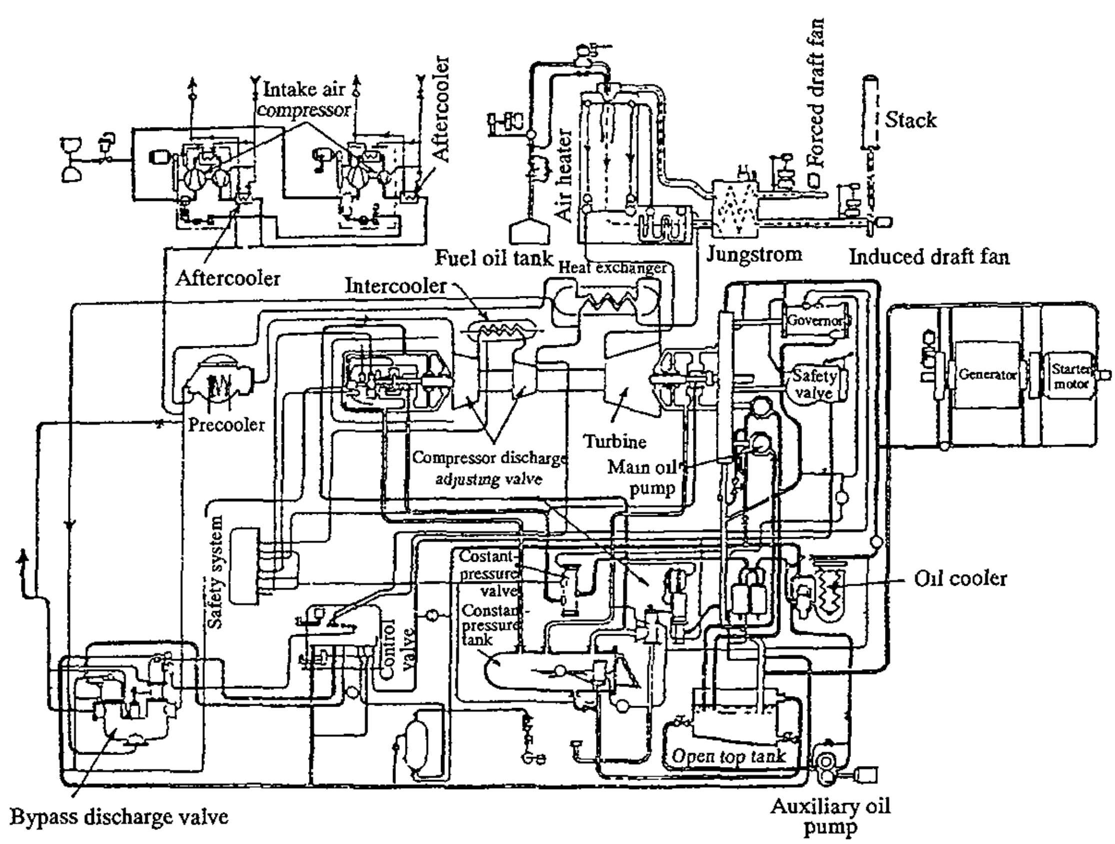
Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	No.GT1-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Gas Turbine Power Station (1)			

Electric power is generated by the gas turbine, which turns with a high-temperature, high-pressure gas. This type of power generation is essentially based on four processes: compression, heating, expansion and heat radiation. To these basic processes, other processes are added: regeneration, intermediate cooling, reheating, etc.

1. Components

A gas turbine system mainly consists of a compressors, heaters, gas turbine, silencers, regenerators, and intermediate coolers.



Configuration of a gas turbine power station

Remarks	Revisions	
	2003/Nov.	Original

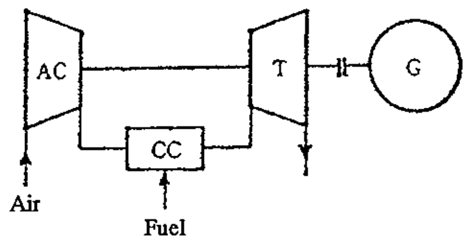
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.GT1-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Gas Turbine Power Station (2)			

(1) Compressors

The compressors apply high pressures to the air. Axial-flow compressors are generally used in thermal power stations. These compressors are multiple-stage compressors which are capable of efficiently compressing a large amount of air under high pressures.

(2) Heaters

The heaters are used to heat high-pressure air. Internal combustion heaters (combustors) are applied to the open cycle system.



AC : air compressor
CC : combustor
T : turbine

Open cycle

(3) Gas turbine

The gas turbine performs adiabatic expansion of a high-temperature, high-pressure gas to generate torque.

(4) Regenerators (heat exchangers: HE)

The regenerators recover the heat retained in the turbine exhaust gas for use as combustion air to greatly improve the thermal efficiency.

(5) Intercoolers

The intercoolers lower the temperature of the air during the compression process to enhance the compressor's efficiency.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.GT1-3
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Gas Turbine Power Station (3)			

(6) Precoolers

The precoolers lower the temperature of the fluidic air in the closed cycle at the compressor inlet to enhance the compressor's efficiency.

(7) Silencers

A gas turbine power station generates undesired noise because it intakes and discharges large amounts of air at high speeds. For this reason, a noise insulating material is installed to cover the ducts and silencers are provided at the intake side. At the discharge side, the air is discharged upward through a chimney to the atmosphere.

2. Description of gas turbine

(1) General

Axial-flow turbines are widely used in the power generation industry. The turbine blades are so designed that the air flow secures an equilibrium in the radial directions. If based on the axial-flow system, an impulse turbine is not differentiated from a reaction turbine. The rotor and blades are made of a special heat resistant alloy to meet the temperature requirements for the service gas.

Recently, new heat resistant materials have been developed and the cooling structure of the blades has been modified. High-efficiency gas turbines have been commercialized for service temperatures around 1100°C.

(2) Open gas turbine

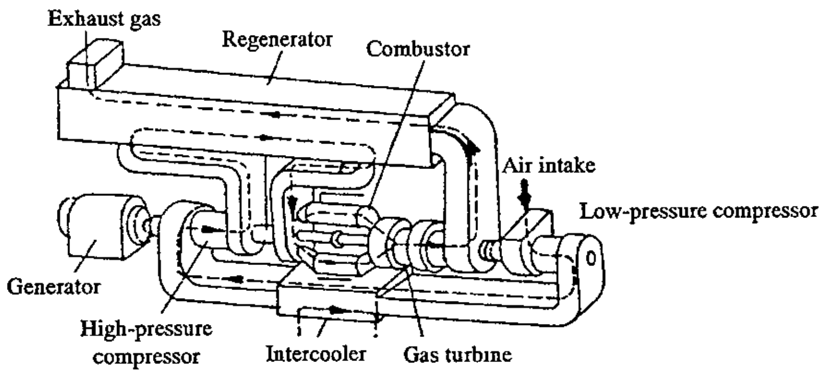
An open gas turbine is a turbine which integrates a combustor and a compressor.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.GT1-4
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Gas Turbine Power Station (4)			

(2) Open gas turbine

An open gas turbine is a turbine which integrates a combustor and a compressor.



Open gas turbine

The air placed under high pressures in the compressor is transferred to the combustion chamber. A small part of this air is used to burn the fuel in the combustion unit. A large amount of high-temperature, high-pressure gas obtained by mixing the majority of high-pressure gas with the high-pressure, high-temperature combustion gas performs adiabatic expansion in the turbine. This process generates torque to the impeller. The exhaust enters the regenerator and preheats the combustion air before being discharged to the external environment.

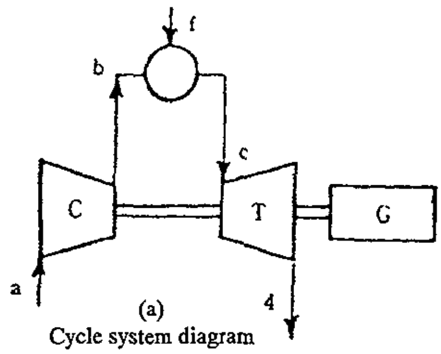
(3) Thermal cycle of gas turbine

In the single cycle:

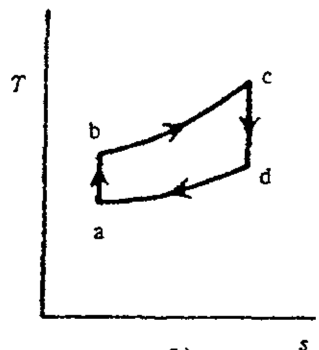
1) The quantity of heat which has changed into work in the gas turbine is represented by the area formed by a, b, c, and d in the *T-s* diagram.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.GT1-5**
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	**Gas Turbine Power Station (5)**			



(a)
Cycle system diagram



(b)
T-s diagram

Thermal cycle of gas turbine

2) The theoretical thermal efficiency is $\eta_c = 1 - \left(\frac{P_a}{P_b}\right)^{\frac{k-1}{k}}$

where P_a, P_b: absolute pressures of the gas at a and b [MPa] and k: specific heat ratio (constant-pressure specific heat / constant-volume specific heat).

The actual gas body is not a perfect gas body, and the compression and the expansion are not perfectly isentropic. Therefore, the theoretical values are slightly different from the actual values. Higher turbine intake temperatures correspond to higher thermal efficiencies.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.GT2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	22	Gas Turbine and its Accssories	
Title	Hydrostatic test			

1. The pressure parts of a gas turbine and its accessories must be able to withstand a hydrostatic test using a water pressure 1.5 times their respective maximum allowable working pressures without leakage.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.GT3
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	22	*Gas Turbine and its Accssories*	
Title	Emergency stop devices			

1. A gas turbine must be equipped with an emergency governor which is actuated at a speed not higher than 1.11 times its rated speed.
2. A gas turbine must be equipped with a device which interrupts the inflow of fuel automatically in the cases specified in the following Items:

(1) In case a trouble occurred with a generator with a capacity of not less than 10,000kVA.

(2) In case gas temperature increase extremely high.

Remarks	Revisions	
	2003/Nov.	Original

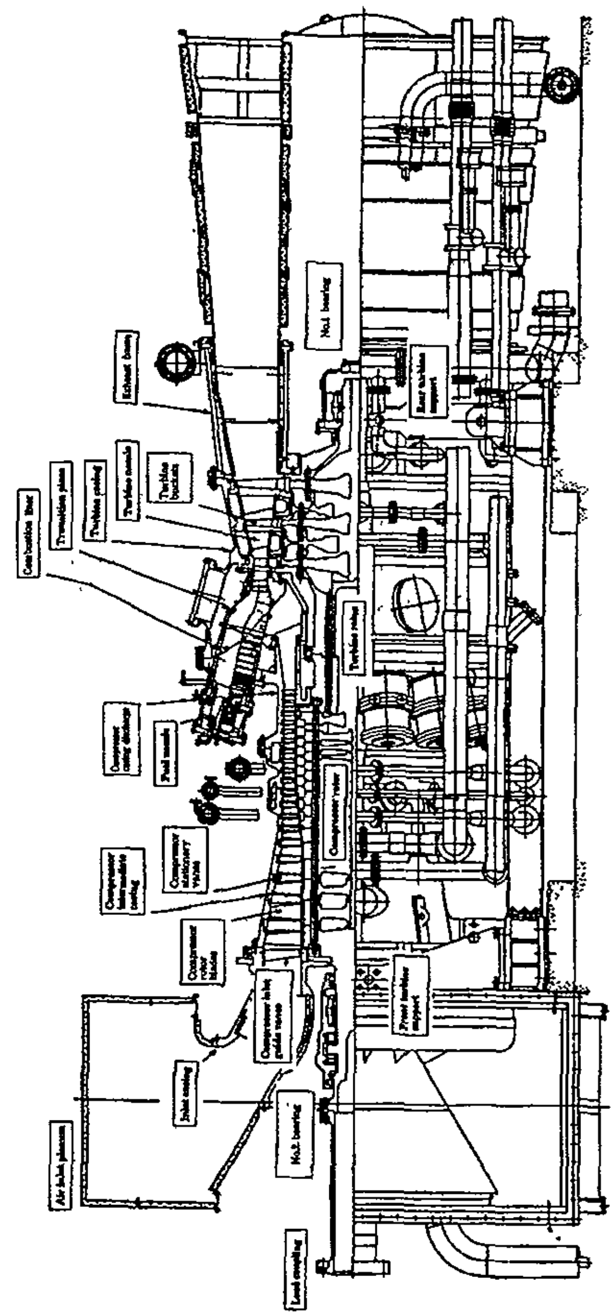
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.GT4
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	22	Gas Turbine and its Accssories	
Title	Measuring devices			

1. A gas turbine must be equipped with devices for measuring the points specified in the following Items:
   a. Speed of a gas turbine
   b. Discharge pressure of the air compressor of a gas turbine
   c. Gas temperature at inlet of a gas turbine
   d. Oil pressure at the bearing inlet of a gas turbine
   e. Oil temperature at the bearing outlet of a gas turbine

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.GT5**
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	22	Gas Turbine and its Accssories	
Title	**Example of Construction of Large Capacity Gas Turbine**			

21-. ːxample of Construction of Large Capacity Gas Turbine



Remarks	Revisions	
	2003/Nov.	Original

Category				
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.GT6-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause			
Title	Type of Gas Turbine Combind cycle			

(4) Combined cycle power generation

This is an exhaust heat recovery power generation system in which the exhaust from an open gas turbine is sent for steam generation to the exhaust heat recovery boiler in a steam power station. Another system is based on a supercharged boiler. The air from the compressor in the gas turbine is fed to the boiler in the steam power station to be combusted as combustion air. The resulting combustion gas is sent to the gas turbine.

Use of combined cycle power generation will improve the total thermal efficiency up to 43%.

Remarks	Revisions	
	2003/Nov.	Original

<table>
<tr><td rowspan="3">Category</td><td>Chapter</td><td>2</td><td>Technical Standards of Electric Power Facilities</td><td rowspan="3">Document No.GT6-2</td></tr>
<tr><td>Paragraph</td><td>3</td><td>Generating Facilities (Thermal)</td></tr>
<tr><td>Clause</td><td>24</td><td>Gas-turbine Combined Cycle and its Accessories</td></tr>
<tr><td>Title</td><td colspan="4">Types of Gas Turbine Combined Cycle</td></tr>
</table>

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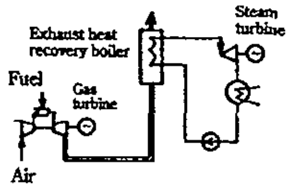
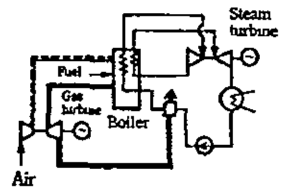
<tr><th>Types</th><th>Systems</th><th>Types</th><th>Systems</th></tr>
<tr><td>Exhaust heat recovery</td><td>
</td><td>Supercharged boiler (Pressurized fluidized bed combustion)</td><td>
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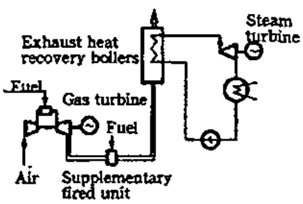
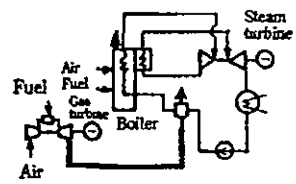
<tr><td>Supplementary fuel to exhaust gas</td><td>
</td><td>Feed water heating</td><td>
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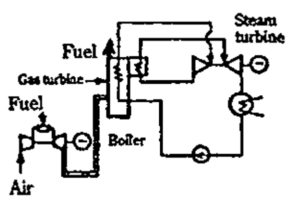
<tr><td>Exhaust gas refiring</td><td>
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Remarks	Revisions	
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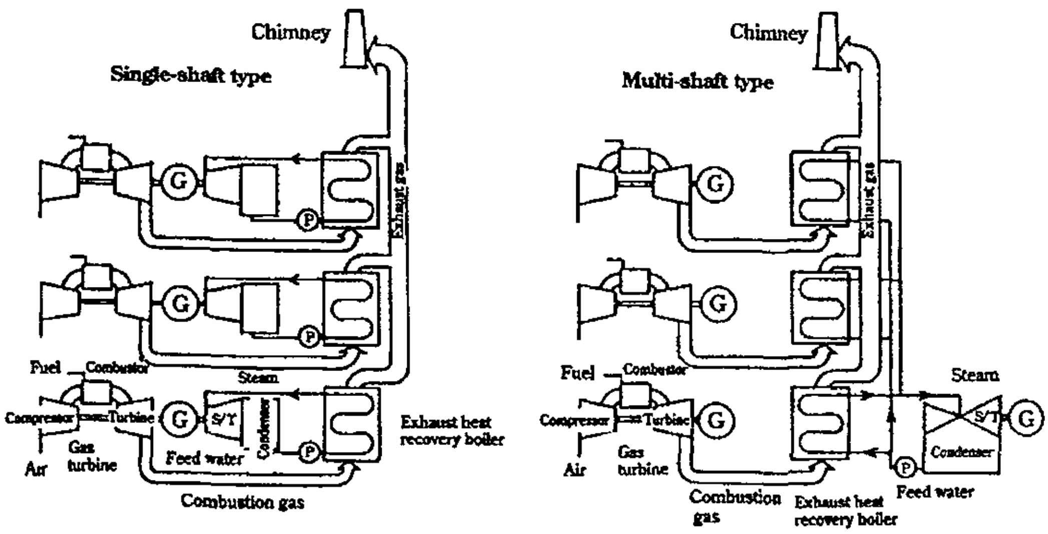
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.GT7
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	22	Gas Turbine and its Accessories	
Title	Conception of Exhaust Heat Recovery Combined Cycle			

