Chapter 6 Waterways

For Article 42 Common Rules

1. Explanation

Paragraph 1

In cases where a waterway has the possibility to be damaged by floods, land slides, etc., the place or the structure needs to be modified or changed.

Or, the countermeasures must be taken to prevent their emergences.

Paragraph 3

At the entrance of an intake, screens must be installed to prevent the inflow of driftwood and debris.

And at the entrance of a waterway, screens and/or a settling basin must be installed if necessary.

Paragraph 5

(1) Materials of waterways

The materials used for waterways shall be equivalent or superior to the materials to be defined in international standards, such as ISO.

As reference, some samples of steel materials for waterways defined by international standards are shown as follows.

ISO ISO 630 (structural steels, E275, E355),
ISO 4950-2 (high yield strength flat steel products, Part2: products supplied in the normalized or controlled condition, E355),
ISO4950-3 (high yield strength flat steel products, Part3 : products supplied in the heat-treated (quenched + tempered) condition, E460)

JIS JIS G 3101 (SS400),
JIS G 3106 (SM400, SM490, SM490Y, SM520, SM570),
JIS G 3114 (SMA400, SMA490, SMA570),
JIS G 3115 (SPV235, SPV315, SPV355, SPV450),
JIS G 3128 (SHY685NS-F),
JIS G 4305 (SUS304),
JIS G 3601,
JIS G 3442(SGPW),
JIS G 3443(STW),
JIS G 3452(SGP),
JIS G 3454 (STPG370, STPG410),
JIS G 3455 (STS370, STS410, STS480),

JIS G 3457 (STPY400),
JIS G 3459 (SUS304TP),
JIS G 3468 (SUS304TPY),
JIS G 3469 (P1H, P2S, P1F),
JIS G 5526 (D),
JIS G 5527 (DF),
JIS G 3201 (SF),
JIS G 5101 (SC),
JIS G 5102 (SCW),
JIS G 5501 (FC)

EN EN 10025 (hot rolled unalloyed structural steel products, S275, S355),
EN 10113-2 (hot rolled products made from weldable, fine grain structural steel (for normalized steel), S355N, S355NL, S420N, S420NL),
EN 10113-3 (hot rolled products made from weldable, fine grain structural steel (for thermomechanically rolled steel), S355N, S355ML,S420M, S420ML),
EN 10137-2 (plates and wide flats made of high yield strength structural steels in the quenched and tempered or precipitation hardened conditions, S500, S550,S620,S690)

ASTM ASTM A36M (standard specification for carbon structural steel),
ASTM A283M (standard specification for low and intermediate tensile strength carbon steel plates),
ASTM A572M (standard specification for high-strength low-alloy columbium-vanadium structural steel),
ASTM A537M (standard specification for pressure vessel plates, heat-treated, carbon-manganese-silicon steel),
ASTM A517M (standard specification for pressure vessel plates, alloy steel, high-strength, quenched and tempered)

(2) Stress analysis

Stress caused by the loads in each member of waterways shall not be surplus the allowable stress of each material defined in international standards, such as ISO

2. Reference

A waterway shall be a structure in which it is easy to inspect or repair necessary points.

The parts of waterways such as waterways, slitting parts, steel pipes or surge tanks should be inspected or repaired.

It is necessary to drain water from these parts, to access these parts and to carry materials and machines to be used for repair.

For example:

1. In the case of a long waterway, it is required that there are adits at the midpoint of the waterway.
2. It is required that gate are installed at an intake and tailrace in order to stop water flow.
3. In the case of a long penstock, It is required that there are manholes at the midpoint of the penstock pipe.
4. It is required that a capable vertical shaft to carry in/out machines is constructed near an intake or a tailrace outlet.

For Article 43 Intakes

1. Explanation

Paragraph 1 “expected loads”

Expected loads in this paragraph are self-weight, hydrostatic pressure, hydrodynamic pressure, mud pressure, seismic force, external water pressure and earth pressure.

In cases where an intake has the possibility to be damaged by aforesaid forces, the place or the structure needs to be modified or changed

Paragraph 3 “to prevent inflowing sediment”

Intake must be designed for inflow velocity of approximately 0.3m/s to 1.0m/s.

The intake sill should be set approximately 1m higher than the crest of a sand flush weir to prevent the entry of sand and stone into a waterway from a river.

Intake sill height is determined considering the expected sedimentation level in front of the inlet.

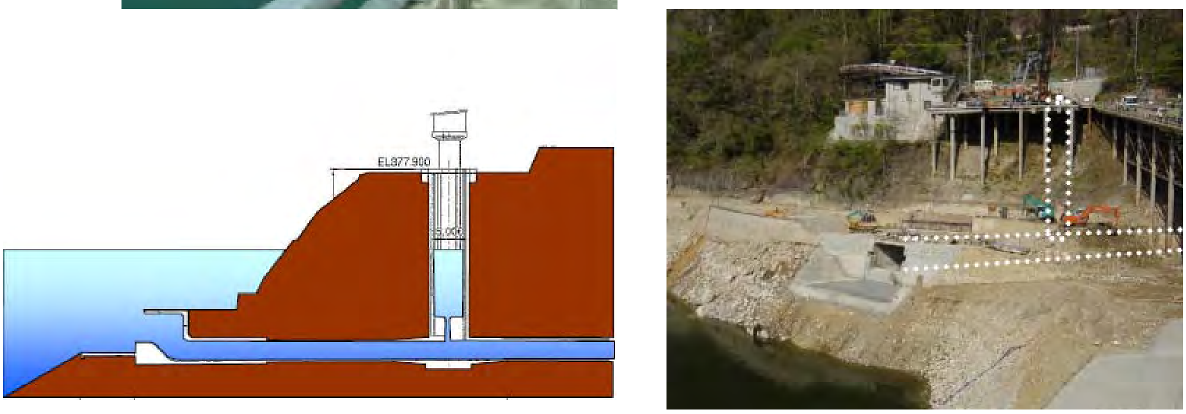
Paragraph 4 “to prevent air intrusion”

Water depth above an intake should be approximately 1.5 to 2.0 times larger than the headrace diameter to prevent entrainment of air during intake of water.

Screens are installed in front of the intake. A bellmouth shaped inlet is often adopted to minimize entrance head loss.

Photograph 43-1 Intake of Run-of-River Type Hydropower Station

Photograph 43-2
Intake of Reservoir Type Hydropower Station



Photograph 43-3 Construction of Reservoir Type Intake

For Article 44 Settling Basins

1. Explanation

Paragraph 1 "expected loads"

Expected loads in this paragraph are self-weight, hydrostatic pressure, hydrodynamic pressure, seismic force, external water pressure and earth pressure.

In cases where a settling basin has the possibility to be damaged by natural hazards, such as flood, and land-slides, the location or the structure of it needs to be modified or changed.

Or, in case of landslides, preventative measures from it must be taken.

Paragraph 2

The first step to determine the capacity of a settling basin is to define the minimum size of the soil and sand to be settled down.

The acceptable size is determined by considering following condition.

(1) To prevent the surface of the waterways and penstocks from the wearing

(2) To prevent turbines from damaging and the runner from wearing.

After finding the soil or sand particle size for the design, the length of a settling basin is obtained as follows:

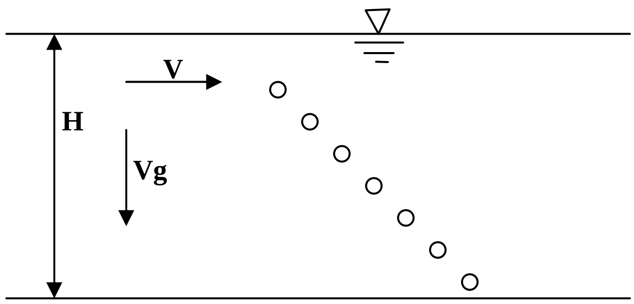


Fig. 44-1 Settling of Soil or Sand Particle

$$L \geq \frac{H}{Vg} \cdot V = \frac{Q}{B \cdot Vg}$$

Where,

L : necessary length (m)

H : water depth (m)

B : width of the settling basin (m)

V : mean flow velocity (m/s) = Q/B*H

Vg : settling velocity (m/s)

Q : water flow rate (m^3/s)

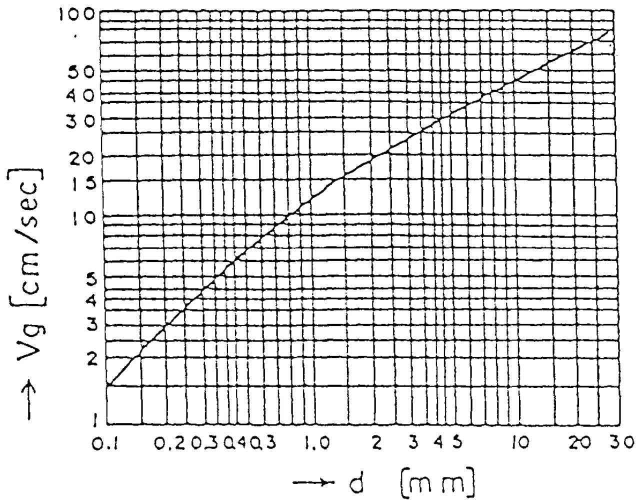


Fig. 44-2 Relationship between Settling Velocity and Particle Size

Relationship between Vg and d (particle size, i.e. a diameter of sediment such as soil and sand)

In practice:

Vg is 0.1 m/s in accordance with diameter of sand, 0.5 or 1 mm;

V should be less than 0.3 m/s, and;

a settling basin should be twice longer than the length obtained abovementioned formula.

Paragraph 3

A settling basin usually equips a sand flushing gate at the downstream of it to discharge the sediments in it effectively.

2. Reference

Photograph 44-1 Settling Basin of the O'Chum 2 Hydropower Station

Photograph 44-2 Settling Basin of the Other Station

For Article 45 Headraces

1. Explanation

Paragraph 1 "expected loads"

Expected loads in this paragraph are self-weight, hydrostatic pressure, internal water pressure, external water pressure, seismic force, earth pressure and surcharges

The loads to be taken into account in designing headrace structure are classified as follows.

Type of headraces	Loads
Tunnel , Open Canal and Culvert	Water pressure, Earth pressure
Aqueduct bridge	Self-weight, Water load, Water pressure, Seismic-force, Superimposed load, Wind load, Thermal load
Inverted siphon	Self-weight, Water load, Water pressure, Seismic-force, Earth pressure Superimposed load, Wind load, Thermal load

Paragraph 5

When air is entrained into a pressure headrace there could be danger that turbines and other facilities are damaged by an air hammer phenomenon.

And the entrained air could cause the increase of head loss and the decrease of turbine efficiency.

Paragraph 5

When a hydraulic gradient line is below the inside crown of a pressure tunnel, negative pressure acts on the tunnel and could cause damage to it.

2. Reference

(1) Type of waterways

Waterways are classified into pressure waterways (pressure conduits) and non-pressure waterways (non-pressure conduits) in terms of hydraulics.

In terms of structure, waterways are classified into open canals, covered canals, culverts, tunnel, aqueducts, inverted siphons, etc.

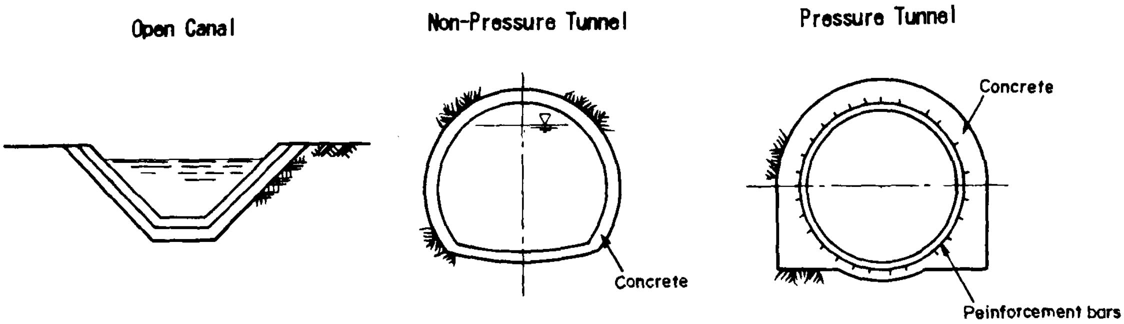


Fig. 45-1 Examples of Waterway Type

Photograph 45-1
Horseshoe Shaped Non-Pressure Tunnel

Photograph 45-2
Circular Shaped Pressure Tunnel

Photograph 45-3
Concrete Type Aqueduct

Photograph 45-4
Steel Pipe Type Aqueduct

Photograph 45-5 Inverted Siphon under Construction

(2) Waterway cross section and friction loss

1. Non-pressure waterway

The cross section dimensions of the non-pressure waterway are determined in relation to the waterway gradient. When the discharge of a power station is determined, a steep waterway gradient provides a smaller canal cross section, thereby reducing the waterway construction cost. This is, however, not always economical because friction loss by the waterway increases and the electricity generating output decreases. Contrarily, a gentle waterway gradient makes the waterway cross section larger and the power output increases due to decreased friction loss. Here, however, the waterway construction cost increases.

It is, therefore, necessary to determine the most economical waterway gradient and waterway cross section in consideration of the waterway construction cost and power output and energy generation.

The velocity of water flow in non-pressure waterways is generally 2 to 3 m/s.

The waterway gradient is generally 1:1,000 to 1:2,000 in the case of open canals and 1:500 to 1:1,500 in the case of tunnels.

Typical cross sections of open canals are rectangular and trapezoidal. A trapezoidal cross section is generally used while the shape of canals for small flow may be rectangular. A horseshoe-shaped cross section is generally used for culverts and tunnels due to the easiness of its construction, its strength against external forces and low cost. The side wall construction is simple if the arch has a larger radius and it is close to a straight line. Therefore, where geological conditions are good, the side wall is constructed perpendicularly or almost straight. Where geological condition is unfavorable, a cross section close to a circle is used to resist external pressure.

2. Pressure waterway

Velocity in a pressure conduit has no relation to its gradient. It is related only to the hydraulic gradient. If the pressure conduit is designed so that the entire conduit is positioned below the hydraulic gradient line connecting the design lowest water level of the intake to the design lowest water level of the surge tank, discharge flows down by hydraulic gradient with no relation to the waterway gradient.

Similar to the relationship between a cross section and friction loss in the case of non-pressure waterways, if the cross section of the pressure tunnel is reduced, construction cost decreases while head loss increases and power output and energy generation decrease. Contrarily, if the tunnel cross section is increased, construction cost increases while head loss decreases and power output and energy generation increase. Several cross sections should be compared and the most economical one should be selected by the relation between the construction cost and benefits.

Velocity in a pressure tunnel is generally 2 to 4 m/s in the case of conventional hydropower projects and 5 to 6 m/s in the case of the pumped storage power projects. In many cases, a waterway has a circular cross section which is the most rational shape in structure. A horseshoe shape is used when the internal pressure is not so high or when geological conditions are good. When maximum power discharge is small, a headrace cross section should be determined to the smallest possible cross section that can be constructed.

3. Structural design of pressure waterways (tunnels)

The following items should be taken into account, in the case of the design of pressure waterways (tunnels).

1) A pressure tunnel must be located in the area where pressure head is positive.
2) A tunnel structure must be that no air intrusion occurs.
3) A tunnel lining must be stable with respect to tensile and bending stress which are caused by internal pressure.

4) Generally, a tunnel lining is reinforced concrete structure. In the case that internal pressure is small and surrounding rocks are solid, reinforcement is not required.
5) It is not economical that only a lining has charge of internal pressure. Generally, the surrounding rocks also have charge of some parts of the internal pressure.
6) Therefore, in order that there is no void between the lining and the surrounding rocks, grouting with low pressure should be taken.
7) In case when there is a possibility that flowing water may soak through the cracks of surrounding rocks, grouting with high pressure should be taken as a countermeasure.
8) In case where the rock cover (i.e. the distance between the waterway and the ground surface) is small, and there are risks that the flowing water in the waterway may soak through the surrounding rocks and may damage the ground surface such as a landslide, steel linings should be applied as countermeasures.
9) In case where there is a large fault with high permeability near the waterway tunnel, countermeasures such as steel linings should be taken to prevent large water leakage.

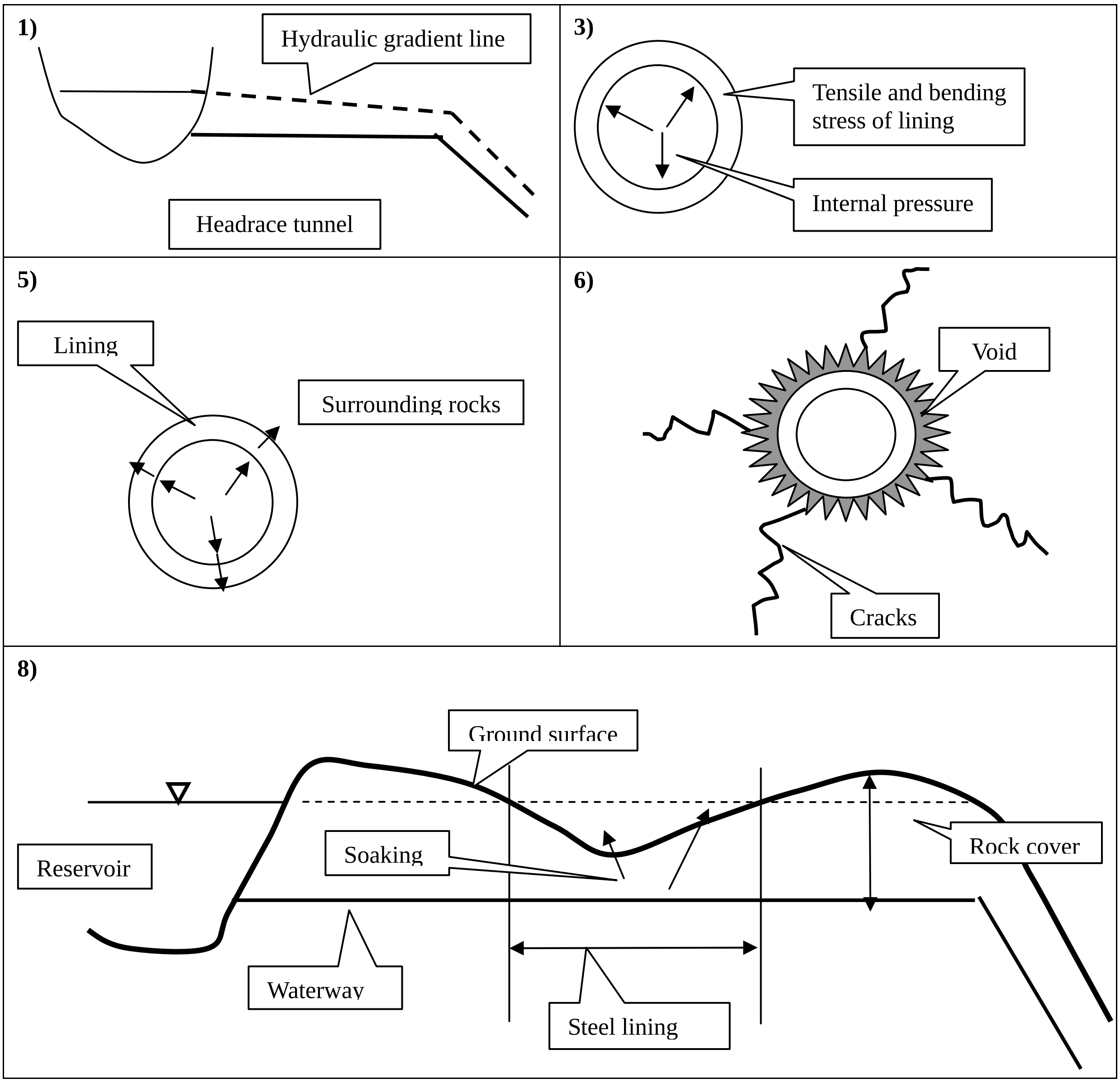


Fig. 45-2 Explanation of Each Item

For Article 46 Head Tanks

1. Explanation

<u>Paragraph 1 “expected loads”</u>

Expected loads in this paragraph are self-weight, internal water pressure, seismic force, external water pressure and earth pressure.

The location of a head tank and the route and structure of a spillway are determined by the surveys of topographic and geologic features ranging from the head tank to the river, together with the surrounding environmental conditions.

Paragraph 2 "adequate water capacity"

Head tank capacity must be large enough to continue operation for 1 to 2 minutes at the maximum power discharge without any supply of water from a headrace.

The water surface area of a head tank must satisfy the following against rapid changes in a water surface level or wave actions during steady operation.

$A/Q \geq 50$

Where,
A : Storage area (m^2)
Q : Maximum plant discharge (m^3/s)

Water level fluctuations against load fluctuations must be within the permissible upper and lower limits.

Paragraph 2 "prevent air intrusion to penstocks"

The water depth at the mouth of a penstock is twice or more than that of the inside diameter of the penstock pipe to prevent air entrainment into the penstock pipe by vortex.

Paragraph 3 "a spillway so that it can control maximum designed discharge safely"

A spillway channel is designed so that the maximum power discharge can be safely discharged at the water level to the extent that no pressure is generally exerted to the top of the headrace when the full load is shut down. Notwithstanding the preceding, the top of the headrace level lower than the discharged water level is permissible when the countermeasure for the excess water pressure is conducted.

As flow is a supercritical in a steeply graded spillway, it could cause impulse waves or cavitation at bends or at discontinuous parts of the channel, and therefore the waterway should be as straight as possible.

As a water surface may swell due to the entrainment of air, the cross section of spillways must be designed with attention to this phenomenon.

In the case of pipe conduits, an air hole is provided at the bends to replenish the air carried away by high-speed water flow.

Even when a spillway is an open canal or covered canal, cut-off projections are constructed on the bottom in the same way as the anchor block of pipe conduits to prevent sliding as well as erosion by leaking water.

An energy dissipator is installed at a spillway end to safely discharge water downstream.

When water from a spillway is discharged directly to a river, attention is paid to its alignment to avoid adverse effect on the river including excessive scouring of the river bed.

Paragraph 6 "sand does not flow into penstocks and turbines"

To accumulate and remove settled sediment, a 1:15 to 1:50 sloping gradient is used as the bottom gradient of head tanks. A groove is provided at its end and a scouring gate equipped to flush sand.

A screen is provided in front of a penstock inlet section. Large stones is not anticipated so the spacing between screen bars of it is smaller than that between screen bars at an intake

Photograph 46-1 Head Tank

For Article 47 Surge Tanks

1. Reference

Surge tanks are classified as follows.

1. Simple type
2. Restricted orifice type
3. Differential type
4. Chamber type
5. Double type (1-4 combined)

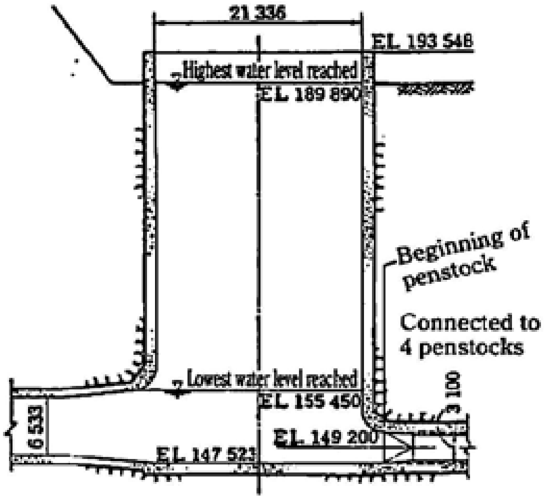


Fig. 47-1 1. Simple Type

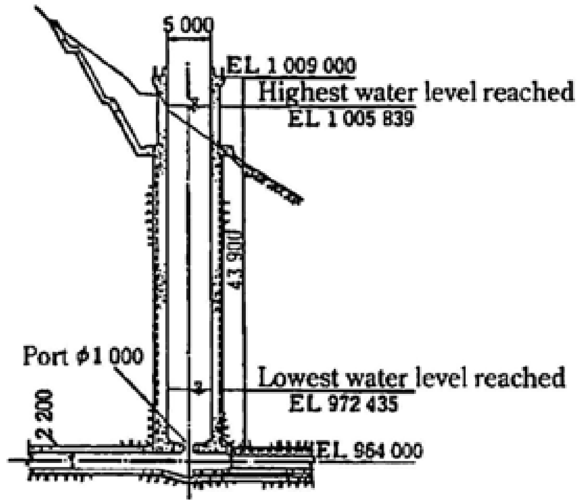


Fig. 47-2 2. Restricted Orifice Type

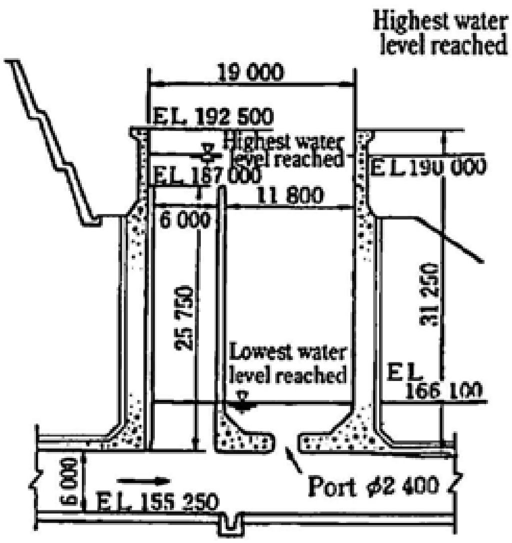


Fig. 47-3 3. Differential Type

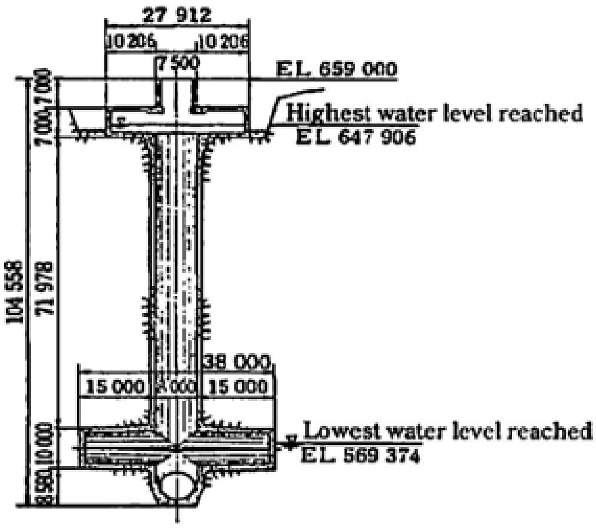


Fig. 47-4 4. Chamber Type

Photograph 47-1 Sample of Surge Tank

Photograph 47-2 Sample of Surge Tank

2. Explanation

Paragraph 1 "expected loads"

Expected loads in this paragraph are self-weight, internal water pressure, seismic force, external water pressure, earth pressure and force caused by wind.

Paragraph 2

Up-and-down oscillation of the free water surface in a surge tank shall not accelerate and return to equilibrium in a short time. In other words, a surging wave shall be restorable and attenuable.

For the evaluation of attenuation performance, "The formula of Tohma-Jaeger" or "The formula of Tohma-Schuller" is generally used on the basis of types.

For example as a numerical analysis, the calculation formula for a restricted orifice type is expressed by the following equations.

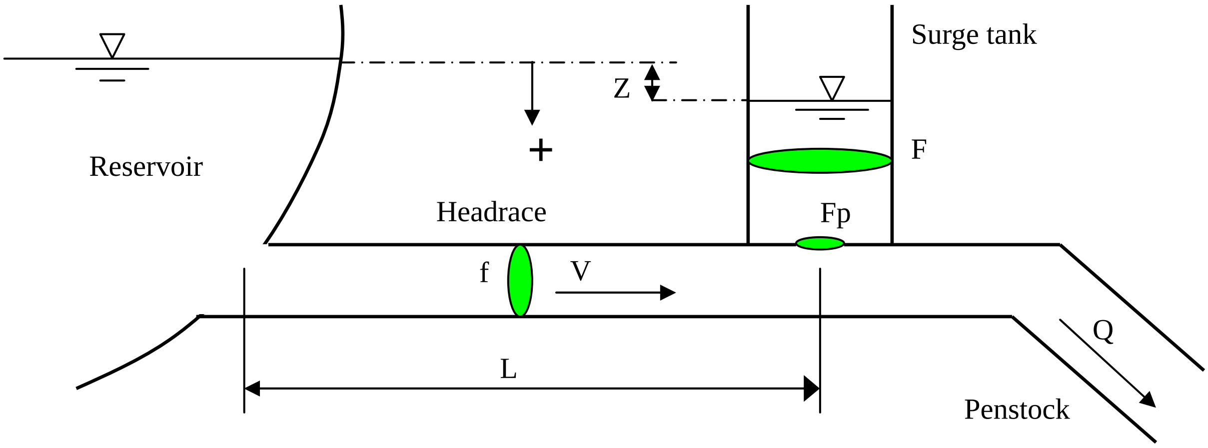


Fig. 47-5 Visual Description of Symbols in Equation for Restricted Orifice Type Surge Tank

Fundamental equation for restricted orifice type surge tank

Motion equation .... $\frac{dv}{dt} = \frac{z - C \cdot |V| \cdot V - k}{L/g}$

Continuity equation........... $\frac{dz}{dt} = \frac{Q - f \cdot V}{F}$

Resistance of orifice.......... $k = \frac{|f \cdot V - Q| \cdot (f \cdot V - Q)}{2 \cdot g \cdot (Cd \cdot Fp)^2}$

Where,

Q : Water discharge (m^3/s)

V : Mean flow velocity (m/s

z : Water level of the surge tank (m)

t : Time (sec)

g : Acceleration of gravity ($9.8 m/s^2$)

L : Headrace length (m)

F : Cross-section area of surge tank (m^2)

Fp : Cross section area of the orifice

C : Coefficient of head-loss

Cd : Discharge coefficient of orifice

Table 47-1 Necessary Study Cases for Design of Restricted Orifice Type Surge Tank

Item	In case of Load increase	In case of Load decrease
Change of load	From half to full	From full to zero
Initial water level in the tank	Low water level	High water level
Roughness coefficient	Minimum number	Maximum number

Coefficient of friction

Examples of Roughness coefficient of friction

Concrete lining : n = 0.0130-0.0135

No lining : n = 0.025-0.030

Penstock : n = 0.0100

In the view point of safety, maximum coefficient friction number shall be adopted when calculating the highest up-surging, and minimum coefficient friction number shall be adopted when calculating the lowest down-surging as follows.

