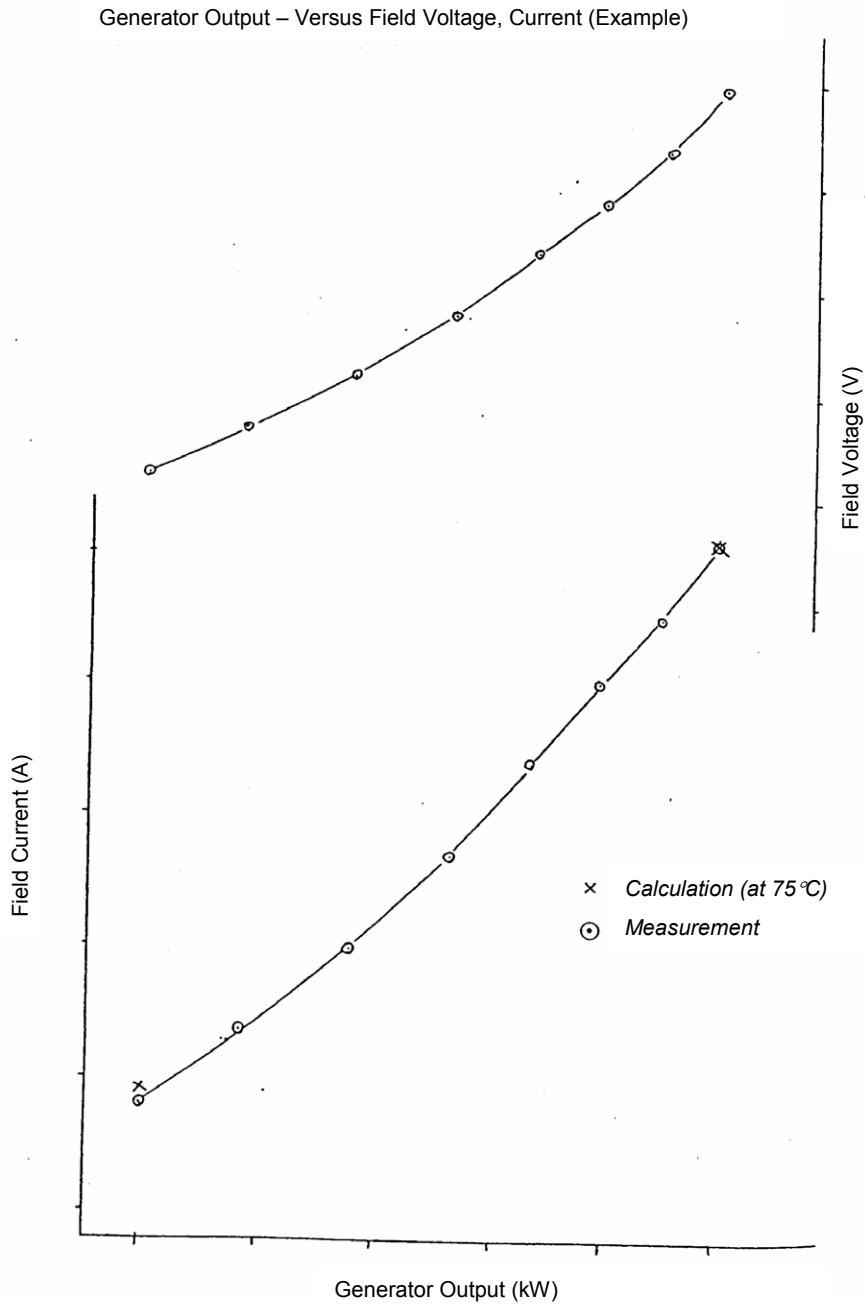
(Francis Turbine)

Out Opening Versus Vibration, Run out, Noise (Example)

- - -  $\Delta$  - - - Max. Hst \_\_\_\_\_ mm  
 —  $\circ$  — Min. Hst \_\_\_\_\_ mm



# Output Versus Gate Opening Test



(2) Load rejection test

1) Purpose:

- a) To ensure that the generator can be stopped safely at load rejection.
- b) To confirm that the rotating speed and the penstock pressure do not exceed the guaranteed value.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