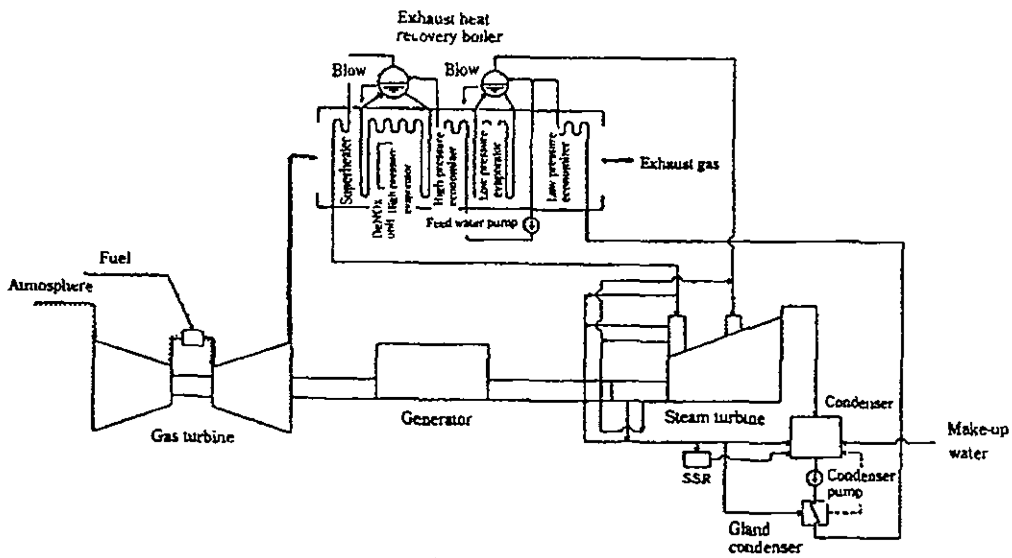
Conception of Exhaust Heat Recovery Combined Cycle
Power Generating Plants



Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.GT8-1
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.GT8-1
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	24	Gas-turbine Combined Cycle and its Accessories	
Title	System Diagram of gas Turbine Combined Cycle Plant (Single Shaft Type)			

(1) Exhaust heat recovery type compound power generation plant

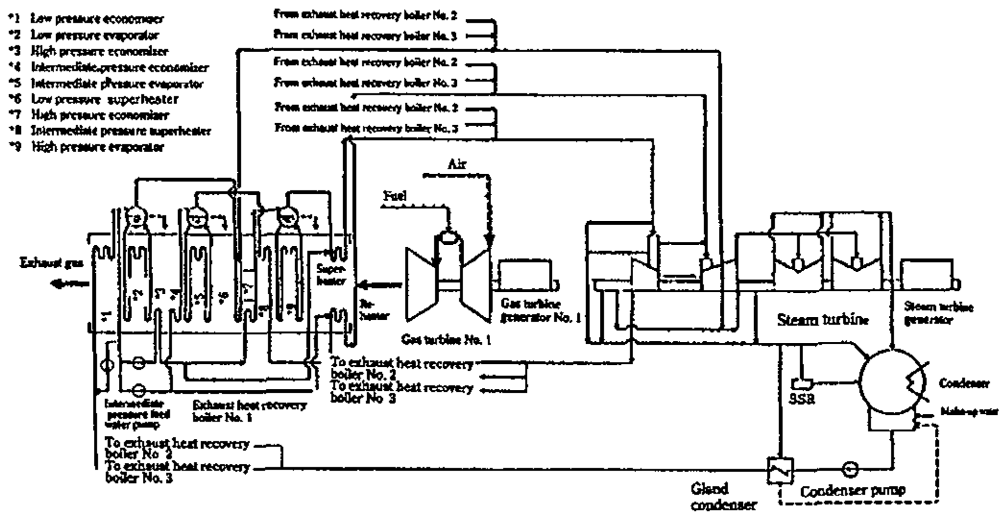


Single-shaft type

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.GT8-2
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	24	Gas-turbine Combined Cycle and its Accessories	

Title	System Diagram of Gas Turbine Combined Cycle Plant (Multo-shaft Type)

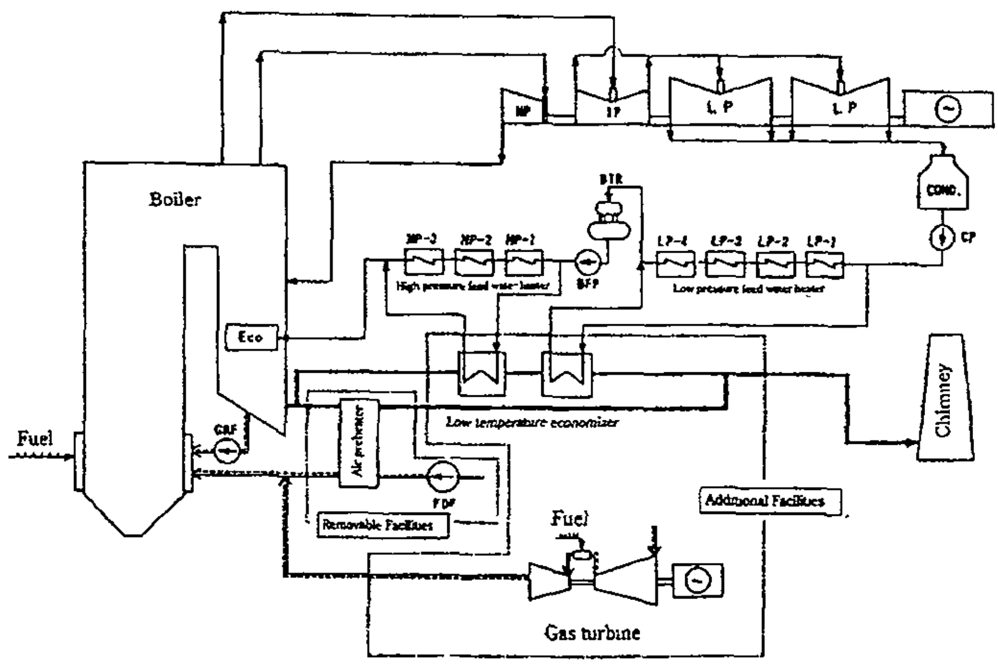


Multi-shaft type

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.GT9**
	Paragraph	3	Generating Facilities (Thermal)	
	Clause	24	Gas-turbine Combined Cycle and its Accessories	
Title	**System Diagram of Gas Turbine Combined Cycle Plant (Exhaust gas full fired Type)**			

(2) Exhaust gas fully-fired combined cycle type power plant



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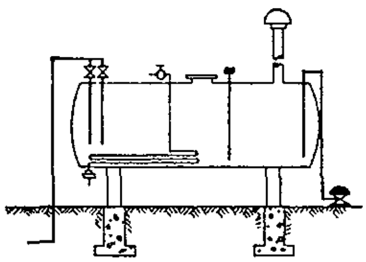
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. FL1-1
	Paragraph	3	Generating Facilities (Thermal Power)	
	Clause		Boiler Accessories	
Title	Fuel Systems (1)			

Fuel-oil Handling

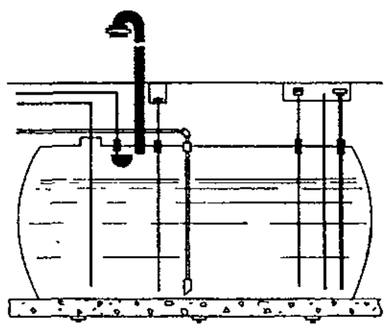
Oil delivered to a storage tank flows through a strainer on the way to the oil-pump suction. The pump discharge oil through heaters and another strainer to the burners. Straining, pumping, and heating equipment in duplicate allow cleaning while maintaining oil flow.

Oil arrives at a plant by ship, barge, tank car, or truck and is usually stored close to the unloading point. Storage tanks usually are fitted with fill pipe, vent pipe, oil gauge, steam smoothing line, sludge pumpout, manhole, low-and high-suction taps, suction heating coil, return line, and electric ground.

The steel tanks may be inside or outside the plant. Cylindrical tanks may be installed above ground or below ground or as semiburied tanks (Fig. 1)



(*a*)



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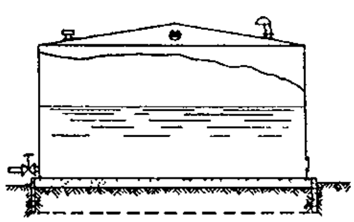


(*c*)

Fig. 1
Fuel-oil storage-tank arrangements:
(*a*) outdoors aboveground;
(*b*) underground;
(*c*) large cone-roofed tank.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	Document No.FL1-2
	Paragraph	3	Generating Facilities (Thermal Power)	
	Clause		Boiler Accessories	
Title	Fuel Systems (2)			

Bulk storage tanks and engine day tanks hold the engine fuel oil. The former receive the oil delivered to the plant and stand outdoors for safety. Pumps draw oil from the storage tank to supply the smaller day tanks in the plant at daily or shorter intervals. Large storage capacity allows purchasing fuel when prices are low. Fig.2 shows a typical tank system. Oil may be delivered by truck, or barge and tanker, with very large capacities.

Storage tanks aboveground must be surrounded by a dike to form a moat large enough to hold the tank contents if the tank should leak. Tanks must have manholes for internal access and repair, *fill lines to receive oil, vent lines to discharge vapors, sounding connections to measure content,* overflow return lines for controlling oil flow, and a suction line to withdraw oil. Coils heated by hot water or steam reduce oil viscosity to lower pumping power needs.

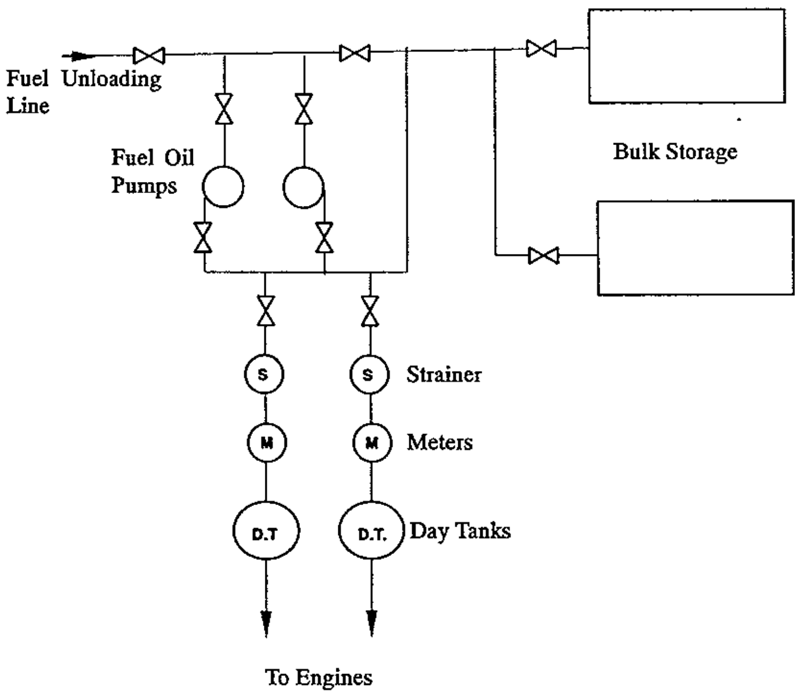
Storage and day tanks, transfer pumps, connecting piping, and injection pumps must be used to burn oil. Storage tanks usually hold at least a 2 weeks' supply.

Delivered oil sometimes holds water, dirt, metallic chips, and other foreign matter that must be removed by filtering or centrifuging. Much of this will settle out in the storage tank, especially with the lighter fuel oils and at higher temperatures. A light degree of contamination may be removed by filters, but heavier fouling requires centrifuging.

Dip-stock measurements give quick spot checks of tank contents, but meters give continuous indications. Fig.2 shows flowmeters between storage and day tanks, but not between the latter and the engines. The return line from the injection systems would make such meters useless since they would measure the gross oil pumped to the injection system, but not the net amount burned by the engine.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. FL1-3
	Paragraph	3	Generating Facilities (Thermal Power)	
	Clause		Boiler Accessories	
Title	Fuel Systems (3)			



Remarks	Revisions	
	2003/Nov.	Original

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GUIDEBOOK
FOR
POWER ENGINEERS

English Edition

VOL. No.3
HYDROELECTRIC POWER

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ELECTRICITY AUTHORITY OF CAMBODIA
ELECTRICITE DU CAMBODGE

Contents of Hydroelectric Power

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Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HG1**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	***Theoretical Water Power, Technical Water Power, Economical Water Power***			

Theoretical water power means the work done by water being dropped with a certain potential height. It is water power described with a unit of watt (W). It is calculated with the following formulas:

$P_e = 9.8 \times Q \times H_e$

$H_e = H_g - H_l$

Where,

P_e: Theoretical water power (kW)

9.8: Gravitational acceleration (m/s^2)

Q: Plant discharge (m^3/s)

H_e: Effective head (net head) (m)

H_g: Gross head (m)

H_l: Head loss (m)

Technical water power means technically feasible water power taking account of turbine efficiency and generator efficiency among theoretical water power.

Economical water power means economically feasible water power among technical water power.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HG2**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	**Gross Head, Head Loss, and Effective Head (Net Head, Rated Head)**			

Gross head is the difference in elevation between a water level at an intake and that of a powerhouse or a tailrace. The former water level is called an intake water level (*IWL*) and the latter is called tail water level (*TWL*)

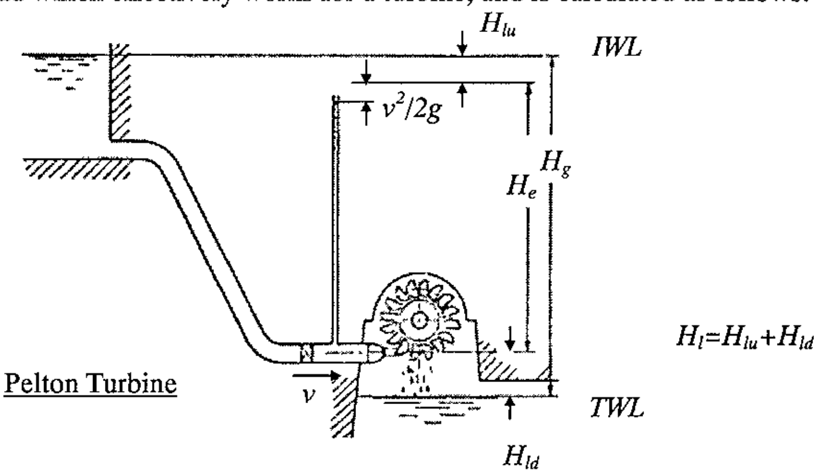
Gross head (H_g) is calculated as follows:

$$H_g = IWL - TWL$$

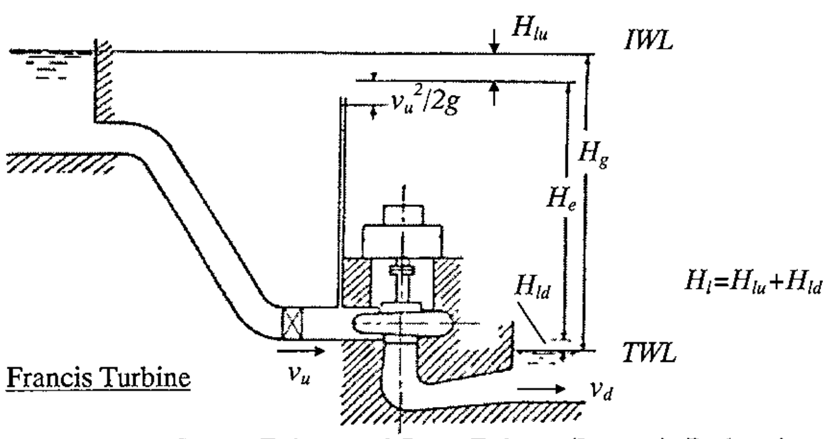
Head loss (H_l) is a loss when water flows down in a hydroelectric power system. It is the sum of head losses such as a potential head loss, a pressure head loss, and a velocity head loss of water flow.