Table 47-2 Criteria for Selection of Coefficient of Friction

Case	Steel pipe	Concrete lining	No lining
Highest up-surging: When full loads are shut off at HWL	Subtract 0.001	Subtract 0.0015	Subtract 0.003
Lowest down-surging: When loads increase from half to full at LWL	Add 0.001	Add 0.0015	Add 0.003

The highest up-surging shall not over the top of the surge tank and the lowest down-surging shall not be lower than the top of the headrace and penstock.

And the result of the calculation for the highest water level and the lowest level of the surging wave shall include some margin.

For Article 48 Penstocks

1. Explanation

Paragraph 1

In accordance with the following types of penstocks, the loads to be taken into account in designing penstocks are as described below.

Table 48-1 Loads Imposed on Penstock

Type	Exposed type	Rock-embedded type	Earth-embedded type
Loads	• “Composite maximum water pressure of hydrostatic pressure, water hammer pressure and pressure rise by surging” • Pipe weight • Thermal loads • External pressure • Water weight in pipe • Seismic force • Forces of flowing water inside the pipe	• “Composite maximum water pressure of hydrostatic pressure, water hammer pressure and pressure rise by surging” • Thermal loads • External pressure	• “Composite maximum water pressure of hydrostatic pressure, water hammer pressure and pressure rise by surging” • Earth pressure • Surcharge loads • Thermal loads • External loads • Water weight in pipe

(1) "Composite maximum water pressure of hydrostatic pressure, water hammer pressure and pressure rise by surging"

The internal pressure to be used for designing shall be the maximum value foreseeable in consideration of the hydrostatic pressure and the pressure rise due to water hammering and surging.

Internal pressures working in steel penstock pipe shells are, in addition to (1) the hydrostatic pressure, (2) pressure variations caused by surging in surge tank and (3) water hammering in penstock pipes generated by turbine load variation.

Penstock pipe shells should be safe from the maximum internal pressure possible to be generated.

In the case of run-of-river type hydropower station with head tank, the load of (1) and (2) shall be considered. And in the case of dam and conduit type hydropower station with surge tank, the load of (1), (2) and (3) shall be taken.

When summing up the pressure rises both by surging and by water hammering, the maximum value which can take place simultaneously should be taken.

In the case of simple surge tanks, however, it is permissible to consider that the pressure rise by water hammering does not overlap on the pressure rise by surging.

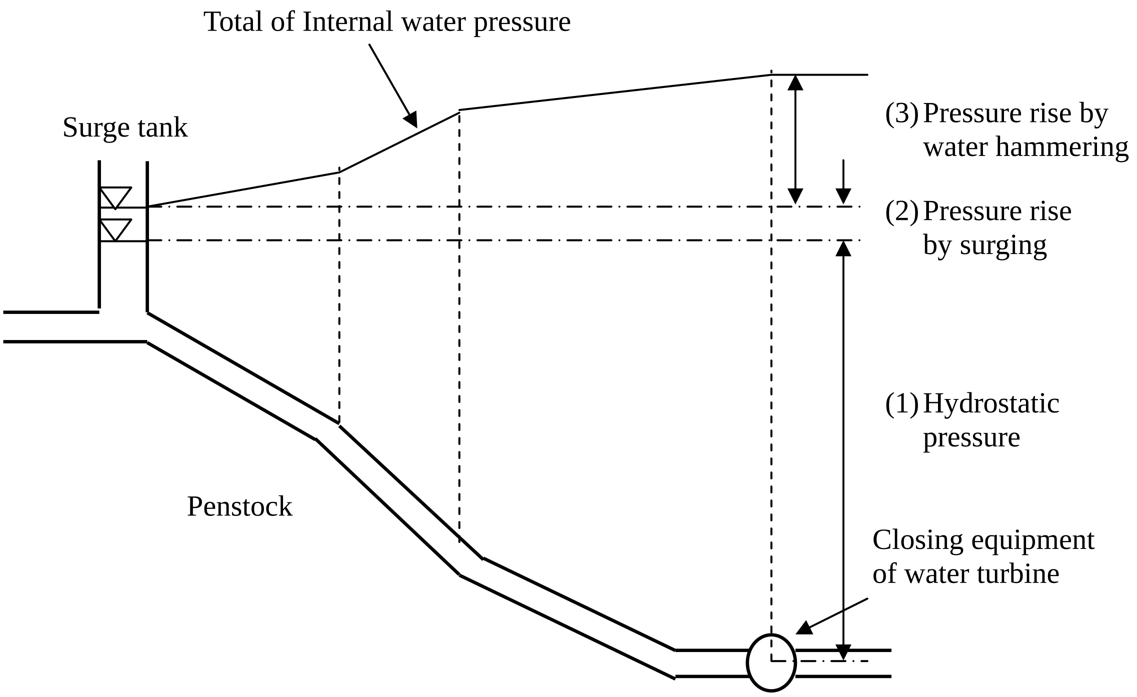


Fig. 48-1 Cross Section Image of Penstock and its Internal Water Pressure

(2) Explanation of the water hammer pressure

Water hammer is caused by velocity fluctuations in penstock pipes inducted by closing equipment operation of water turbines.

Water hammer occurs at the place of closing equipment (maximum) and, decreasing through the penstock pipes, propagates to the water surface of the head tank or surge tank (minimum=0).

The closing equipment of Francis turbines and Kaplan turbines is a guide vane and the closing equipment of Pelton turbine is a needle valve.

Formula for the propagation velocity of pressure wave is described as follows.

$$\alpha_i = \frac{1}{\sqrt{\frac{w}{g} \cdot \left(\frac{1}{k} + \frac{1}{E} \cdot \frac{D}{t}\right)}}$$

Where,

α_i : Propagation velocity of pressure wave of number penstock pipe i (m/s)

w : Unit weight of water ($1 tf/m^3$)

g : Acceleration of gravity (m/s^2)

K : Elastic coefficient of water ($\fallingdotseq 2.1 \times 10^5 tf/m^2$)

E : Elastic coefficient of steel ($\fallingdotseq 2.1 \times 10^7 tf/m^2$)

D : Diameter of steel penstock pipe (m)

t : Thickness of steel penstock pipe (m)

Therefore, the average propagation velocity of pressure wave is described as follows.

$$\alpha_m = \frac{\sum L_i}{\sum \left(\frac{L_i}{\alpha_i}\right)}$$

Formula for the pressure rise due to the water hammering without pressure regulators are classified into the following (A) and (B) depending upon Allievi's pipeline constant ρ:

Notations

$\rho = \frac{\alpha_m \cdot v_0}{2 \cdot g \cdot H_0}$ .... Allievi's pipeline constant

$\theta = \frac{\alpha_m \cdot T}{2 \cdot L_0}$ .... Closing time constant of a closing equipment

$n = \frac{\rho}{\theta}$

Where,

h_0 : pressure rise due to water hammering at a closing equipment (m)

H_0 : Hydrostatic pressure after entirely shutting off a closing equipment at the turbine end (m)

L_0 : Length of pipe line (m)

$v_0 = \frac{\sum v_i \cdot l_i}{L_0}$: Average velocity

l_i : Pipe length of section i (m)

v_i : Velocity of section i (m/s)
T : Closing time of a closing equipment (s)
g : Acceleration of gravity (m/s^2)
α_m : Average propagation velocity of pressure wave (m/s)

1) In case of $\rho>1$:

When $\frac{h_0}{H_0} \geq 50\%$, $\frac{h_0}{H_0} = \frac{n}{2} \cdot (n+\sqrt{n^2+4})$

When $\frac{h_0}{H_0} < 50\%$, $\frac{h_0}{H_0} = \frac{2 \cdot n}{2-n}$

When $\frac{h_0}{H_0} \fallingdotseq 30\%$, $\frac{h_0}{H_0} \fallingdotseq 1.10n$

2) In case of $\rho<1$:

$$\frac{h_0}{H_0} = \frac{2 \cdot n}{1+n \cdot (\theta-1)}$$

Pressure rise "h" due to water hammering at an arbitrary point is shown in Fig.48-2.

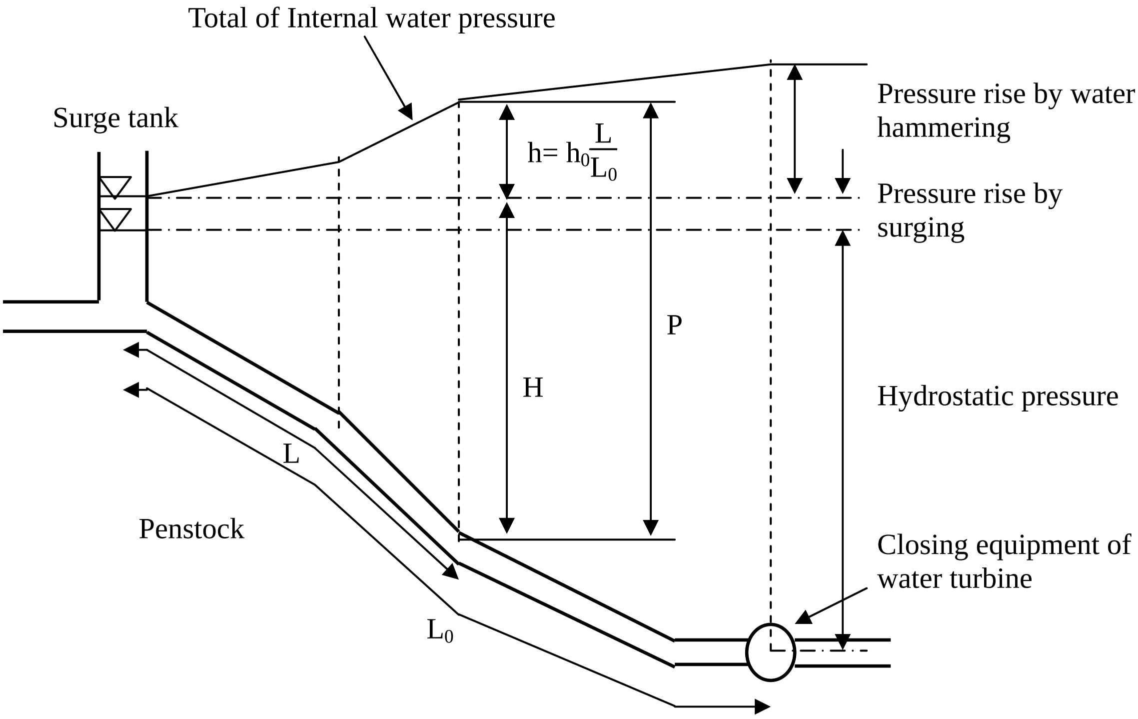


Fig. 48-2 Relationship of h and h_0

(3) "External pressure"

As for the design of the external pressures of penstock pipes, the maximum pressures which may take place during drainage, when a penstock pipes is empty, as well as under construction shall be taken into consideration.

Various pressures act on penstock pipes such as negative pressure during drainage, seepage pressures of bedrocks acting on embedded portions, and concrete pressures and grout pressures during construction works.

A penstock pipes must be of a structure capable of withstanding the maximum external pressures possible to taking the above into consideration.

(4) Materials of penstock pipes

Materials used for penstock pipes shall be equivalent or superior to the materials to be defined in international standards, such as ISO.

(5) Stress analysis

Stress caused by the loads in each member shall not be surplus the allowable stress of each material defined in international standards, such as ISO.

<u>Paragraph 2</u>

When a hydraulic gradient line is below the inside crown of a penstock pipe, negative pressure acts on the penstock pipe and could cause damage severely to it.

<u>Paragraph 4 “serious”</u>

A penstock must be constructed so that water leakage does not damage the surrounding grounds.

<u>Paragraph 5</u>

(1) “Location of anchor block”

An anchor block shall be installed at the bend section of penstocks basically.

An anchor block shall also be installed at straight portion, as the case may be.

A penstock pipe supported on the ground or in a tunnel shall be furnished with anchor blocks at bends to resist the force which tends to exceed the resisting force due to weight of the pipes and weight of water in the pipes and tends to cause displacement of the pipes.

An anchor block shall also be installed at the intermediate point in long straight portion between bends, to limit the pipe length between expansion joints and the anchor blocks, and consequently to limit the displacement due to longitudinal forces and temperature change.

(2) “Foundation of anchor blocks”

An anchor block shall be installed on the foundation with sufficient bearing capacity. If this is difficult, the foundation works shall be conducted so as to have sufficient bearing capacity.

Expected loads in this paragraph for the calculating the stability of an anchor block shall be those listed below.

1. Self-weight of the anchor block

2. Weight of pipes and water borne by the anchor block
3. Axial thrust
4. Centrifugal force acting on a bend pipe portion
5. Unbalance force acting on a bend portion
6. Seismic force

(3) “Stability conditions for anchor block”

An anchor block shall be safe against overturning, sliding and crushing.

A resultant force acting on an anchor block tends to overturn and slide the anchor block. In order to be safe against an overturn, all forces acting on an anchor block including a reaction force and self-weight should be combined on the assumption of the worst conditions, and its resultant line of action should be positioned in the middle third of the base of the block.

To be safe against the sliding, a component of a resultant force acting on an anchor block perpendicular to the bottom, should be larger than the value obtained by driving a component of a resultant force parallel to the bottom by a sliding factor at the bottom of the anchor block.

The following standard values have been taken as the sliding coefficient between an anchor block and the ground.

1. For good bedrock 0.75
2. For soft and week bedrock and gravel layer 0.50
3. For clay 0.30

To be safe against crushing, the compressive stress generated in an anchor block should not exceed the bearing capacity of the foundation and the allowable stress of concrete.

For the detailed explanation of “sliding, overturning and overstressing “, refer to “concrete gravity dam”.

2. Reference

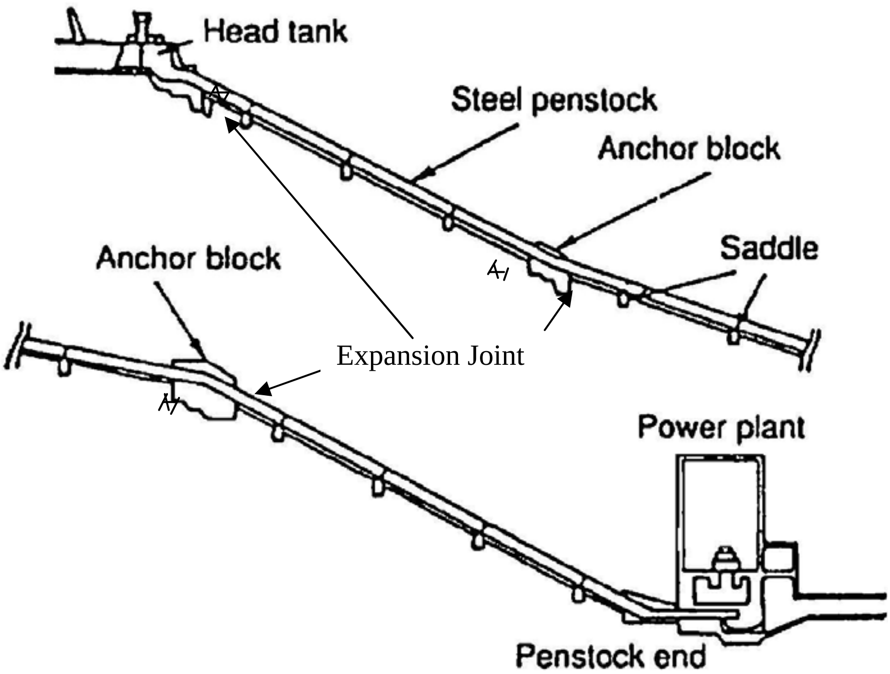
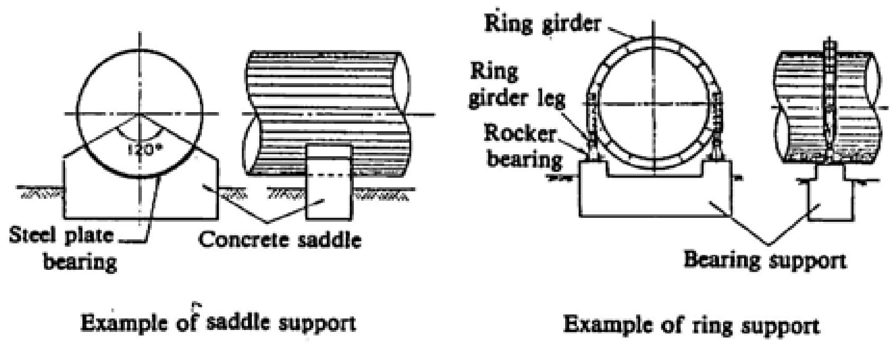


Fig. 48-3 Exposed Type Penstock



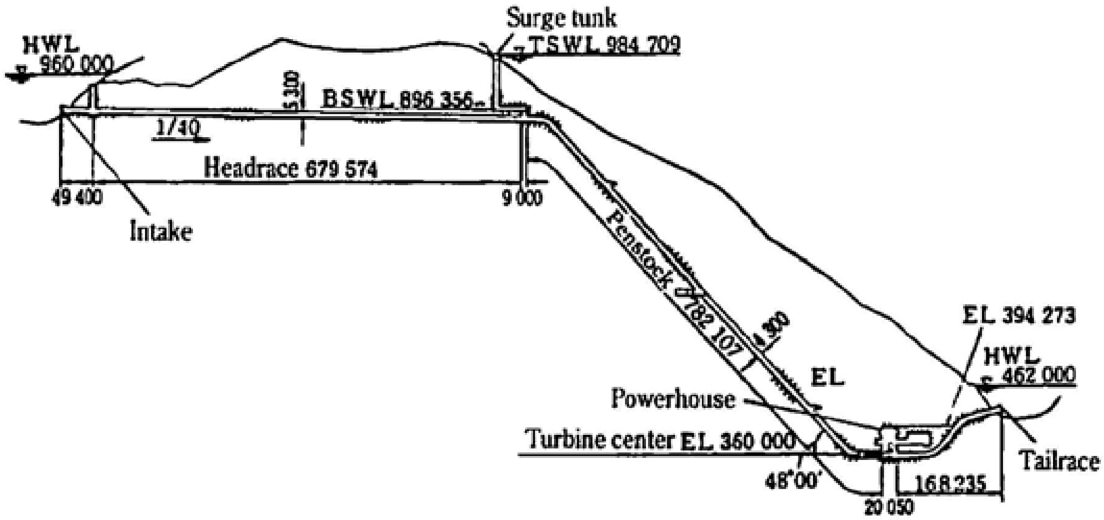
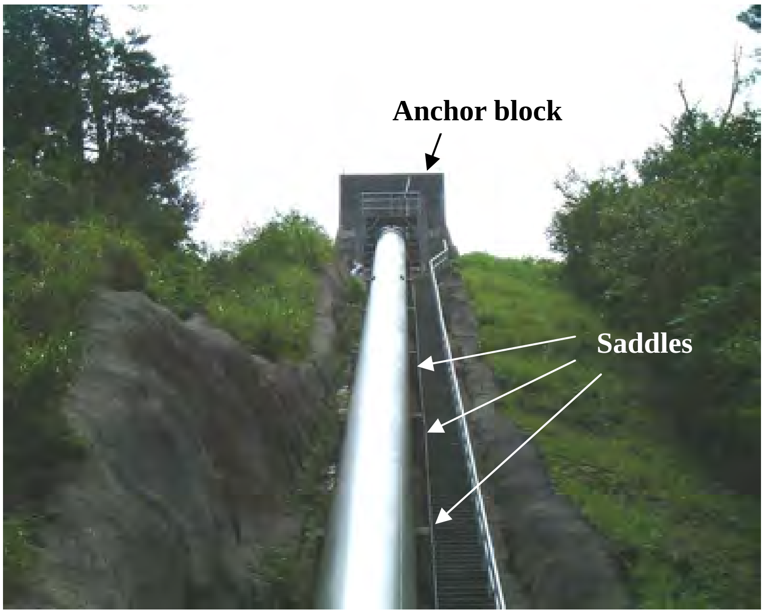


Fig. 48-4 Embedded Type Penstock

Photograph 48-1 Penstock of O'Chum 2 Hydropower Station

Photograph 48-2 Penstock View from Head Tank



Photograph 48-3 Penstock, Anchor Block and Saddles

(1) Expansion Joint

1. An expansion joint shall be attached at a place where an excessive stress or deformation is liable to be generated in an axial direction by a temperature change or other external force.
2. An expansion joint shall be strong and watertight, and be of such structure as to exert its function thoroughly over expansion and contraction.
3. The range of temperature changes for penstock pipes used for calculating the expansion length shall be determined taking account of maximum and minimum temperatures at the site.
4. As for the length of a slide type expansion joint, more than 5cm allowance shall be given as a calculation value.

Photograph 48-4 Expansion Joint and Scaffold for Inspection of it

For Article 49 Tailraces

The explanation of Article 45 (Headraces) is applied correspondingly to the explanation of Article 49 (Tailraces).

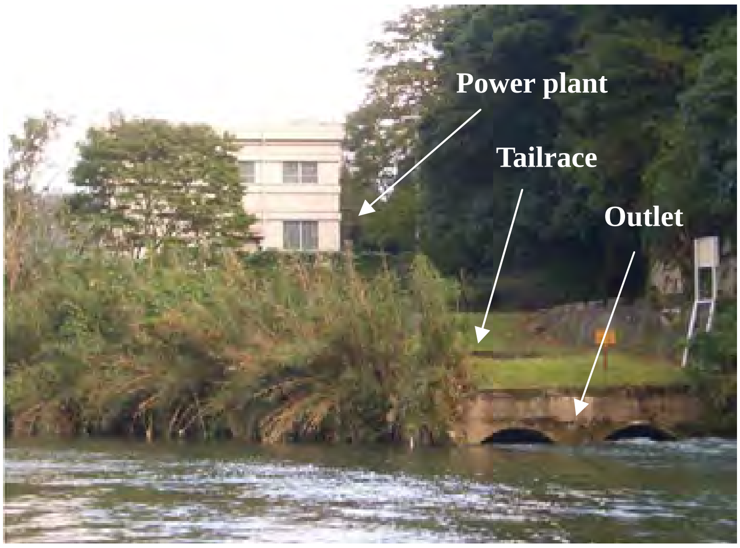
1. Explanation

Paragraph 1

An outlet shall be stable against expected load, such as self-weight, hydrostatic pressure, hydrodynamic pressure, mud pressure, seismic force, external water pressure and earth pressure.

2. Reference

Photograph 49-1 Powerhouse and Outlet of O'Chum 2 Hydropower Station



Photograph 49-2 Tailrace and Outlet of Other Sites

For Article 50 Gates, Valves and Auxiliaries

1. Explanation

Paragraph 1

(1) Loads to be considered

Expected loads in designing hydraulic gates are self-weight, hydrostatic pressure, seismic force, sediment pressure, wave height by wind, wave height by earthquake, dynamic pressure during earthquake, wind load and effect by temperature changes, changes in hydraulic pressure by following water, and load increase due to vibrations caused by changes in the hydraulic pressure.

In addition, the operating loads described as follows shall be considered.

1. Frictional force of wheel rotation
2. Rubber seal friction force
3. Frictional force of sedimentary silt
4. Uplift and down- pull force of the overflow
5. Uplift and down- pull force of the bottom flow

(2) Combination of loads

The loads in designing shall be considered in combination with the following:

1. Normally: self-weight, hydrostatic pressure, sediment pressure, wave pressure, buoyancy, wind load, effect by temperature change, hydraulic pressure changed by flowing water and load increase due to vibrations caused by the hydraulic pressure change, and gate opening force.
2. During earthquake: self-weight, hydrostatic pressure, sediment pressure, wave pressure, buoyancy, hydrodynamic pressure during earthquake, and inertia force during earthquake.

(3) Materials of hydraulic gates

The materials used for gates and valves shall be equivalent or superior to the materials to be defined in international standards, such as ISO.

(4) Stress analysis

The stress caused by the loads in each member shall not be surplus the allowable stress of the each material defined in international standards, such as ISO.

Paragraph 2

In order to keep a hydraulic gate (gate and valve), watertight, various shapes of elastic materials are used. Soft rubbers are generally used for a low hydraulic pressure and hard rubbers for a high hydraulic pressure. Under high pressure, the rubbers are pressed against a seal plate. Metal is sometimes used as a seal material.

Power equipment capable of operating gates anytime without fail shall be provided for hydraulic gates. For small size gates, however, manual equipment may be installed.

Paragraph 3

When a hydraulic gate is operated, its own weight, friction force, up-lift force, and down-pull force are at work, so the gate should be equipped with a hoisting device having sufficient capacity, thus ensuring easy and reliable operation.

Auxiliary power equipment for operating a gate shall be provided for an important hydraulic gate, such as a spillway gate. The auxiliary power equipment shall be capable of operating a hydraulic gate promptly without any failure, even if the normal power service is interrupted.

Paragraph 4

In designing a hydraulic gate to be operated under high pressure, attention should be paid to the fact that “the shape of the gate leaf and guide” and “the air supply to the backside of the gate” are related to vibrations.

Paragraph 5

Since a hydraulic gate is used for a long time, it is necessary to make a thorough investigation into the water quality at the site in advance to consider corrosion and wear in the design of the gate leaf, gate guide, anchorage and hoisting devices.

2. Reference

(1) Types of gates and valves

The types and names of commonly used hydraulic gates and valves are shown below.

1. Gates

1) Roller Type

- Fixed wheel gate (roller gate)
- High pressure roller gate
- Caterpillar gate (roller mounted gate)
- Ring seal gate
- Long span wheel gate
- Multistage wheel gate

2) Hinged Type

- Radial gate
- High pressure radial gate
- Sector gate
- Drum gate

- Bottom hinge flap gate
- Visor gate
- Miter gate

3) Slide Type

- Slide gate
- High pressure slid gate
- Jet flow gate
- Ring follower gate
- Stoplog

4) Other Types

- Rolling gate
- Cylinder gate
- Sliding gate

The above-mentioned hydraulic gates generally consist of gate leaves, bearings, gate guides, and anchorage and gate hoist.

A gate leaf consists of the part directly subject to hydraulic pressure and the part to transmit the load acting on the leaf to the anchorage. The gate guide is a part placed in concrete, where a watertight portion of the hydraulic gate touches the water sealing material. The anchorage is a part to transmit a load from the bearing of a leaf to the concrete, and those other than the hinged type are generally called gate guides.

The gate hoist is a device to open and close the gate leaf.