	Measurement point	Communication	Name	Note
1.	Commander			
2.	Safety director			
3.	Watt meter VAR meter			Generator active power Generator reactive power
4.	Volt meter			Generator voltage
5.	Current meter			Generator current
6.	Volt meter Current meter			Field voltage Field current
7.	Tachometer			Rotating Speed
8.	Scale Stop watch			Servomotor stroke
				Closing time of servomotor
9.	Oil press. tank			Oil pressure and oil level
10.	Pressure meters			Water pressure of penstock Water pressure of draft tube Water pressure of runner-back/side Water pressure of spiral case
11.	Water level detector gauge			Maximum and minimum of water level in surge tank
12.	Dial indicator Gap sensor			Shaft runout of upper and lower shaft
				Shaft runout of turbine shaft
13.	Vibration sensor			Vibration of upper and lower bracket
				Vibration of turbine head cover
14.	Dial indicator			Deflection of lower bracket
15.	Generator and			Ambient temperature in generator room
16.	Operator			

5) Measurement conditions:

- a) This measurement is performed during overhaul.
- b) This measurement is a wet test.
- c) The generator should be operated normally.

d) Equipment to be locked for the test and other conditions are as follows:

- Equipment to be locked:
  - No electrical lock
  - No mechanical lock
- Other conditions:
  - None

6) Measurement procedure

- a) The heads to be tested will be available as high heads. Loads to be tested are 1/4, 2/4, 3/4 and 4/4 of the rated loads.
- b) The test start at 1/4 load.
- c) The generator is operated at the rated speed, voltage and power factor.
- d) The water level in the surge tank should be stable.
- e) The transient status of wicket gate, pressure in the penstock and draft tube, rotating speed and generated voltage, current, active power, reactive power, field voltage and field current should be recorded by the oscillograph.
- f) After the above conditions are completed, the test should be started.
- g) If any conditions are changed, such as adjustment of closing time of the wicket gate, the same test should be performed after finishing the proper adjustment.

7) Measurement schedule

The following schedule is shown for reference.

- 8:00 Meeting before the measurement
  - Prepare for the measurement
- 8:50 Operator starts the generator
- 8:55 Call "Five minute before" from commander and ring the bell
- 9:00 Call "3-2-1-Measurement" from commander and ring the bell
  - Measure each item
  - Reporting from points to recording person

8) Table for measurement

Refer to the table "Load rejection test"

The table is based on the measurements for the Francis turbine. These measurements should be changed according to actual condition of the turbine to be measured.

9) Judgment criteria

- a) The measurement results should be judged based on the values guaranteed in the contract.

Guaranteed values

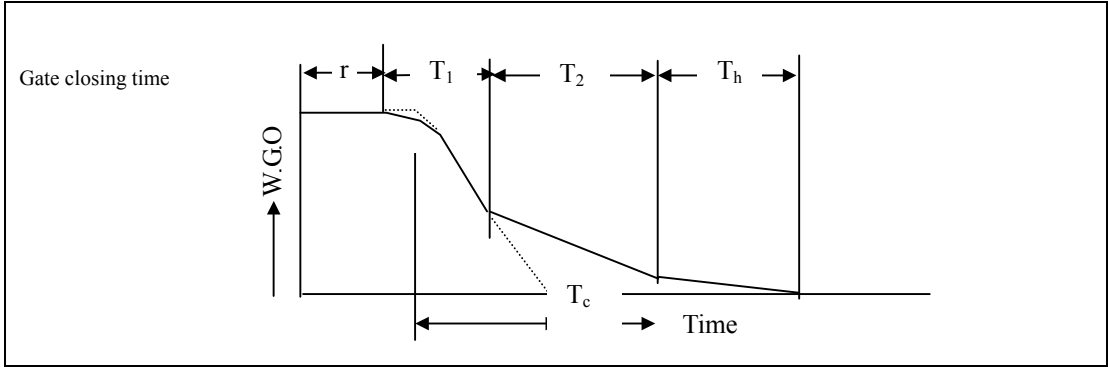
- Variation ratio of voltage ( $\Delta V$ ): below        % (at p.f.        %)
- Variation ratio of rotating speed ( $\Delta v$ ): below        %
- Maximum water pressure ( $P_{max}$ ): below        m
- Dead time of governor closing: below        sec