Effective head (H_e) is a head which effectively works for a turbine, and is calculated as follows:

$$H_e = H_g - H_l$$



Pelton Turbine



Francis Turbine

Source Turbines and Pump Turbines (Japanese), Denkisyoin

Remarks	Revisions	
Turbines and Pump Turbines (Japanese), Denkishoin		
	2003/Nov	Original

Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HG3
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	**Maximum Output (Maximum Capacity) and Maximum Plant Discharge**			

Maximum output is a power output which a certain power plant is able to generate. It is often used in the same context as an installed capacity and a rated capacity of the power plant.

Maximum plant discharge is the largest water flow discharged by a power plant. It is a basis for determining an installed capacity and for designing a waterway and turbine of a power plant.

Maximum output corresponding to a maximum plant discharge is calculated with the following formula:

$$P_{max} = 9.8 \times Q_{max} \times H_e \times \eta_t \times \eta_g$$

Where,
P_{max}: Maximum output (kW)
H_e: Effective head at maximum plant discharge (m)
Q_{max}: Maximum plant discharge (m^3/s)
η_t: Turbine efficiency at maximum plant discharge
η_g: Generator efficiency at maximum plant discharge

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HG4
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	**Firm Peak Output (Firm Peak Capability, Firm Peak Power) and Firm Peak Plant Discharge**			

Firm peak output is a power output which a certain power plant is able to generate almost everyday in a year, for example 90 to 95 % of the days in a year.

Firm peak plant discharge is a water flow discharged by a power plant almost everyday in a year. It is usually a water flow which is subtracted water flows incapable of using for generation such as discharge for irrigation, fishery, tourism, and river function preservation from the water flow during drought.

Firm peak output corresponding to a firm peak plant discharge is calculated with the following formulas:

$$P_f = 9.8 \times Q_f \times H_{ef} \times \eta_{tf} \times \eta_{gf}$$

Where,
P_f: Firm peak output (kW)
H_{ef}: Effective head at firm peak plant discharge (m)
Q_f: Firm peak plant discharge (m^3/s)
η_{tf}: Turbine efficiency at firm peak plant discharge
η_{gf}: Generator efficiency at firm peak plant discharge

Firm peak output is a numerical basis for evaluating an electric power supply capability and economy of a run-off-river type hydroelectric power project. The power supply service level (non-interruption level) is set, for example, at 90 to 95 % or in some cases 98 %, depending on importance of power supply in a service area. Firm peak plant discharge is, therefore, determined to meet the above level.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	***Document* No.HG5**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	**Annually Available Generated Energy (Annually Available Energy Generation, Annually Available Energy Production)**			

Annually available generated energy means generated energy capable of one-year generation at a certain power plant assuming no forced outages and no plant outages due to inspection, maintenance, and repair works.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HG6**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	**Annual Generated Energy (Annual Energy Generation, Annual Energy Production)**			

Annual generated energy is less than annually available generated energy by a loss of generated energy caused by forced outages and plant outages due to planned inspection, maintenance and repair works.

Outage energy means energy unable to be generated due to the above plant outages.

Outage rate means the proportion of the outage energy to annually available generated energy.

The annual generated energy is calculated with the following formula.

(Annual generated energy) = (Annually available generated energy) x (1 - Outage rate)

Remarks	Revisions	
	2003/Nov	Original

Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	No.HG7
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	**Plant Factor**			

Hydroelectric power plant wastes a river water flow that is available for a plant discharge when its operation is stopped due to inspection, maintenance, and repair works. In this case, the plant is not able to generate 100 % of the annually available generated energy.

The ratio of annual energy generation to electric energy produced at continuous operation for one year at maximum output is called a plant factor.

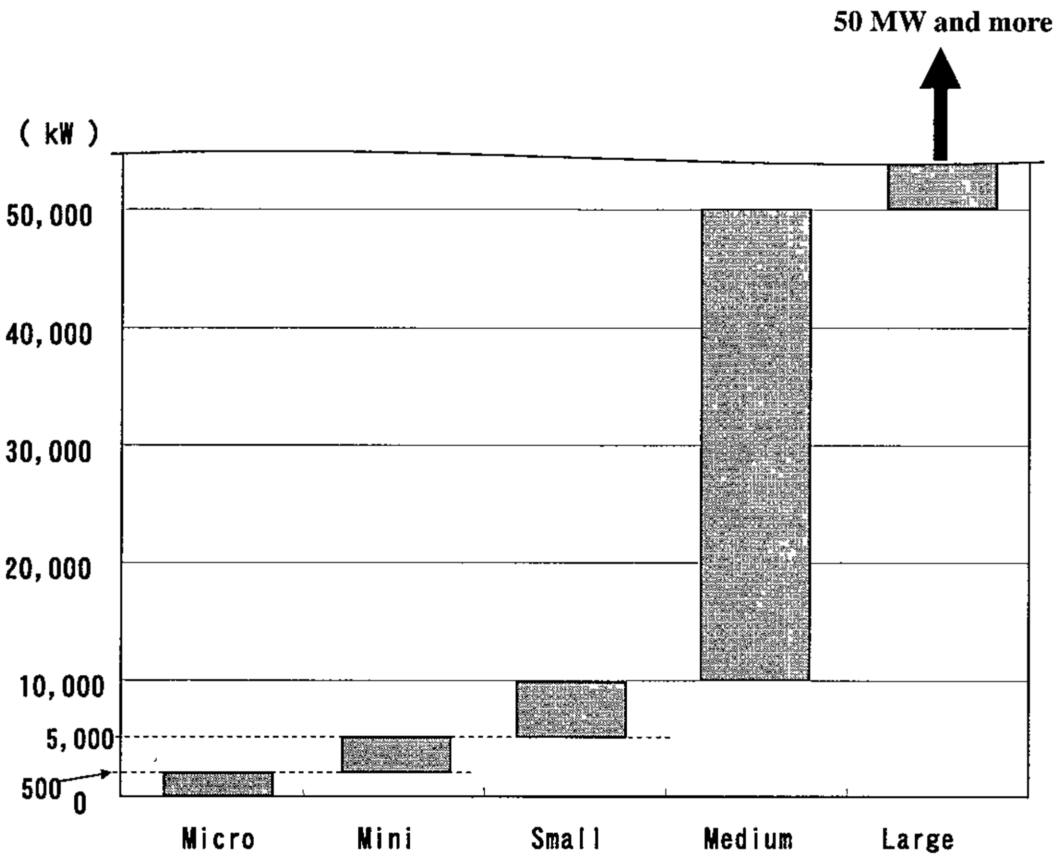
(Plant factor: %) = (Annual energy generation: kWh) / (Maximum output: kW) / 8,760 (hours) x 100

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HG8-1
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	Classification of Hydroelectric Power Plant (1)			

1. Classification by capacity in Cambodia

(1) Large: 50MW and more;
(2) Medium: 10MW and more, under 50MW;
(3) Small: 5MW and more, under 10MW;
(4) Mini: 500kW and more, under 5MW; and
(5) Micro: under 500kW.



Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HG8-2
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	Classification of Hydroelectric Power Plant (2)			

2. Classification by operational role in power system

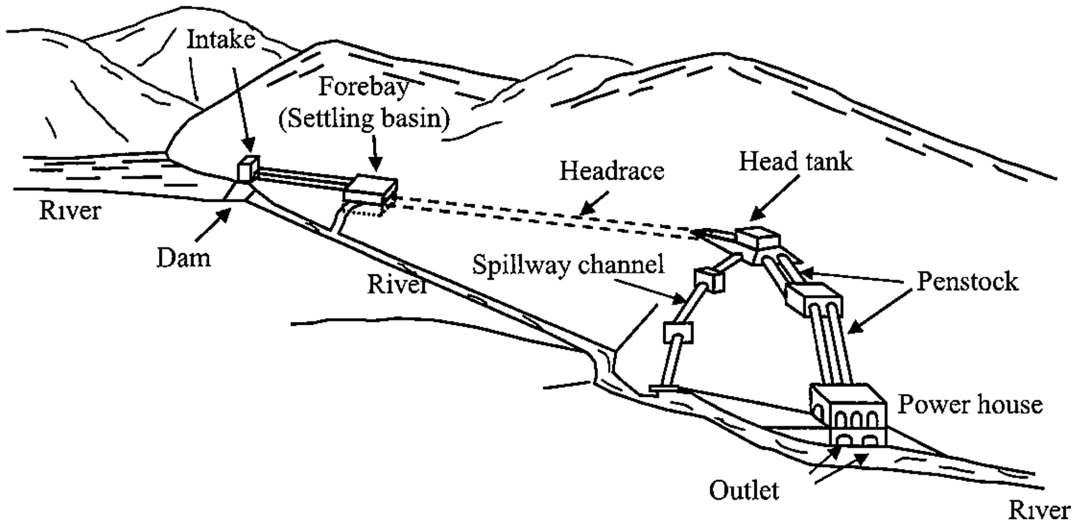
- Hydroelectric Power Plant
  - Conventional HP
    - Run-off-river Type HP
    - Regulating Pond Type HP
    - Reservoir Type HP
  - Pumped Storage HP
    - Recirculating Pumped Storage Type HP (Pure Pumped Storage Type HP)
    - Multiple-use Pumped Storage Type HP (Pumped and Natural Flow Storage Type HP)

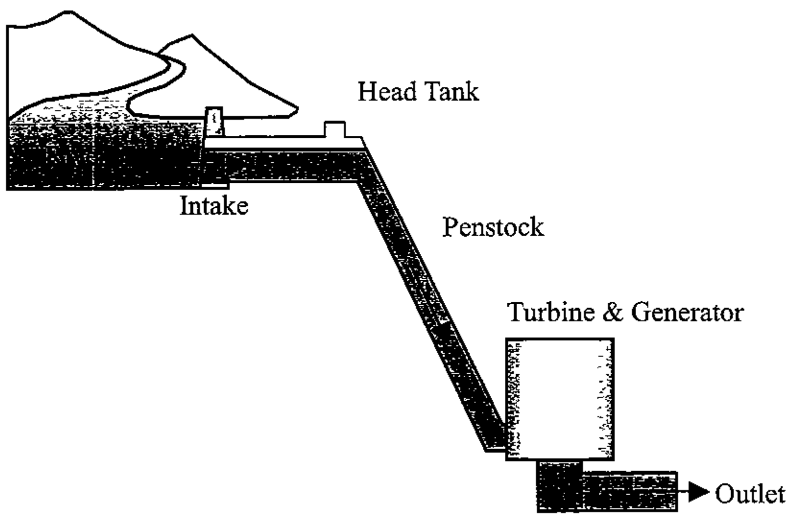
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HG8-3
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	Classification of Hydroelectric Power Plant (3)			

2-1 Conventional HP

2-1-1 Run-off-river type

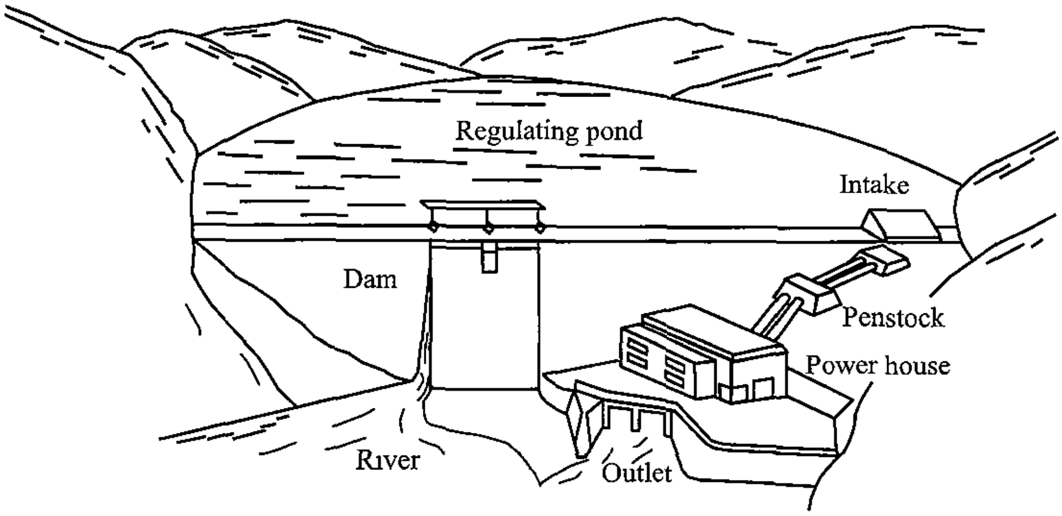


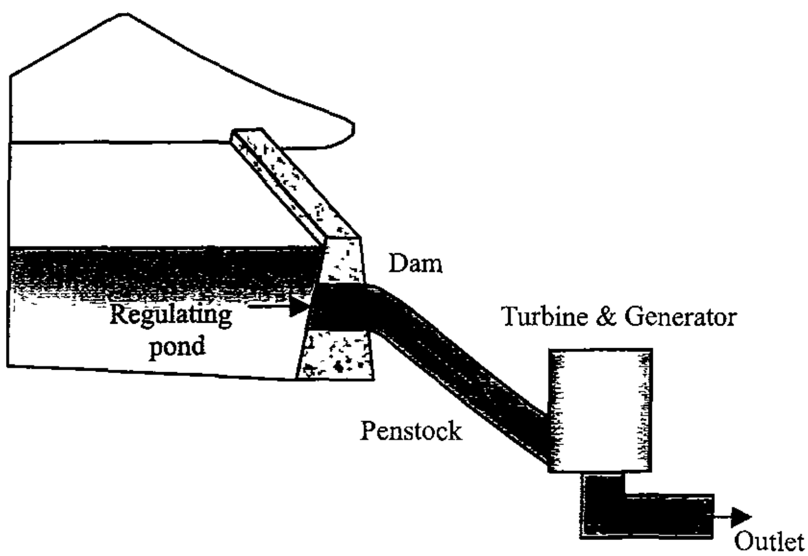


Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.HG8-4
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	**Classification of Hydroelectric Power Plant (4)**			

2-1-2 Regulating pond type

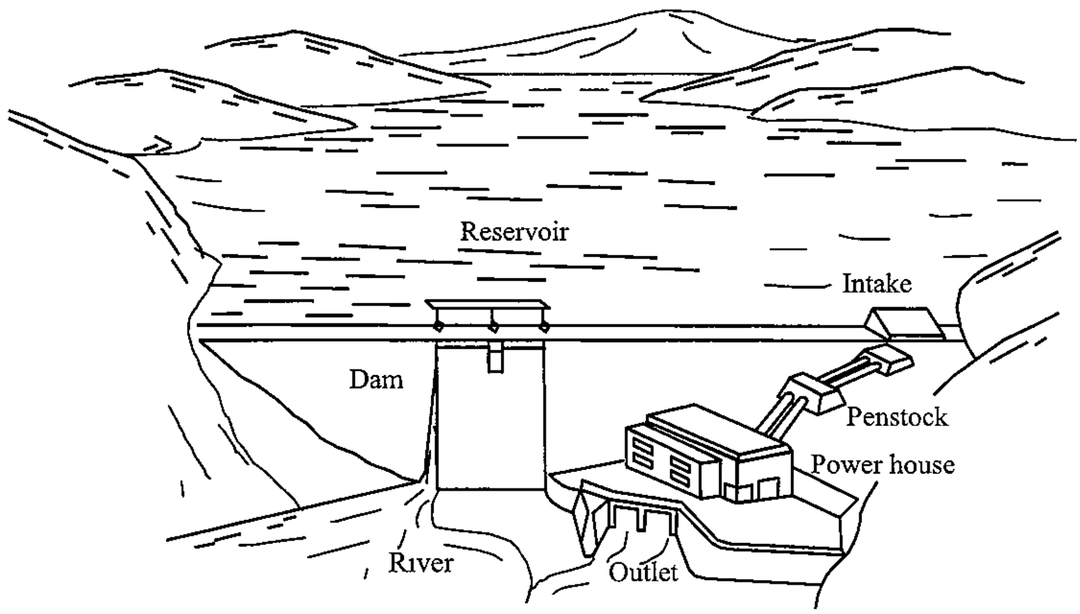


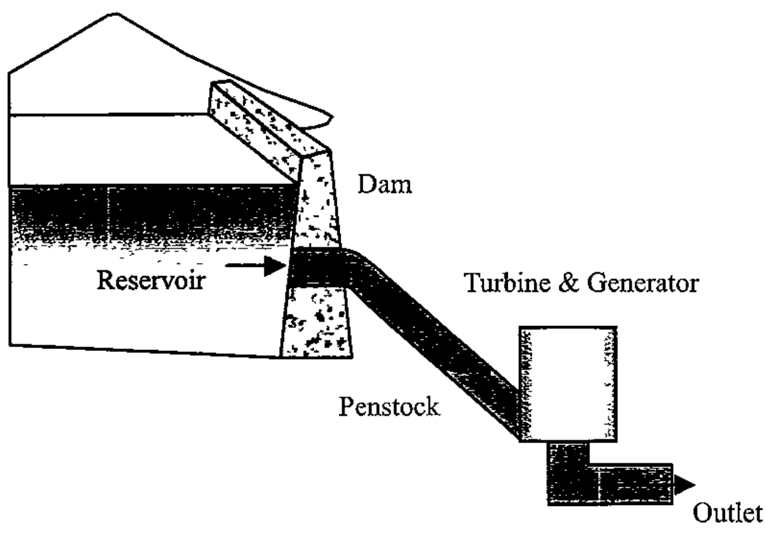


Remarks	Revisions	
	2003/Nov.	Original

Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	No.HG8-5
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	Classification of Hydroelectric Power Plant (5)			