2. Valves

1) Hollow jet valve
2) Sleeve valve
3) Cone valve
4) Gate valve (sluice valve)
5) Butterfly valve
6) Rotary Valve

Typical types of gates and valves are shown as follows:

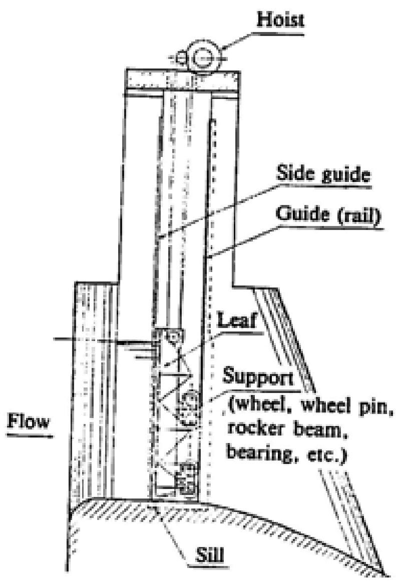


Fig. 50-1 Fixed Wheel Gate

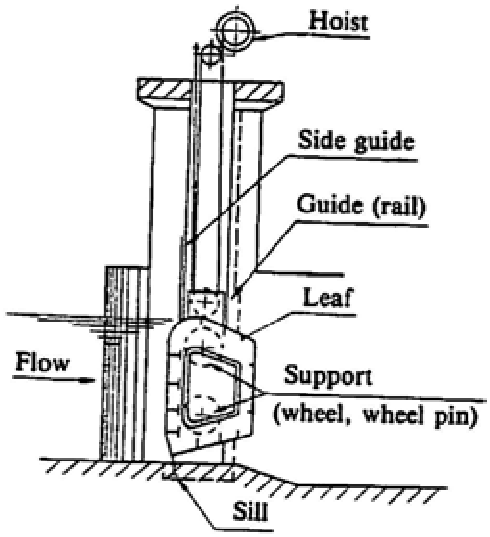


Fig. 50-2 Long Span Wheel Gate

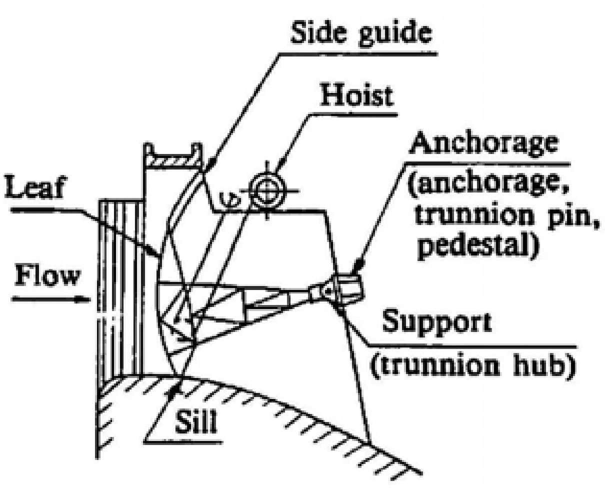


Fig. 50-3 Radial Gate

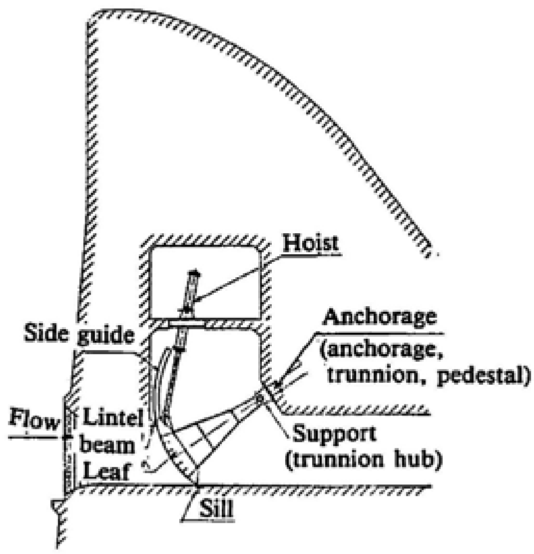


Fig. 50-4 High Pressure Radial Gate

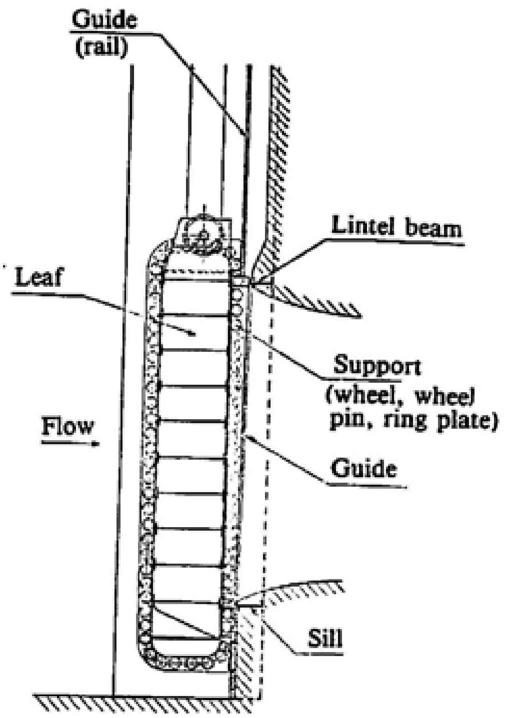


Fig. 50-5 Caterpillar Gate

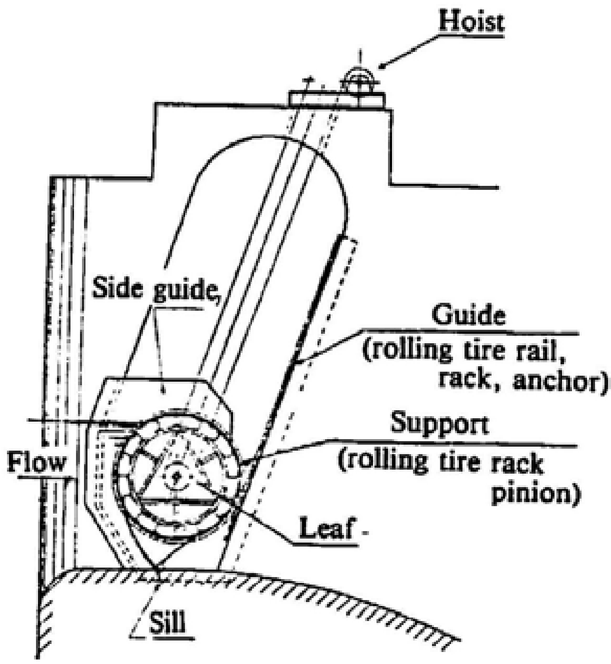


Fig. 50-6 Rolling Gate

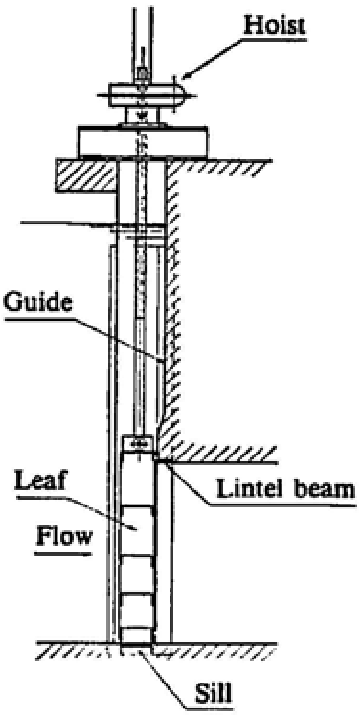


Fig. 50-7 Slide Gate

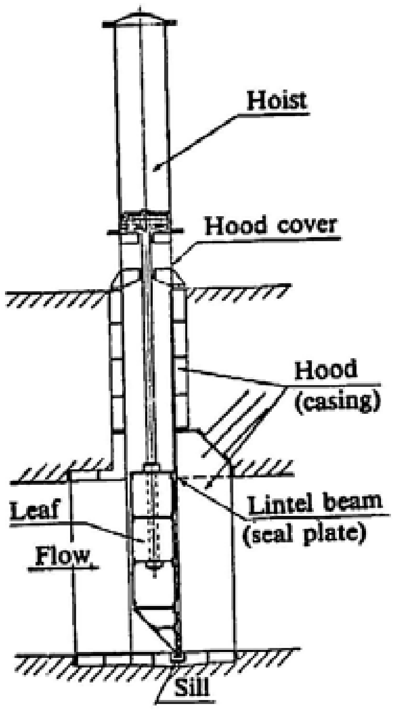


Fig. 50-8 High Pressure Slide Gate

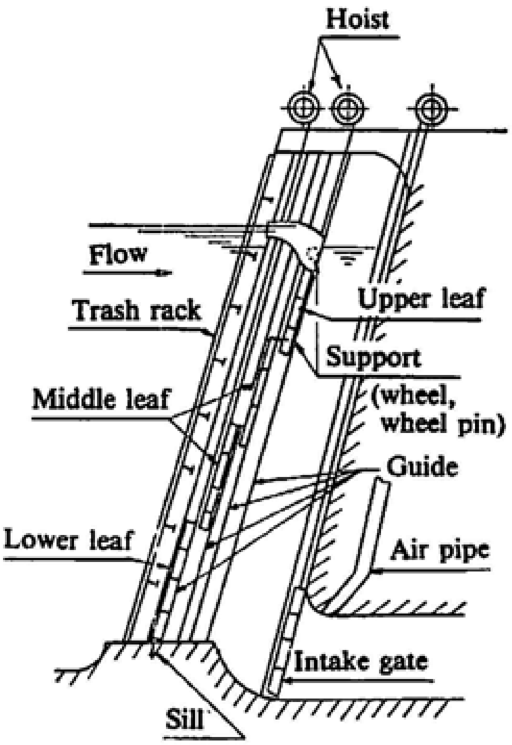


Fig. 50-9 Multistage Wheel Gate

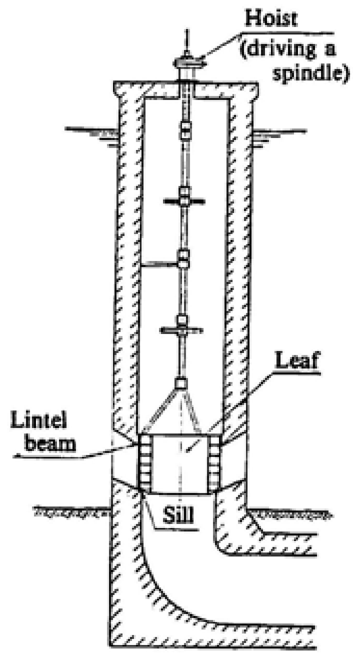


Fig. 50-10 Cylinder Gate

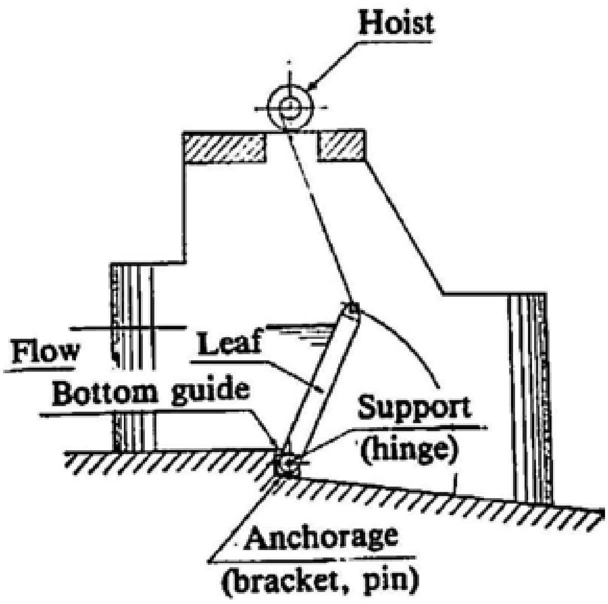


Fig. 50-11 Bottom Hinge Flap Gate

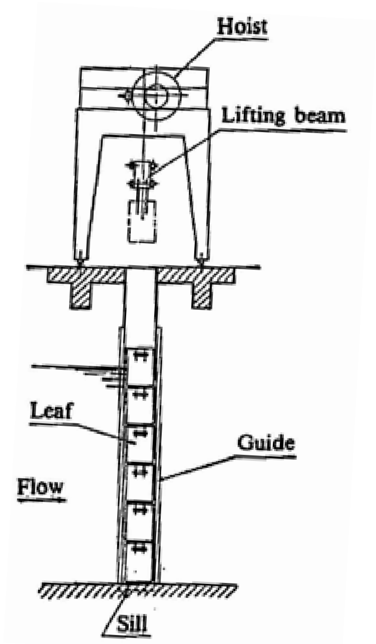


Fig. 50-12 Stoplog

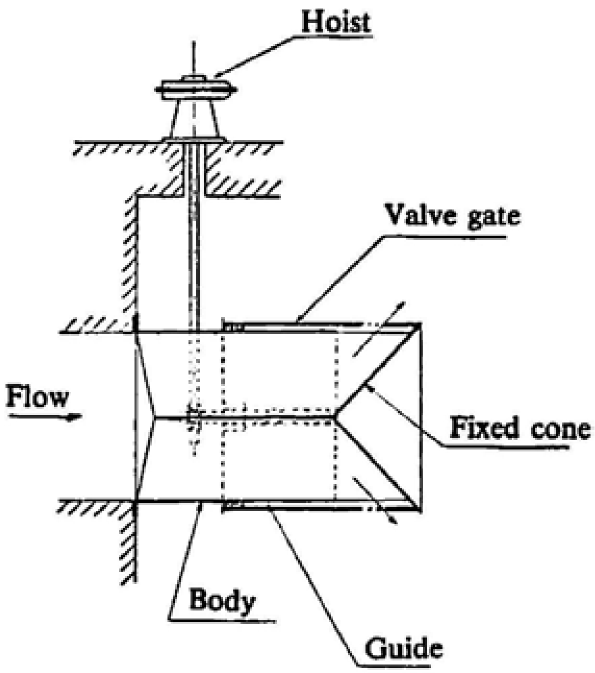


Fig. 50-13 Cone Valve

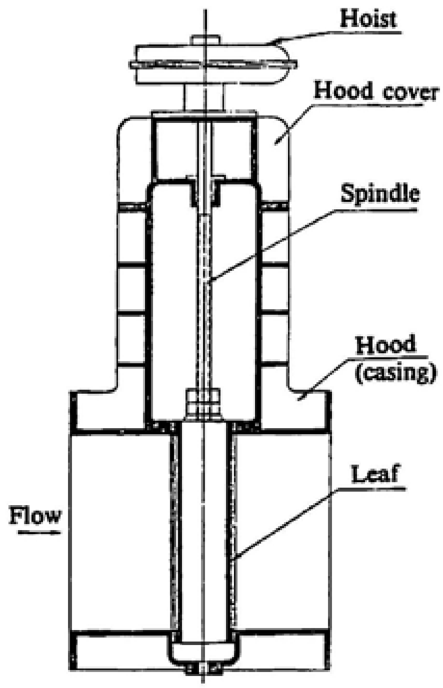


Fig. 50-14 Gate Valve

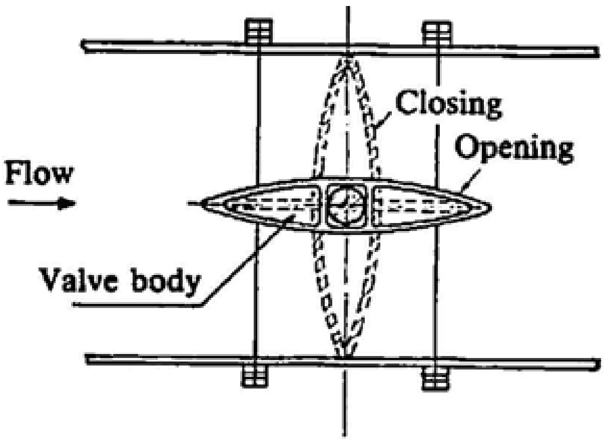


Fig. 50-15 Butterfly Valve

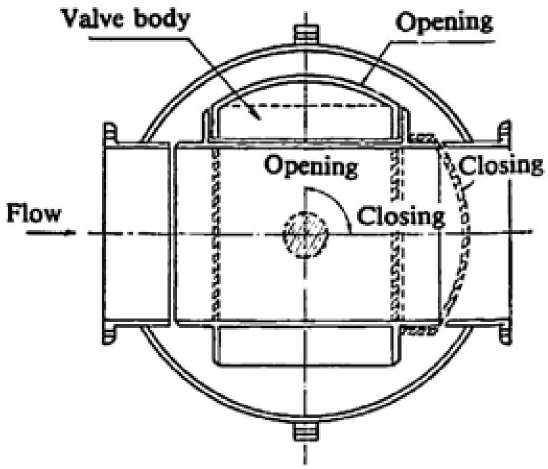


Fig. 50-16 Rotary Valve

Photograph 50-1 Radial Gate

Photograph 50-2 Fixed Wheel Gate

Photograph 50-3 Roller Section

Photograph 50-4 Fixed Wheel Gate

Photograph 50-5 Rolling Gate

The types, shapes, sizes and numbers of hydraulic gates shall be determined in accordance with the installation location, purposes and conditions of use.

And the types and shapes of hydraulic gates can be classified in terms of installation place, purpose and conditions of use as follows.

(2) Gates for dams and power generation

1. Spillway gates

Since spillway gates are normally installed at the overflow portion of a dam and are in full-time use, inspections and repairs are restricted, thus requiring attention to this point.

In general, a wheel gate and radial gate are used.

2. Conduit gates (orifice gates) and valves

   Since conduit gates and valves are installed inside a dam or downstream of a dam, and since discharge often occurs under high water pressure, it is necessary to select a type which has a rigid structure and unfailing operation.

   Many of the operating system are of the hydraulic type, and generally the following types of gates and valves are used.
   Slide gate, high pressure slide gate, wheel gate, high pressure wheel gate, caterpillar gate, radial gate, high pressure radial gate, ring follower gate, ring seal gate, jet flow gate, hollow jet valve, cone valve, sleeve valve, etc.

3. Gates for intakes, settling basins and head tanks

   The gates are installed for intakes, settling basins and head tanks and are used when a settling basin, headrace, head tank, or steel penstock are inspected or repaired.

   Generally a fixed wheel gate or a slide gate is used. However, a high pressure gate, caterpillar gate, or a high pressure radial gate is used when the water pressure is high.

4. Valves for penstocks

   In order to regulate the water at both ends of penstocks, the following valves are generally used.
   Butterfly valve, gate valve (sluice valve), rotary valve, etc.

5. Tailrace gates

   Tailrace gates are installed at a tailrace and are used when turbines and a draft tubes are inspected or repaired and for the purpose of preventing a backward current in floods.

   The types generally used are as follows.
   Slide gate, fixed wheel gate, etc.

6. Sediment flush gates

   Sediment flush gates are in full-time use and are installed to flush the sediments accumulated at a dam, settling basin, headrace, or head tank together with the water.

   Thus its structure should be rigid and reliable operation should be ensured.

   The following types of gates are generally used.
   Slide gate, fixed wheel gate, radial gate, etc.

   The conduit gates and valves mentioned in paragraph 2. above may be used when the water head is high.

7. Surface water withdrawal gate and selective water withdrawal gate

   These gates are to intake warm water on the surface or to intake water from any layer, in accordance with fluctuations in the water level in reservoir.

   Since they are in full time use and are submerged in water, they require reliable operation.

   The types of gates generally used are as follows.
   Slide gate, fixed wheel gate, multistage wheel gate, stoplog, telescope type cylinder gate, multistage semi-cylindrical gate, etc.

8. Gate for repair

   For a hydraulic gate used to inspect and repair a crest spillway gate, a simple structure with easy transportation is required.

   Therefore, the following gates are generally used.
   Floating gate, stoplog, wheel gate, slide gate, etc.

(3) Gates for intake weirs (head works) and estuary weirs

1. Spillway gates

   The spans of these gates are longer than that of the crest spillway gates at dams. Generally, a fixed wheel gate, bottom hinge flap gate or long span wheel gate is used.

2. Discharge sediment gates

   These gates are used to discharge the sediments upstream of the weir and thus the gates are in full-time use.

   Accordingly, a gate of rigid structure and sturdy wear- resistance should be selected.

   Generally, a fixed wheel gate or a radial gate is used.

3. Regulation gate

   These gates are used to regulate the outlet discharge to downstream and control the reservoir water level.

   These are in almost full time use during overflows or bottom-discharge.

   The leaf shape should be good in terms of hydraulic characteristics.

   A fixed wheel gate, radial gate or bottom hinge flap gate is used and double leaf wheel gate or a gate with flap is frequently used.

4. Intake gates, settling basin gates and headrace gates

   These gates are used when an intake, settling basin or headrace is inspected or repaired and when regulating or branching the water flow.

Generally, a fixed wheel gate, slide gate or bottom hinge flap gate is used.

5. Fishway gates

These gates are installed for step type fishways where the upstream water level fluctuates greatly.

A bottom hinge flap gate is frequently used.

Photograph 50-6 Hoist of Intake Gate

Chapter 7 Powerhouse and Other Facilities

For Article 51 Powerhouse Structures

1. Explanation

Paragraph 1

Powerhouse structures shall be stable against expected loads, such as self-weight, hydrostatic pressure, seismic force, and rock or earth pressure.

Paragraph 2 "vibrations"

Strong vibrations occur around turbines. It is necessary that the structure around turbines is stable with respect to the vibrations.

Paragraph 3 "floods"

Generally, 50 to 100 years return period flood is used in the design of powerhouses.

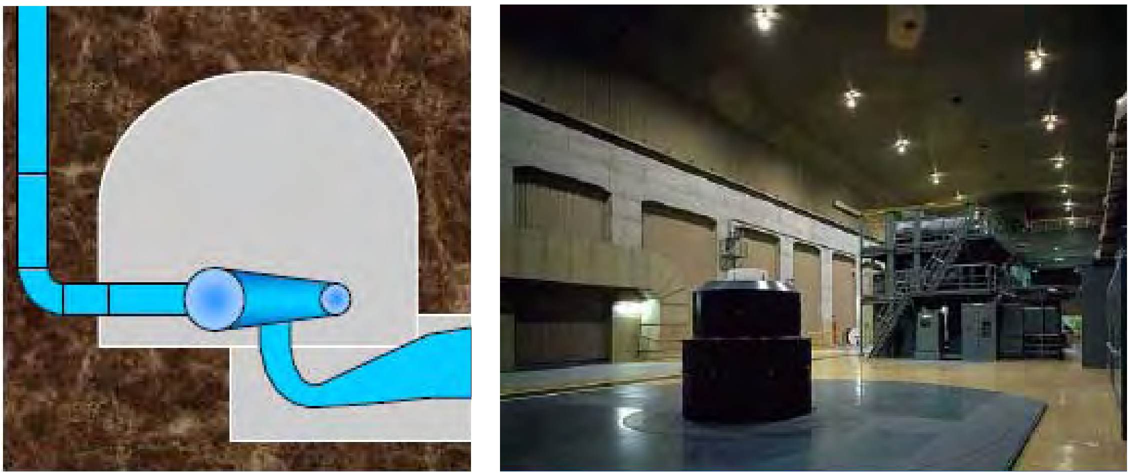
2. Reference

Photograph 51-1
Powerhouse of O'Chum 2 Hydropower Station

Photograph 51-2
Inside of O'Chum 2 Powerhouse

Photograph 51-3 Ground Surface Type Powerhouse and Outlet

Photograph 51-4 Semi-Underground Type Powerhouse



Photograph 51-5 Underground Type Powerhouse

For Article 52 Other Facilities

1. Explanation

Paragraph 1

Permanent facility such as maintenance road, in the case opened to public, shall be designed in accordance with the design standard or regulation of object facility.

Photograph 52-1 Temporary Road for Construction

Photograph 52-2 Road for Construction and Maintenance (opened to the public)

Chapter 8 Reservoirs

For Article 53 Prevention of Landslide

1. Commentaries

Paragraph 2 “harmful leakage”

A little water leakage is inevitable, but serious water leakage, the occurrence of large landslide and damage to the functioning of the reservoir shall be avoided.

2. Explanations

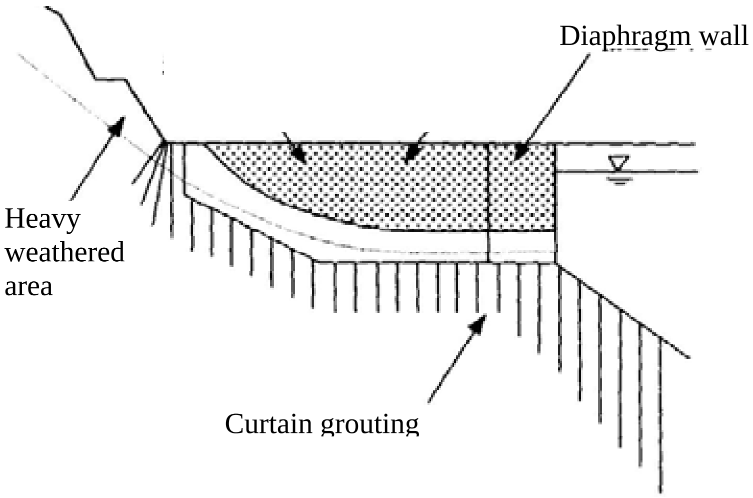


Fig. 53-1 (1) Example of Diaphragm Concrete Wall

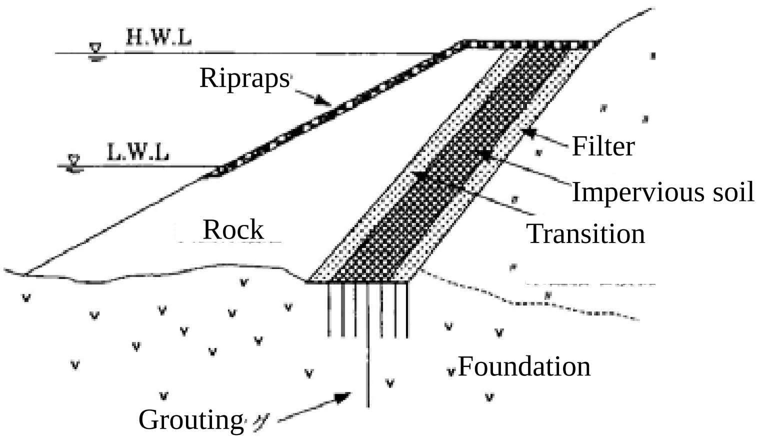


Fig. 53-2 (2) Example of Soil Seepage Control Work

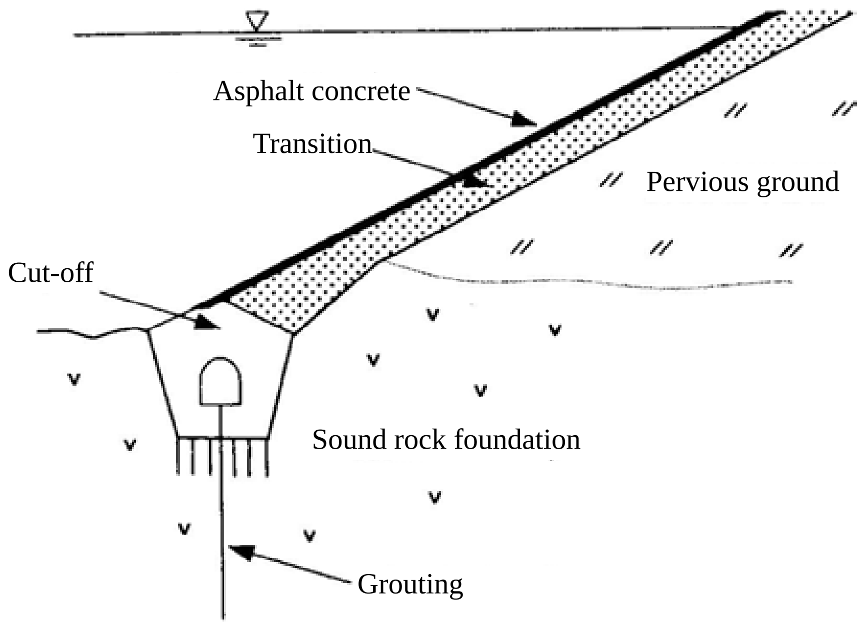


Fig. 53-3 (3) Example of Asphalt Concrete Seepage Control Work

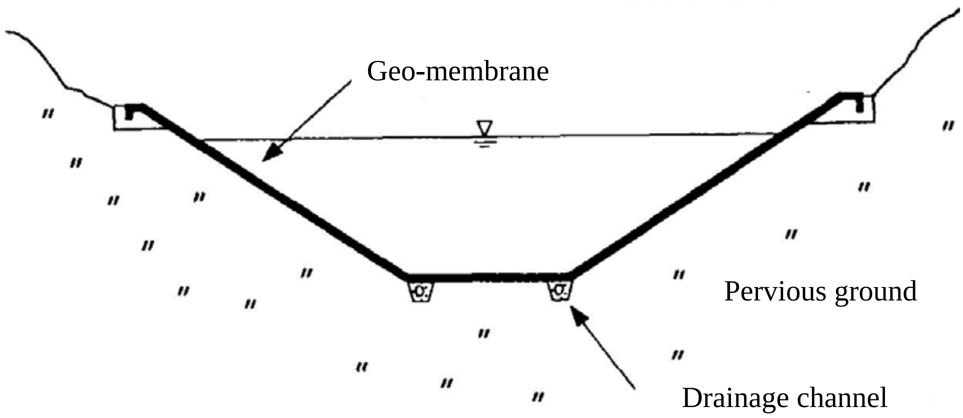


Fig. 53-4 (4) Example of Geo-Membrane Seepage Control Work

For Article 54 Sedimentation and Water Quality

1. Commentaries

<u>Paragraph 1 "serious reduction of reservoir capacity"</u>

A little decrease of effective storage is inevitable. But sedimentation which decreases much effective storage shall be avoided.

<u>Paragraph 2 "appropriate measures"</u>

Measures depend on each reservoir. The proper measures must be taken at a reservoir when the situation warrants them. A selective intake, a surface intake, a bypass channel, an aeration and so on are countermeasures against water quality deterioration. It is necessary to compare costs with effects of countermeasures.

Chapter 9 Downstream

For Article 55 Regulation of Discharge to Downstream Areas

1. Explanations

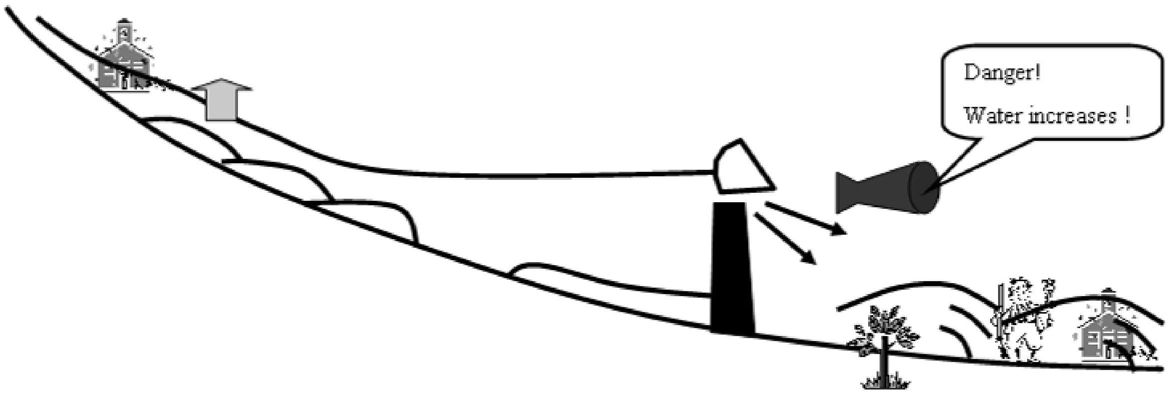


Fig. 55-1 Warning by Sirens and Sending Notice to Populations Downstream Area

Appropriate measures such as warning by sirens and sending notice to populations downstream area shall be taken so that damage to downstream may be minimized.

For Article 56 Facilities to Discharge to Downstream Areas

1. Commentaries

“with the capability to discharge a required amount of water”

Strong vibration is expected during restricted openings of a valve or gate for discharging a required small amount of water.

Part 3
Electrical Facilities

Chapter 10 General Provision

For Article 60 Insulation for Electrical Circuits and Lines

The electrical circuits and lines shall be insulated from ground in order to prevent them from fire caused by leakage current, electrical shock and telecommunication hindrance. The insulation for electrical circuits and lines can be applied for not only medium and high voltage but also low voltage electrical circuits and lines. Therefore, grounding point of low voltage side electrical circuits and lines shall be insulated from the ground by insulator.

However, following cases are exempted from grounding work.

Table 60-1 Exemption Point of Grounding Work

Exemption	Detailed Cases
Grounding work point which is stipulated in SREPTSHP for exemption	1. Grounding work point of low voltage circuits. 2. Grounding work point to be connected to neutral point. 3. Grounding work point for secondary circuit of instrument transformer. 4. Grounding work point for combination of high voltage and low voltage electrical line. 5. Grounding work point for multi-grounding of high voltage electrical lines.
Grounding work point for control circuit	Working voltage of electrical circuits and lines are 150V or less which to be connected to low voltage circuits and transformer.
Unavoidable cases to use the electrical equipment not to be insulated from the ground	Testing transformer, reactor for power line carrier system, power supply for electric fence, X-ray machine etc.
Equipment that installation is not easy	Electric bath tub, electric furnace, electric boiler, electric cell.