- b) To confirm there is no abnormality due to load rejection

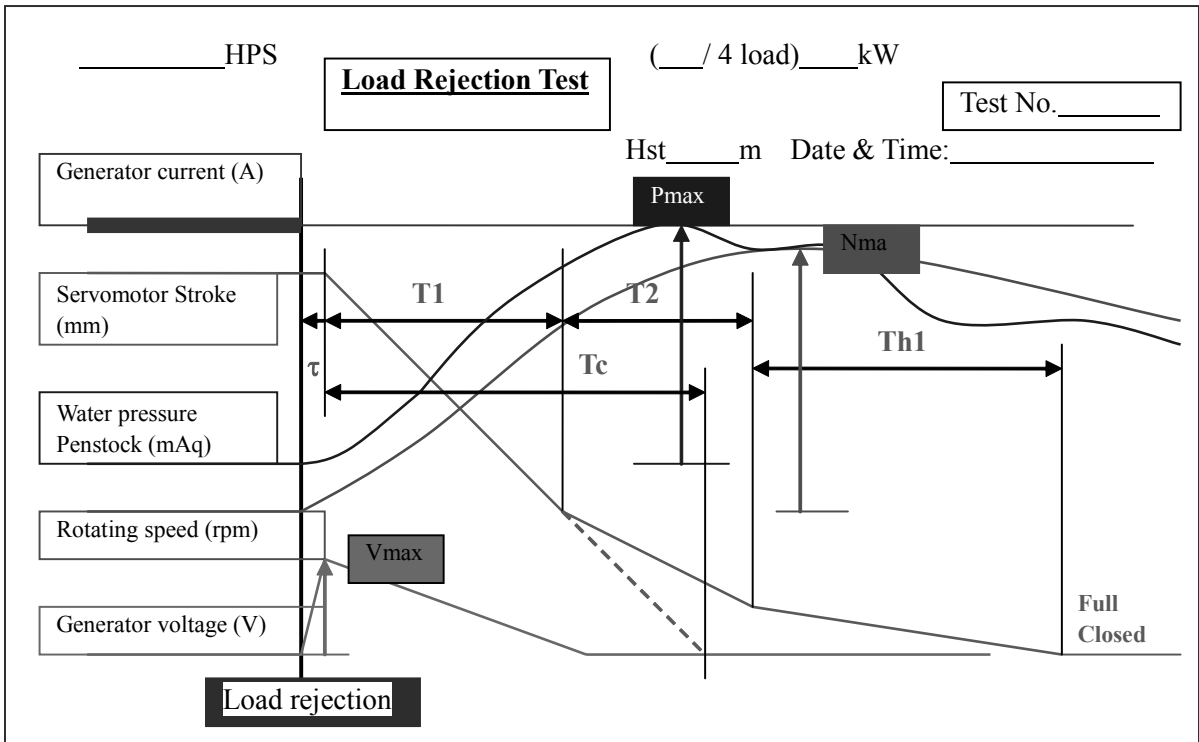
### Load rejection test

Load		%	1/4	2/4	3/4	4/4	-		
Time		h-m							
System voltage	At load	kV							
	After rejection	kV							
Generator	Output		MW						
	Voltage	At load	kV						
		Maximum							
		Stabilized							
		Variation ratio		%					
	Current		kA						
	Reactive power		MVAR						
	Frequency		Hz						
Ex.	Voltage	V							
	Current	A							
Turbine	Main servomotor	Stroke	At load	mm					
			Stabilized						
		Closing	T <sub>1</sub>	sec.					
			T <sub>2</sub>						
	Speed	At load	min <sup>-1</sup>						
		Maximum							
		Stabilized							
		Variation ratio		%					
	Penstock Pressure	At load	m						
		Maximum							
Stabilized									
Variation									
Static head									
Turbine	Spiral case pressure		At load	m					
			Maximum						
			Stabilized						
	Runner back pressure (Outer)		At load	m					
			Maximum						
			Stabilized						
	Runner side pressure		At load	m					
			Maximum						
			Stabilized						
	Draft tube pressure		At load	m					
			Maximum						
			Minimum						
			Stabilized						
Pressure oil tank	Oil press	At load	MPa						
		Minimum							
	Oil level	At load	mm						
		Minimum							
Water level	Upper reservoir EL		m						
	Lower reservoir EL								
	Static head just before load rejection (URWL-LRWL)		m						
	Surge tank	At load	m						
		Maximum							
Minimum									
Stabilized									
Oil temperature		°C							
Room temp. G/M, P/T									
Penstock pressure variation = Max. pressure - static head at load Static head at load = Upper reservoir W.L just before load rejection – turbine center Voltage variation ratio = $\frac{\text{Max. voltage} - \text{At loading voltage}}{\text{Rated voltage}}$ Speed variation = $\frac{\text{Max. speed} - \text{At loading speed}}{\text{Rated speed}}$ t Wicket gate servomotor stroke _____ mm Turbine center EL _____ m Gauge center EL _____ m (Gauge height: _____ m)									