2-1-3 Reservoir type



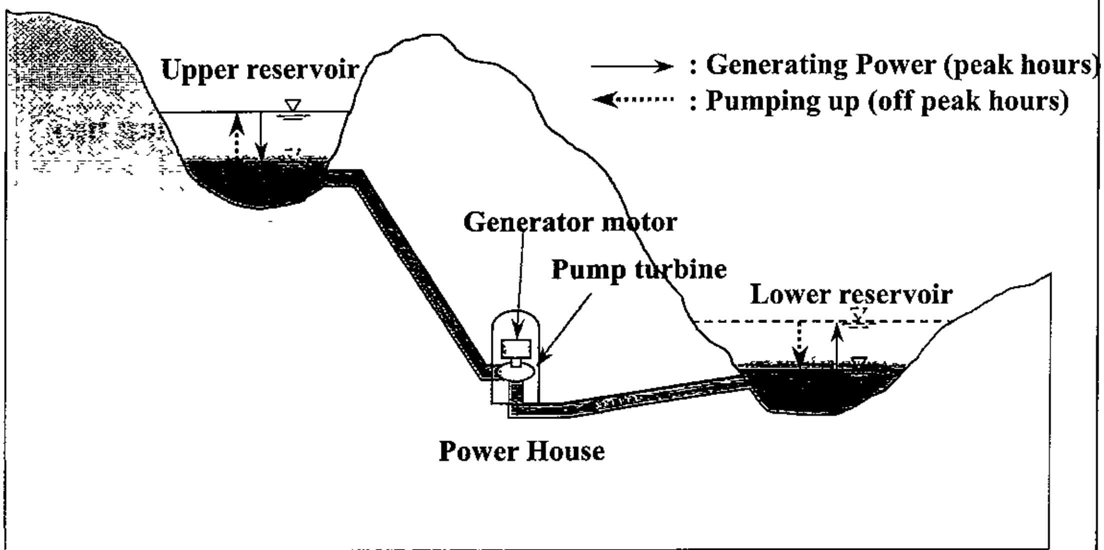


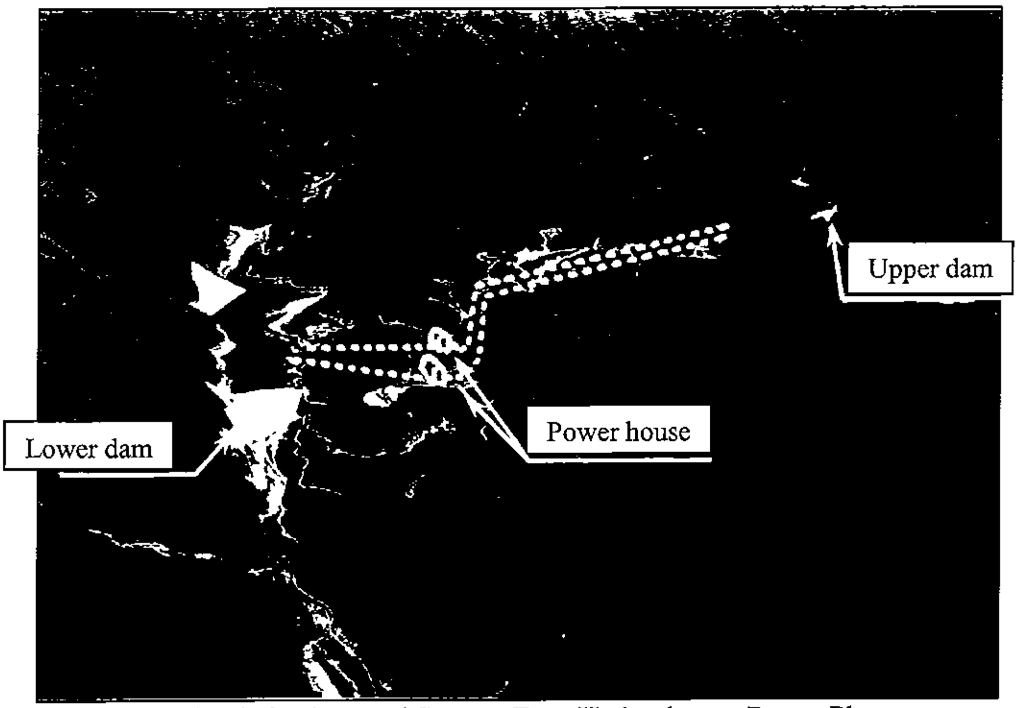
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HG8-6
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	Classification of Hydroelectric Power Plant (6)			

2-2. Pumped Storage Type

2-2-1 Recirculating pumped storage type (pure pumped storage type)





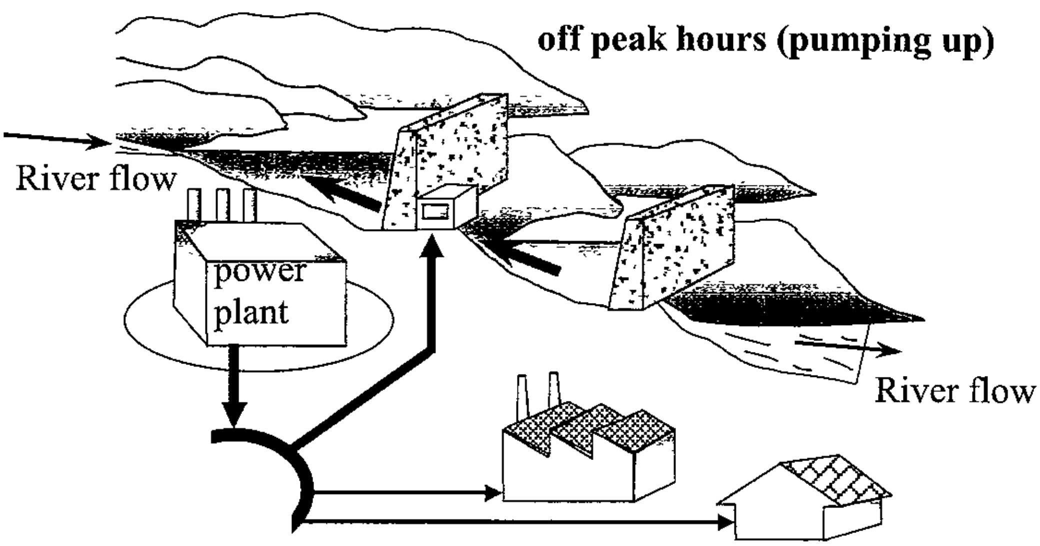
Recirculating Pumped Storage Type Hydroelectric Power Plant

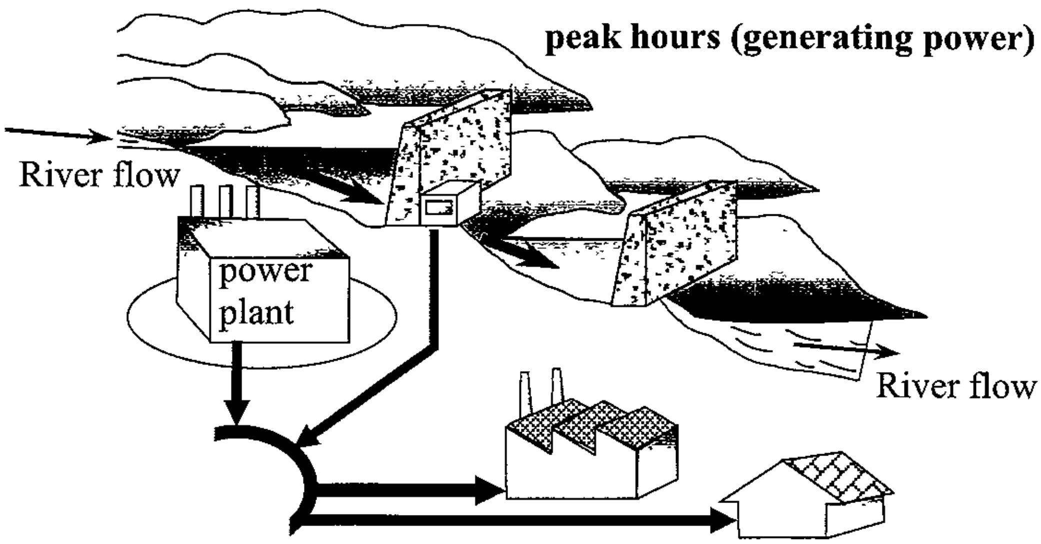
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HG8-7
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	Classification of Hydroelectric Power Plant (7)			

2-2-2 Multiple-use Pumped Storage Type (Pumped and natural flow storage type)

Multiple-use Pumped Storage HP is a combination of a Conventional HP and a Recirculating Pumped Storage HP



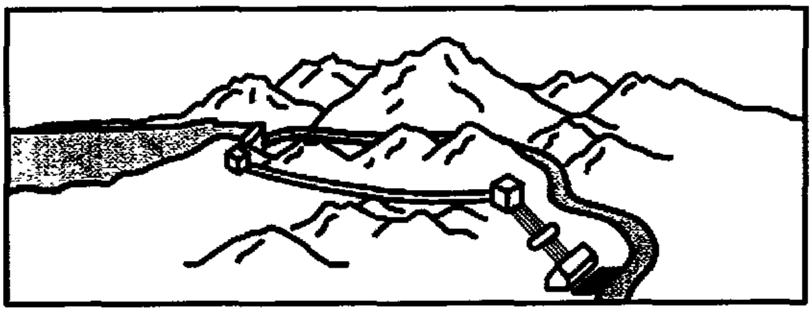


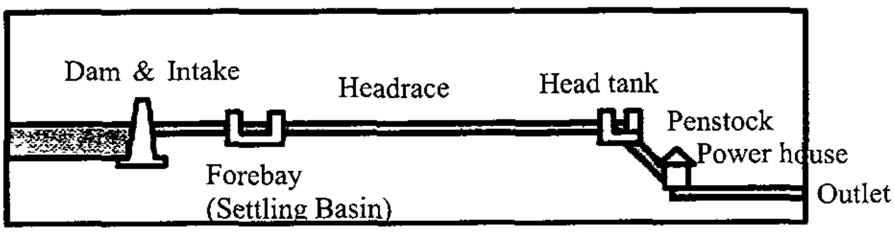
Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.HG8-8
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HG8-8
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	Classification of Hydroelectric Power Plant (8)			

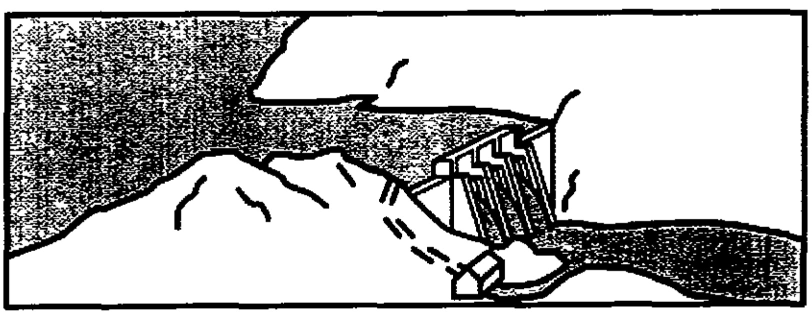
3. Classification by method of water head acquisition

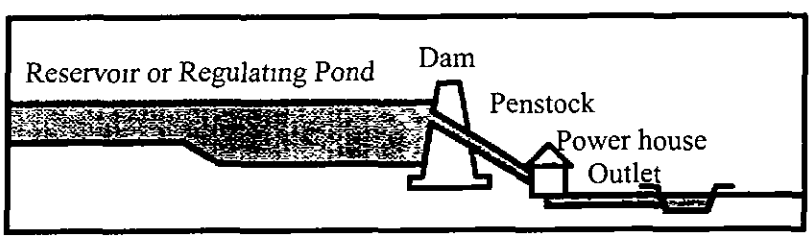
3-1 Waterway type





3-2 Dam type

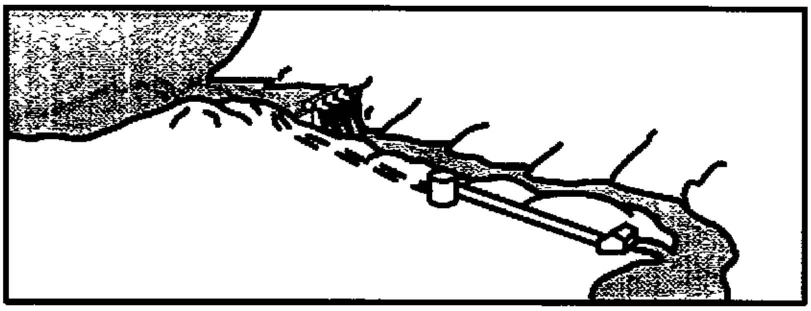


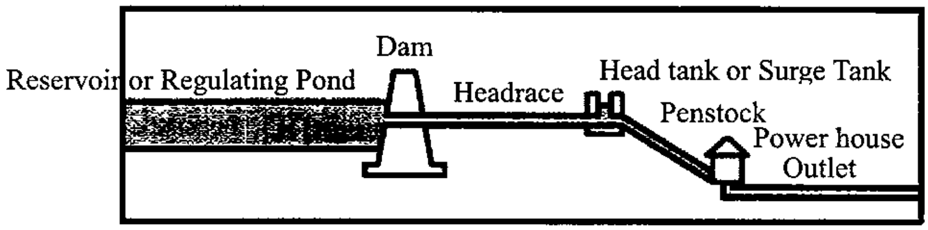


Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HG8-9**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	**Classification of Hydroelectric Power Plant (9)**			

3-3 Dam and waterway type





Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HG8-10
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	Classification of Hydroelectric Power Plant (10)			

4. Classification by regulation procedures

According to the "Sub-decree on Environmental Impact Assessment Process", hydroelectric power plant projects with capacity 1 MW and more are required the Initial Environmental Impact Assessment (IEIA) procedures. Furthermore, the Environmental Impact Assessment (EIA) procedures are required if the projects are crucial for environment.