For Article 61 Prevention of Disconnection of Electrical Wires and Cables

The hard drawn copper wire, annealed copper wire, copper alloy, hard drawn aluminum wire, aluminum alloy, copper clad steel wire, aluminum clad steel wire, aluminizing steel wire and galvanizing steel wire which have enough electric conductivity and tensile strength shall be used for bare wires, guy wires, grounding wire, protective wire, protective net, telecommunication wires and other metallic wires as follows;

Table 61-1 Electric Conductivity and Tensile Strength of Metallic Wire

Type of Metallic Wire	Electric Conductivity	Tensile Strength (N/mm^2)
Hard drawn copper wire (diameter 12mm or less)	96% or more	(462-10.8d) or more
Annealed copper wire	98% or more	196 or more
Silicon bronze wire (diameter 5mm or less)	45% or more	558 or more
C-alloy wire (diameter 5mm or less)	35% or more	863 or more
Cadmium copper alloy wire (diameter 5mm or less)	85% or more	501 or more
Heat resistance copper alloy wire (diameter 5mm or less)	95% or more	408 or more
Hard drawn aluminum wire (diameter 6.6mm or less)	61% or more	155 or more
I-aluminum alloy wire (diameter 6.6mm or less)	52% or more	309 or more
High strength aluminum alloy wire (diameter 6.6mm or less)	53% or more	218 or more
Heat resistance aluminum alloy wire (diameter 6.6mm or less)	57% or more	155 or more
High strength heat resistance aluminum alloy wire (diameter 6.6mm or less)	53% or more	218 or more
Special strong copper clad steel wire (diameter 5mm or less)	19% or more	1,290 or more
Strong copper clad steel wire (diameter 5mm or less)	29% or more	839 or more
Ultra strong aluminum clad steel wire (diameter 5mm or less)	14% or more	1,570 or more
Special strong aluminum clad steel wire (diameter 5mm or less)	20% or more	1,270 or more
Strong aluminum clad steel wire (diameter 5mm or less)	22% or more	1,080 or more
Aluminum clad steel wire (diameter 5mm or less)	30% or more	392 or more
Aluminizing steel wire (diameter 5mm or less)	-	1,140 or more
Ultra strong galvanizing clad steel wire (diameter 5mm or less)	-	1,960 or more
Special strong galvanizing clad steel wire (diameter 5mm or less)	-	1,670 or more
Galvanizing clad steel wire (diameter 5mm or less)	-	686 or more
Aluminum clad steel invar wire (diameter 5mm or less)	-	932 or more
Galvanizing invar wire (diameter 5mm or less)	-	1,030 or more
Anti-corrosive wire	-	294 or more

d: diameter of metallic wire (mm)

For Article 62 Connection of Electrical Wires and Cables

The electrical wires and cables shall be connected so as not to increase their resistance and not to decrease the tensile strength by 20% or more. Therefore, connection device such as sleeve shall be used or shall be soldered. However, the soldering of tensile point may decrease the strength caused by annealing, therefore, sleeve connection shall be employed in general. Joint terminal, branch connector and Britannia joint are employed for jumper terminal.

In case of connection of aluminum wire, aluminum alloy, copper and copper alloy, countermeasure of electric corrosion shall be necessary for connection point.

For Article 63 Thermal Strength for Electrical Equipment

The thermal strength for electrical equipment shall be confirmed that the temperature rise of the electrical equipment does not exceed the maximum allowable temperature of the electrical equipment for each thermal class as shown below.

Table 63-1 Thermal Class for Electrical Equipment

Thermal Class	Class Temperature (°C)
A	105
E	120
B	130
F	155
H	180

For Article 64 Prevention of Hazard of Medium and High Voltage Electrical Equipment

Medium and high voltage electrical equipment shall not be installed at any power facilities other than hydropower station in general.

However, following cases are permitted for installation of medium and high voltage electrical equipment.

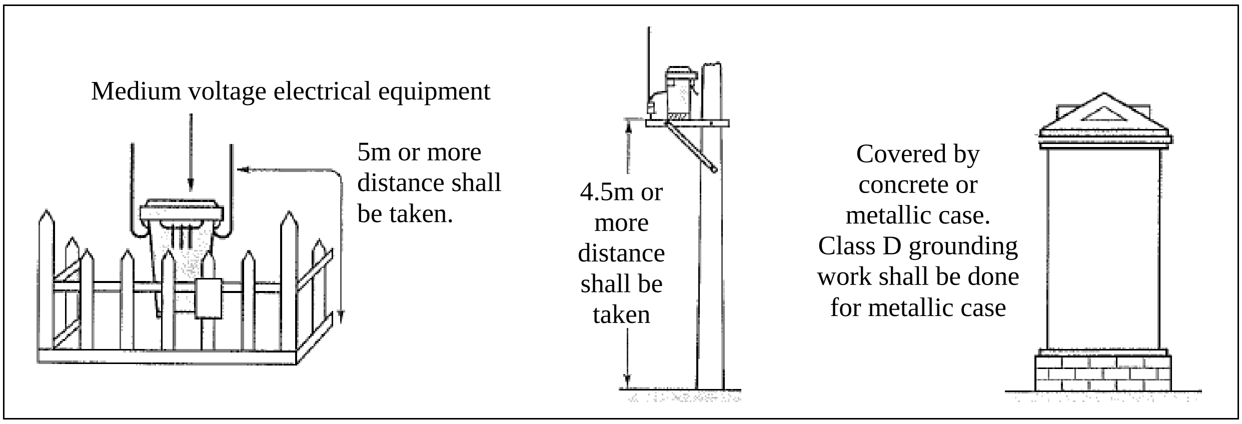
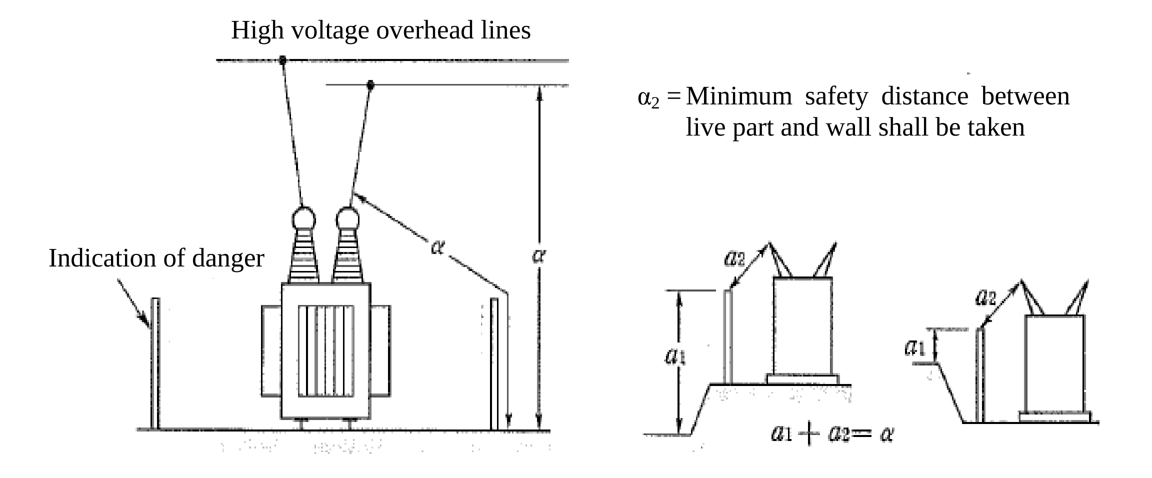


Fig. 64-1 Installation of Medium Voltage



Distance to live part   Concept of distance

Fig. 64-2 Installation of High Voltage

Table 64-1 Total Distance of Height of Fence, Wall and Live Part

Voltage Classification	Total Distance of Height of Fence, Wall and Live Part
35kV or less	α = 5m
Over 35kV and 160kV or less	α = 6m
Over 160kV	α = 6m+12cm/10kV

Note: In case of 180kV: $\alpha = 6m + 0.12 \times 2 = 6.24m$
In case of 220kV: $\alpha = 6m + 0.12 \times 6 = 6.72m$

For Article 65 Method for Grounding of Electrical Equipment

As for class C and D grounding work, top of the earth electrode can be surfaced as mentioned below. However, earth electrode of class A and B grounding shall be buried under depth of 75cm or more and covered by insulated materials for 2 meter upward from ground surface.

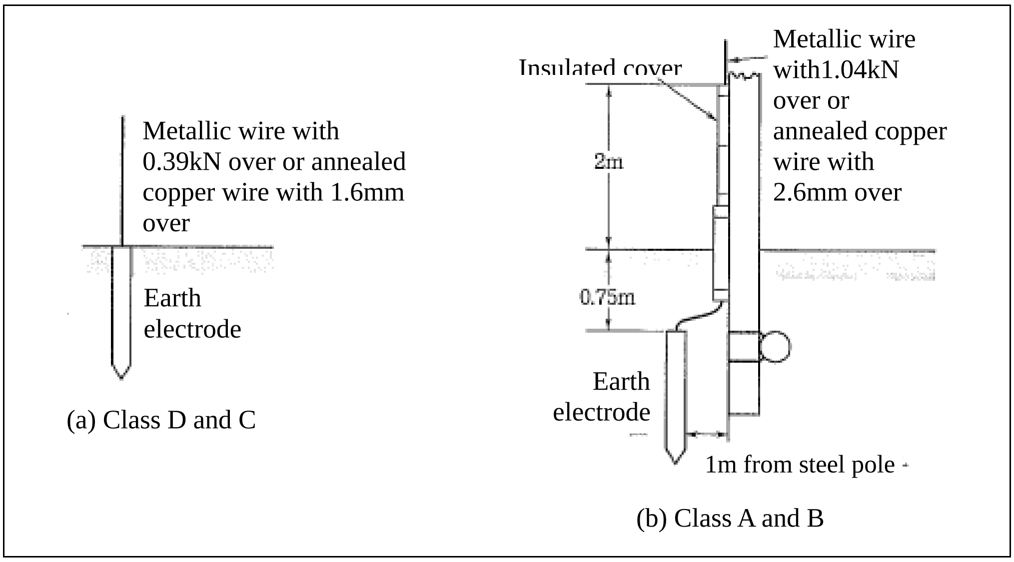


Fig. 65-1 Method for Grounding

For Article 67 Prevention of Fire Caused by Transformers Connected to Medium and High Voltage Circuits and Lines

Neutral point of low voltage side of transformer which is to be connected to high and medium voltage circuits and lines shall be grounded. However, single phase transformer with 300V or less or transformer with delta connection cannot ground, so that following terminal grounding is permissible (Fig.67-1).

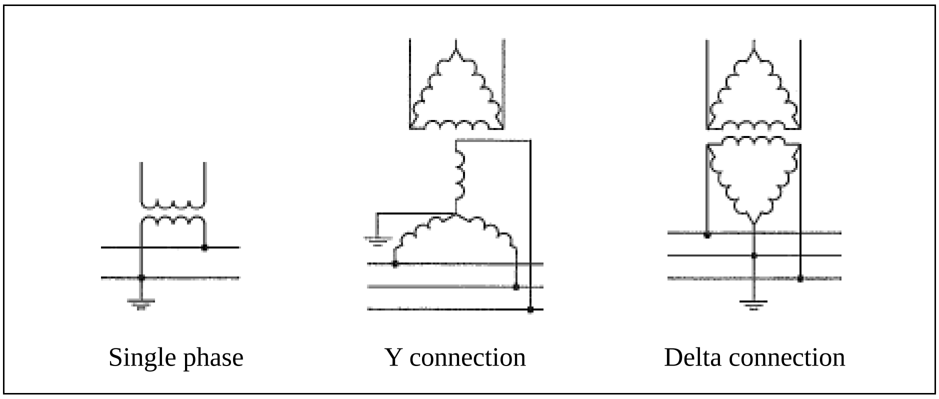
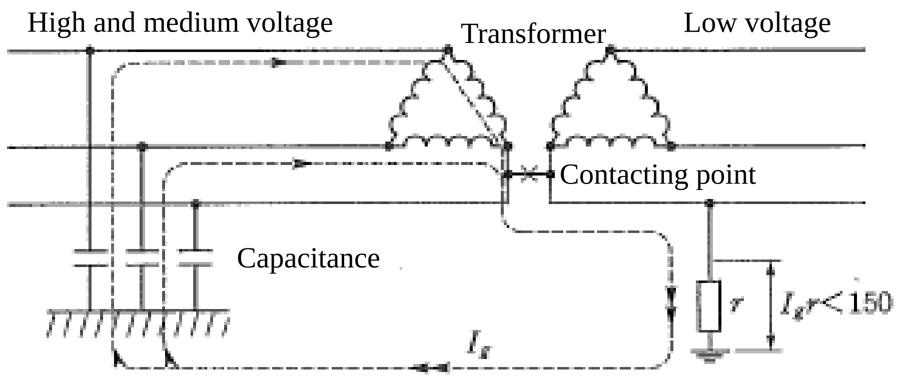


Fig. 67-1 Grounding Point of Low Voltage Side of Transformer

In this case of earth resistance, the product of one line grounding current by earth resistance shall be 150V or less (Fig.67-2). This grounding work shall be done at transformer's place in general. However, if required resistance value cannot be obtained due to soil condition, the grounding work can be done within 200m in distance from transformer as shown follow. But hard drawn copper wire with tensile strength of 5.26kN or diameter of 4mm shall be used for overhead grounding wire (Fig.67-3).



I_g : Fault current r : Earth resistance of Class B

Fig. 67-2 Class B Grounding Work

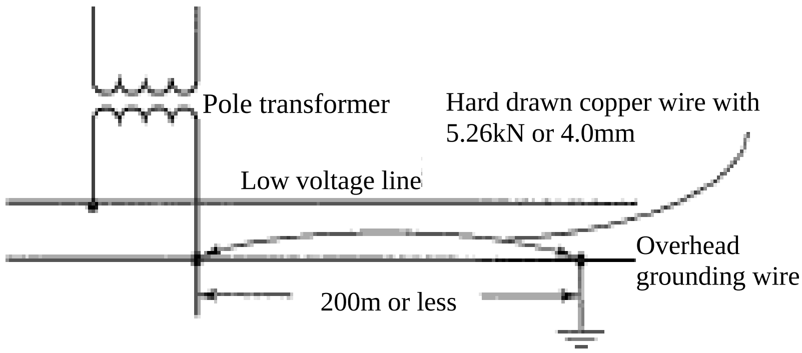


Fig. 67-3 Grounding Point for Single Grounding

In the case that required earth resistance cannot be obtained by single grounding due to soil condition, collaborative overhead grounding wire can be permissible. As for installation of collaborative overhead grounding wire, hard drawn copper wire with tensile strength of 5.26kN or diameter of 4mm shall be used and every transformer shall be grounded (Fig.67-4). If grounding work shall be done at transformer's place, it shall be grounded within 200m in distance from the transformer.

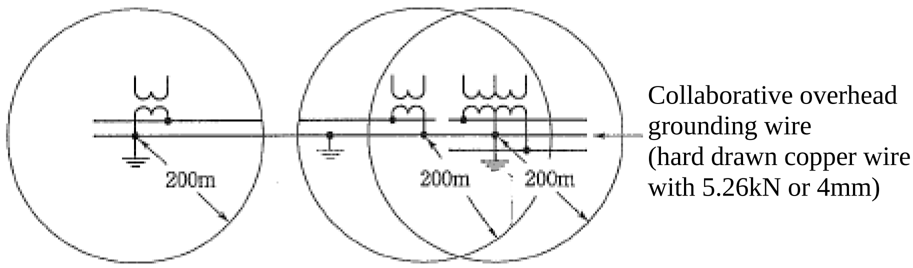


Fig. 67-4 Grounding Point of Collaborative Grounding

Even though area of collaborative overhead grounding wire is not stipulated, required combined resistance shall be obtained every 0.5km radius area (Fig.67-5). The 0.5km radius area can be selected voluntarily, and overlapping shall not be allowed. In case of collaborative overhead grounding, value of earth resistance shall be 300Ω or less.

○ Grounding point ✕ Opening point for measurement

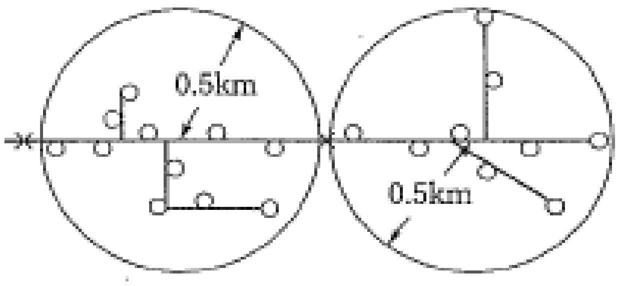


Fig. 67-5 Area of Collaborative Grounding

For Article 68 Restriction of High and Medium Voltage Transformer Convert Directly into Low Voltage

Transformer which converts high and medium voltage into low voltage directly shall not be installed except for the followings;

1) Transformer for electric furnace purpose
2) Transformer to be installed at hydropower station
3) Transformer to be connected to high voltage overhead transmission line
4) Transformer voltage is less than 35,000V and shall have automatic cutting off device in case of contacting high voltage winding and low voltage winding
5) Transformer voltage is less than 100,000V and shall have contact preventing plate between high voltage winding and low voltage winding for class B grounding work.
6) Transformer voltage is 150,000V or less and shall have automatic cutting off device in case of ground fault within 2 seconds.

For Article 69 Protection for Electrical Wires, Cables and Electrical Equipment against Over-current

Low voltage fuse to be used as over-current circuit breaker and to be installed horizontally shall be as follows;

(1) It shall withstand 1.1 times of rated current.
(2) It shall be fused in accordance with the specifications shown in the following table.

Table 69-1 Characteristics of Fuse

Rated Current	Time (minutes)	
	1.6 Times of Rated Current	2.0 Times of Rated Current
30A or less	60	2
Over 30A, 60A or less	60	4
Over 60A, 100A or less	120	6
Over 100A, 200A or less	120	8
Over 200A, 400A or less	180	10
Over 400A, 600A or less	240	12
Over 600A	240	20

Low voltage distribution circuit breaker to be used as over-current circuit breaker shall be as follows;

(1) It shall not be operated automatically by rated current

(2) It shall be operated automatically in accordance with the specifications shown in the following table

Table 69-2 Characteristics of Low Voltage Distribution Circuit Breaker

Rated Current	Time (minutes)	
	1.25 Times of Rated Current	2.0 Times of Rated Current
30A or less	60	2
Over 30A, 50A or less	60	4
Over 50A, 100A or less	120	6
Over 100A, 225A or less	120	8
Over 225A, 400A or less	120	10
Over 400A, 600A or less	120	12
Over 600A, 800A or less	120	14
Over 800A, 1,000A or less	120	16
Over 1,000A, 1,200A or less	120	18
Over 1,200A, 1,600A or less	120	20
Over 1,600A, 2,000A or less	120	22
Over 2,000A	120	24

Low voltage overload protective device and circuit breaker or fuse for short circuit protection to be used as over-current circuit breaker shall be applied only for low voltage motor circuit and shall be as follows;

(1) Circuit breaker for short circuit protection shall be as follows;

1) It shall not be operated automatically by rated current
2) Setting tripping current shall be less than 13 times of rated current
3) In case of 1.2 times of setting tripping value, it shall be tripped automatically within 0.2seconds.

(2) Fuse for short circuit protection shall be as follows;

1) It shall withstand 1.3 times of rated current

2) In case of 10 times of setting tripping value, it shall be fused automatically within 20 seconds.

Overload protective device and circuit breaker or fuse for short circuit protection shall be installed at the same container.

Circuit breaker for short circuit protection or fuse for short circuit protection with capability of cutting off short circuit current shall be installed before burnout of short circuit current by overload protective device.

In case of combination of overload protective device and fuse for short circuit protection, rated current of fuse for short circuit protection shall be less than setting tripping value of overload protective device.

Over-current circuit breaker shall have capability for cutting off its short circuit current. Enclosed fuse to be used for medium voltage shall withstand 1.3 times of rated current and to be fused by 2 times of rated current within 120 minutes.

Medium voltage open fuse to be used for over-current circuit breaker shall withstand 1.25 times of rated current and to be fused by 2 times of rated current within 2 minutes. Over-current circuit breaker shall have capability of cutting off in case of short circuit and shall have status device which can indicate open or close condition easily.

For Article 70 Protection against Grounding Fault

Electrical circuits and lines to be connected to low voltage electrical equipment over 60V with metallic case shall have automatic cutting off device in case of grounding fault except for the following cases.

1) Electrical equipment to be installed at hydropower station
2) Electrical equipment to be installed at a dry place
3) Electrical equipment with 150V in ground voltage to be installed other than wetting place
4) Grounding resistance of class C and D grounding work for electrical equipment is less than 3Ω.
5) Electrical equipment with double insulation
6) Insulating transformer to be installed at power system side and not to be grounded electrical equipment side of insulating transformer
7) Electrical equipment to be covered with rubber or synthetic resin
8) Electrical equipment to be connected to secondary side of induction motor
9) Earth leakage breaker to be installed inside of electrical equipment and power outlet is protected so as not to be damaged.

Low voltage electrical circuits and lines less than 300V to be connected to medium and high voltage circuits and lines by transformer shall have automatic cutting off device in case of grounding fault.

Following medium and high voltage electrical circuits and lines or its adjacent place shall have automatic cutting off device in case of grounding fault.

(1) Outgoing point of hydropower station
(2) Incoming point from other
(3) Installation place of distribution transformer

Chapter 11 Electrical Equipment for Hydropower Station

For Article 75 Insulation Level of Transformers

This article is stipulated for necessary insulation level after installation of transformer at hydropower station. Electrical circuits and lines of transformer shall have enough insulation level following dielectric strength test. In this article, insulation level is stipulated but it is not obligation.

If dielectric strength is already confirmed, it satisfies stipulated insulation performance and test at site can be done by normal voltage to ground for 10 minutes.

Dielectric strength of transformer shall be of withstanding under the test voltage in the following table for 1 minute (Except nominal voltage from 187kV to 500kV).

Table 75-1 Power Frequency Test Voltage for Transformer Winding

(kV)

Nominal Voltage	Test Voltage	Nominal Voltage	Test Voltage
3.3	16	110	230
6.6	22	154	325
11	28	187	225*
22	50	220	265*
33	70	275	330*
66	140	500	635*
77	160		

Note*: Testing time of Nominal voltage from 187kV to 500kV shall be as follows: $\frac{120 \times \text{Rated Frequency}}{\text{Tested Frequency}}$ (Second)

For Article 76 Insulation Level of AC Electrical Equipment except Transformers

Dielectric strength of AC electrical equipment is stipulated in order not to cause any dielectric breakdown in case of normal use and having enough insulation level. Therefore, electrical equipment shall have enough insulation performance withstanding dielectric strength test.

If dielectric strength is already confirmed, it satisfies stipulated insulation performance and test at site can be done by normal voltage to ground for 10 minutes.

For Article 77 Insulation Level of Electrical Equipment to be Connected to DC Circuit

(1) Minimum test voltage of 500V is determined by taking into deterioration of insulation level and necessity of dielectric strength consideration.

(2) Applying AC voltage to DC circuit, $\sqrt{2}$ time of DC voltage is same as AC voltage. It can be verified that 1.5 times of multiple value of test voltage for less than the maximum voltage of 7,000V for AC circuit.

For Article 93 Structure, Performance and Installation of Load Breaker Switch and Disconnecting Switch

In SREPTSHP, load breaker switch means the switch which it has capability of cutting off the load current.

1. Installation Place

Load breaker switch and disconnecting switch shall be installed for dividing the electrical circuits and lines for maintenance and operation purpose. For medium and high voltage electrical circuits and lines, load breaker switch shall be installed at one side of circuit breaker for transformer, both sides of circuit breaker for transmission line and capacitance.

Low voltage load breaker switch and disconnecting switch are not stipulated in SREPTSHP, however, it is desirable to comply with the provision for the medium and high voltage load breaker switch and disconnecting switch described in SREPTSHP.

2. Performance

Disconnecting switch is to be originally operated in no current condition. But in special cases, disconnecting switch can be operated such as excitation current of transformer, charging current of lines and bus-bar, loop current of lines and circuits and small load current. However, if application is not appropriate, it may cause earth fault and short circuit fault, and the necessary operating capability is as stipulated in SREPTSHP.

Operating capability of disconnecting switch varies according to structure, installation, wind velocity, wind direction and so on. Horizontal double break, horizontal single break vertical single break disconnecting switch somehow have operating capability.

Limitation of operating capability for disconnecting switch is shown as follows;

Table 93-1 Limitation of Operating Capability for Outside Disconnecting Switch

Rated Voltage (kV)	Clearance Between Phases (mm)		Lagging Current (A)	Leading Current (A)
	Single Break	Others		
7.2	Over 800	Over 400	4	2
12	Over 800	Over 600	4	2
24	Over 1,000	Over 750	2	2
36	Over 1,000	Over 900	2	2
72	Over 1,500	Over 1,500	2	1
84	Over 1,800	Over 1,700	2	1
120	Over 2,500	Over 2,200	3	1
168	Over 3,000		3	1
204	Over 3,500		3	0.5
240	Over 4,000		2	0.5

3. Structure

Medium and high voltage load breaker switch and disconnecting switch cannot be recognized for their operating condition easily and not clear whether circuit to be charged or not sometimes, thus, it may cause accidents. Therefore, status indication device linked with motion shall be installed. Operating status cannot be recognized easily means that equipments cannot be seen from outside such as enclosing housing or covered.

Equipment which might be operated naturally by vibration or other causes shall have locking device, safety clutch or other device to prevent operation.

Disconnecting switch which separates live part and dead part for maintenance shall have locking device in order not to misoperate.

Load breaker switch and disconnecting switch shall have enough mechanical strength because in case of short circuit, they suffer mechanical shock due to electromagnetic force of sudden current. Therefore, electromagnetic force by short circuit current shall be considered for designing and installation and short circuit current at installation place shall be also considered.

Interlocking for both side of disconnecting switches is desirable if related circuit breaker is closed condition. If interlocking is not available, other method shall be considered in order not to open operation.

For Article 95 Structure, Performance and Installation of Surge Arrester

1. Installation of Surge Arrester

(1) Article 95, 1, (1) of SREPTSHP is stipulated for protection of electrical equipment, reducing lightning voltage and prevention of dielectric breakdown. In this article, surge arrester is to reduce the terminal voltage within required value against shock over voltage and have restoration capability without interruption. Equipment such as an expulsion fuse and discharge gap are not included in surge arrester and to be regarded as substitute surge arrester. General term in this article such as surge arrester and substitute surge arrester are regarded as surge arrester etc. The surge arrester shall be located as close as possible to equipment to be protected ideally. However, location of surge arrester is determined taking arrangement of equipment, circuit condition, importance, insulation strength and economical condition into consideration.

(2) Article 95, 1, (2) a) of SREPTSHP, short electrical line to be connected to neighborhood can omit the surge arrester because there is less possibility of intrusion of lighting voltage.

(3) Article 95, 1, (2) b) of SREPTSHP, in case of medium and high voltage electrical lines are connected in one bus-bar, lightning voltage is reduced by connected line’s surge impedance. If intrusion voltage is 50% of flash over voltage, lightning voltage will be less than discharge inception voltage and installation of surge arrester is not necessary practically.

(4) There is not any transformer at switching station and no installation of surge arrester is stipulated. However, installation of surge arrester is preferable at important switching station, medium voltage consumer less than 500kW and location where lightning occurs with great frequency.

2. Installation of Protective Air Gap

Traditional idea of insulation coordination is that main transformer is regarded as the most important equipment and to be protected properly and then surge arrester is located to protect whole area of bus-bar such place as bus-bar or transformer terminal. However, due to emerging of large scale hydropower recently, area of bus-bar spreads also and equipments to be located far away from surge arrester cannot be protected and incoming (or outgoing) point is the weakest point of the area.

Therefore, installation of surge arrester at every incoming point is desirable. But it is not economically and generally protective air gap is employed for the protection. V-t characteristics of protective air gap is almost same and individual study is necessary in case of other cases.

(1) Purpose for installation of protective air gap

The protective air gap has following disadvantage in comparison of surge arrester.

1) Flash over voltage is higher.
2) Flash over voltage is different depending on polarity.
3) Discharge characteristic is affected by meteorological condition.
4) No restore capability
5) Development of high frequency voltage

However, the protective air gap is effective against lightning if location is appropriate. Effects of the protective air gap are shown as follows;

1) Protective air gap can protect against flash over voltage of line side equipment in case of opening of circuit breaker.
2) Protective air gap can protect against near-by lightning.
3) Protective air gap can decrease frequency of flash over in case of multiple lightning.

(2) Consideration on selection for gap of protective air gap

1) V-t characteristics of protective air gap shall be less than V-t characteristics of protected equipment.
2) 50% of flush over voltage×1.05 shall not be more than Lightning Impulse Withstand Level (LIWL) of protected equipment.
3) Both polarities of lightning surge shall be considered.
4) Protective air gap shall not discharge so frequently by switching surge.

3. Type of incoming equipment and lightning protection

Lightning protection of incoming equipment can be summarized as follows according to V-t characteristics of each equipment.