(Sample Data of Oscillograph)



(3) Load test

1) Purpose:

a) To ensure that the generator can be operated without any trouble under full load operation.

2) Date: \_\_\_\_\_

3) Place: Unit\_\_\_ in \_\_\_\_\_Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Measurement
1. Commander			
2. Safety director			
2. Instruments Wattmeter VAR meter Voltmeter Ammeter Voltmeter			System voltage Generator active power Generator reactive power Generator voltage Generator current Generator frequency Generator watt hour Field Voltage, Field Current
3. Turbine pit 1			Wicket gate stroke
4. Water pressure meters			Water pressure of penstock Water pressure of spiral case Water pressure of runner back Water pressure of runner side Water pressure of draft tube
5. Generator room 1			Shaft run-out of generator upper shaft
6. Turbine pit 2			Shaft run-out of generator lower shaft Shaft run-out of turbine shaft
7. Pressure oil tank			Oil pressure of pressure oil tank
8. Oil Tank			Oil temperature of oil tank
9. Resistance type thermometers 1			Coil temperature of generator stator (Red, Yellow and blue phase) Oil temperature of generator thrust bearing Oil temperature of generator upper guide bearing Oil temperature of generator lower guide bearing
10. Resistance type thermometers 2			Oil temperature of turbine guide bearing Water temperature at air cooler inlet Air temperature at air cooler inlet Air temperature at air cooler outlet
12. Transformer			Oil temperature at generator transformer
13. Dial type thermometers			Water temperature at air cooler inlet Water temperature at thrust bearing outlet Water temperature at generator lower guide bearing outlet Water temperature at turbine guide bearing outlet

Measurement point	Communication	Name	Measurement
14. Generator, turbine and transformer room			Ambient temperature in generator room Ambient temperature in turbine room Ambient temperature in generator transformer room
15. Outside of power house			Ambient temperature outside of powerhouse
16. Upper reservoir			Water level upper reservoir
17. Lower reservoir			Water level lower reservoir
18. Operator			
19. Bell and recording person			

5) Measurement conditions:

- a) This measurement is performed during overhaul.
- b) This measurement is a wet test.
- c) The generator should be operated normally.
- d) Equipment to be locked for the test and other conditions are as follows.
  - Equipment to be locked:
    - No electrical lock
    - No mechanical lock
  - Other conditions:
    - None

6) Measurement procedure

- a) Operator keeps the generator to the rated speed, voltage, output and power factor.
- b) Interval of these measurements is every 10 minutes in the first hour and every 30 minutes after one hour.
- c) Assigned persons should take care of abnormal vibration, shaft run-out, oil leakage, water leakage and abnormal sound of the main unit, and any abnormality of the auxiliary machines observed during the load test.
- d) Test should be continued until each temperature is saturated.

7) Measurement schedule

The following schedule is shown for reference.

- 8:00 Meeting before the measurement  
Move to measurement points
- 8:50 Operator start the generator
- 8:55 Call "Five minute before" from commander and bell ring
- 9:00 Call "3-2-1-Measurement" from commander and bell ring  
Measure the each item  
Reporting from points to recording person
- 9:10 Call "3-2-1-Measurement" from commander and ring the bell  
Measure each item  
Reporting from points to recording person ·····

8) Table for load measurement

Refer to the table "Load test"

The table is based on the measurements for the Francis turbine. These measurements should be changed according to the actual condition of the turbine to be measured.

9) Judgment criteria

a) The measurement results should be judged based on the value guaranteed in the contract.