Remarks	Revisions	
Sub-decree on Environmental Impact Assessment Process (August 11, 1999)		
	2003/Nov.	Original

Category				Document No.HG9
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	Planning of Hydroelectric Power Development			

Outline of planning of hydroelectric power development is as follows;

1. Plant configuration

- Selection of dam and power house site

  To select dam site and power house site (or outlet site) in consideration of the river flow, topography, and geology of the planned river area;

- Layout of waterways and roads

  To draw a route and layout of the waterways and roads for construction and maintenance such as intake, forebay, headrace, head tank or surge tank, penstock, tailrace, and outlet in consideration of the topography and geology,

2. Maximum plant discharge

To set the maximum plant discharge on the basis of the river flow at the dam site/sites;

3. Calculation of power output and energy generation

To calculate the power output and energy generation from the product of the discharge multiplied by the head between the intake/intakes and the power house in consideration of head losses;

4. Construction cost estimates

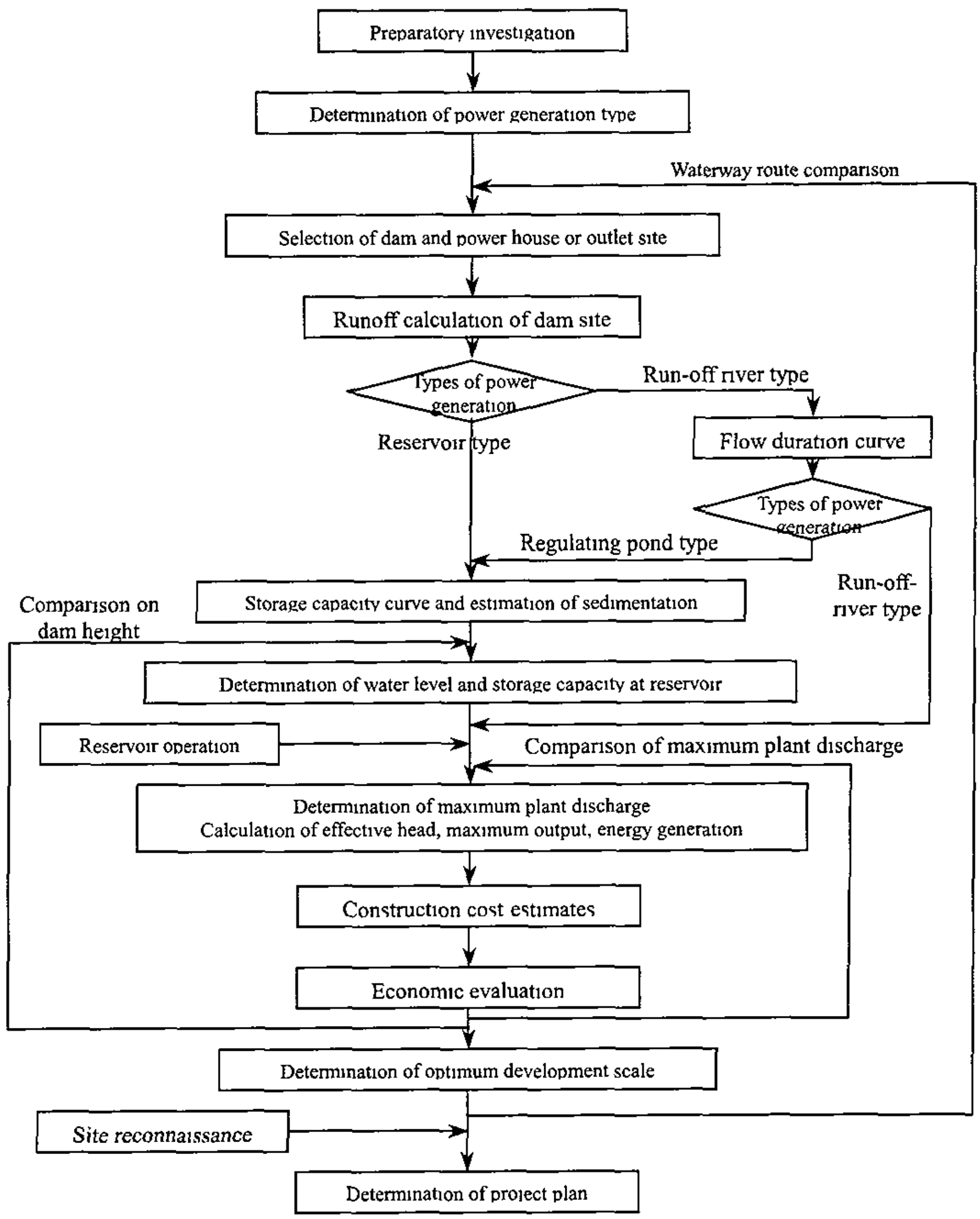
To estimate the construction cost of the dam, waterway, powerhouse, and other civil works and the turbine, generator and other electric facilities, thereby obtaining the construction cost for the entire project.

5. Evaluation of the project

To study and evaluate the project from the aspects of engineering, economy, and environment then to complete the plan.

Remarks	Revisions	
	2003/Nov	Original

Category				Document No.HG10
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	**Flow Chart for Hydroelectric Power Planning**			



Remarks	Revisions	
Guide Manual for Development Aid Programs and Studies of Hydro Electric Power Projects, 1996, New Energy Foundation		
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HG11
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	**Important Data for Planning of Hydroelectric Power Plant**			

Important and essential data required in planning hydroelectric power plant are topographic maps and runoff data. Other data such as hydrology, meteorology, and geology are also important data for the planning and feasibility study on hydroelectric power plant.

1. Topographic maps
Plant discharge of hydroelectric power plant is determined by the river flow available at the dam site. The watershed (or catchment) area is necessary for calculation of the river flow. The head is determined by the difference in elevation between the water level at intake and that at outlet. The waterway route connecting these sites is determined from topographic maps.

Topographic maps are required to compute the watershed (or catchment) area and the head. If available, the more accurate the maps are, the more reliable study or planning is conducted.

2. Runoff data
The most important and essential data for drawing up a hydroelectric power development is runoff data because it is basis of energy production of a hydroelectric power plant that affects feasibility of the power plant particularly economy. It is necessary that the runoff data be observed at the dam site or adjacent to the dam. If river flow is not recorded in the project site or nearby, it is necessary to prepare runoff data of the project site using data available, including runoff data of adjacent rivers.

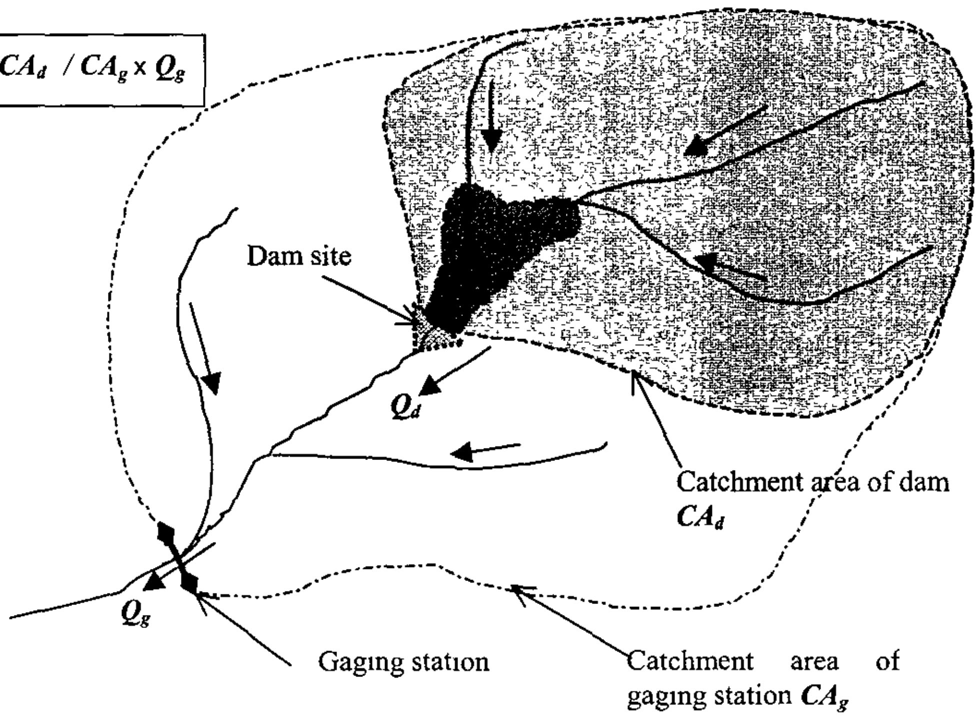
The runoff data shall be observed and recorded by installing river flow gaging stations for a long period enough to plan and study the hydroelectric power plant.

3. Other important data
- Hydrological data
- Meteorological data
- Geological data
- Data concerning power demand, power supply, and transmission line to the power plant
- Master plan of river basin development
- Environmental laws and regulations
- Existing vested water utilization rights and licenses
- Data concerning construction cost
etc.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HG12**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	-	General	
Title	**Relation between Runoff of Dam Site and that of Gaging Station**			

$$Q_d = CA_d \ / CA_g \times Q_g$$



Relation between runoff of dam site and that of gaging station

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD1-1**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Reservoirs (1)**			

This standard do not make any differences in reservoirs, regulating ponds, and ponds. "Reservoir" means a general term for reservoirs, regulating ponds, and ponds that mean stored water impounded by one or more dams, or land on which the water is impounded to the largest water storage in this standard.

1. Reservoir

Reservoir is a large pond in water storage capacity. It is capable of regulating seasonal fluctuation of river flow according to annual schedule of the plant operation.

River flow fluctuates significantly throughout the course of one year. Plant discharge can be increased by storing surplus water in a wet season and then the stored water can be released in a dry season. Thus, a relatively equalized discharge can be obtained and stable electric power supply can be done.

2. Regulating Pond

Regulating pond is also a large pond in water storage but generally smaller than a reservoir. It is capable of regulating water flow for daily or weekly plant operation.

River flow fluctuates greatly by season but does not change largely in the course of one day or week. On the other hand, power demand does change sharply in a day or a week. Regulating pond regulates water flow for a day or a week by storing water when the demand is low in the middle of the night or on Sunday, and then using it at peak load time.

3. Pond

Pond is a very small reservoir in water storage capacity with a small and low dam so called a weir. It is not capable of regulating water flow for power generation even for daily plant operation. Thus, a hydroelectric power plant with only a pond or ponds generates electricity just corresponding to a water flow normally less than the natural river flow. This type of power plant is called a run-off-river type hydroelectric power plant.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD1-2
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Reservoirs (2)**			

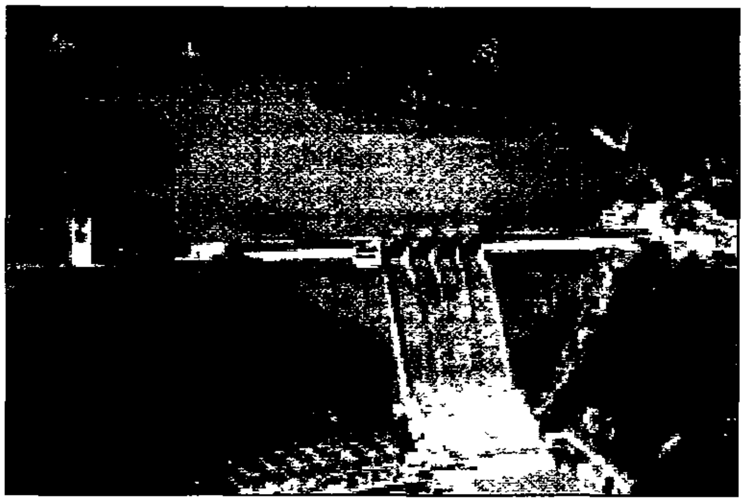
Reservoirs shall meet the following:

1. In case of large reservoirs installation, the permeability of surrounding ground and possibility of landslides shall be investigated. Particularly, narrow ridges and landslide areas shall be sufficiently investigated; and
2. Water sealing measures and countermeasures against landslides shall be taken so that installation of reservoirs may not cause harmful water leakage through the surrounding ground, seepage failure of surrounding ground, and landslides.

Remarks	Revisions	
	2003/Nov.	Original

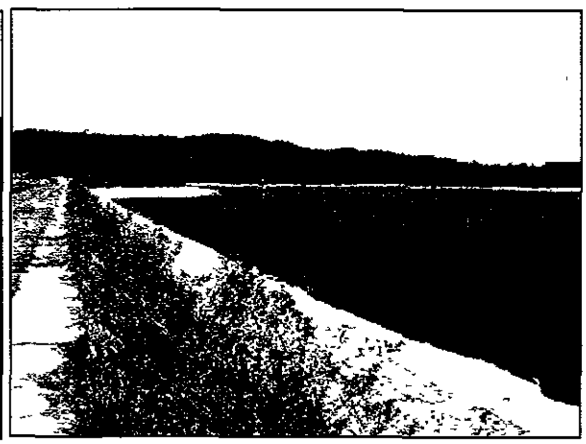
Category				Document No.HD1-3
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	Reservoirs (3)			

1. Reservoir



Reservoir

O Chum 1 Reservoir

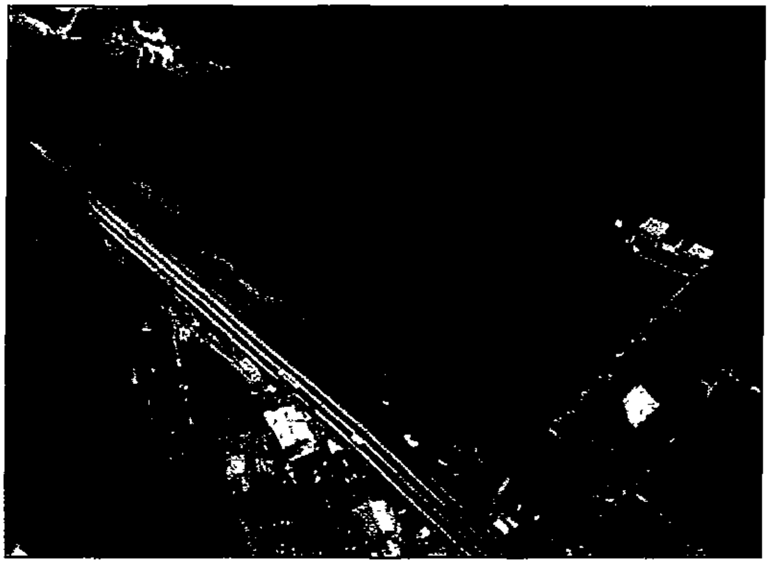


Kirirom 1 Reservoir

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD1-4**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Reservoirs (4)**			

2. Regulating Pond



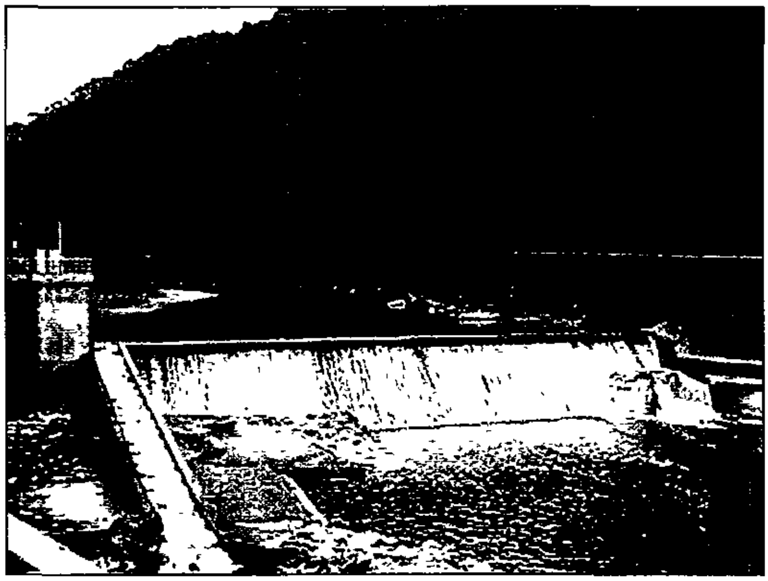
Regulating pond

O Chum 2 Regulating pond

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD1-5
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	Reservoirs (5)			

3. Pond



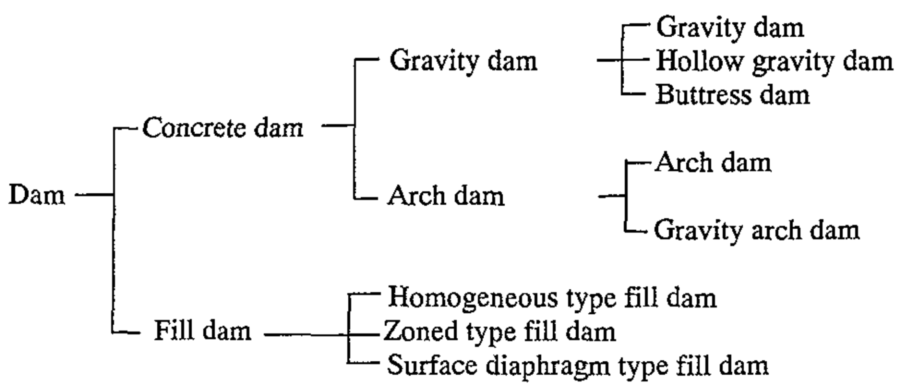
Pond

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD2-1**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Dam types (1)**			

1. The following dam types shall be adopted for dams in principal in order to meet the Standard:
(1) Concrete dams such as gravity dams and arch dams; and
(2) Fill dams.
2. In case dams are structurally stable and safe, the above Section 1 may not apply.