(1) Circuit Breaker

According to V-t characteristics of Fig. 95-1, lightning protection of circuit breaker shall be summarized as follows;

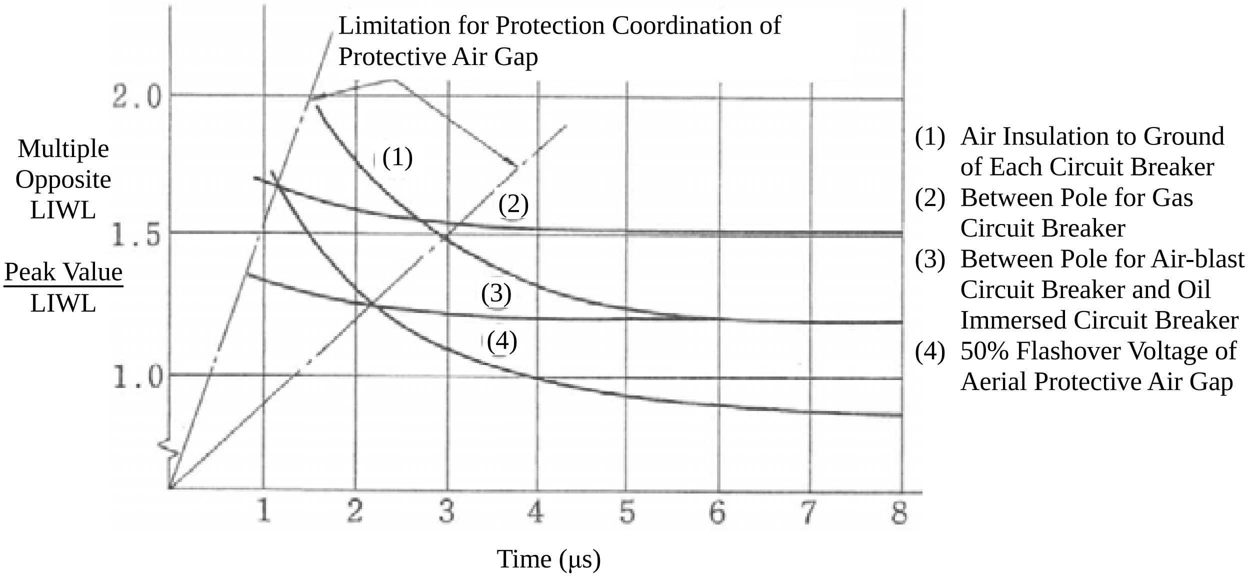


Fig. 95-1 Comparison of V-t Characteristics for Circuit Breaker

Table 95-1 Lightning Protection of Circuit Breaker

Breaker Type	Insulation to the earth	Insulation between phases	Protection
Air-blast circuit breaker	Insulated by air, therefore, V-t characteristic is the same as protective air gap. Protection can be done by protective air gap. Characteristics curve (1)	V-t characteristic is flat comparison with insulation to the earth. Protection cannot be done by protective air gap all cases. Characteristics curve (3)	In case of anticipation of steep lightning voltage, surge arrester at incoming point is necessary for protection of phase insulation.
Gas circuit breaker	Air insulated portion is as the same as air blast circuit breaker. In the gas, V-t characteristic is flat but it has capability more than 150% of LIWL in many cases. Therefore, protection can be done by protective air gap Characteristics curve (1)	In the gas, it has capability more than 150% of LIWL in many cases. Therefore, it is necessary to consider insulation between air insulation portion and the earth. Characteristics curve (2)	Taking account air insulated portion, protection can be done by protective air gap.
Oil circuit breaker	Air insulated portion is as the same as air-blast circuit breaker. Therefore, protection can be done by protective air gap. Characteristics curve (1)	V-t characteristic is more flat in comparison with air insulated portion but insulation strength of phase is relatively high. Possibility of phase flash over is low. Characteristics curve (3)	Oil circuit breaker has high insulation strength between phases. Therefore, protection can be done by protective air gap.

(2) Disconnecting switch

Insulation of disconnecting switch is considered only air insulation to ground, V-t characteristics of disconnecting switch is the same as V-t characteristics of protective air gap. Therefore, protection can be done by the protective air gap.

(3) Bushing type of current transformer

Inside of bushing type of current transformer is filled of oil and V-t characteristics is the same as V-t characteristics of oil circuit breaker. Therefore, protective air gap cannot protect against steep lightning voltage in some cases.

It is not economical to install the surge arrester only for current transformer. In case of anticipation of steep lightning voltage, one rank higher insulation level is employed or current transformer shall be located inner side of circuit breaker.

(4) Capacitance voltage transformer

There is enough allowance of insulation against lightning surge in the structural reason. Therefore, special attention is not necessary for capacitance voltage transformer.

For Article 96 Structure, Performance and Installation of Control Gear and Metal Enclosed Switchgear

1. Structure

In Article 96, Paragraph 1 is stipulated for inspection and repair of control gear and metal enclosed switchgear which are for supervision of the operation and control.

2. Installation

Any equipment to be installed at medium and high voltage control gear shall have grounded wire net or insulated material for safety inspection or shall be provided with inspection route.

Any equipment to be installed at medium and high metal enclosed switchgear shall have grounded metal plate or insulated partition for safety.

For Article 97 Structure, Performance and Installation of Gas Insulated Switchgear

1. Coverage

As for the gas insulated switchgear, SF_6 gas insulated switchgear is subject of regulation at present. However, low pressure of SF_6 insulated switchgear is out of subject because it is no problem in security point of view and only more than 100kPa is subject of regulation. Nitrogen filled equipment is out of subject because nitrogen is used for prevention of deterioration not for the insulation.

2. Pressure Container

The pressure container to be exposed to the air shall be tested in accordance with provisions in SREPTSHP. The pressure container not to be exposed to the air is not stipulated in SREPTSHP because it is protected against the outside.

3. Maximum Working Pressure

Standard maximum working pressure for pressure test and safety valve is as follows;

(1) Single pressure type

Pressure rise caused by temperature fluctuation, solar radiation and electricity shall be taken into consideration.

(2) Double pressure type

1) High pressure

Operation pressure of safety valve shall be taken into consideration.

2) Low pressure

Pressure rise caused by temperature fluctuation, solar radiation and electricity shall be taken into consideration.

Pressure balance between high and low pressure room shall be taken into consideration.

Operation pressure of safety valve shall be taken into consideration.

(3) Definition of maximum working pressure

Maximum working pressure means the maximum allowable pressure at designated temperature at the top of pressure container after installation.

(4) Determination of maximum working pressure

Maximum working pressure for gas insulated switchgear shall be determined in accordance with the above mentioned concept.

4. Material and Structure

SF_6 gas insulated switchgear is widely used for circuit breaker and integrated switchgear. The SF_6 gas switchgear is under development such as structure, ceramic, insulation material of synthetic resin, mechanical strength, compactness, high voltage etc. and it is hard to regulate it under the present situation. Therefore, regulation for the material and structure is not stipulated in SREPTSHP in order not to impede technical development.

For Article 98 Structure, Performance and Installation of Bus-bar and Conductor

1. Mechanical Strength of Bus-bar, Conductor and Supporting Insulator

Mechanical strength is stipulated in SREPTSHP because bus-bar, conductor and supporting insulator may suffer from mechanical shock due to short-circuit of electrical circuits and lines.

2. Clearance of Bus-bar

Clearance of bus-bar at hydropower station shall have collaborated dielectric strength among the transformer, instrument transformer, supporting insulator and bushing. Dielectric strength of bus-bar shall not be less than equipment and clearance of bus-bar shall be determined in order not to arise flush over caused by power frequency voltage, switching impulse and lightning impulse.

Wire of outside strain type bus-bar may swing due to wind load and minimum clearance shall be taken even at the worst.

Following table shows minimum clearance of bare bus-bar.

Table 98-1 Minimum Clearance of Bare Bus-bar

Nominal Voltage (kV)	Minimum Clearance (cm)	
	Between Phases	To the Ground
3.3	9	7
6.6	12	9
11	19	15
22	35	25
33	48	35
66	85	65
77	100	76
110	140	108
154	190	150
187	---	150 to 180
220	---	200

Note: 1. There is no discrimination between indoor and outdoor.
2. Minimum clearance of phase is minimum distance between each conductor
3. Minimum clearance of ground is minimum distance between conductor and the ground or un-insulated object.

For Article 99 Structure, Performance and Installation of Turbine

1. Mechanical Strength

In Article 99, paragraph 2, 3 and 4 are stipulated for mechanical strength and, concerning to water pressure, rotating speed and vibration, following shall be also stipulated:

(1) Water pressure

Allowable value of water pressure is shown in maximum water pressure.

1) Maximum momentary pressure

The maximum momentary pressure is maximum water pressure in case of sudden change of inflow water to turbine.

The maximum water pressure is considered to be maximum value taking static head, water hammer pressure and raising of water head by surge tank into consideration.

In order to seek an accurate water pressure fluctuation, water flow inside of water way shall be calculated by elastic and rigid theory. However, actually value can be taken by correction of approximate value practically.

The water hammer pressure at turbine center is calculated by Allievi's abbreviated formula taking some allowance.

The water hammer pressure at turbine center by Allievi's abbreviated formula is as follows:

$$H_m = \frac{n}{2}\left(n + \sqrt{n^2+4}\right)H_c$$

Where,

n : $\dfrac{LV_0}{gT_cH_c}$

L : length of penstock (m)

g : acceleration of gravity (m/s^2)

H_c : maximum water level-turbine center level (m)

V_c : water velocity at maximum discharge (m/s)

T_c : Closing time of water inlet (s)

2) Momentary pressure variation

Difference between maximum water pressure at test and static head of turbine center at stand still condition is called momentary pressure variation. Ratio of momentary pressure value to static head is also called momentary pressure variation.

The momentary pressure variation in case of load rejection δp(%) is shown in following formula.

$$\delta_p = \frac{\Delta H}{H_{st}} \times 100$$

Where,

$\Delta H = P_{max} - P_{st}$: momentary pressure value (mH_2O)

P_{max} : maximum water pressure of turbine center at load rejection (mH_2O)

P_{st} : Water pressure of turbine center at stand still condition (mH_2O)

H_{st} : Static head in case of stand still condition (mH_2O)

When there are more than 2 turbines, value shall be of all turbines stopped.

Uniform indication for tolerance limit value of δ_p is difficult in the same way as indication of maximum momentary pressure. Therefore, actual circumstances shall be taken.

(2) Rotating speed

Maximum speed of rotating part occurs normally at load rejection and allowable limit is shown in momentary speed variation.

The momentary speed variation δ_n is calculated by the data of governor test in following formula:

$$\delta_n = \frac{N_m - N_i}{N_{sp}} \times 100$$

Where,

N_i : rotating speed before change of load (r/min)

N_m : transient maximum rotating speed at sudden change of load (r/min)

N_{sp} : Rated rotating speed (r/min)

Limit value of δ_n is determined by relation of maximum momentary pressure and GD^2 and can not be determined uniformly due to actual circumstances of power stations.

Mechanical strength against run away speed is normally as following:

The turbine and its auxiliary equipment shall withstand 2 minutes operation safely in case of maximum run away speed.

The turbine and its auxiliary equipment are designed to have some allowance normally and have enough mechanical strength. However, thermal strength of bearing is not sufficient and can not be operated for long period.

(3) Vibration

There are mechanical source and hydraulic source for the turbine vibration. Main mechanical source is unbalance of rotating part and centrifugal force by unbalance increases proportionally square of speed and variation increases closely to resonance curve.

Main hydraulic sources are swirl flow at draft tube, combination of number of runner vane and guide vane, clearance around runner, Karman vortex and wood stuck in guide vane. There is not any standard or criteria for vibration for operation of turbine.

2. Installation for Rapid Shut Off Device of Water Inflow and Outflow

(1) Concept

Rapid shut off device of water inflow and outflow shall be installed in order to secure safety of turbine-generator and downstream area. Installation of inlet valve is deleted from SREPTSHP because device other than inlet valve can attain required function. It is required to install shut off device at anywhere in the waterway so as not to cause any security hindrance.

Except turbine-generator which can withstand run away speed, turbine-generator shall be stopped in a short time viewpoint of security reason and stopping of water by shut off device rapidly within a limit is required.

(2) Rapid shut off device of water inflow and outflow

1) Guide vane or needle valve which has emergency function
2) Inlet valve which has capability to shut off the running water
3) Water intake with emergency closing device, penstock guard valve, head tank with sluice gate or valve

(3) Emergency closing function of guide vane or needle valve

For the guide vane or needle valve which has emergency closing function by means of load adjusting device with protective closing function for turbine-generator to stop the turbine reliably, reliable stopping device for turbine is as follows:

1) Pressure tank which has enough capacity to stop the turbine-generator without replenishment of oil.
2) Water pressure self-closing type of guide vane, needle valve
3) Counter weight and spring closing type method
4) Emergency oil pressure tank closing method
5) Emergency servomotor closing method
6) Combination of self-closing and other closing method

(4) Inlet valve for shut of running water

Inlet valve which has capability of shut off running water means inlet valve to be installed for shut off the water inflow or outflow rapidly.

Inlet valve combination with guide vane or needle valve normally to be installed is not categorized to be to the above mentioned type of inlet valve.

Traditionally, inlet valve has capability to shut off running water for security reason and back up function.

(5) Emergency closing device for water gate

Emergency closing device which has capability to descend the gate without power source by clutch and its descending speed is normally 4 to 8 m/min.

Brake is used for speed control of descending the gate and there are fan brake, centrifugal brake, hydraulic brake, dynamic brake, hydraulic control, pole-change motor and manual brake.

(6) Stopping device for discharge water

By the time of stopping the turbine from run away speed by discharge of water, stopping device for discharge water shall be installed at anywhere in the waterway on condition that rotating part is structurally secure. These devices are inlet valve, guide vane, needle or water gate and their operation can be done manually at site.

(7) Discharging of water by the time of stopping the turbine

If there is not possibility of any danger to downstream area by discharging of water by the time of stopping the turbine from run away speed, following shall be applied.

When flow control of turbine cannot be controlled, structure shall be secured if rotating part of turbine is designed for withstanding run away speed.

If flow control of turbine cannot be controlled, it is not problem of secure on the condition that there is no possibility to increase discharge water to downstream or increasing discharge water but not any danger to person or facilities.

Therefore, in case of satisfaction of both structural and water-use point of view, it is not necessary to install emergency closing device of running water.

“There is no possibility to increase discharge water to downstream” means that water flow of turbine such as Pelton turbine, Francis turbine and Crossflow turbine do not exceed maximum discharge in case of run away speed.

Chapter 12 Auxiliary Equipment

For Article 101 Classification of Grounding Work

Major grounding work points to be done are as follows;

Table 101-1 Grounding Work Point

Classification of Grounding Work	Grounding Work Point
Class A	• Contact preventing device between high and medium voltage • Secondary circuit of high voltage instrument transformer • Steel base and metallic case of high and medium voltage electrical equipment • Surge arrester • Protective net for coming close, closing over of high voltage and road
Class B	• Contact preventing device between high/medium and low voltage
Class D	• Secondary circuit of medium voltage instrument transformer • Steel base and metallic case of low voltage (300V or less) electrical equipment • Catenary wire of overhead cable • Protective net, protective wire • Metallic wire • Metallic sheath and connection box for underground cable
Class C	• Steel base and metallic case of low voltage (over 300V) electrical equipment

For Article 102 Grounding of Electrical Equipment

1. Grounding for Steel Base of Electrical Equipment and Metallic Case

If grounding wire conforms to grounding work of Article 101, the grounding wire can be used in common.

2. Grounding for Stabilizing Winding and Ideal Winding of Transformer

The stabilizing winding of transformer is kind of delta connection winding which is not connected to external circuits and lines in order to reduce zero phase sequence impedance of star connection winding.

The ideal winding of transformer is kind of winding which used to be as a transformer winding or to be used for future expansion.

The built-in winding of transformer is kind of induction winding which is used for voltage regulator.

If protection against abnormal voltage from other winding to stabilizing for ideal winding is necessary, there is method for installation of lightning arrester or surge absorber or more simple way to ground any one terminal of winding circuits and lines. In this case, there are two ways that one is grounding of metallic frame at inside of electrical equipment, other way is grounding using bushing and these methods are considered to be the same as metallic frame of electrical equipment.

3. Grounding for Neutral Point of Low Voltage Side Transformer

Purpose of class B grounding work at neutral point of low voltage circuits or any terminal for transformer to be connected to medium, high and low voltage is to prevent any electrical shock or insulation breakdown caused by internal fault, breaking of wire. However, electrical shock or leakage current for grounding work at low voltage side may increase in comparison with un-ground method and if prevention of those accidents are very important, contact prevent type transformer shall be used and grounded instead of grounding of low voltage side.

4. Grounding for Secondary Circuits of Instrument Transformer

In application, “proper one point” is stated to prevent malfunction because secondary circuits and line of instrument transformer generally spread over control board widely.

5. Grounding for Surge Arrester

Grounding point of surge arrester may increase electrical potential due to large discharge current and may cause any damage to other electrical equipment. Therefore, grounding resistance shall be reduced as low as possible in comparison with provision resistance to prevent increasing of electrical potential.

Surge absorber discharge gap equipment also shall be installed in the same way as surge arrester.

6. Grounding for Primary Circuits of Voltage Transformer

Grounding for primary circuits and lines of voltage transformer is grounded at neutral point by delta connection or any proper point is also grounded.

Coupling capacitor for power line career shall be grounded and stated in application of grounding.

7. Grounding for Steel Structure

Most of steel structure is installed with lightning equipment generally and therefore, this article is stipulated with the same concept as steel base of electrical equipment. Also this article applies to architectural steel structure and framing structure with the same purpose of steel structure. Especially, fixed type hot line insulator washing machine is also stipulated in this article because it may come close to live part mostly and leakage of current through water spraying. However, fixed type hot line insulator washing machine with grounding device in the same manner as steel structure for common use is not necessary for dual installation of grounding device. Grounding for mobile type jet washing nozzle shall conform to same as above also.

8. Other

It is better to ground some equipment if necessary even though it is not stipulated in this article at hydropower station. For example, if there is metallic object to be insulated close to extremely high voltage equipment, it may suffer electrical shock caused by electrostatic induction or electromagnetic induction.

Also metallic fence to be installed at hydropower station shall be grounded in the same reason. However, in case of grounding for metallic fence, isolated grounding shall be desirable except for extending ground net to outside.

For Article 103 Type of Grounding Wire

1. Minimum Cross Section of Grounding Wire

Minimum cross section of grounding wire stipulated in Article 103 is based on mechanical strength. Even if grounding wire can pass through current, cross section shall be more value than those in Table 103-1 of SREPTSHP.

2. Strength of Grounding Wire

Grounding wire mentioned in Article 103 shall have enough tensile strength or minimum cross section to be used.

3. Cross Section of Grounding Wire

Grounding wire to be used for hydropower station shall be determined taking fault current and duration for reference in Fig. 103-1 into consideration and shall take some allowance.

Generally, fault current is considered as one line ground fault, however rare occurred multi line ground fault shall be taken into consideration also. Fault duration time is considered to be the time of operation of circuit breaker, but in case of backup protection, back up protective time shall be taken.

Fig. 103-1 is calculated from following formula.

$$A = \sqrt{\frac{8.5 \times 10^{-6} \times S}{\log_{10}\left(\frac{t}{274} + 1\right)}} \times I$$

Where,

A : Cross section of grounding wire (mm^2)

I : Grounding fault current (A)

S : Fault duration time (S)

t : Allowable temperature rise for blown-out by current(K)

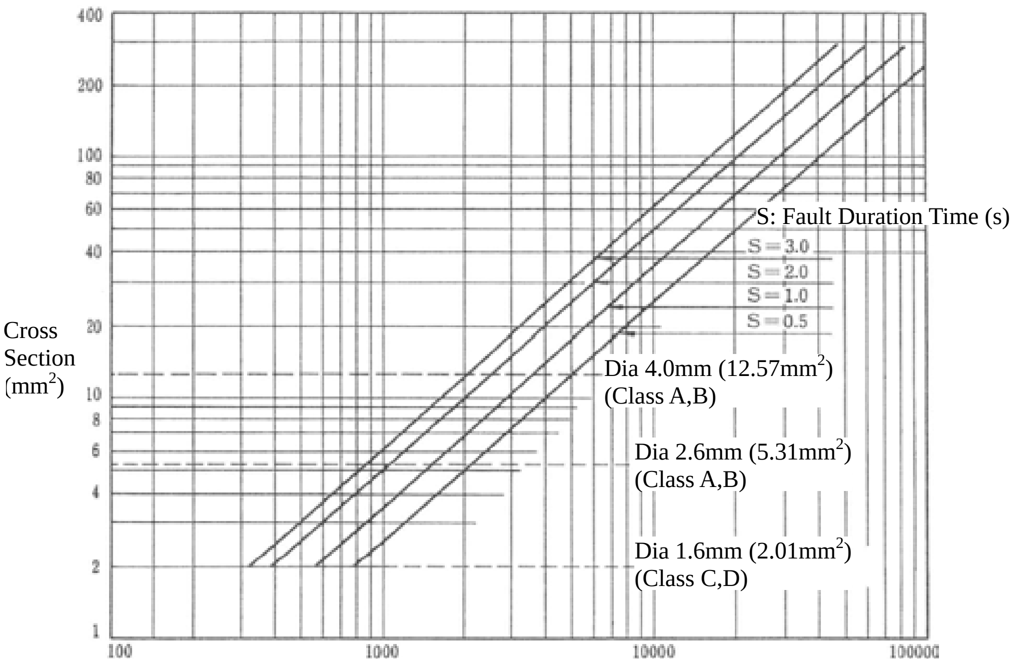


Fig. 103-1 Cross Section of Grounding Wire

4. Type of Grounding Wire

Copper wire or copper band shall be used for grounding wire taking corrosion of long term use into consideration. Generally, grounding wire will not be loaded by tensile strength. Therefore, annealed stranded copper wire shall be employed taking execution of works into consideration.

5. Grounding Wire for Secondary Circuits and Lines of Instrument Transformer

Generally, secondary circuit of instrument transformer shall be grounded at control board. In this case, cross section of grounding wire shall be more than those stated in Table 103-1 in SREPTSHP obviously. If multi control cables which have enough mechanical strength will be used for grounding wire between instrument transformer and control board, cross section of conductor between 2.0~3.5mm^2 is acceptable.

For Article 104 Installation of Grounding Electrode and Grounding Wire

1. Danger Prevention for Surrounding Area of Grounding Electrode

There are mesh network method, grounding rod driving method and grounding plate burying method in general for grounding work. Other than above mentioned method, grounding electrode shall be installed in such a manner so as not to cause any danger to human body, livestock or other facilities due to the electrical potential difference caused by grounding fault.

2. Danger Prevention for Fault Extension

(1) On occasion of lightning striking to the lightning arrester, the large electrical potential difference arises between grounding wire and electrical equipment due to running of large current. Therefore, in this article is that in case of installing grounding wire for lightning arrester and electrical equipment together, it may cause any danger to human body or livestock due to the electrical potential difference.

(2) This article stipulates for danger of any danger to human body or other facilities caused by the electrical potential difference through telecommunication line and control cable.

3. Restriction of Installation

This article stipulates for purpose of grounding work prevention of any danger caused by contacting of high and low voltage electrical circuits and lines, insulation breakdown of electrical equipment. If grounding wire to be connected circuit breaker or power fuse is open, person, livestock or other facilities shall be exposed danger of the high electrical potential due to un-grounding condition.

4. Thermal Strength for Grounding Wire

There are fastening, crimp and welding method for installation and connection of grounding wire. However, connection part of grounding wire shall withstand temperature rise due to running of large current. For example, in case of connection by solder, it is desirable not to use solder because its melting temperature is 180ºC.

For Article 105 Volume of Pressure Oil Container

1. Determination of Pressure Oil Container and Pressure Oil Pump

Pressure oil container and pressure oil pump other than for inlet valve shall be determined as follows.

(1) Full Capacity of Pressure Oil Container

Full capacity of pressure oil container shall have to execute first stage operating duty and second stage operating duty according to Table 105-1 from oil level for minimum oil pressure of normal operating range to oil level for allowable minimum oil pressure of normal operating range. Supply from oil pressure pump shall be taken for first stage operation.

Range of gauge pressure of 0.1MPa(1.0kg/cm^2) shall be set between oil pressure after first stage operation and oil pressure at the beginning of second stage operation.

Table 105-1 Operating Duty and Oil Consumption

Type of Turbine	Type of Oil Supply System	Oil Consumption for 1st stage Operating Duty	Oil Consumption for 2nd stage Operating Duty
Francis Turbine	General	2Vg+Vr+2Vc	Vg+Vr+Vv+Vc
	Special	–	Vg+Vr+Vv+Vc
Kaplan Turbine Diagonal Turbine	General	2(Vg+Vrn)+2Vc	Vg+Vrn+Vv+Vc
	Special	–	Vg+Vrn+Vv+Vc
Pelton Turbine	General	2Vd+Vn+2Vc	Vd+Vn+Vv+Vc
	Special	–	Vd+Vn+Vv+Vc

1) As for the type of turbine, “General” applies for reservoir type and regulating type hydropower station.
2) “Special” applies for run-off-river type hydropower station
3) 1st stage operating duty means duty to accomplish from minimum oil pressure and level of normal operating range to shutdown oil pressure.
4) 2nd stage operating duty means duty to accomplish from shutdown oil pressure to allowable minimum oil pressure of normal operating range.
5) Designation

2Vg : Oil consumption for two strokes operation of guide vane servomotor (l)
Vg : Oil consumption for one close operation of guide vane servomotor (l)
Vr : Oil consumption for one close operation of relief valve (l)
Vrn : Oil consumption for one close operation of runner vane servomotor (l)
2Vd : Oil consumption for two strokes operation of deflector servomotor (l)
Vd : Oil consumption for one close operation of deflector servomotor (l)
Vn : Oil consumption for one close operation of needle servomotor (l)
Vv : Oil consumption for one close operation for inlet valve servomotor (l)
Vc : Control oil (l)

(2) Capacity Calculation of Pressure Oil Container

Capacity of pressure oil container shall be calculated by following procedure.

1) Oil consumption for first stage operation

$$V_A = V_{X1} + \frac{ql}{60}(T_c{'}+T_o) - \frac{Q}{1.05 \times 60}(T_c{'}+T_o)$$

$$V_A = V_{X1} - \frac{1.5}{60}V_X(T_c{'}+T_o)$$

Where,

V_A : Oil consumption for first stage operation (l)
V_{X1} : Required oil for first stage operating duty (l)

V_X : V_g+V_c (l) Francis turbine

$V_g+V_{rn}+V_c$ (l) Kaplan turbine

$V_d+V_n+V_c$ (l) Pelton turbine

ql : Leakage oil (l/min)

Q : Discharge from pressure oil pump (l/min)

T_c' : Equivalent closing time of servomotor (s)

T_o : Opening time of servomotor (s)

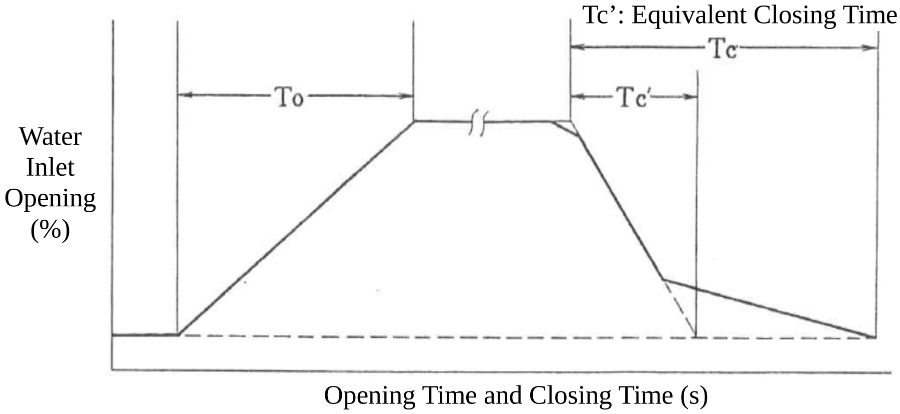


Fig. 105-1 Correlation of Water Inlet Opening and Closing Time

2) Oil consumption for second stage operation

$$V_B = V_{X2} + \frac{ql}{60}T_e$$

Where,

V_B : Oil consumption for second stage operation (l)

V_{X2} : Required oil for second stage operating duty (l)

$V_g+V_r+V_v+V_c$ (l) Francis turbine

$V_g+V_{rn}+V_v+V_c$ (l) Kaplan turbine

$V_d+V_n+V_v+V_c$ (l) Pelton turbine

ql : Leakage oil (l/min)

T_e : Operating time of second stage

Table 105-2 Leakage Oil

Type of Turbine	ql (l/min)
Francis turbine, Pelton turbine	10
Kaplan turbine, Diagonal turbine(vertical motion servomotor)	20
Diagonal turbine(Rotating servomotor)	50

3) Relation between Air Capacity and Pressure of Pressure Oil Container

a. First Stage Operating Duty Relation

$(P_1+1)V_1^n = (P_1'+1)(V_1+V_A)^n$

$P_1' = (P_1+1)\left(\frac{V_1}{V_1+V_A}\right)^n - 1 > P_2$

b. Air Quantity corresponds to Oil Pressure beginning of Second Operation

$(P_1+1)V_1^n = (P_2+1)V_2'^n$

$V_2' = V_1\left(\frac{P_1+1}{P_2+1}\right)^{\frac{1}{n}}$

c. Second Stage Operating Duty Relation

$(P_2+1)V_2'^n = (P_2'+1)(V_2'+V_B)^n$

$P_2' = (P_2+1)\left(\frac{V_2'}{V_2'+V_B}\right) - 1 > P_3$

d. Air Quantity corresponds to Oil Pressure beginning of Second Operation

$V_2 = V_1\left(\frac{P_1+1}{P_2+1}\right)^{\frac{1}{n'}}$

Where,

P_1 : Oil pressure beginning first stage operation (kg/cm^2)
P_1' : Oil pressure after first stage operation (kg/cm^2)
P_2 : Oil pressure beginning second stage operation (kg/cm^2)
P_2' : Oil pressure after second stage operation (kg/cm^2)
P_3 : Allowable minimum oil pressure (kg/cm^2)
V_1 : Air quantity corresponds to oil pressure beginning first stage operation (l)
V_2 : Air quantity corresponds to oil pressure beginning second stage operation (l) (for capacity calculation of pressure oil container)
V_2' : Air quantity corresponds to oil pressure beginning second stage operation (l) (for calculation of oil pressure)
V_A : Oil consumption of first stage (l)
V_B : Oil consumption of second stage (l)
n : Politropic index = 1.3
n' : Politropic index = 1.0

4) Full Capacity of Pressure Oil Container

Full capacity of pressure oil container shall be calculated as follows in accordance with results of the above.