Guaranteed value (for reference)

- Maximum temperature of bearing (°C): below 65 °C
- Temperature rise of stator coil: below 80 K (at ambient temperature below 40 °C)
- Temperature rise of rotor coil: below 80 K (at ambient temperature below 40 °C)

## Load test

Measurement item	Instrument	Location	9:00	9:10	9:20	9:30	9:40	9:50	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30
1. Svsstem voltage	Voltmeter															
2. Generator active power	Wattmeter															
3. Generator reactive power	Varmeter															
4. Generator voltage	Voltmeter															
5. Generator current	Ammeter															
6. Generator frequency	Hz meter															
7. Generator watt hour	Watt hour															
8. Field Voltage	Volt meter															
9. Field Current	Am meter															
10. Wicket gate stroke	W.G scale															
11. Water pressure of penstock	Pressure gauge															
12. Water pressure of spiral case	Pressure gauge															
13. Water pressure of runner back	Pressure gauge															
14. Water pressure of runner side	Pressure gauge															
15. Water pressure of draft tube	Pressure gauge															
16. Shaft run-out of generator upper shaft	Dial indicator															
17. Shaft run-out of generator lower shaft	Dial indicator															
18. Shaft run-out of turbine shaft	Dial indicator															
19. Oil pressure of pressure oil tank	Oil level gauge															
20. Oil temperature of oil tank	Bar type thermometer															
21. Coil temperature of generator stator (Red, Yellow and blue phase)	Resistance type thermometer															
22. Oil temperature of generator thrust bearing	Dial thermometer and Resistance type thermometer															
23. Oil temperature of generator upper guide bearing	Dial thermometer and Resistance type thermometer															
24. Oil temperature of generator lower guide bearing	Dial thermometer and Resistance type thermometer															
25. Oil temperature of turbine guide bearing	Dial thermometer and Resistance type thermometer															
26. Water temperature at air cooler inlet	Resistance type thermometer															
27. Air temperature at air cooler inlet	Resistance type thermometer															
28. Air temperature at air cooler outlet	Resistance type thermometer															
29. Oil temperature at generator transformer	Dial thermometer															
30. Water temperature at air cooler inlet	Dial thermometer															
31. Water temperature at thrust bearing outlet	Dial thermometer															
32. Water temperature at generator lower guide bearing outlet	Dial thermometer															
33. Water temperature at turbine guide bearing outlet	Dial thermometer															
34. Ambient temperature in generator room	Bar type thermometer															
35. Ambient temperature in turbine room	Bar type thermometer															
36. Ambient temperature in generator transformer room	Sound meter															
37. Ambient temperature of outside of powerhouse	Bar type thermometer															
38. Water level upper reservoir																
39. Water level lower reservoir																

(4) Simplified efficiency test

1) Purpose:

a) To measure turbine efficiency with a portable flow meter.

2) Date: \_\_\_\_\_

3) Place: Unit \_\_\_\_\_ in \_\_\_\_\_ Hydropower Station

4) Assigned persons:

Measurement point	Communication	Name	Note
1. Control room as Commander	WT 1		
2. Safety director			
3. Penstock	WT 2		One assistant is need.
4. Headrace	Tel		
5. Tailrace	WT 3		
6. Servomotor stroke	4		
7. Cubicle room	WT4		
8. Penstock pressure	4		
9. Surge chamber	Tel		
10. Turbine operator	1		

Notice: WT is the walkie-talkie's number. The person who has just a number in the column in the table should communicate the measurement value to the person who has the same WT number .

5) Measurement conditions:

a) This measurement is performed during overhaul.

b) This measurement is a wet test.

c) The efficiency of the turbine should be measured under normal operation.

d) Equipment to be locked and other conditions are as follows:

- Equipment to be locked:

No electrical lock

No mechanical lock

- Other conditions:

The other turbines should be stopped (or operated at constant output).

6) Measurement procedure

a) Operator starts the turbine by normal procedure.

b) Turbine output should be kept constant during the measurement.

c) Each measurement should be performed after 5 minute or more from output change.