Classification of Dam Type

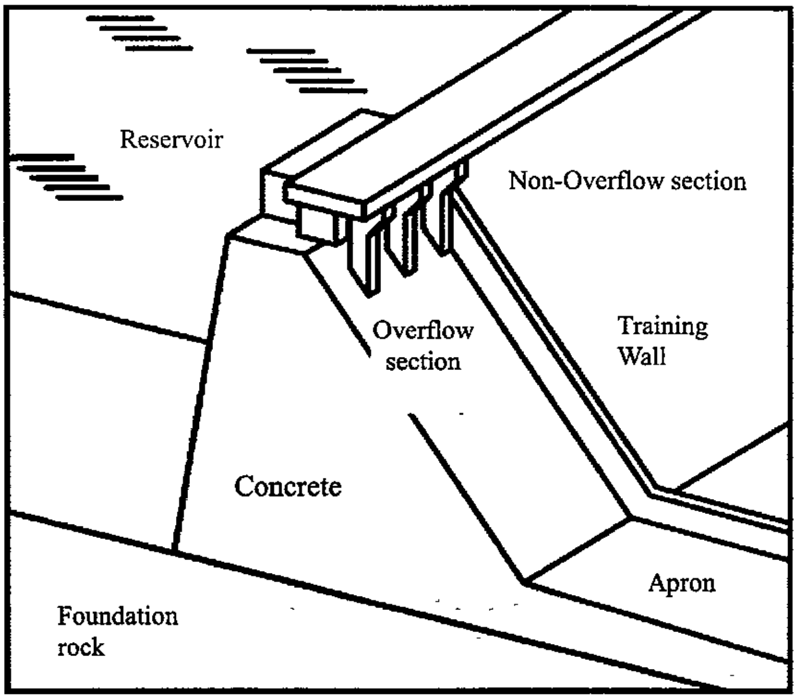


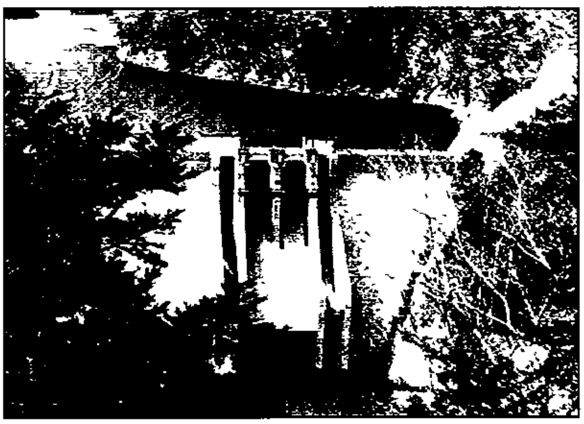
Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.HD2-2
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Dam types (2)**			

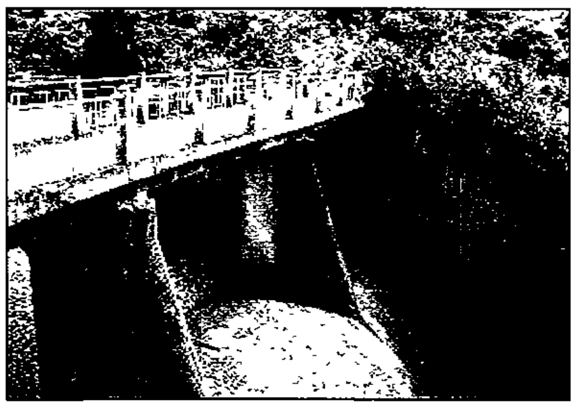
Examples of Concrete Dam

1. Concrete Gravity Dam





Concrete Gravity Dam

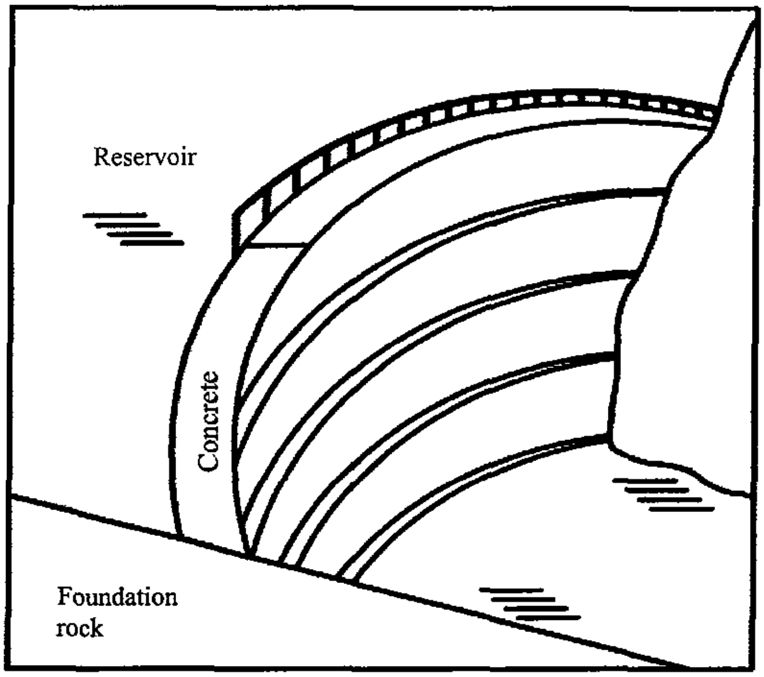


O Chum 2 dam

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD2-3
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	Dam types (3)			

2. Concrete Arch Dam

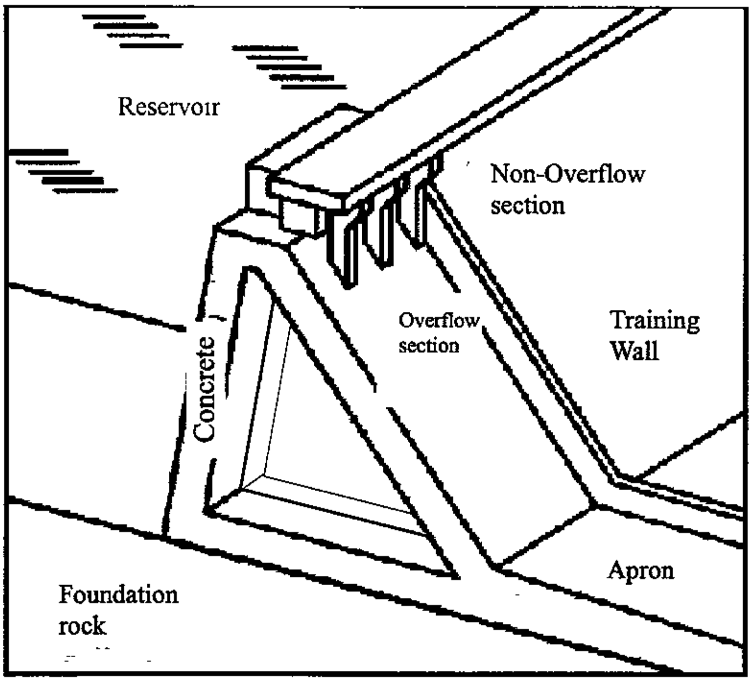


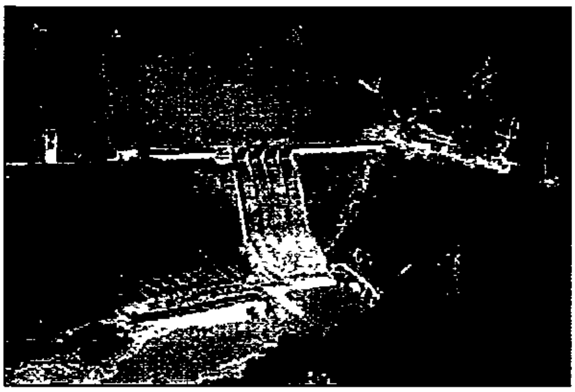
Concrete Arch Dam

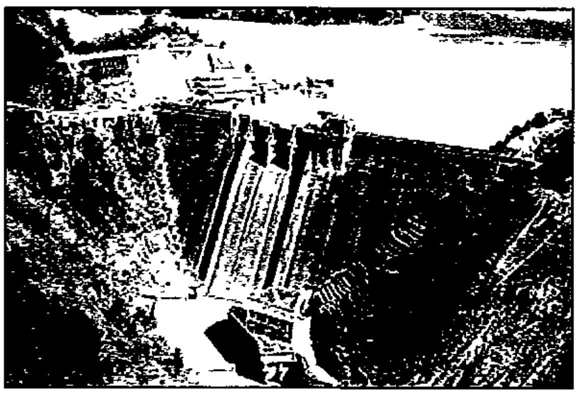
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD2-4
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	Dam types (4)			

3. Concrete Hollow Gravity Dam







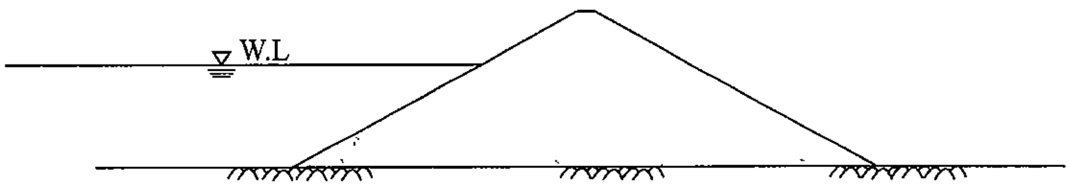
Concrete Hollow Gravity Dam

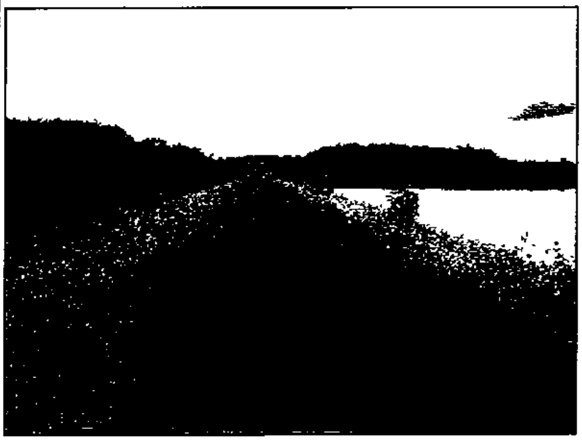
Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.HD2-5
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Dam types (5)**			

Examples of Fill Dam

1. Homogeneous Type Fill Dam





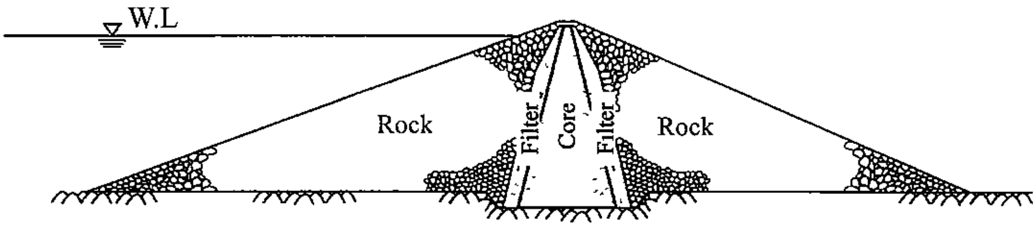
O Chum 1 dam

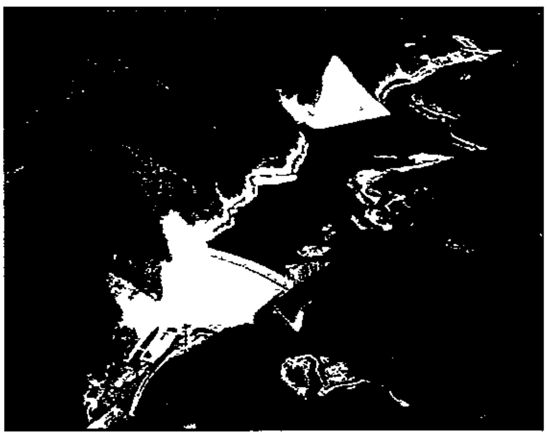
Kirirom 1 dam

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD2-6
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	Dam types (6)			

2. Zoned Type Fill Dam





(Arial view)

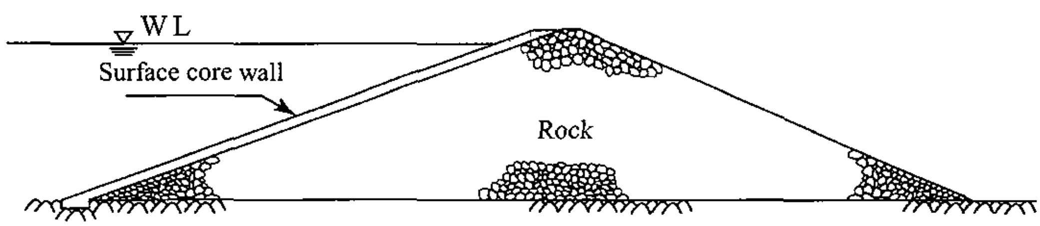
(View from the downstream)

Zoned Type Fill Dam

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD2-7**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Dam types (7)**			

3. Surface Diaphragm Type Fill Dam



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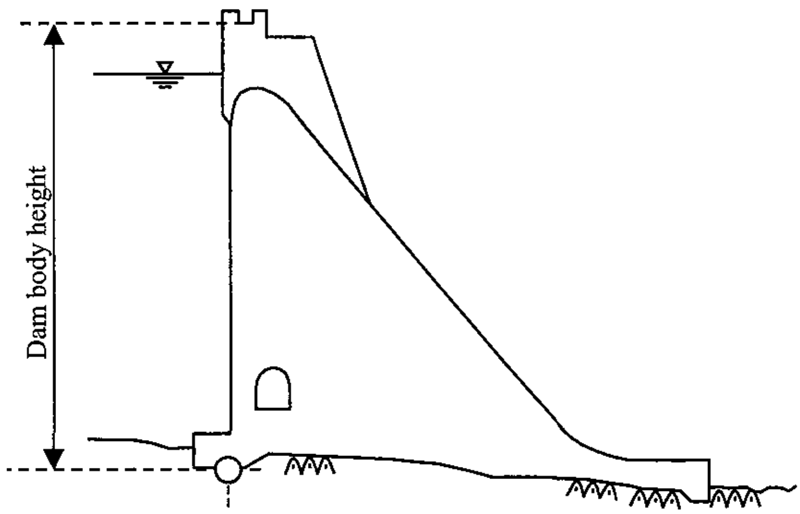
Surface Diaphragm Type Fill Dam

Remarks	Revisions	
http://www2u.biglobe.ne.jp/~damu/photo/library/kobuchi.jpg		
	2003/Nov.	Original

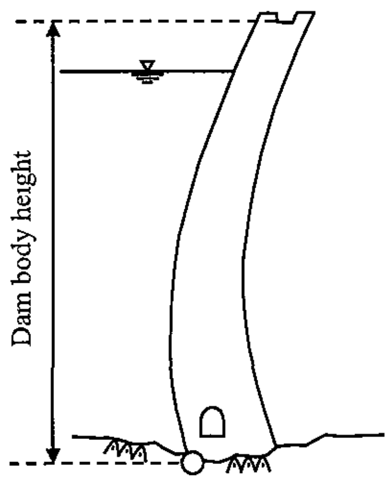
Category				Document No.HD3-1
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	Dam Body Height (1)			

"Dam body height" means a difference in elevation between the lowest part of dam body foundations and the crest of the non-overflow section of the dam body.

Definition of Dam Body Height by dam type.



1. Concrete Gravity Dam

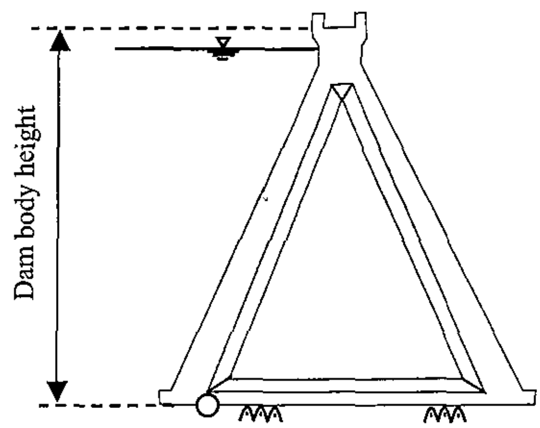


2. Concrete Arch Dam

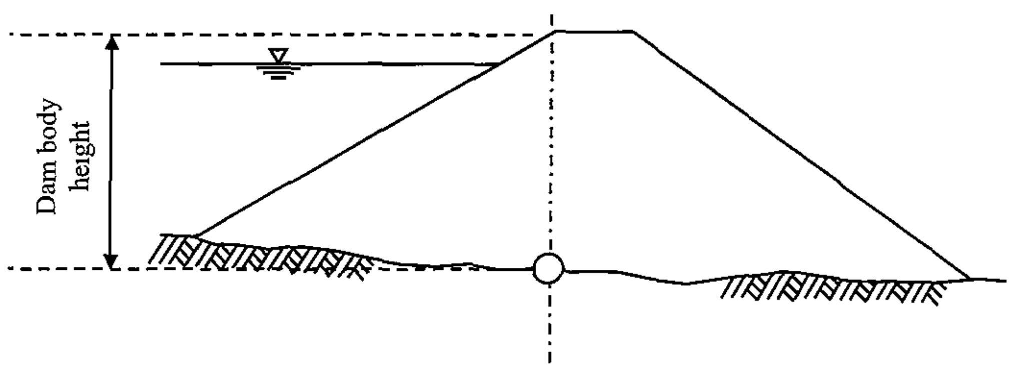
Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD3-2**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Dam Body Height (2)**			

Definition of Dam Body Height by dam type (cont.)