$V = V_2 + V_B + V_R$

Where,

V : Full capacity of pressure oil container (l)

V_R : Capacity of residual oil (l)

(3) Capacity of Pressure Oil Pump

1) Exclusive Use for Governor

Capacity of pressure oil pump for governor shall have enough capacity for close and open operation for guide vane and runner vane, deflector and needle within 40 seconds and shall be calculated from following formula. Moreover, 5% of decreasing of discharge quantity shall be taken due to long-term deterioration.

$Q = (1.5V_X + ql) \times 1.05$

Where,

Q : Discharge quantity of pump (l/min)

V_X : $V_g + V_c$ (l) Francis turbine

$V_g + V_{rn} + V_c$ (l) Kaplan turbine, diagonal turbine

$V_d + V_n + V_c$ (l) Pelton turbine

ql : Leakage oil (l/min)

2) Sharing with Inlet Valve

In case of sharing with governor and inlet valve, bigger value from the above quantity or following quantity shall be employed.

$$Q = \left(\frac{V_{VO}}{T_{VO}} \times 60 + ql\right) \times 1.05$$

Where,

Q : Discharge quantity of pump (l/min)

V_{VO} : Oil consumption for one open operation for inlet valve servomotor (l) (Including by-pass valve)

T_{VO} : Opening time of inlet valve (s)

ql : Leakage oil (l/min)

(4) Compressed Air Supply System

1) Air Supply Method

Air supply method to oil pressure container shall be from un-loader oil pressure less than 2.5MPa, and from air compressor oil pressure more than 2.5MPa.

2) Capacity of Air Compressor

Air compressor shall have enough capacity to increase 0.1MPa from minimum oil pressure of normal operating range within 30 minutes.

3) Capacity of Air Container

Capacity of air container shall be 10% of air quantity inside oil pressure container and shall not interfere with air supply taking air supply method into consideration.

2. Determination of Pressure Oil Container and Pressure Oil Pump exclusive use for Inlet valve

Pressure oil container and pressure oil pump exclusive use for inlet valve shall be determined as follows.

(1) Full Capacity of Pressure Oil Container

Full capacity of pressure oil container shall execute first stage operating duty and second stage operating duty according to Table 105-3 from oil level for minimum oil pressure of normal operating range to oil level for allowable minimum oil pressure of normal operating range. Supply from oil pressure pump shall be taken for first stage operation.

Range of gauge pressure of 0.1MPa(1.0kg/cm^2) shall be set between oil pressure after first stage operation and oil pressure at the beginning of second stage operation.

Table 105-3 Operating Duty and Oil Consumption

First Stage Operation	Turbine	General Special	1V 2V
Second Stage Operation	Any Equipment	−	1V

1) Hydropower station to be required line charge, which does not have emergency power supply system or will be required electric supply reliability especially.
2) 1st stage operating duty means duty to accomplish from minimum oil pressure and level of normal operating range to shutdown oil pressure.
3) 2nd stage operating duty means duty to accomplish from shutdown oil pressure to allowable minimum oil pressure of normal operating range.
4) Designation
   1V : Inlet valve servomotor Open→Close, or Close→Open 1 stroke
   2V : Inlet valve servomotor Open→Close→Open 2 strokes

(2) Capacity Calculation of Pressure Oil Container

Capacity of pressure oil container shall be calculated following procedure.

1) Oil consumption for first stage operation

$$V_A = V_{X1} \times 1.05 - \frac{Q(T_c+T_o)}{60}$$

Where,

V_A : Oil consumption for first stage operation (l)

V_{X1} : Required oil for first stage operating duty (l)

Q : Discharge from pressure oil pump (l/min)

T_c : Closing time of inlet valve (s)

T_o : Opening time of inlet valve (s)

2) Oil consumption for second operation

$$V_B = V_{X2} \times 1.05$$

Where,

V_B : Oil consumption for second stage operation (l)

V_{X2} : Required oil for second stage operating duty (l)

3) Relation between air capacity and pressure of pressure oil container

a. First stage operating duty relation

$$(P_1+1)V_1^n = (P_1'+1)(V_1+V_A)^n$$

$$P_1' = (P_1+1)\left(\frac{V_1}{V_1+V_A}\right)^n - 1 > P_2$$

b. Second stage operating duty relation

$$(P_2+1)V_2^n=(P_2'+1)(V_2+V_B)^n$$

$$P_2' = (P_2+1)\left(\frac{V_2}{V_2+V_B}\right)^n - 1 > P_3$$

$$V_2 = V_1\left(\frac{P_1+1}{P_2+1}\right)$$

Where,

P_1 : Oil pressure beginning first stage operation (kg/cm^2)

P_1' : Oil pressure after first stage operation (kg/cm^2)

P_2 : Oil pressure beginning second stage operation (kg/cm^2)

P_2' : Oil pressure after second stage operation (kg/cm^2)

P_3 : Allowable minimum oil pressure (kg/cm^2)

V_1 : Air quantity corresponds to oil pressure beginning first stage operation (l)

V_2 : Air quantity corresponds to oil pressure beginning second stage operation (l) (for capacity calculation of pressure oil container)

V_A : Oil consumption of first stage (l)

V_B : Oil consumption of second stage (l) n : Politropic index

Politropic index shall be 1.3 in case of operating time of 1minutes, 1.2 in case of operating time of 3 minutes.

4) Full Capacity of Pressure Oil Container

Full capacity of pressure oil container shall be calculated as follows in accordance with results of the above.

$V = V_2+V_B+V_R$

Where,
V : Full capacity of pressure oil container (l)
V_R : Capacity of residual oil (l)

(3) Capacity of Pressure Oil Pump

Minimum capacity of pressure oil pump shall be chosen at a bigger value for either of opening or closing the inlet valve within 10 minutes without supply from pressure oil container.

(4) Compressed Air Supply System

1) Capacity of Air Compressor

Capacity of air compressor shall have enough capacity to increase 0.1MPa from minimum oil pressure of normal operating range within 30 minutes.

2) Capacity of Air Container

Capacity of air container shall be 10% of air quantity inside oil pressure container and shall not interfere with air supply taking into air supply method consideration.

For Article 106 Volume of Compressed Air Container

Air container stipulating in SREPTSHP is switching device, circuit breaker, or separated air container to be attached to air container.

Air container shall have enough capacity such as for one more time close and open operation at least due to security reason of electrical power circuit. In case of consideration for reclosing, necessary air capacity shall be supplied.

As for AC circuit breaker, air container to be attached to circuit breaker shall have enough capacity at least 2 times of open and close operation at rated making current and interrupting current without supplying of air.

Indoor circuit breaker with voltage less than 36kV shall have capacity for 1 time of open and close operation.

For Article 108 Safety Valve and Pressure Gauge of Pressure Oil and Compressed Air Supply System

1. Installation Place of Safety Valve

Safety valve shall be installed at place in which it can be inspected easily and shall have every step of pressure stage. The installation place to be said in this article are pressure container and back of pressure deducing valve for pressure oil supply system and end stage, air container and back of pressure deducing valve for compressed air supply system respectively. If there is installation restriction for them, they shall be installed at adjacent places. “Adjacent places” to be said in this article is interpreted as piping nearby original installation place not through valve. However, in case of applying accumulator of bladder type, installation of safety valve near pressure pump is acceptable because of simple design and structural reason. Therefore in this case, it can be interpreted as adjacent places.

2. Pressure Gauge

Pressure gauge can be installed at anyplace which can measure pressure at any times as following

1) To install directly to oil pressure container and air pressure container
2) To install by exclusive pipe to oil pressure container and air pressure container
3) To install at source of supply piping
4) If unavoidably at load side piping, to install close to pressure container as much as possible.

In case of using tap for the pressure gauge, handle shall be open when direction is the same as tube axial and close when direction is right angle direction as tune axial. As for high pressure valve, indication of valve shall be conformed as in the above manner.

For Article 111 Phase and Status Indication Device for Medium and High Voltage Bus-bar

1. Phase Indication Device for Medium and High Voltage Bus-bar

Article 111 states provisions regarding phase indication device in order to provide security assistance and to prevent misoperation and misconnection. Indication method is not stated, however, different color and different symbol are normally adopted and coordinated phase indication is desirable for same power system.

Location for indication device shall be easily seen and indication device shall be placed in several places for the complicated circuit. Especially indoor electrical room, every room shall have the phase indication.

2. Status Indication Device for Medium and High Voltage Bus-bar

This article states basically the same as the above mentioned article but is defined to secure the security during maintenance work or operation of switching device. “Connected Position” means not only stationary connected position but also status during operation which is not necessary to be indicated automatically or simultaneously. Therefore, it is favorable that connection diagram shall be indicated on the blackboard or paper for the status of switching device at all times. As for easily indication such as a proviso, it is not stipulated in this article due to security reason.

For Article 112 Installation of Prevention Facility for Invasion of Small Animals

1. Purpose and Coverage Area of Prevention Facility

Article 112 is to prevent any accident caused by invasion of small animals such as a snake, a cat and a rat into inside facility of hydropower station and outdoor electrical facility of voltage 100kV or less.

On the occasion of the provision of prevention facility, appropriate installation method and location shall be chosen taking surrounding environment and reliability into consideration.

The outdoor electrical facility of voltage over 100kV has not been covered in Article 112 because there has not been any accident for it.

2. Practice of Prevention Facility

For prevention method of small animal’s invasion into outdoor electrical facility, there are some methods as follows:

1) Cable hole shall be filled by sand or putty.
2) Ventilation hole and window shall be covered by net.
3) Net or snake rail fence shall be used at fence, gate and gutter.

For Article 113 Installation of Emergency Power Supply System

1. Coverage Area and Purpose of Circuit Separation or Inter-lock Devices

In order to prevent human body who works outside the premises from electrical shock by back electrical voltage from emergency power supply circuit to ordinary power supply circuit in case of outage. This shall be applied to dam-waterway type hydropower station, building and factories.

2. Installation Method of Inter-locking Devices

Installation method of inter-locking devices shall be as following;

(1) Interlocking devices shall be installed at switching device of ordinary and emergency power supply circuit electrically and mechanically

(2) Changeover switch shall be installed at connection point of ordinary and emergency power supply circuit.

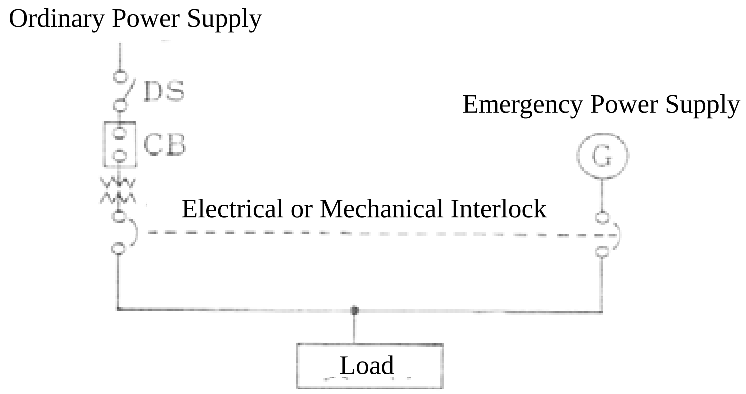


Fig. 113-1 Interlock Device of Electrical or Mechanical

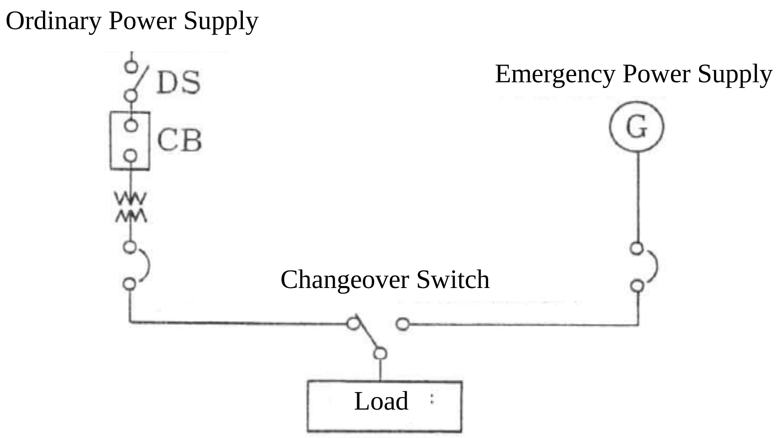


Fig. 113-2 Interlock Device of Changeover Switch

Chapter 13 Electrical Facilities for Station Service

For Article 115 Application for Electrical Wiring

Annealed copper wire with diameter 1.6mm or more, MI cable with diameter 1.0mm^2 or more, other equivalent wire or higher shall be used for low voltage electrical wiring.

However, the above is not applied to the following cases in which working voltage is 300V or less.

1) Annealed copper wire with diameter 1.2mm or more is used for lighting sign device and status indication device by plastic conduit, metallic conduit, metal raceway, metal duct, floor duct or cellular duct works.
2) Multi-core cable with diameter 0.75mm^2 or more, cab-tire cable are used for lighting sign or status indication device and shall have automatic cut off device in case of over-current.
3) Cord or cab-tire cable with diameter 0.75mm^2 or more.
4) Cable for elevator

Chapter 14 Electrical Facilities for Outgoing Line

For Article 130 Prevention of Entry by Unauthorized Persons into Hydropower Station

Hydropower station to be equipped with medium and high voltage device shall be equipped with the following facilities so as not to allow entering of unauthorized person its premises.

1) Fence or wall
2) No entry indication device at the entrance
3) Locking device at the entrance

When fence, wall and live part of high voltage come close each other, total distance of height of fence, wall and live part of high voltage shall be following table.

Table 130-1 Distance of Height of Fence, Wall and Live Part of High Voltage

Voltage Classification	Total Distance of Height of Fence, Wall and Live Part of High Voltage
35kV or less	5m
Over 35kV and 160kV or less	6m
Over 160kV	6m+12cm/10kV

For Article 131 Prevention of Climbing Supporting Structure of Overhead Electrical Lines

Scaffolding and fittings shall not be installed at 1.8m or less in height from ground surface for supporting structure of overhead electrical lines except for the following cases.

1) Supporting structure with enclosure type scaffolding and fittings
2) Supporting structure with climbing prevention device
3). Installation of fence and wall around supporting structure
4) Un-accessible place such as mountainous region

For Article 132 Height for Overhead Lines

(1) Height of low and medium voltage overhead lines shall be as follows;

1) Crossing the road: 6m or more
2) Crossing the railway: 5.5m or more
3) Crossing the pedestrian bridge (low voltage): 3m or more
4) Crossing the pedestrian bridge (medium voltage): 3.5m or more
5) Other than the above cases: 5m or more

(2) Height for feeder line to be installed below the bridge can be reduced till 3.5m regardless of the above clause (1).

(3) Low or medium voltage overhead lines to be installed at above the surface of the water shall be kept so as not to cause any danger to shipping operation.

(4) Height for high voltage overhead lines shall be in accordance with the following table.

Table 132-1 Height from Ground Surface

Voltage Classification	Height from Ground Surface
35kV or less	5m or more (6m for crossing the road)
Over 35kV and 160kV or less	6m or more (5m for un-accessible place)
Over 160kV	6m or more (5 m for un-accessible place)+12cm/10kV

(5) High voltage overhead lines to be installed above the surface of the water shall be kept so as not to cause any danger to shipping operation.

For Article 134 Prevention of Electrical Shock Caused by Electrostatic or Electromagnetic From Overhead Lines

High voltage overhead electrical lines shall be installed in the following manners so as not to cause any electrostatic induction to telecommunication equipment for electric power system.

(1) Induction current shall be less than 2μA every 12km of telecommunication lines (working voltage is less than 60,000V)

(2) Induction current shall be less than 3μA every 40km of telecommunication lines (working voltage is more than 60,000V)

High voltage overhead electrical lines shall be installed in such a manner so as to be less than 3kV of electrostatic induction at 1 meter from ground and not to affect any danger to human body by electrostatic induction.

For Article 137 Prevention of Hazard to Other Electrical Wires, Cables and Structures by Underground Electrical Cables

When underground cable is close or crossing over underground telecommunication lines, such underground cable shall be installed in sturdy nonflammable or self extinguishing flame resistance pipe so as not to contact directly each other.

However, following cases are not applicable.

1) Telecommunication cable is a flammable resistance optical fiber cable
2) Underground cable is low voltage
3) Medium and high voltage underground cable shall be installed so as not to contact directly.
4) Manager for telecommunication lines agrees and clearance is 10cm or more.(working voltage is less than 170,000V)

When high voltage underground cable is close or crossing over flammable or toxicity pipe contained, such underground cable shall be installed in sturdy nonflammable or self extinguishing flame resistance pipe so as not to contact directly each other.

For Article 145 Prohibition of Installation for Electrical Lines at Cliff

Low and medium voltage electrical lines shall not be installed except for the following cases;

1) To be installed on the building
2) To be installed at the road
3) To be installed at the railway
4) To be installed at cable way
5) To be installed crossing over with other lines less than 3m distance

Installation of electrical lines at cliff shall be as follows;

(1) Distance of supporting point shall be 15m or less
(2) Insulated metallic arm, flame resistance and water resistance insulator shall be used
(3) Appropriate protective device shall be used for person against damage
(4) In case of installation together with low and medium voltage lines, medium voltage line shall be installed over the low voltage line and its distance shall be kept 50cm or more.

For Article 147 Prohibition of Connection for Telecommunication Equipment for Power Supply System to Other Telecommunication Equipment for Power Supply System of High Voltage Electrical Lines at Urban Area

Telecommunication lines to be installed with high voltage overhead lines or to be connected them directly shall not be connected telecommunication lines at urban area. However, if there are protective device at connection point and relay coil, Article 147 is not applicable.

The telecommunication lines to be installed at urban area shall not be installed with high voltage overhead lines. However, if telecommunication lines are tensile strength of 5.26kN or more, insulated cable with diameter 4mm or more, optical fiber cable, Article 147 is not applicable.

For Article 151 Protection for Underground Lines

Cable shall be used for underground electrical circuits and lines and also to be installed by conduit type, closed conduit type or direct laying type installation method.

The conduit type installation shall withstand heavy weight such as a vehicle. The closed conduit type installation shall withstand heavy weight such as vehicle and shall have flame resistance device or fire extinguishing system. The direct laying type installation shall have 1.2 m or more earth covering where it is affected heavy weight, 0.6m or more for other places and in order to protect any shock, following installation manners shall be employed.

(1) Cover by protective material such as trough
(2) Cover by sturdy plate in order not to affect vehicle or heavy weight object
(3) Cover by sturdy outer layer of cable
(4) Pipe type pressure cable and cover by sturdy plate

For Article 154 Installation for Telecommunication Equipment for Electric Power System

The telecommunication equipment for electric power system shall be provided for the following places.

1) Between dispatching center and un-remote supervisory control hydropower station, control center for hydropower station and administrative office for transmission line
2) Between 2 or more dispatching center and general dispatching center
3) Between different general dispatching center which are different power system
4) Between hydropower station and water measurement station, meteorological station
5) Between important hydropower stations
6) Between important hydropower stations, control center for hydropower station
7) Between hydropower stations, control center for hydropower station, and administrative office
8) Between hydropower station, substation, control center for hydropower station, dispatching center, administrative office and meteorological observatory, meteorological station, fire station

High voltage overhead transmission line or medium voltage overhead transmission line with length of 5km or more shall be equipped with portable or mobile telecommunication facilities at appropriate places.

Chapter 15 Measuring and Protective Device

For Article 157 Measuring Device for Hydropower Station

1. Change of Measurement

Optional changeable measuring device can be permissible.

2. Location of Measuring Device

Measuring device shall not be necessarily to indicate the value at control board and not to be defined exact installation location. For example, thermometer of transformer is not required to read at control board if it is located at transformer.

3. Installation of Recorder

Recorder which can monitor operating condition such as voltmeter, ammeter, wattmeter and thermometer can be used instead of indicator.

Indication method on the Cathode Ray Tube (CRT) through computer shall be also permissible due to development of monitor and control equipment.

4. Measuring Device for Generator

(1) Total value of ammeter and wattmeter of generator at control center can be permissible instead of each generator value. Also current or output of power station to be monitored by means of measuring connecting line of current or output also can be permissible.

(2) Temperature measuring method for generator stator winding shall be of embedded temperature detector. However, small size of generator stator core can be measured by indirect method such as putting putty to the object.

(3) Temperature measuring method for generator bearing shall be of embedded temperature detector. However, small size of generator bearing can be measured by indirect method such as thermo-label and portable thermometer.

5. Measuring Device for Main Transformer at Hydropower Station

(1) Ammeter and wattmeter for transformer shall be provided at primary or secondary side for 2 winding, two winding for 3 winding taking operation and technical view point into consideration. For example, 3 winding is operated as 2 winding and following cases are not applicable.

1) Common voltmeter which can measure for voltmeter of bus-bar and station service transformer.
2) Omission of ammeter and wattmeter which can measure value by means of addition and subtraction of ammeter and wattmeter for station service transformer.

3) Common measuring device which can measure generator or reactive power compensator facilities.
4) Total value of transformer can be permissible if circuit breaker paralleling primary and secondary side.

(2) Voltmeter shall be provided at each winding of on-load tap changing transformer. However, if primary side voltage can be measured from power supply side of substation, it is not necessary to provide voltmeter at each winding.

(3) Thermometer for transformer shall be provided so as to monitor the winding's insulation. Direct measurement of winding temperature is difficult due to technical reason. Generally, temperature shall be measured by coolant which is correlated with winding's temperature.

6. Installation for Voltmeter of Distribution Line

(1) Voltmeter of distribution line at control center shall not be necessary on condition that there is automatic voltage regulator, recorder or maximum/minimum indicator.

(2) Recorder of distribution line voltage or maximum/minimum indicator at un-continuous monitoring system shall not be necessary on condition that there is automatic voltage regulator at power station or monitoring device at administrative office.

(3) There is not any measuring device of distribution line for no-continuous patrol system because it does not have distribution line.

7. Installation for Synchroscope

Synchroscope shall not be necessary if there is not other power supply system other than generator in connected power system or capacity of generator is small comparison of connected power system.

8. Measuring Location for Watthour Meter

As for watthour meter or var hour meter, they are stipulated mainly for operation of hydropower station in this article. Location of measuring device for planning of facility purpose is not defined in this article.

9. Installation for Ammeter or Wattmeter for Transmission Line

Ammeter for transmission line shall not be necessary if transmission line current can be measured by ammeter of generator or main transformer.

For Article 158 Protective Device for Turbine and Generator

Turbine and generator are normally coupled directly and their protective devices are closely related each other. Therefore, automatic shut down and automatic cutting off are indicated together in the same table.

1. Over-current Protective Device

If there is not circuit breaker between generator and transformer, both equipments shall be protected together because generator or transformer can not be protected individually. Over-current protective device shall be common for generator and transformer, which shall be protected by high voltage side of circuit breaker accordingly.

Over-current protective device can be permissible such as over-current relay, voltage restraint over-current relay, low voltage starting over-current relay and under voltage relay in order to prevent burnout of generator and supplying fault current to failure point.

Especially, generator with synchronous reactance over 100% shall be cutoff from electrical circuits and lines in case of short-circuit failure of generator circuit such as under voltage relay.

2. Internal Failure Protective Device for Generator

There are phase (layer) short fault and winding grounded fault for internal failure of generator and differential relay might be used generally but it is not necessarily confined.

3. Bearing Temperature Rise Protective Device

In case of remarkable temperature rising for turbine and generator bearing, turbine generator shall be automatically stopped or cutoff even though they are not required in accordance with Table 158-1 in SREPTSHP in order to minimize damage for bearing and simplify the restoration.

4. Over-Voltage Protective Device

Over voltage protective device shall automatically cutoff and no excitation condition in order to protect from abnormal voltage to generator due to external failure or failure of AVR.

5. Installation for Oil Pressure Supply System, Electrically-driven Guide Vane, Needle or Deflector

In case of occurrence of abnormal condition for turbine and generator, installation for oil pressure supply system, electrically-driven guide vane, needle or deflector shall be provided in accordance with in SREPTSHP in order to stop unit securely. Emergency power supply system for electrically-driven guide vane, needle or deflector shall be independent from normal power supply system and self contained battery which can stop turbine and generator without power supply is also applicable. As for capacity of oil pressure container, Article 105 of SREPTSHP shall be referred.

Exception of counter weight closing device is that it is regarded as back up device.

For Article 159 Protective Device for High Voltage Transformer

1. Protection of Transformer without High Voltage Side Circuit Breaker

In case of omission of high voltage side of circuit breaker of transformer, power supply side of circuit breaker shall be tripped by operation of internal failure protective device or over-current protective device.

2. Forced Cool Type

Forced cool type is cooling method which coolant shall be circulated forcibly in order to cool transformer winding and core directly.

3. Protective Device for Cooling Device Failure

It is failure of forced cooling device such as stopping of pump, fan, cutting off of cooling water and loss of power supply for fan.

4. Conception of Bank Capacity

Bank shall have enough capacity so as not to affect to other transformer’s operation in case of separation from concerned power system.

5. Over-current Protective Device

Over-current protection for transformer covers short-circuit, overload and bus-bar protection.

In case of occurrence of transformer failure, it might cause hindrance and influence of power supply so that over-current protective device shall be provided mandatorily.

6. Internal Failure Protective Device

Buchholz relay, pressure relay and differential relay are used for internal failure protective device of bank capacity more than 10,000kVA and important failure shall be cut off automatically and other failure can be alarmed.

As for internal failure for protective device of bank capacity less than 5,000kVA, buchholz relay and pressure relay shall be mainly used and installation of alarm device shall be provided.

For Article 160 Protective Device for Gas Insulated Switchgear

Gas insulated switchgear is electrical equipment which is insulated by compressed gas such as sulfur hexafluoride (SF_6) gas.

In case of remarkable decrease of gas pressure, necessary protective device shall be provided taking decreasing of dielectric strength into consideration.

According to SREPTSHP, alarm device of pressure decrease, measuring device of gas pressure or alarm device shall be provided in case of remarkable pressure decrease.

In this case, remarkable decrease means that insulated gas pressure may decrease to insulation breakdown.

For Article 161 Earth Fault Protective Device for Electrical Circuits and Lines

1. Purpose of Earth Fault Protection for Electrical Circuits and Lines

Continuation of earth fault for electrical circuits and lines may cause fire due to electrical shock and electric leakage. It interferes with normal electric power supply indirect and prompt cut-off device shall be necessary.

Fundamentally, earth fault shall be detected at power supply side, and then operation of circuit breaker and stopping of transmission of electric power and installation of earth fault protective device at outgoing point of power station etc. are indicated specifically according to above mentioned method.

Countermeasure against sneak current from other lines shall be necessary in case of multiple lines at incoming point and incoming point shall be regarded as outgoing point in case of changing of direction of current other than normal condition.

One electrical circuits and lines supply several consumers generally and in this case internal earth fault of one customer shall not cause fault for other customers. Therefore, installation of earth fault protective device is stipulated even though difference of responsibility between receiving end and private electrical facilities.

Reliability of electric power supply needs an advance more and more in the future and highly reliable protective device, electrical equipment and configuration of power system shall be considered in order to prevent spreading of accident and minimize influence to the other power system.

For Article 167 Fire Extinguisher System for Transformer

1. Transformer for Neutral Grounding System

Fixed type fire extinguishing system shall be provided for transformer with neutral grounding system.

2. Transformer for Isolated Neutral Grounding System

Fire extinguishing system for transformer with isolated neutral grounding system shall be arranged in accordance with the following table.

Table 167-1 Installation Criteria of Fire Extinguisher for Isolated Neutral Grounding System

Floor Space	Transformer Capacity		
	Less than 1,000kVA	1,000kVA or more, less than 10,000kVA	Over 10,000kVA
Less than 200m^2	Fire Extinguisher	Fire Extinguisher	Fire Extinguisher and Fix type Fire Extinguisher
Over 200m^2	Fire Extinguisher and Large Size Fire Extinguisher	Fire Extinguisher and Fix type Fire Extinguisher	

Countermeasure against fire is basically as follows;

1) Fire resistance structure for transformer room
2) Windowless for transformer room
3) Shut down of ventilation system

Moreover, localization by fire limit, countermeasure of fire spreading to other object and initial fire extinguishing are also effective.

As for neutral grounding system, fixed type fire extinguisher shall be provided taking emission of large arc energy in case of accident and large volume of insulation oil into consideration.

Fixed type fire extinguisher shall be also provided for isolated neutral grounding system with floor space over 200m^2, capacity over 1,000kVA. As for floor space less than 200m^2 and capacity over 10,000kVA, it is desirable to install fixed type fire extinguisher taking large volume of insulation oil into consideration. Other transformer can be extinguished by large size fire extinguisher or other extinguisher.

Part 4
Examination and Inspection

Chapter 16 General Provisions

For Article 168 Definitions

Paragraph 2

The participants in the implementation of hydropower business and their role at each stage are shown in Fig. 168-1 below.

Since the first stage of developing project, the participant who participates in the hydropower business as the "Developer" is defined as the "Owner" or "Project Owner" in SREPTSHP.

For starting the business as an electric power service provider (an enterprise), the Project Owner should apply the License from EAC to be a Licensee or hire a parson or an organization who applies the License to be a Licensee on behalf of the Project Owner.