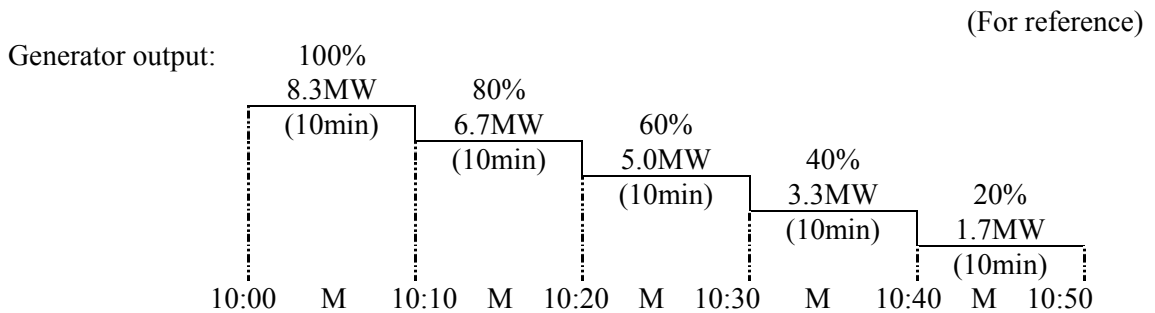
d) It is better to perform a trial measurement before the actual measurement.

7) Measurement schedule

The following schedule is shown for reference.

- 8:00 Meeting before measurement  
Move to measurement points
- 8:50 Confirmation of assigned person at every point from control room
- 8:59 Call "One minute before" from commander (Trial)
- 9:00 Call "3-2-1-Measurement" from commander (Trial)  
Measure the each item (Trial)  
Reporting from points to recording person (Trial)
- 9:55 Reconfirmation of assigned person at every point
- 10:04 Call "One minute before" (Actual)
- 10:05 Call "3-2-1-Measurement" (Actual)  
Measure each item (Actual)  
Reporting from points to recording person (Actual)

The following figure shows the output schedule of the simplified efficiency test for unit 1 in the Laxapana hydropower station.



8) Table for measurement

Refer to table "Simplified efficiency test"

9) Judgment criteria

- a) The measurement results should be judged based on the value guaranteed in the contract in consideration of secular change.

### Simplified efficiency test

PS Name:

Survey date:

Unit Number:

Weather:

Flow coefficient:

Room temperature: degree Celsius

Outside temperature: degree Celsius

Measurement point	Unit	Practice	10:05	10:15	10:25	10:35	10:45	Remarks	
Generator	Generator output	MW						Control room	
	Generator reactive power	MVar						Control room	
	Time of 100kWh or 200kWh	min sec						Cubicle room, Blue letter 100kWh	
	Calculated G. output	MW							
	Generator voltage	kV						Control room	
	Generator current	A						Control room	
	Field winding voltage	V						Control room	
	Field winding current	A						Control room	
	Power factor (p.f.)	%							
	Frequency	Hz	-	-	-	-	-	-	Control room
	Coil temperature	°C	-	-	-	-	-	-	
Turbine	Rotational speed	min <sup>-1</sup>						Control room	
	Wicket gate opening	mm	-	-	-	-	-		
	Needle opening #1	mm						Servomotor stroke (0MW, 31mm)	
	Needle opening #2	mm						Servomotor stroke (0MW, 34mm)	
	Needle opening #3	mm	-	-	-	-	-		
	Needle opening #4	mm	-	-	-	-	-		
	Deflector Opening	%						Servomotor stroke	
Discharge	Used flow (discharge)	m <sup>3</sup> /s						Penstock A	
Head	Water level of Intake	ft inch						Headrace	
	Water level of surge chamber	m						Surge Chamber	
	Water level of tailrace (weir)	m						Tailrace	
	Penstock pressure gauge (in)	ft						Penstock pressure	
	Penstock pressure gauge (out)	ft						Penstock pressure	



Measurement point		Unit	Practice	10:05	10:15	10:25	10:35	10:45	Remark
Calculated Head	Water level of intake	EL.m							
	Water level of surge chamber	EL.m							
	Turbine center	EL.m							
	Pipe loss	m							
	Pressure head	m							
	Goss head	m							
	Effective head	m							
Gene. Loss	Iron loss	kW							
	Mechanical loss	kW							
	Resistance of stator winding	$\Omega$							
	Resistance loss	kW							
	Floating load loss	kW							
	Field loss	kW							
	Total generator loss	kW							
Efficiency	Generator efficiency	%							
	Turbine output	MW							
	Turbine input	MW							
	Turbine efficiency	%							
	G-T efficiency	%							
Converted value to the specification	Effective head	m							
	Discharge	m <sup>3</sup> /s							
	Turbine output	kW							