3. Concrete Hollow Gravity Dam

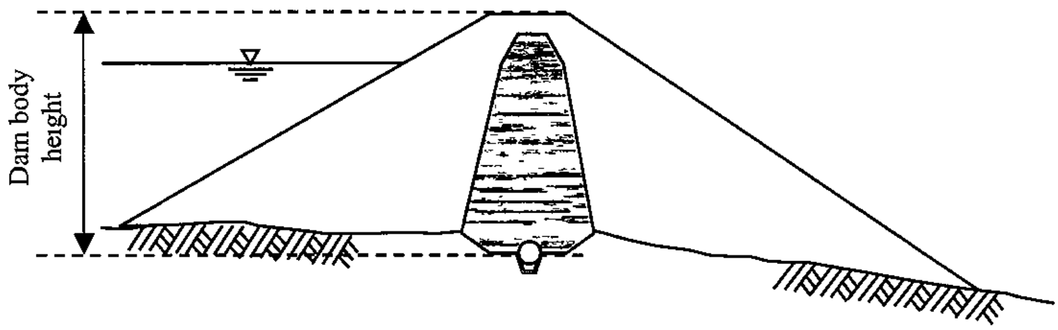


4. Homogeneous Type Fill Dam

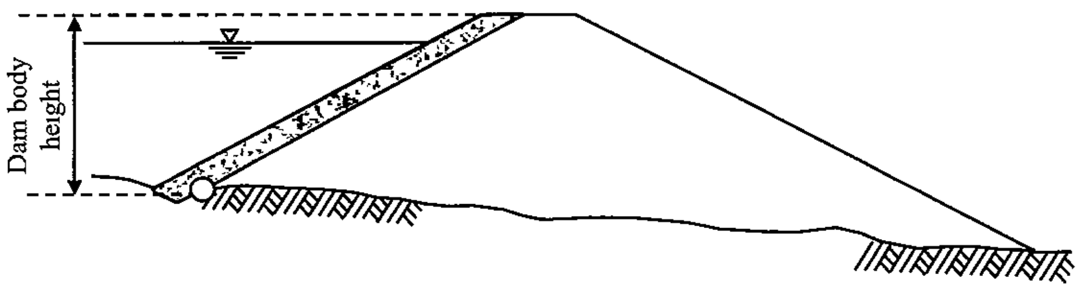
Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD3-3**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Dam Body Height (3)**			

Definition of Dam Body Height by dam type (cont.)



5. Zoned Type Fill Dam



6. Surface Diaphragm Type Fill Dam

Remarks	Revisions	
	2003/Nov	Original

Category				Document No.HD4-1
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Inflow Design Flood (1)**			

Inflow design flood shall be properly set for every dam based on hydrological observation, research, and study, taking account of the impacts caused by dam failure to human safety, properties, economy, environment and so on.

Examples of inflow design flood, in Japan, U.S.A, and China.

1. Japan (Example of "Ministerial Ordinances on Regulating Technical Standards Related to Hydropower Stations, JFY1998")

Inflow design flood for dams with the height 15m or more shall be the maximum flood among the following three methodologies:

(1) The flood expected to occur once every 200 years at the direct upstream of the dam. In case the flow derived from this calculation is inappropriate in terms of the calculation method, 1.2 times of the flood expected to occur once every 100 years should be applied;

(2) The maximum flood ever experienced at the direct upstream of the dam; and

(3) The flood estimated on the basis of hydrological or meteorological data for the largest floods that occurred in the watershed where the dam is to be built and another watershed with similar hydrological or meteorological properties to the watershed.

1.2 times larger flood than the above maximum flood is applied as an inflow design flood of a fill dam.

Inflow design flood which is the flood expected to occur once every 100 years at the direct upstream of the dam, shall be applied to dams lower than 15m in height without purpose of flood control.

2. U.S.A.

Example of "Civil Engineering Guidelines for Planning and Designing Hydroelectric Development" American Society of Civil Engineers

Hazard level	Size of dam	Design flood discharge
Low	Small	50-year to 100-year flood
	Intermediate	100-year flood to 1/2 PMF
	Large	1/2 PMF to PMF
Significant	Small	100-year flood to 1/2 PMF
	Intermediate	1/2 PMF to PMF
	Large	PMF
High	Small	1/2 PMF to PMF
	Intermediate	PMF
	Large	PMF

Remarks	Revisions	
- Ministerial Ordinances on Regulating Technical Standards Related to Hydropower Stations, 1998, Japan - *Civil Engineering Guidelines for Planning and Designing* Hydroelectric Development, American Society of Civil Engineers		
	2003/Nov.	Original

Category				
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD4-2
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Inflow Design Flood (2)**			

U.S.A (cont.)

Hazard level classifications:

Hazard level	Explanation
Low	No loss of life expected because no permanent structures for human habitation exist downstream of the dam. Minimal economic loss is expected because the area is undeveloped, or has only occasional structures for agricultural or other use.
Significant	Few deaths expected, due to lack of concentrated (urban) development and few habitable structures. Economic loss would be appreciable due to significant agricultural or industrial development.
High	Numerous deaths expected. Excessive property damage to communities, industry or agriculture.

Dam size classifications:

Category	Reservoir capacity (acre-feet)	Height of the dam (feet)
Small	between 50 and 1,000 ($0.062 \sim 1.23 \times 10^6 m^3$)	between 25 to 40 (7.62 ~ 12.2 m)
Intermediate	between 1,000 and 50,000 ($1.23 \sim 61.7 \times 10^6 m^3$)	between 40 to 100 (12.2 ~ 30.5 m)
Large	more than 50,000 ($61.7 \times 10^6 m^3$)	more than 100 (30.5m)

3. China

Inflow Design Flood

Annual Exceedance Probability (unit: years)

Structure ranking		1	2	3	4	5
Normal operation	Permanent Structure	500	100	50	30	20
Emergency operation	Earth dam, rock fill dam, masonry dam with fine materials	10,000 or PMF	2,000	1,000	500	200
	Concrete dam, masonry dam with coarse materials, and other river structure	5,000	1,000	500	200	100

In case a dam with a large reservoir whose collapse may result in a relatively large disaster to the downstream area, and a fill dam with an important intermediate scale reservoir or an extremely important small reservoir, PMF shall be applied as an inflow design flood under emergency

Remarks	Revisions	
Civil Engineering Guidelines for Planning and Designing Hydroelectric Development, American Society of Civil Engineers		
	2003/Nov.	Original

Category			Document No.HD4-3
	Chapter	2	Technical Standards of Electric Power Facilities
	Paragraph	3	Generating Facilities (Hydroelectric Power)
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities
Title	**Inflow Design Flood (3)**		

China (cont.)

Structure ranking

Project ranking	Permanent structure ranking		Temporary structure ranking
	Major structure	General structure	
I	1	3	4
II	2	3	4
III	3	4	5
IV	4	5	5
V	5	5	-

Prescribed in GB50199

Project ranking

Project ranking	Storage capacity (10^6m^3)	Hydro-electric power plant	Flood control		Counter-measure against flooding	Irrigation	Water service
		Installed capacity (MW)	Urban and industrial area	Farmland (10^3ha)	Drainage area (10^3ha)	Irrigation land area (10^3ha)	City water and mine industry
I	>1,000	>750	Very important	>333	>133.3	>100	Very important
II	1,000~100	750~250	Important	333~67	133.3~40	100~33.3	Important
III	100~10	250~25	Intermediate	67~20	40~10	33.3~3.3	Intermediate
IV	10~1.0	25~0.5	Normal	20~3.3	10~2.0	3.3~0.3	Normal
V	<1.0	<0.5	-	<3.3	<2.0	<0.3	-

Prescribed in GB50199

Remarks	Revisions	
GB50199, China		
	2003/Nov.	Original

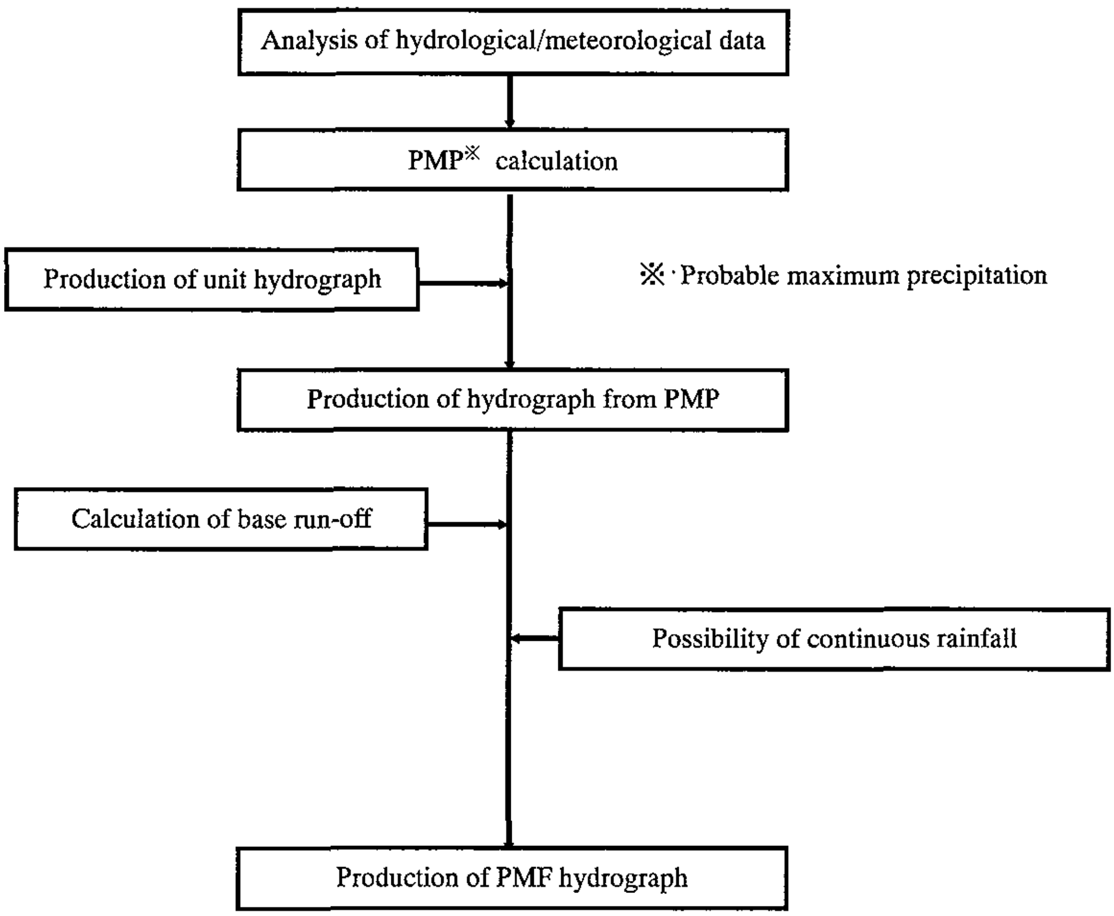
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD5
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	PMF (Probable Maximum Flood)			

PMF (Probable Maximum Flood)

PMF is generally defined as flood expected when the theoretically worst hydrological and meteorological conditions are combined in an area.

It is necessary to consider the two factors of "run-off due to rainfall" and "base run-off" that form PMF. It is also necessary to examine the possibility of rainfall occurring in a few day intervals.

A flow chart of PMF calculation is described as follows.



Flow of PMF calculation

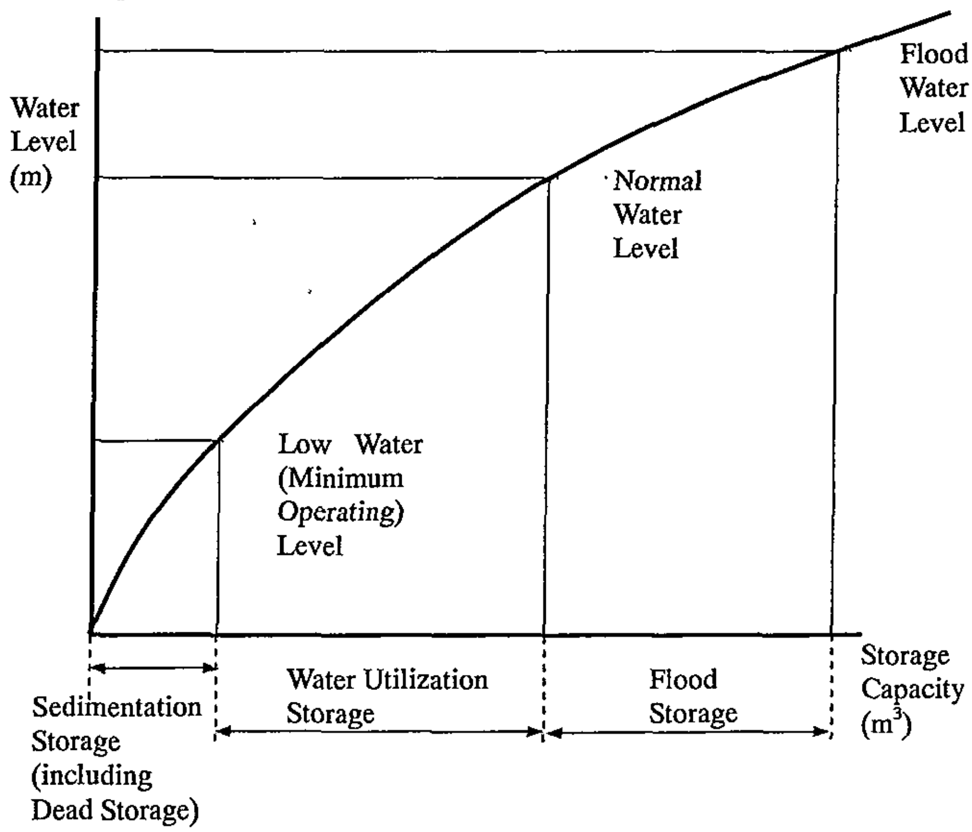
Remarks	Revisions	
	2003/Nov.	Original

Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD6
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Basic Water Levels**			

Basic water levels, on which the specifications of dams are to be determined, shall be set as follows:

1. "Normal Water Level" shall be the highest level of water stored in a reservoir of a dam during a non-flood period;
2. "Flood Water Level" shall be the highest water level when an inflow design flood flows over a spillway. In the case that the storage effect of a reservoir is obviously identified, the flood water level may be the water level deducted the height in consideration of the storage effect from the highest water level; and
3. "Low Water Level" shall be the lowest level of water stored in a reservoir of a dam under normal reservoir operation.