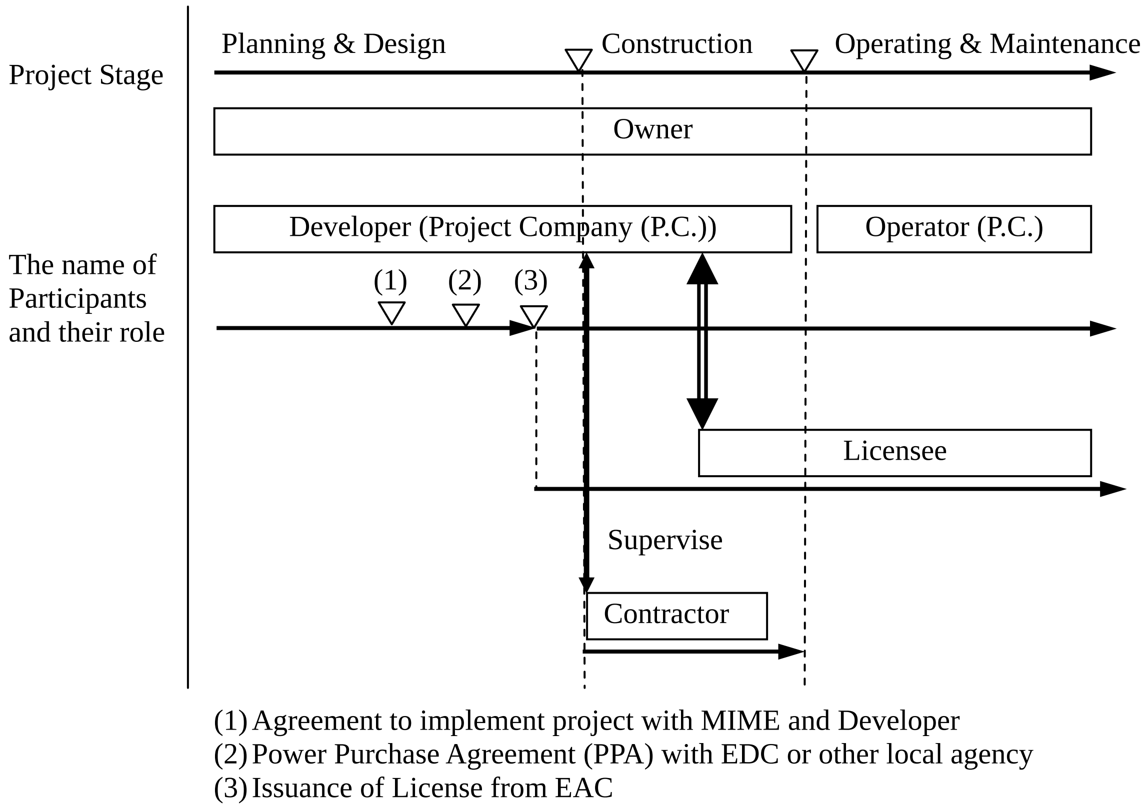


Fig. 168-1 Participants in Hydropower Business and their Role

Paragraph 3

The definition of the "Inspector" shall be depending on the competence and the responsibility of the supervisory agency in accordance with the related law and/or regulations in the Kingdom of Cambodia.

The Framework of the Supervisory Agency and the Inspector at each project stage is as described in Fig. 168-2. Inspection Committee is organized as the Inspector under the supervisory agency of MIME until the project commissioning (during the Planning & Design stage and Construction stage) and EAC takes the role of Inspector after project commissioning (during the Operation & Maintenance stage).

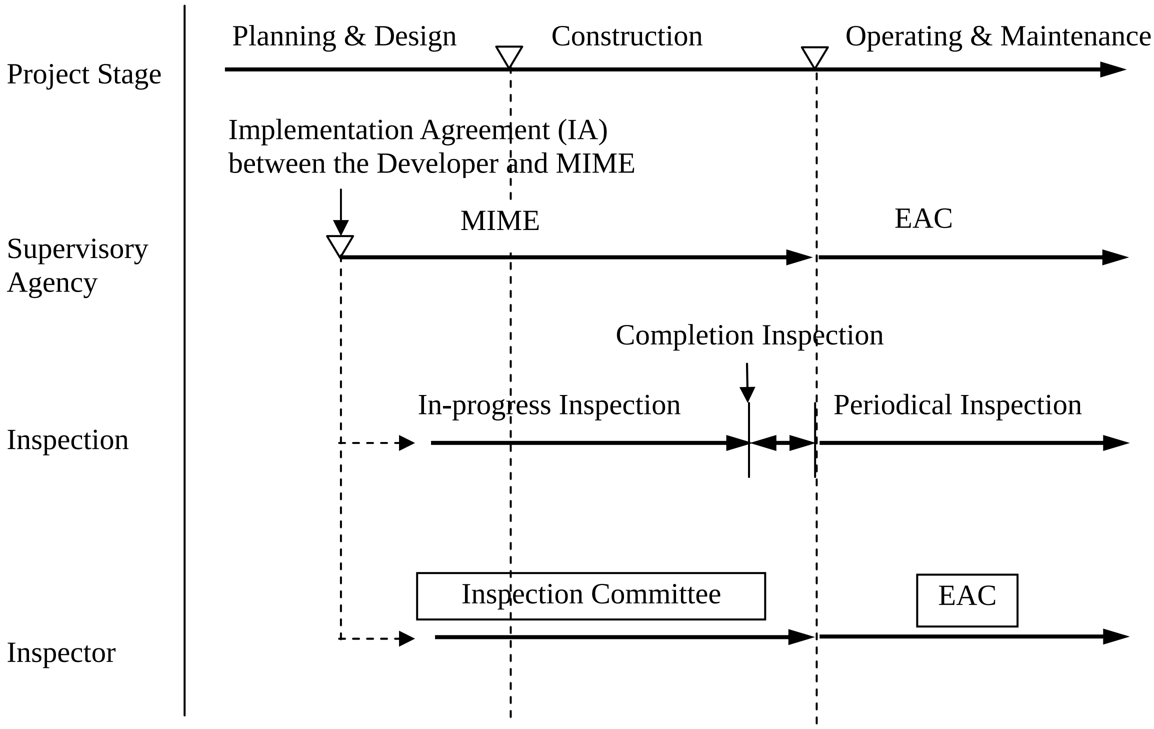


Fig. 168-2 Framework of Supervisory Agency and Inspector

Chapter 17 Examination and Inspection on Civil Structures and Hydromechanical Equipment

Section 1 In-progress Inspection

For Article 171 General provisions

Before starting construction of a hydropower station, the Project Owner shall submit the application form for each inspection stipulated in Articles 172, 173 and 174 to the Inspector describing necessary information as required for the Inspector’s examination.

The details of the information to be submitted to the Inspector are as shown below.

For Article 172 Scope of Examination for Commencement of Construction

The information to be submitted to the Inspector for the Examination for Commencement of Construction shall include at least the items listed below in principle unless otherwise accepted by the Inspector for the basic parameters if such information has been already submitted to the MIME at the Feasibility Study Stage:

1. General Information of the Project

Item	Required Information
1. General feature of the project	- Project location - Major parameters (water levels, storage capacity, etc.) of reservoir - Major parameters (dimension, capacity, etc.) of project structures - Major parameters related to power and energy output - Other principle description of the project - Drawings showing project outline including project layout plan, general structure plan, typical cross section of major facilities, etc.
2. Basic data and information	- Hydrological and meteorological parameters including river runoff data*1
3. Basic design information	- Explanation on determination of power discharge (the maximum discharge for power generation) - Calculation sheet of effective head and generating output*2
4. Environmental information	- Description about natural and social environmental condition.*3
5. Technical Specifications	- Copy of technical specifications to be used for construction works

*1. Without accurate river runoff data, energy generation and reservoir storage capacity can not be calculated and deigned. Therefore, river runoff data are one of the most important information to establish hydropower project. Since river flow condition is different at each site depending on weather and geographical features, long-term and accurate runoff data collection at or near the project site is essential for hydropower planning.

*2. Calculation of head loss and effective head

*3. Management of natural and social environment shall be of according with the related environmental laws and/or regulations.

2. Information of Dam and Spillway

Item	Required Information
1. General Information	- Dam type, dam height, crest length, crest width, dam volume, etc. - Major drawings of dam, spillway and gates including plan, profile and typical cross section
2. Basic parameters	- Design flood calculation - Sedimentation calculation
3. Reservoirs and Regulation Pond	- Storage capacities (total storage capacity, effective storage capacity, surcharge storage capacity) - Water levels (normal high water level (full supply level), low water level (minimum supply level), surcharge water level and maximum flood water level)
4. Foundation of Dam	In the case that the dam is classified as “Large” or ”Medium,” or has difficult foundation problems and/or is of unusual design even if the dam is classified as “Small” as shown in Table 21-2 - Geology of foundation - Improvement work of dam foundation*1
5. Dam design and construction	- General construction plan - Freeboard calculation - Dam stability - Concrete materials*2
6. Spillway design and construction	- Spillway type and discharge capacity - Model test result and/or calculation of spillway flow including energy dissipator - Gate type, number and dimensions of major elements - Type and capacity of gate driving device
7. Other discharge device	- Type, major dimensions, elevation, capacity of the other discharge device

*1. As for explanation of the improvement work of dam foundation, definite method such as “replacement of week foundation with concrete” or “consolidation grouting, curtain grouting or other grouting, if any” shall be described.

*2. As for concrete materials, the type of “cement”, “aggregate”, “admixture mineral”, etc., shall be described respectively.

3. Information of Intake, Settling Basin and Outlet

Item	Required Information
1. General information	- Dimension and elevation of major structures of intake, settling basin and outlet - Major structural drawings of intake, settling basin and outlet
2. Design and construction	- Structural calculation of intake tower - Outlet design in terms of protection of original river course and surrounding ground
3. Intake Gate	- Type and dimensions of major elements of intake gate
4. Other Gate and/or Stoplog	- Type and dimensions of major elements of other gates and/or stoplog at settling basin and outlet, if any

4. Information of Headrace and Tailrace

Item	Required Information
1. General information	- Geological information - Length of headrace and tailrace (tunnel, closed conduit, open channel, aqueduct bridge, siphon, etc., separately) - Dimension and elevation of headrace and tailrace structures - Major drawings of headrace and tailrace including layout plan, profile and typical cross sections
2. Design and construction	- Design head - Discharge capacity - Lining design - Structural calculation of aqueduct bridge, siphon, etc., if any

5. Information of Head Tank and Surge Tank

Item	Required Information
1. General information	- Type and general layout of head tank and surge tank - Dimension and elevation of major structures of head tank and surge tank - Major structural drawings of head tank and surge tank
2. Design and construction	- Surging calculation - Stability calculation - Structural design calculation for exposed type surge tank - Type and discharge capacity calculation of head tank spillway - Outlet design in terms of protection of original river course and surrounding ground

6. Information of Penstock

Item	Required Information
1. General Information	- Geological information - Length of penstock for each section - Dimension and elevation of penstock - Major drawings of penstock including layout plan, profile and typical cross sections
2. Design and Construction	- Design internal pressure calculation - Structural calculation of pipe support structures (anchor blocks and saddles) - Pipe diameter and thickness design including material class of steel - Pipe stability calculation including arrangement of expansion joints

7. Information of Reservoir and Regulating Pond

Item	Required Information
1. General Information	- Longitudinal section view and cross section view of reservoir or regulating pond - Elevation-storage capacity curve - Back water calculation sheet

8. Construction schedule

The following information is required regarding the construction schedule:

(1) General construction schedule including preparatory work schedule as well as major milestones. Schedule shall be described in a bar-chart form for major work categories (excavation, embankment, concrete placing, steel works, etc.) of each major structure separately.

(2) Construction plan and method of river diversion, flood treatment during construction of dam body, initial reservoir impounding including diversion closure.

For Article 173 Scope of Inspection on Dam foundation

Prior to the commencement of construction work of dam body such as dam concrete placing or embankment of fill material at the dam site, the Project Owner shall conduct the dam foundation inspection in the presence of the Inspector.

For the Inspection, the Project Owner shall prepare "Inspection Sheet" and submit the documents to the Inspector in advance.

The example of items to be described in the "Inspection Sheet" is as follows.

1. General information of dam	• Dam height, crest length and maximum width of dam bottom • Dam volume • Maximum compressive stress and maximum tensile stress • Maximum principal compressive stress and maximum principal tensile stress • Uplift coefficient • General information of geological feature of dam foundation • General information of dam foundation treatment
2. Dam body materials	(1) Concrete materials 1) Cement and aggregate (Cement) Manufacturer, type of cement and name of cement plant (Fine aggregate) Classification by particle size, exploitation place and transportation method (Coarse aggregate) Classification by particle size, exploitation place and transportation method (Admixture mineral) Types and manufacturer 2) Mix proportion • Maximum size of coarse aggregate (mm) • Range of slump (cm) • Unit water content (kg/m^3) • Unit cement content (kg/m^3) • Water- cement ratio (%) • Absolute sand-coarse aggregate ratio (%) • Weight of fine aggregate per unit volume of concrete (kg/m^3) • Weight of coarse aggregate per unit volume of concrete (kg/m^3) • Weight of AE agent per unit volume of concrete (cc/m^3 or kg/m^3) • Weight of admixture per unit volume of concrete (cc/m^3 or kg/m^3) • Target strength (MPa) • Coefficient of variation (%)

	(2) Other materials 1) Soil materials • Specific gravity • Unit weight (Dry) • Unit weight (Wet) • Unit weight (Saturated) • Water content • Internal friction coefficient • Coefficient permeability 2) Natural materials other than Soil materials • Specific gravity • Unit weight (Dry) • Unit weight (Wet) • Unit weight (Saturated) • Internal friction coefficient
3. Construction facilities	• Type, capacity and the number of units
4. Construction method	(1) Concrete dam body • Block size of concrete placing • Lift height of concrete placing • Concrete placing volume per one day • Curing method (2) Other dam body • Spreading depth • Compaction method
5. Foundation condition of inspection area	• Geological distribution and structure, and the nature of foundation rock • Condition of faults • Condition of bedding, joint and crack
6. Foundation treatment method of inspection area	• Grouting type, location, drill depth, drilling diameter, and mix proportion of grout and inject pressure
7. Drawings	• Dam structure, ground map after excavation, geological map, • Plan view map, longitudinal section and cross section with inspection area • Concrete placing plan of concrete dam or embankment plan of fill type dam • Plan of foundation treatment such as grouting plan

The Inspection method and criteria are as explained in the table blow.

Item	Inspection method
1. Durability and strength of dam foundation	By visual inspection on site and geologic map around site, the conformity to the following criteria shall be verified: <Criteria> • The situation of dam foundation such as rock type, rock quality classification, condition and distribution of weak zone shall not significantly different from inferior to the expected conditions that were assumed in the design stage in the viewpoint of dam safety. • The shear strength on dam foundation shall not be significantly different from that assumed in design stage. • Water tightness of dam foundation shall be improved by foundation treatment to a satisfactory level. • Obstacles on dam foundation such as gravel and weak zone for embankment of dam body shall be removed.

<table>
<tr><th>Item</th><th>Inspection method</th></tr>
<tr><td>2. Work plan of Improvement of dam foundation</td><td>By comparing required parameters specified in the approved technical specifications prepared by the Project Owner for the construction work with the records of construction to be obtained in the construction stage, conformity of the construction work to the following criteria shall be verified:
<Criteria>
• The improvement work of dam foundation by means of grouting or others in terms of shall satisfy required strength and water tightness for safety
• Large faults and fracture zone shall be appropriately replaced or treated by concrete or other appropriate method.</td></tr>
</table>

For Article 174 Scope of Inspection prior to Initial Reservoir Impounding

Prior to initial reservoir impounding, the Project Owner shall implement the Inspection prior to Initial Reservoir Impounding in the presence of the Inspector.

For the inspection, the Project Owner has to prepare “Inspection Sheet” and submit it to the Inspector in advance.

The example of items to be described in the “Inspection Sheet” is as follows.

<table>
<tr><td>1. General information of dam and dam body materials</td><td>• Same items in the same title of “Inspection of Dam Foundation”</td></tr>
<tr><td>2. Construction method and construction records</td><td>(1) Adopted construction method and construction records
(2) General information about construction of temporary diversion channel or temporary diversion conduit
(3) Joint grouting
• Injection period
• Injection method
• Injection records</td></tr>
<tr><td>3. Foundation grouting</td><td>• Records
<table>
<tr><th>Classification</th><th>Curtain grouting</th><th>Consolidation grouting</th><th>Other grouting</th></tr>
<tr><td>Grouting hole depth</td><td></td><td></td><td></td></tr>
<tr><td>Interval of grouting holes</td><td></td><td></td><td></td></tr>
<tr><td>Final grouting pressure</td><td></td><td></td><td></td></tr>
<tr><td>Injection volume per 1m</td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>4. Test result of gates</td><td>• Result of operation test under regular power source condition and emergency power source condition
• Result of operation test under local control condition and remote control condition
• Result of welding inspection.</td></tr>
<tr><td>5. General information of reservoir impounding plan</td><td></td></tr>
<tr><td>6. General information of reservoir inside</td><td></td></tr>
</table>

7. Impounding impact on other water utilization and its countermeasure	
8. Drawings	• Dam structure (Plan view, upstream elevation, downstream elevation and typical cross sections) • Actual concrete placing for concrete dam or actual embankment for fill type dam • Actual construction work and plugging work of temporary diversion channel or temporary diversion conduit • Temperature before joint grouting and gap of Joint grouting • Injection performance of ground foundation grouting • Plan view of reservoir and regulation pond • Dam operation rule including flood management

The Inspection method and criteria are explained as follows.

Item	Inspection method
1. Appropriateness of construction work of dam and related structures(Civil structures)	By comparing the approved technical specifications prepared by the Project Owner for the construction work with the construction record, the conformity of the construction works to the following criteria shall be verified: <Criteria> (1) Embankment works of dam body • The item of embankment works such as quantity of concrete or soil material shall conform to the approved technical specifications (2) Dimensions of dam body and related structures • The dimensions such as type, scale, and elevation of dam body and related structures such as spillways shall conform to the approved technical specifications (3) Improvement work of dam foundation • The grouting works for dam foundation shall be appropriate in viewpoint of dam safety (4) Grouting work for dam concrete joint • The grouting works for dam concrete joint should be implemented as designed
2. Appropriateness of impounding plan of reservoir	By examination on the initial impounding plan of reservoir, the conformity of the plan to the following criteria shall be verified: <Criteria> (1) Plan of water level raising rate in the reservoir • The plans shall not exert a harmful influence to stability of dam body and surrounding area (The rate of 1.0m/day or less is preferable in general.). (2) Flood control method from reservoir • Flood control method shall be appropriate in viewpoint of safety for downstream area (3) Plugging work of diversion tunnel or drain pipe • Diversion tunnel or drain pipe shall certainly plugged.

Item	Inspection method
3. Appropriateness of impounded structures (Civil structure)	By visual inspection of impounded structures related to civil structures, the conformity of the construction work to the flowing criteria shall be verified: <Criteria> (1) Dam body and spillway • There shall not be defects such as wide cracks beyond criteria on the surface of dam body and spillway structure in viewpoint of safety. (2) Dam monitoring facilities (instrumentation) • The instrumentation facilities shall work properly. (3) Leakage water from reservoir to surroundings • There shall not be large amount of leakage water over set criteria from the reservoir to the surroundings that may affect to dam safety as well as environment. (4) Preparation of plugging work of diversion tunnel and drain pipe • The preparation and execution of plugging work shall conform to the approved design and technical specifications for construction works. (5) Barriers for structures • Barriers such as fences, walls, alarm sign board shall be installed appropriately. (6) Condition of surrounding area • There shall not be faults such as landslide to surroundings.
4. Appropriateness of impounded facilities (Hydromechanical equipment)	By visual inspection of structures on hydromechanical equipment, the conformity of the construction work to the following criteria shall be verified: <Criteria> (1) Surface appearances on spillway gate, intake gate and other hydromechanical equipment • The dimensions shall correspond with those in design stage. • There shall not be fault such as abnormal deformation of structures, inferiority of coating, loose of wire rope, etc., in viewpoint of safety. (2) Non-destructive inspection on hydromechanical structures • The structures shall not have any problem exceeding the specified criteria by the result of radiographic inspections and ultrasonic ones. (3) Water tightness • The fitting condition between gate leaf and guide and sill shall be fine. • The water tightness shall be kept. (4) Operating test on auxiliary (standby) power equipment • The auxiliary (standby) power equipment shall work properly and there shall not be any fault that affects safety. (5) Opening/closing test • The gates shall open and close properly and there shall not be fault that affects safety. (6) Test of emergency limit switch • The emergency limit switch shall work properly and there shall not be any fault that affects safety.

Section 2 Completion Inspection

For Article 175 General provisions

After completion of hydropower construction, the Project Owner (or Licensee) shall submit the application form to the Inspector describing necessary information to confirm all civil structures and hydromechanical equipment and electrical facilities conform to SREPTSHP. After being authorized by the Inspector, the operation of the hydropower station can be commenced.

The detail of the documents to be submitted are shown as below.

The example of items to be described in the “Inspection Sheet” is as follows.

1. Civil structures	(1) Dam which is classified as “Large” or ”Medium,” or has difficult foundation problems and/or is of unusual design even if the dam is classified as “Small” as shown in Table 21-2 • Amount of leakage and uplift after impounding • Result of the spillway gate operating test (2) Headrace and tailrace • Outline of geological features, types and amount of tunnel support and reinforcing bar in the concrete lining • Concrete lining thickness • Leakage condition and its countermeasure • Records of grouting (injection volume and pressure) • Cracks on concrete lining • Measured value of roughness of coefficient • Result of leakage test in pressure tunnel (3) Surge tank • Records of grouting (injection volume and pressure) • Result of surging test (full load rejection case and rapid load increase case) (4) Penstock • Records of grouting (injection volume and pressure) • Total length of welding line • Result of radiographic testing
2. Drawings	(1) Structures and their location (2) Outline of each facility (3) Completion picture of each facility

For Article 176 Scope of Completion Inspection

The Inspection method and criteria are explained as follows.

Item	Inspection method
1. Appropriateness of dam, spillway and reservoir (Civil structures)	By visual inspection and inspection of measurement data, the conformity of the construction works to the following criteria shall be verified: <Criteria> (1) Dam • The dimensions shall correspond with that of the design. • The construction work shall be implemented properly. • There shall not be defects such as wide cracks beyond criteria on the surface of structures in viewpoint of safety. (2) Seepage/leakage water from dam and reservoir • There shall not be large amount of seepage/leakage water exceeding set criteria that exert a harmful influence to safety of dam and reservoir. (3) Measurement value of dam • The measurement value of dam that affects stability of dam such as uplift, deformation, temperature, openings of joint, pore pressure shall not exceed design value.
2. Appropriateness of intake structures (Civil structures)	By visual inspection and inspection of dimensions, the conformity of the construction works to the following criteria shall be verified. <Criteria> (1) Dimensions of intake structure • The dimensions of intake structure related to concrete structures shall conform to the approved technical specifications on construction work. (2) Condition of surface appearances • The dimensions of intake structure related to concrete structures shall correspond with that in the design. • The construction works shall be implemented properly. • There shall not be defects such as wide cracks and deformation exceeding the set criteria in concrete structures that affect safety of structures. (3) Inflow situations to intake • Inflow situations to intake structure shall be fine.
3. Appropriateness of settling basin (Civil structures)	By visual inspection and inspection of dimensions, the conformity of the construction works to the following criteria shall be verified: <Criteria> (1) Dimensions of settling basin • The dimensions shall correspond with those in design. (2) Condition of surface appearances • The surface appearance of settling basin shall conform to the approved technical specifications on construction work. • The construction works shall be implemented properly. • There shall not be wide crack and deformation exceeding the set criteria in concrete structures that affect safety of structures.

Item	Inspection method
4. Appropriateness of headrace, waterway and tailrace waterway (Civil structures)	By visual inspection and inspection of dimensions, the conformity of the construction works to the following criteria shall be verified: <Criteria> (1) Dimensions of headrace waterway • The dimensions of headrace waterway and tailrace waterway such as length, gradient, shape, thickness of lining concrete, etc., shall conform to the approved technical specifications on construction work. (2) Condition of surface appearances • The surface appearance shall conform to the approved technical specifications on construction work. • The construction works related to concrete structures shall be implemented properly. • There shall not be fault such as wide cracks, deformation and leakage water exceeding the set criteria in concrete structures that affect safety of structures. (3) Effects of grouting works (In case of pressure conduit) • The grouting works on pressure conduit shall work properly for preventing leakage water.
5. Appropriateness of head tank or surge tank (Civil structures)	By visual inspection and inspection of dimensions, the conformity of the construction works to the following criteria shall be verified: <Criteria> (1) Dimensions of head tank or surge tank • The dimensions of head tank or surge tank shall conform to approved design. (2) Condition of surface appearances • The surface appearance shall conform to the approved technical specifications on construction work. • The construction works shall be implemented properly. • There shall not be fault such as wide cracks and deformation exceeding the set criteria in concrete structures that affect safety of structures. (3) Fluctuation of water level in surging • The range of fluctuation of water level of surge tank shall not exceed that designed. (4) Condition of spillways • The spillways shall have proper functions so that spilling water could flow down safely and would not affect downstream safety. (5) Condition of surging in surge tank • The fluctuation of water level in surge tank shall be within that in the design and it shall return to equilibrium in calculated period.
6. Appropriateness of spillway gates and other hydromechanical equipment for spilling water	By visual inspection and inspection of measurement data, the conformity of the construction works to the following criteria shall be verified: <Criteria> • The dimensions shall correspond with those in the design. • There shall not be defects such as deformation of structures, imperfect water-tightness, inferiority of coating, loose of wire rope, abnormal noise at rotating parts, harmful vibration, one side suspending of gate etc. in viewpoint of safety. • At the same time, operating speed, electrical current and voltage of driving device, and oil pressure of oil hydraulic device shall be as designed, and winding condition of wire rope shall be fine.

Item	Inspection method
7. Appropriateness of penstock	By visual inspection and inspection of dimensions, the conformity of the construction works to the following criteria shall be verified: <Criteria> (1) Dimensions of penstock • The dimensions of penstock such as length, thickness, diameter, type of material, joint arrangement, supporting way, number and type of anchor blocks and saddles shall conform to the design and approved technical specifications for construction work. (2) Condition of surface appearances • The dimensions shall correspond with that in design. • The coating works on the surface shall be implemented properly • There shall not be defects such as wide cracks exceeding the set criteria in anchor blocks and saddles that affects safety of structures. • There shall not be leakage water from expansion joint of pipe that affects safety of structures. (3) Vibration • There shall not be vibration that affects safety of structures. (4) Welding • Related structures shall not have any inferiority exceeding the specified criteria by the result of radiographic inspections and ultrasonic ones. (5) Maximum internal water pressure • The internal water pressure shall not exceed design value in case of load rejection.

Section 3 Periodical Inspection

For Article 177 General provisions

After commencement of operation, in order to confirm the safety of civil structures and hydromechanical equipment, state and working conditions of those works and equipment shall be checked periodically.

For Article 178 Scope of Periodical Inspection

1. Dams

(1) General

Dam safety shall be judged comprehensively not only by visual inspection but also by evaluating monitoring data on performance of dams, if available. In addition to the inspection on dams, appropriateness of measuring instruments and relevant structures shall be also checked elaborately at the periodic inspection.

(2) Concrete dams

The following requirements shall be fulfilled in order to secure stability and safety of concrete dams.

1) Appearance

Settlement and horizontal movement of the dam shall not be observed by checking alignment visually at the crest of the dam;

Severe erosion that may damage the dam safety shall not be observed at around abutment of the dam due to water flow;

Newly developed excessive cracks or progress of existing conspicuous cracks, which may damage the dam safety, shall not be observed on the dam and in the inspection gallery;

Severe deterioration due to the alkali-aggregate reaction or water quality of the reservoir shall not be observed on the surface of the dam.

2) Leakage and Seepage

Leakage from joints of concrete dams and seepage from drain holes to reduce uplift shall be stable approximately or variable slightly depending on reservoir water level and temperature, excluding transitional period just after the impoundment of reservoir. If seepage rate through drain holes in foundation decreases, it shall be checked carefully that the decrease of seepage rate does not cause the increase of uplift pressure;

Indication of piping in dam foundations shall not be observed when checking turbidity in leakage or seepage water from drain holes in foundation etc.

3) Displacement

Horizontal displacement of dams shall be linked properly and stably together with reservoir water level and temperature;

Conspicuously irregular or abnormal performance shall not be observed in comparison with precedent records of displacement obtained by instrumental monitoring or survey work.

4) Uplift

Uplift pressure shall be less than or equal to the design assumption;

Uplift pressure shall be linked properly and stably together with reservoir water level and tail water level, or to be constant approximately;

This paragraph shall be applied to concrete dams where uplift pressure is measured.

(3) Fill dams

The following requirements shall be fulfilled in order to secure stability and safety of fill dams.

1) Appearance

Conspicuous cracks shall not be observed at the crest or the slopes of fill dams;

Sliding, erosion, sinkholes or uneven settlement shall not be observed at the crest or the slopes of fill dams;

There shall be no plants or trees on the crest or the slopes, excluding those specified in the design.

2) Leakage and seepage

Leakage from dams and foundations shall be stable or change rationally, considering precipitation, reservoir water level, groundwater level and time-dependent clogging in seepage path. This provision is applied to fill dams where facilities to measure leakage are installed.

3) Deformation

Settlement of fill dams shall be within very slow deformation level due to consolidations, excluding large settlement at initial stage;

Horizontal deformation of fill dams shall be stable after reservoir water level reaches the normal high water level first, excluding very slight plastic movement.

4) Pore water pressure

Pore water pressure inside impervious zone of fill dams and in their foundation shall be linked properly and stably together with reservoir water level, or be constant approximately, excluding transitional period just after impoundment of reservoir. This provision is applied to fill dams where piezometers are installed inside impervious zones of fill dams and in their foundations;

Phreatic surface in the abutment of the fill dam shall be stable approximately, taking precipitation and variation of reservoir water level into consideration. This provision is applied to fill dams where groundwater level gauges are installed at abutment.

5) Others

In case that the dam site locates in an area where activities of termite are anticipated, existence of nest of termite inside soil part of fill dams and soil foundation shall be checked by careful observation or by using proper equipment such as a ground-penetrating radar periodically.

In addition to the provisions prescribed above, the following requirements shall be fulfilled for each dam type.

6) Homogeneous earthfill dam

A phreatic surface inside homogeneous fill dam shall be stably below design level, and be safe for piping.

7) Rockfill dam with impervious core

In case that pore water in downstream rockfill may not be drained smoothly and quickly due to low permeability, the provision on a phreatic surface in homogeneous earthfill dam shall be applied to the downstream rockfill.

8) Rockfill dam with upstream facings

Damage of upstream facing due to settlement of rockfill etc., shall not be observed;

Deterioration that may threaten the water-tightness of facing shall not be observed;

Notable increase of leakage from joints or face slab shall not be observed not only at periodic inspection but also during operation.

Furthermore, in case that a rockfill dam with impervious core or a homogeneous earthfill dam is applied in pumped storage power stations, stability of the upstream slope shall be sufficiently maintained for rapid change of reservoir water level.

(4) Spillways

The following requirements shall be fulfilled in order to secure sustainable stability, safety and reliable function of spillways.

1) Impediment such as driftwoods left during flood, excessive growth of grass and weed, trees, debris, or landslide deposits shall not be observed at an approach part and chute channel of a spillway;

2) Severe erosion of spillway chutes shall not be observed in order to secure safety of spillways and their foundation;

3) Severe deterioration of spillway concrete shall not be observed in order to prevent successive erosion or structural instability;

4) Severe cracks and spalling in spillway concrete shall not be observed in order to prevent washout of fine materials behind the concrete slab, erosion, more cracks, or structural instability of spillway chutes and walls;

5) Misalignment or deformation of spillway chutes and walls shall not be observed. Once those geometrical abnormalities are found, causes shall be investigated carefully, clarified and removed properly, and abnormalities shall be repaired so as to secure structural safety and smooth water flow;

6) Severe relative displacement such as gaps and offset at the joints shall not be observed in order to prevent successive erosion due to cavitation;

7) Undermining around the spillway outlets due to discharge shall be checked periodically. Dams and appurtenant structures located near the spillway outlet shall be protected securely against undermining;

8) Drainage system shall be workable properly, in case spillway chutes or walls are equipped with a drainage system to reduce back pressure.

2. Waterways

(1) Pressurized waterways

Scope of application

Pressurized waterways may be used as headrace tunnels, penstocks and tailrace tunnels etc. From structural viewpoint, the following type or combination thereof is employed for pressurized waterways:

1) Unlined tunnels;
2) Concrete-lined tunnels;
3) Steel-lined tunnels;
4) Steel penstocks;
5) Reinforced plastic penstocks.

This article shall be applied to periodic inspection for the above-mentioned structures. Furthermore technical requirements on air valves and supports of penstocks are also stipulated in this article as important appurtenances. As for reinforced plastic penstocks, fiber reinforced plastics (FRP) or fiber reinforced plastics and mortar (FRPM) are stipulated here.

1) Unlined tunnels

The following requirements shall be fulfilled in unlined tunnel. This is to be checked by visual inspection:

a. Rock mass around tunnels shall be stable, and a large-scaled rock fall shall not be observed inside tunnels.
b. Severe erosion shall not be observed in unlined tunnels.
c. Sedimentation that may impede smooth water flow shall not be observed inside tunnels.

2) Concrete-lined tunnels

The following requirements shall be fulfilled in concrete-lined tunnels. These are to be checked by visual inspection:

a. Excessive leakage or seepage shall not be observed;
b. Cracks, spalling, and deformation of concrete lining that may damage structural safety of tunnels shall not be observed;
c. Excessive abrasive erosion shall not be observed on lining concrete;

d. Sedimentation that may impede smooth water flow shall not be observed inside tunnels.

3) Steel-lined tunnels

The following requirements shall be fulfilled in steel-lined tunnels. These are to be checked by visual inspection:

a. Excessive damages, deformation, corrosion and leakage shall not be observed on the surface of steel liner;
b. Excessive rust, peeling, cracks shall not be observed for coating on a steel surface.

4) Steel penstocks

The following requirements shall be fulfilled in steel penstocks. These are to be checked by visual inspection. In addition to those checks, shell thickness of aged and exposed penstocks shall be checked by an ultrasonic thickness gauge etc., at fixed points on penstock shells at periodic inspection.

A. Outside of exposed steel penstocks

a. Excessive damage, deformation, corrosion, pitting, deterioration and leakage shall not be observed at penstock shells, welded joints, and expansion joints;
b. Signs of significant rusting, pitting, cracks or other defects shall not be observed at welded joints;
c. Bolted or riveted joints shall be secure and free from excessive rust and deterioration. Bolts and rivets shall not be loosened or dropped out;
d. Excessive deterioration or defects shall not be observed on coating of a steel surface.

B. Inside of steel penstocks

a. Excessive corrosion, pitting and deterioration shall not be observed at penstock shells and welded joints;
b. Excessive deterioration or defects shall not be observed on coating of a steel surface.

5) Reinforced plastic penstocks

The following requirements shall be fulfilled in FRP or FRPM penstocks. These are to be checked by visual inspection:

a. No leakage from joints shall be observed;
b. Excessive deterioration, damages or abrasion shall not be observed on the surface of penstock shells. If protection layer is lost even partially, immediate repair work shall be carried out in order to protect the inner structural layer.

Obvious change in stiffness of FRP or FRPM penstock shells shall not be observed. Because it may be symptom that failure strength of FRP or FRPM shells reduce by long term loading.

It can be checked by measuring strain change of exposed penstock shells during dewatering or watering-up.

6) Air valves

Integrity of air valves shall be checked in order to secure proper operation and protection of penstocks during watering-up, dewatering, and usual operation.

7) Penstock supports

a. Settlement or movement that may damage structural safety of penstocks shall not be observed at support structures of penstocks.
b. Excessive damage, deformation and deterioration shall not be observed at concrete support structures.
c. Excessive corrosion, pitting and deterioration shall not be observed at steel parts of supports.

(2) Unpressurized waterways

Scope of application

Unpressurized waterways may be used as canals, headrace tunnels, and tailrace tunnels etc. From structural viewpoint, open channels, unpressurized tunnels, culverts, pipe conduits, or combination thereof is employed for unpressurized waterways. This article shall be applied to periodic inspection for those structures.

1) Open channels

The following requirements shall be fulfilled for open channels in order to secure safety and smooth water flow:

a. Side slopes of the open channels shall be stable;
b. Excessive erosion shall not be observed at side slopes and bottom of channels;
c. Excessive sedimentation shall not be observed inside channels.

2) Unpressurized tunnels

The following requirements shall be fulfilled for unpressurized tunnels in order to secure safety and smooth water flow:

a. Excessive cracks, spalling, and deformation of concrete lining that may damage structural safety shall not be observed for concrete-lined tunnels;
b. Rock mass around tunnels shall be stable for unlined tunnels;
c. Excessive erosion or sedimentation shall not be observed inside tunnels.

3) Culverts

This paragraph shall be applied to concrete culverts. The following requirements shall be fulfilled for concrete culverts in order to secure safety and smooth water flow:

a. Excessive cracks, spalling, and deformation of concrete that may damage structural safety shall not be observed for culverts;
b. Excessive erosion or sedimentation shall not be observed inside culverts.

4) Pipe conduits

This paragraph shall be applied to steel pipe conduits. Provisions of steel penstocks stipulated in Paragraph 5 of For Article 48(Penstocks) in Explanation Sheet shall be also applied to the unpressurized pipe conduits.

3. Auxiliary Structures to Waterways

(1) Intakes and outlets

The following requirements shall be fulfilled at intakes and outlets in order to secure sustainable safety and their function:

1) Excessive damage, deformation, cracks, and abrasive erosion shall not be observed at intakes and outlet structures;
2) Sedimentation or other obstacles that may impede smooth water flow shall not be observed in front of intakes and outlets.

(2) Settling basins

The following requirements shall be fulfilled at settling basins in order to secure sustainable safety and their function:

1) Excessive damage, deformation, cracks, and abrasive erosion, which may damage normal function of settling basins, shall not be observed at settling basins;
2) Facilities to remove sediment in settling basins shall be operable as designed;
3) Excessive sedimentation, which may impede smooth water flow in settling basins, shall not be observed.

(3) Surge tanks and head tanks

The following requirements shall be fulfilled at surge tanks and head tanks in order to secure sustainable safety and their function:

1) Excessive damage, deformation, cracks, and abrasive erosion shall not be observed at surge tanks and head tanks;

2) Conspicuous collapse, landslides and excessive seepage, which may damage stability and safety of surge tanks and head tanks, shall not be observed at surrounding slopes of those structures;
3) Excessive damage, deformation, corrosion, pitting and deterioration shall not be observed at steel shells or steel liners for steel or steel-lined surge tanks. Excessive deterioration or defects shall not be observed on coating of steel in those surge tanks.

(4) Spillways at head tanks

The following requirements shall be fulfilled at spillways of head tanks in order to secure safety of the public and civil structures. The first item shall be checked by visual observation on surrounding state of spillway outlets:

1) Excess water caused by output change at power stations shall be discharged downstream safely, including proper energy dissipation and minimal influence to the downstream area;
2) In case that steel pipes are employed as spillways of head tanks, the provisions on steel penstocks shall apply to steel conduits.

4. Powerhouses

(1) Structures of powerhouses

The following requirements shall be fulfilled at powerhouses:

1) Conspicuous deformation, cracks and excessive seepage shall not be observed at the concrete structures such as underground walls and foundations of powerhouses;
2) Conspicuous deformation, cracks and damages shall not be observed at walls or posts to support overhead cranes.

(2) Rock supports

The following requirements shall be fulfilled at arches and sidewalls in underground powerhouses and appurtenant caverns.

1) Conspicuous deformation or cracks, which may damage safety of the caverns, shall not be observed at concrete lining or shotcrete;
2) Drop out of heads of rock anchors or rockbolts shall not be observed;
3) Excessive seepage, which may cause mechanical instability of surrounding rock masses or may exceed an allowable drainage capacity, shall not be observed;
4) In case of unlined caverns, symptoms for serious instability of the surrounding rock masses shall not be observed.

(3) Slope stability around powerhouses

Conspicuous collapse, landslides or excessive seepage, which may vitiate sustainable operation of powerhouses, shall not be observed at the surrounding slopes of on-ground powerhouses.

5. Hydromechanical Equipment

(1) Gates and valves

This article shall be applied to the following gates and valves:

1) Spillway gates;
2) Intake gates;
3) Valves and gates of outlet works;
4) Control gates at head tanks;
5) Draft gates;
6) Tailrace gates.

The following requirements for gates and valves shall be fulfilled. This may be checked by operation or maintenance records at periodic inspection:

1) It shall be confirmed that gates or valves work normally and smoothly;
2) Notable deterioration, damages or deformation on gate leaves and guide frames shall not be observed;
3) Excessive deterioration or defects shall not be observed for coating on a steel surface;
4) Sufficient water-tightness shall be maintained for gates and valves.

(2) Gate hoists

The following requirements for gate hoists shall be fulfilled. These may be checked by operation or maintenance records at periodic inspection:

1) Movement of hoists shall be smooth;
2) Hoists shall work normally by ordinary power supply and by standby power supply respectively;
3) Serious damage, deformation, corrosion, and deterioration shall not be observed at steel part of hoists;
4) Excessive deterioration or defects shall not be observed for coating on steel parts of hoists.

(3) Standby power supply

The following requirements for standby power supply shall be fulfilled. These shall be checked by test operation at periodic inspection:

1) Standby power supply shall start quickly;
2) Rated power output shall be as designed stably;
3) Temperature increase during operation shall be within guaranteed limit;
4) Abnormal noise and excessive vibration shall not be observed;
5) All necessary expendable supplies and material such as oil, water and fuel shall be provided in order to meet emergency operation;
6) There shall not be any leakage of oil, cooling water, or fuel.

6. Reservoir and River Environment at Downstream of Dams

(1) Slope stability

Signs of collapse or landslides, which may cause the loss of lives and property existing around reservoirs, and serious damage to dams, shall not be observed at reservoir areas;

Signs of collapse or landslides of slopes caused by operation of hydropower stations, which may damage power station structures and equipment, lives and property at the riverside, shall not be observed at the downstream area of dams and power stations. Downstream areas where the Owner is responsible for public safety in relation to power generation activities shall be agreed with the Authority in advance.

(2) Sedimentation in reservoirs

During flood, unusual water level rise due to sedimentation may cause flood damage to the public at around inlet and upstream of reservoirs. In order to prevent such damages, excessive sedimentation shall not be observed at those areas.

Severe sedimentation that may induce dangerous influences to dams shall not exist. This shall be checked by latest survey record on sedimentation.

(3) Erosion of riverbed and riverside

Erosion at riverbed or riverside at downstream of dams and power stations due to power generation and flood release shall not be serious for surrounding environment. Progress of erosion shall not be notable.

7. Measuring Instruments

(1) Condition and performance of measuring instruments

There shall be no serious damages on measuring instruments and relevant structures;

The site where measuring instruments and relevant structures are installed shall be safe and stable, and free from unfavorable obstacles for measuring such as severe sedimentation;

The measuring instruments shall work normally, and shall be protected adequately from natural accidents or artificial disturbances.

(2) Calibration of equipment

Official equipment calibration shall be performed for measuring instruments used in monitoring and observation for performance of structures and relevant natural conditions. This provision shall be applied to the instruments for which the official calibration is mandatory;

As for other measuring instruments except for those prescribed in the preceding paragraph, normality of the measuring instruments shall be checked by comparing them with results of other independent measurement if applicable.

Chapter 18 Examination and Testing

For Article 181 Measuring Method of Grounding Resistance

1. Application of Measuring Method

Measuring method of grounding resistance shall be done as follows;

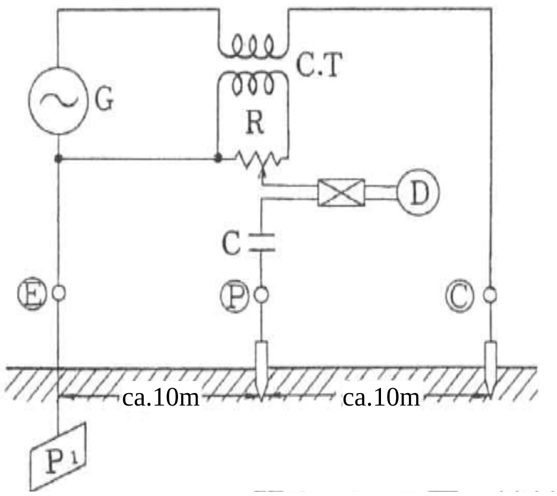
Table 181-1 Measuring Method of Grounding Resistance

Grounding Method		Measuring Method
Individual Grounding	Grounding by each equipment	Direct reading earth resistance meter
Connection Grounding	Grounding by connected equipment	
Widespread Mesh Grounding	Mesh grounding, grounded at intersection point especially to be necessary low Grounding resistance	Fall of potential method

2. Measurement by Direct Reading Earth Resistance Meter

(1) Measuring Circuit

Measurement by direct reading earth resistance meter is as shown in the following;



E : Applied Measuring Grounding Terminal
P : Auxiliary Grounding Terminal (for voltage detection)
C : Auxiliary Grounding Terminal (for current detection)
CT : Current Transformer
R : Slide Rheostat
D : DC Galvanometer
G : Power Source
C : Condenser of DC Blocking for Grounding Current
P1 : Applied Earth Electrode

Fig. 181-1 Measuring Circuit for Direct Reading Earth Resistance Meter

(2) Measuring Method

According to Table 181-1, E-terminal shall be connected to applied earth electrode, auxiliary earth electrode shall be sunk into ground at a distance of 10 meters from each electrode straight line, and grounding resistance can be read directly from dial reading when dial shall be regulated to adjust center cinnabar line.

3. Measurement by the Fall of Potential Method

(1) Measuring Circuit

Measurement by fall of potential method is following;

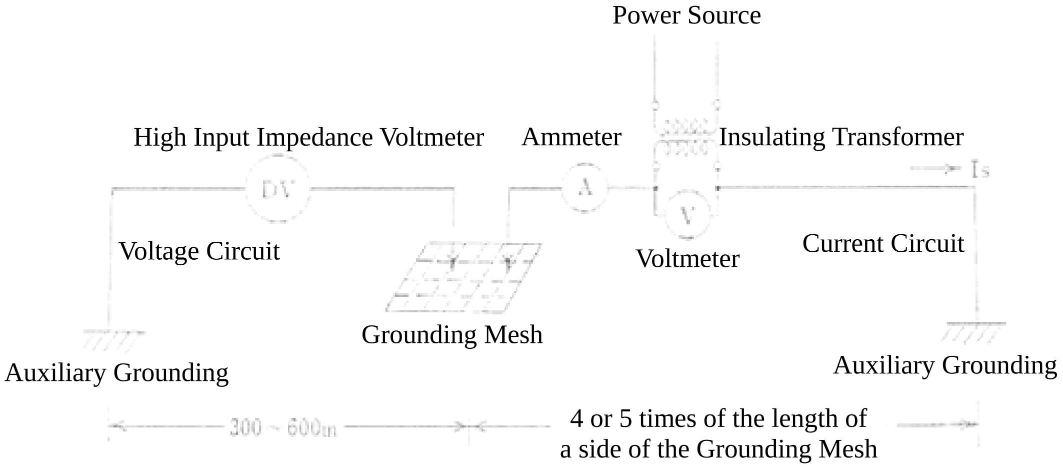


Fig. 181-2 Measuring Circuit for the Fall of Potential Method

(2) Measuring Method

According to Fig. 181-2,

Is : Grounding current of current circuit (A)

Vs : Reading value of high input impedance voltmeter (V)

Grounding resistance $R = \frac{Vs}{Is} [\Omega]$

However, except influence of inductive voltage against voltage circuit and in order to delete the error of ground floating potential by grounding current, true value of voltage raise of ground system shall be calculated at first according to Fig. 181-3 of vector diagram,

$$Vso = \sqrt{\frac{Vs1^2 + Vs2^2 - 2Vo^2}{2}} [V]$$

Where,

Vs1 : Reading value of high input impedance voltmeter when measurement (V)

Vs2 : Reading value of high input impedance voltmeter when polarity reversal (V)

Vo : Reading value of high input impedance voltmeter when grounding current Is is 0(V)

Therefore, true value of grounding resistance Ro shall be calculated

$$Ro = \frac{Vso}{Is} [\Omega]$$

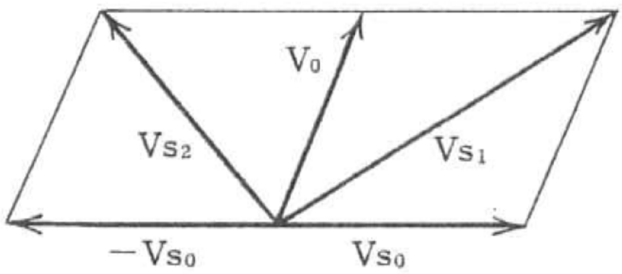


Fig. 181-3 Vector Diagram

(3) Precaution for Measurement

1) In order to reduce the inductive potential against voltage circuit, current circuit shall take over 90 degree of phase angle (refer to Fig. 181-4). In the same reason mentioned above, voltage circuit shall not be paralleled to other transmission and distribution line.
2) In case of grounding of one phase or neutral point of power source of current circuit, current circuit shall be isolated from voltage circuit by isolating transformer.
3) In case of measurement of voltage, high internal resistance voltmeter shall be used such as digital type voltmeter.
4) Grounding current value of current circuit shall be more than 20A.
5) Grounding resistance shall be measured several times by changing connection point of voltage circuit and current circuit and average value shall be calculated.

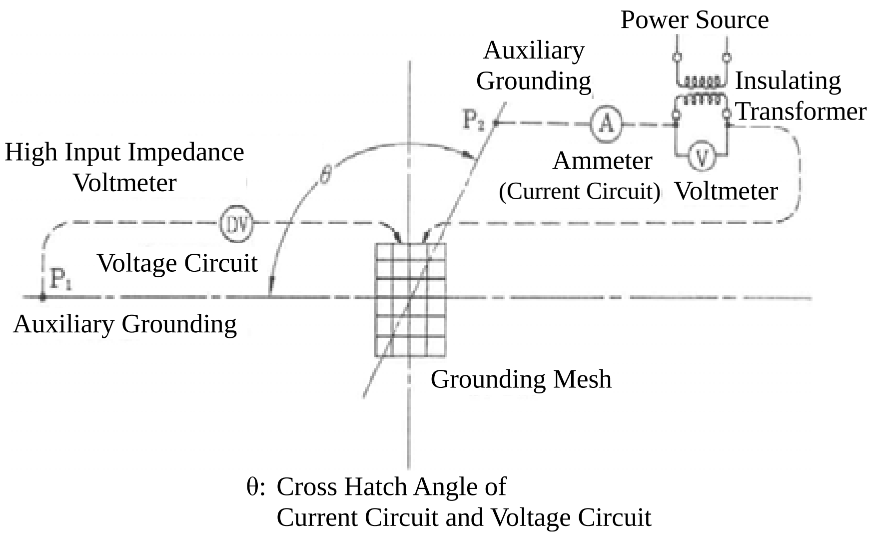


Fig. 181-4 Cross Hatch Angle of Current Circuit and Voltage Circuit

For Article 182 Measuring Method of Insulation Resistance

1. Purpose for Measuring Procedure of Insulation Resistance

(1) In order to decide whether insulation level is enough or not, conducting the dielectric strength test is ideal by voltage value and time value. However, measurement of insulation resistance is

uncomplicated and unforeseen ground fault and short-circuited fault would be prevented if control circuit, electric power circuit and wiring are checked periodically.

(2) Measurement of insulation resistance for high and medium voltage circuit is to verify at the time of dielectric strength test for applied voltage is not hindrance, whether insulation is not abnormal and resume the operation is not hindrance after long term stop.

2. Precaution for Measurement

(1) If electrostatic capacity of measured equipment is large and cannot measure insulation resistance within 1 minute, indicating needle stopping value shall be insulation resistance value. After the testing, electric charge shall be discharged by earth to ground.

(2) On occasion of measurement for cable or electrical wiring, protective terminal shall be used if necessary in order not to remove error due to surface leakage current.

(3) Insulation resistance value varies remarkably with temperature, humidity and contamination. Therefore, record of weather, temperature and humidity shall be taken and kept.

(4) If same electrical circuit of insulation resistance is measured periodically, weather, temperature, measuring method shall be maintained.

For Article 183 Insulation Resistance Value

1. Insulation Resistance Value for Low Voltage Circuit

Insulation resistance value for low voltage circuit shall be in such a manner so as not to damage any electrical shock to the person if 1mA of leakage current would be going through human body. The 1mA of leakage current was determined based on the condition that there is not any danger to the human body if leakage current goes through one spot.

Essentially, insulation resistance value varies with season, temperature, humidity and different value would show accordingly. If insulation resistance value shows large value, it is tentative value and not guaranteed value.

2. Insulation Resistance Value for High and Medium Voltage Circuit

Insulation resistance value for high and medium voltage circuit varies with temperature, humidity, circuit voltage and structure of insulation and deterioration of insulation resistance value varies with kind of electrical equipment. Therefore, following formula and figure are for reference in general.

(1) Insulation Resistance Value for Rotating Machine

$$\text{Minimum Insulation Resistance Value} = \frac{\text{Rated Voltage (V)}}{\text{Rated Output (kVA)} + 1{,}000}\ [\mathrm{M\Omega}]$$

(2) Insulation Resistance Value for Oil-Immersed Transformer

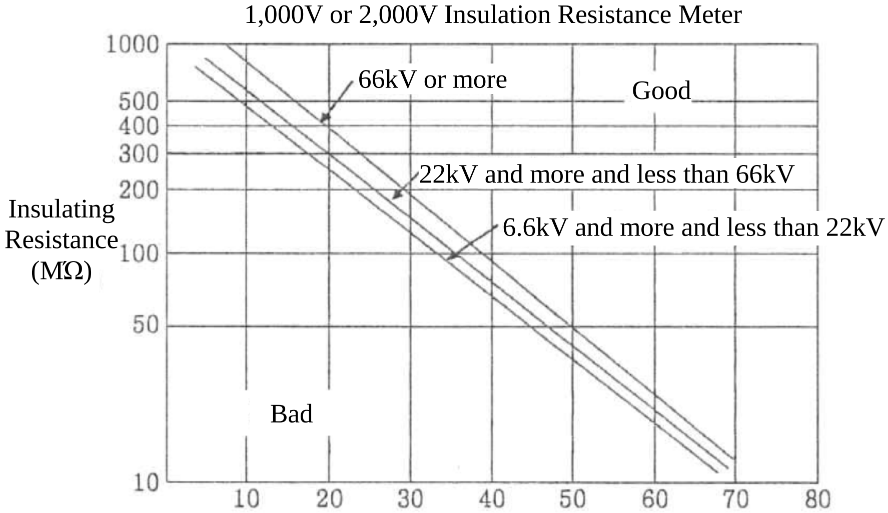


Fig. 183-1 Allowable Insulating Resistance for Transformer

For Article 185 Dielectric Strength Test Method for Electrical Equipment

Article 185 states about test which are capable at site after the installation of electrical equipment.

(1) Dielectric strength of multi-core cable between core and core may be less strength than that between core and ground, so that dielectric strength of multi-core cable between core and core also is stipulated.

However, cable which is covered by ground potential conductor such as SL cable, if dielectric strength between core and ground is higher than stipulated value, dielectric strength between core and core is obviously higher than stipulated value. So that dielectric strength test between core and core is not necessary.

(2) On the occasion of actual test, test for the bus-bar and electrical equipment are not necessary. Every voltage level of circuit shall be tested as far as the test facility permits the capacity.

(3) If earthed voltage transformer, coupling capacitor, lightning surge absorber, earth detect capacitor, re-striking voltage limiting capacitor, arrester, and coupling reactor have dielectric strength, dielectric strength test at site shall be omitted.

Dielectric strength test for neutral grounding resistance and grounding reactor also shall be omitted.

(4) On the occasion of DC dielectric strength testing for cable to be used for AC circuit, dielectric test can be conducted including gas insulated switchgear which is to be connected to cable.

However, applying DC voltage to the gas insulated switchgear, it is necessary to consult with manufacturer in advance. In this case, gas insulated switchgear applied by DC voltage can omit the AC voltage dielectric strength test.

<u>Precaution for Testing</u>

(1) If there are underground cables, large capacity generators and condensers in the tested circuit, charging current may reach considerable current, capacity of testing transformer shall be divided appropriately.

(2) On the occasion of dividing testing circuit, open and close area shall be verified in advance and then applied voltage area shall be verified in accordance with plan.

(3) Removing earthed voltage transformer, capacitance voltage transformer, arrester and surge absorber from testing circuit is desirable.

(4) Earthing for search coil of generator, not voltage applying winding of instrument transformer shall be confirmed before testing. This is to prevent the danger from induced voltage.

(5) If rectifier to be connected series, short-circuited for both poles is desirable for testing.

For Article 186 Operation Test for Hydropower Station

1. Protective Device Test

Protective device test is to verify the stop sequence of turbine and generator, operation of circuit breaker after detecting the abnormal condition of hydropower station.

The test shall be done in standstill condition in principle.

2. Operation Test for Circuit Breaker and Switching Device

If there is interlocking device for the switching device so as not to cut off the load current mistakenly, operation test shall be done so as not to verify the interlocking function.

Compressed air container, compressed air supply system, pressure oil container and pressure oil supply system shall be tested also.

3. Test for Pressure Oil and Compressed Air Supply System

Safety valve test, automatic start-stop operation test for pressure oil and compressed air supply system shall be done in accordance with SREPTSHP.

However, common use oil pump operating continuously is not necessary automatic start-stop test.

4. Automatic Start-Stop Operation Test for Turbine

Automatic start-stop operation test is to verify the start-stop sequence from stop to load and load to stop with step by step operation by master control switch at control board and each operation time shall be measured.

5. Load Rejection Test

Load rejection test is to verify not exceeding the limited value for the rotating speed, generator voltage and pressure rise of penstock by opening of circuit breaker and confirm the sequence from load to no-load condition normally.

Method and precautions of test are as follows:

(1) In case that 2 or more units take water from 1 penstock, simultaneous load rejection test shall be done after load rejection test for each unit.

However, test result to be obtained from load rejection test of each unit after commercial operation and safety for simultaneous load rejection test can be presumed by the above test, the result is not necessary the simultaneous load rejection test.

(2) Rotating speed, generator voltage and power factor before the load rejection shall be maintained at rated value as much as possible.

However, maintaining of rated power factor is hard, power factor of each load rejection test of 1/4, 2/4, 3/4, 4/4 shall be the same power factor to the rated power factor as much as possible.

(3) Automatic voltage regulator and over-voltage control device shall be at normal setting value.

(4) Load rejection test results conducted periodically or temporary shall be compared with provisions test record and verify the acceptability.

(5) Speed variation and generator voltage variation are as follows:

$$\text{Speed variation} = \frac{\text{maximum rotating speed (r/min.)} - \text{rotating speed before rejection (r/min)}}{\text{rated rotating speed (r/min.)}} \times 100(\%)$$

$$\text{Generator voltage variation} = \frac{\text{maximum voltage (V)} - \text{voltage before rejection (V)}}{\text{rated voltage (V)}} \times 100(\%)$$

6. Emergency Stop Test

In case of occurrence of internal failure for generator or transformer during the operation, generator shall be paralleled off and also turbine shall be stopped.

This test is to verify the emergency stop sequence such as operation of protective relay, paralleled off the generator, turbine stop safely and smoothly.

The emergency stop test shall be done at 1/4 rated load condition and shall be measured time for each step by stopwatch from operation of protective relay to complete stop of turbine.

7. Quick Stop Test

In case of occurrence of decreasing of oil pressure or losing of control power source during the operation, speed control of turbine is unable and turbine may reach the runaway speed.

This test is to verify the quick stop operation sequence in case of decreasing oil pressure or losing of control power source to stop the turbine safely and smoothly.

Common use and auxiliary oil pump shall be stopped and locked not to start automatically. Operation of oil pressure relay and pressure gauge at oil container also shall be verified during the decreasing of oil pressure at setting value.

8. No-load, No-excitation Test

Hydropower station has no-load, no-excitation or no-load, excitation mode as a protective system, stop sequence of unit shall be verified accordingly.

This test shall be done in the same manner as emergency stop test of 1/4 load condition.

9. Sudden Load Increase Test

After stabilizing of surge tank water level, load shall be increased with the prescribed speed from 1/4 load to 4/4 load and condition of waterway shall be verified.

In case that plural unit takes water from 1 penstock, simultaneous sudden load increase test shall be done.

In addition to the reservoir water level, increasing speed of load shall be coordinated with civil structures section sufficiently.

Variation of reservoir water level depends on design of waterway. Therefore, if it is verified at completion test, periodical sudden load increase test is not necessary.