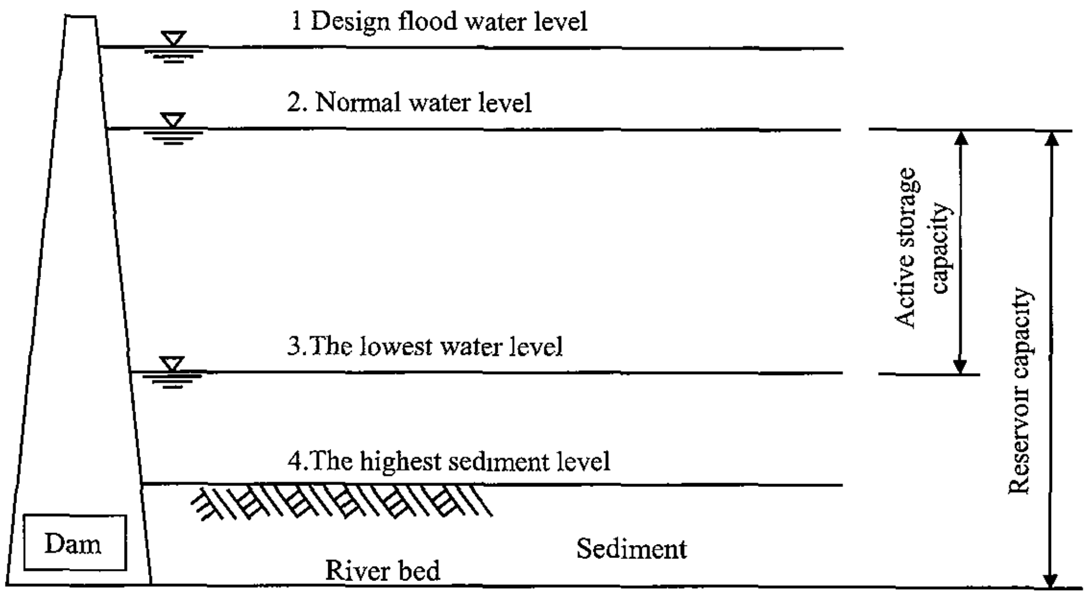
Example of Basic Water Level



Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.HD7
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Examples for Reservoir Water Level**			

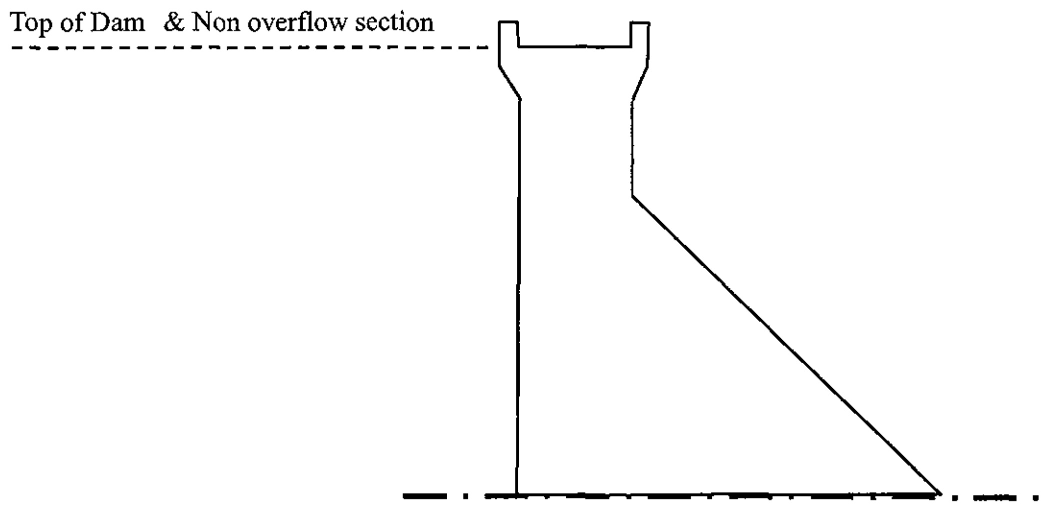
1. Design flood water level
2. Normal water level
3. The lowest water level
4. The highest sediment level



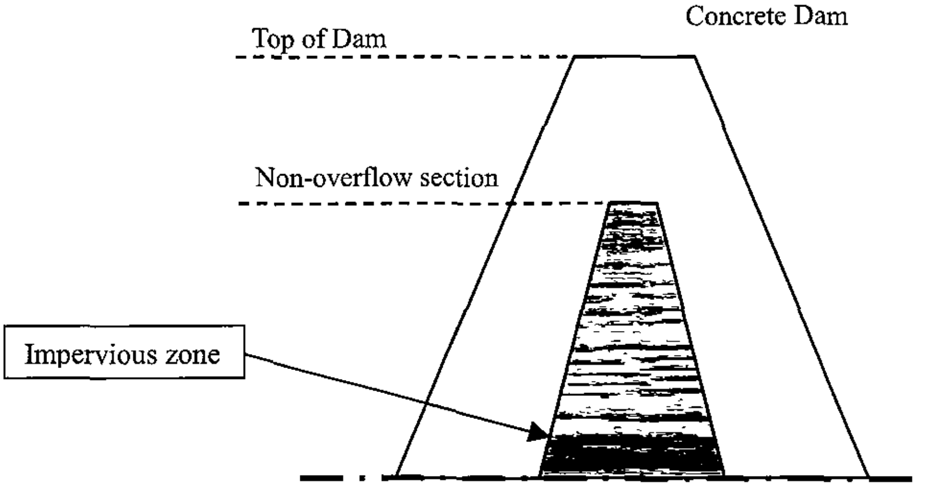
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD8-1
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Position of Non-Overflow Portion (1)**			

1. The position of a non-overflow portion of a dam body shall be higher than either the level of the normal water level plus a freeboard or that of the flood water level plus a freeboard.
2. The position of a non-overflow portion of the fill type dam body shall be equal to the crest height of its impervious zone.



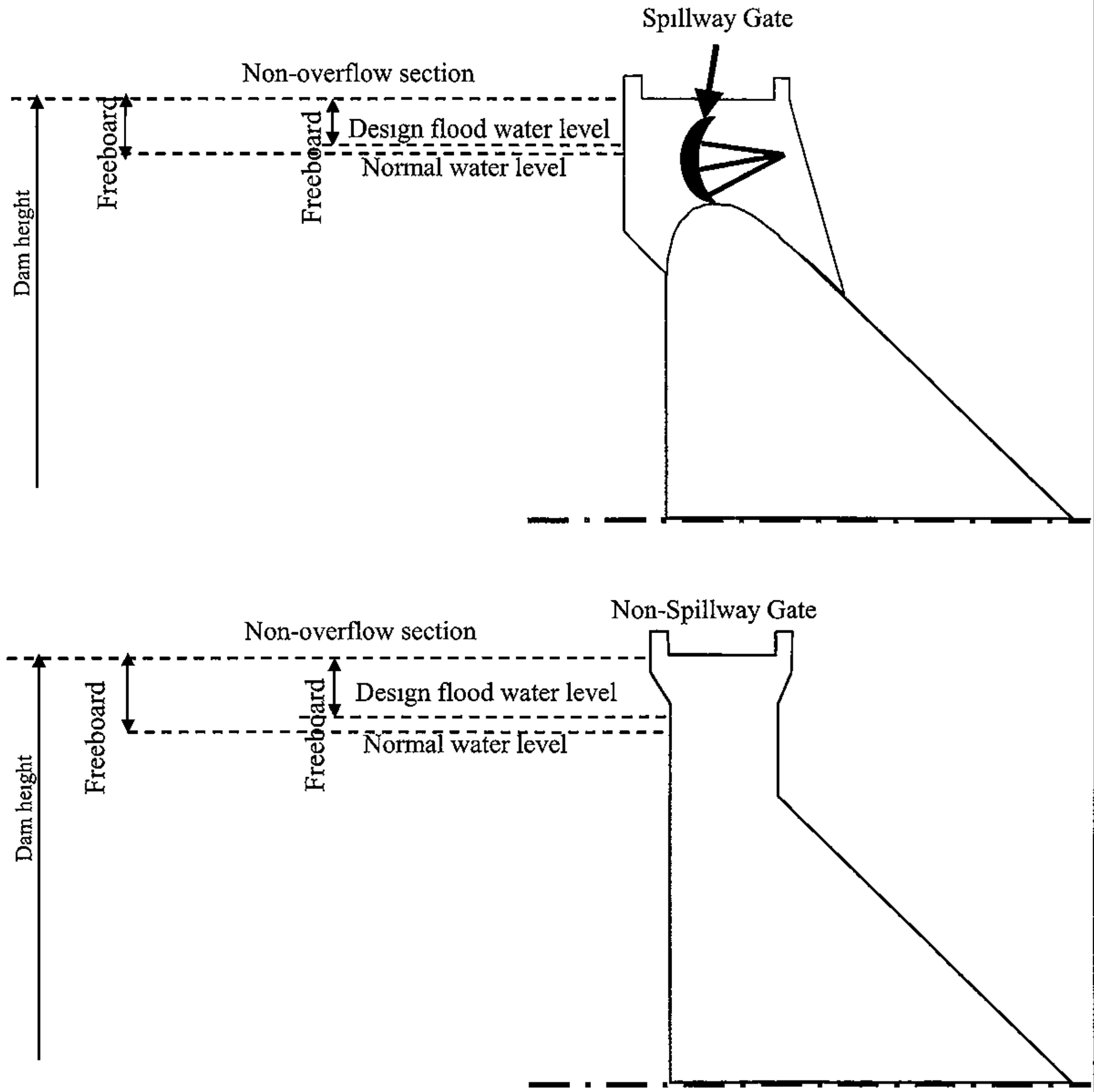
Concrete Dam



Fill Dam (Zoned Type)

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD8-2**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Position of Non-Overflow Portion (2)**			



Concrete Dam

Remarks	Revisions	
	2003/Nov.	Original

Category				Document
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD9
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Freeboard**			

Freeboard shall be set for the flood water level and the normal water level of the dam respectively in consideration of type of the dam, wind-induced waves, earthquake-induced waves, and existence of a spillway gate.

Example of freeboard in Japan

(1) Freeboard for normal water level (normal freeboard)

$h_w + h_e + h_a + h_i$ and 2m or higher

(2) Freeboard for flood water level (minimum freeboard)

$h_w + h_a + h_i$ and 1m or higher

Where,
h_w : the wave height caused by wind
h_e : the wave height caused by earthquake
h_a : 0.5 m in case the dam has a spillway gate and 0 m otherwise
h_i : 1 m for a fill dam and 0 m for a concrete dam.

Remarks	Revisions	
Interpretation of Technical Standards for Hydropower Stations, 1998, Japan		
	2003/Nov.	Original

Category				Document
Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD10**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	

Title	**Loads Acting on Dam Bodies**

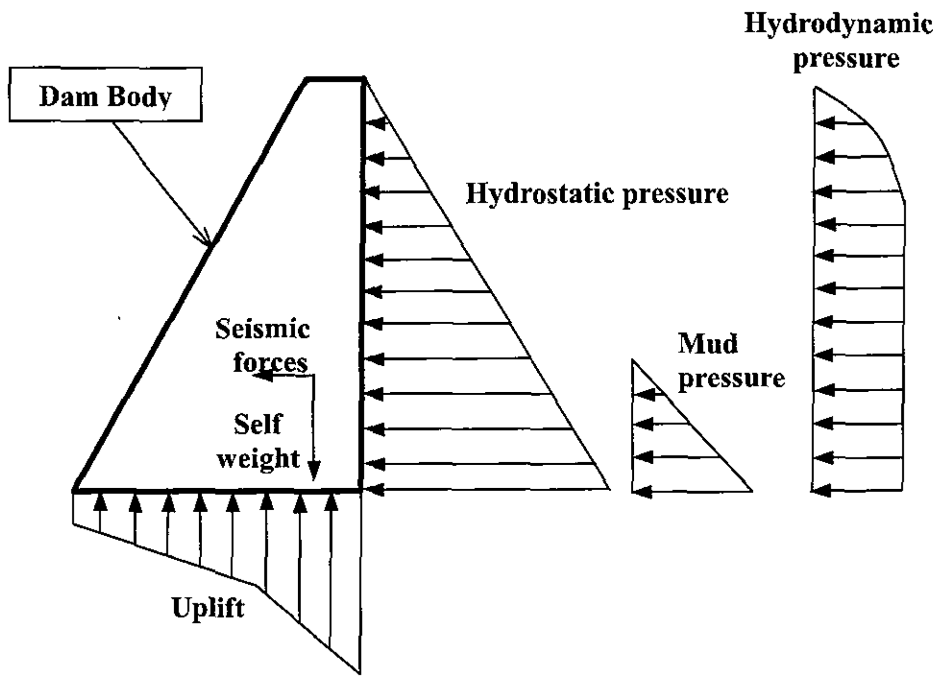
Loads acting on dam bodies, which are considered for design of the bodies, shall be set corresponding to the following table:

Loads Acting on Dam Bodies

Type of dam	Concrete gravity dam	Concrete arch dam	Fill dam
Loads	- Self-weight - Hydrostatic pressure - Hydrodynamic pressure - Mud pressure - Seismic forces - Uplift	- Self-weight - Hydrostatic pressure - Hydrodynamic pressure - Mud pressure - Seismic forces - Uplift - Temperature load	- Self-weight - Hydrostatic pressure - Seismic forces - Pore pressure

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD11-1
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Calculations of Loads Acting on Dam Bodies (1)**			



1. Self weight

Self weight shall be calculated based on the density of the dam material.

For gravity dams in Japan with a height less than 15 m, the unit weight of concrete can be 2 3 t/m^3.

2. Hydrostatic pressure

Hydrostatic pressure shall be imposed perpendicularly on the surface contacting the dam and calculated based on the value derived from the following formula:

$P = gW_oH$

Where,

P: the hydrostatic pressure at a random point on the contacting surface (in units kPa);

g: the gravity per unit mass (9.8 N/kg);

W_o: the unit weight of water (in units t/m^3); and

H: the unit weight of water between the water level in the upstream directly of the dam plus the surge level and a random point on the contacting surface (in units m).

Remarks	Revisions	
Interpretation of Technical Standards for Hydropower Stations, 1998, Japan		
	2003/Nov.	Original

Category				Document No.HD11-2
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	Calculations of Loads Acting on Dam Bodies (2)			

3. Hydrodynamic pressure

Hydrodynamic pressure shall be imposed on a vertical surface, and calculated based on the value derived from the formula given under a). In case the upstream end of the dam is a slope, it can be calculated based on the value derived from the formula given under b):

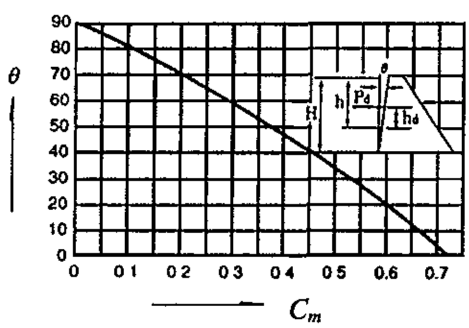
a) $$P_d = \frac{7}{8} g W_0 k_1 \sqrt{Hh}$$: Westergaard's approximate formula

b) $$P_d = gCW_0 k_1 H$$

$$C = \frac{C_m}{2}\left[\frac{h}{H}\left[2-\frac{h}{H}\right]+\sqrt{\frac{h}{H}\left[2-\frac{h}{H}\right]}\right]$$: Zanger's formula

Where,

P_d: the hydrodynamic pressure at a random point on the upstream end (in units kPa);
g: the gravity per unit mass (9.8 N/kg);
W_0: the unit weight of water (in units t/m^3);
k_1: the design seismic coefficient;
H: the depth of water between the water level in the direct upstream of a dam and the foundation at the direct upstream of a dam (in units m);
h: the depth of water between the water level in the direct upstream of a dam and a random point on the cross section surface (in units m); and
C_m: the value obtained from the below diagram.



θ : Angle of the slope at the upstream end of the dam to the vertical line

4. Seismic forces

Seismic force acting on the dam body shall be deemed as acting horizontally on the dam body as static design seismic coefficient. Design seismic coefficient shall be determined by considering various parameters, including the level of seismic activity at the dam site, geological conditions of the foundation, type of dam, and reservoir operational conditions.

Remarks	Revisions	
Interpretation of Technical Standards for Hydropower Stations, 1998, Japan		
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD11-3
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	

Title	*Calculations of Loads Acting on Dam Bodies (3)*

Example of the design seismic coefficient in Japan

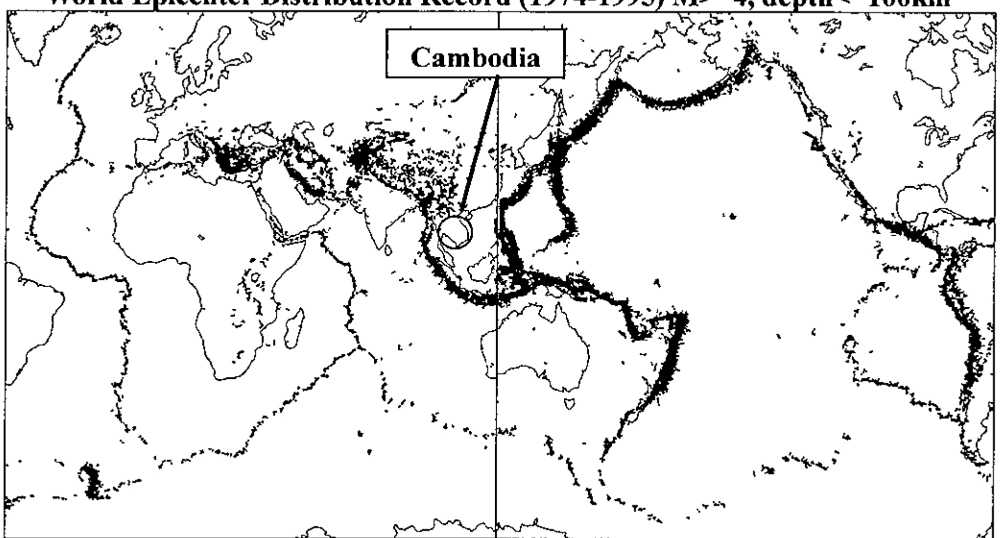
Type of dam		Gravity dam and hollow gravity dam	Arch dam	Fill dam	
				Material used for the dam is roughly homogeneous	The others
Minimum design seismic coefficient	Severe earthquake zones	0.12	0.24	0.15	0.15
	Moderate earthquake zones	0.12	0.24	0.15	0.12
	Minor earthquake zones	0.10	0.20	0.12	0.10

Remarks	Revisions	
Interpretation of Technical Standards for Hydropower Stations, 1998, Japan		
	2003/Nov.	Original

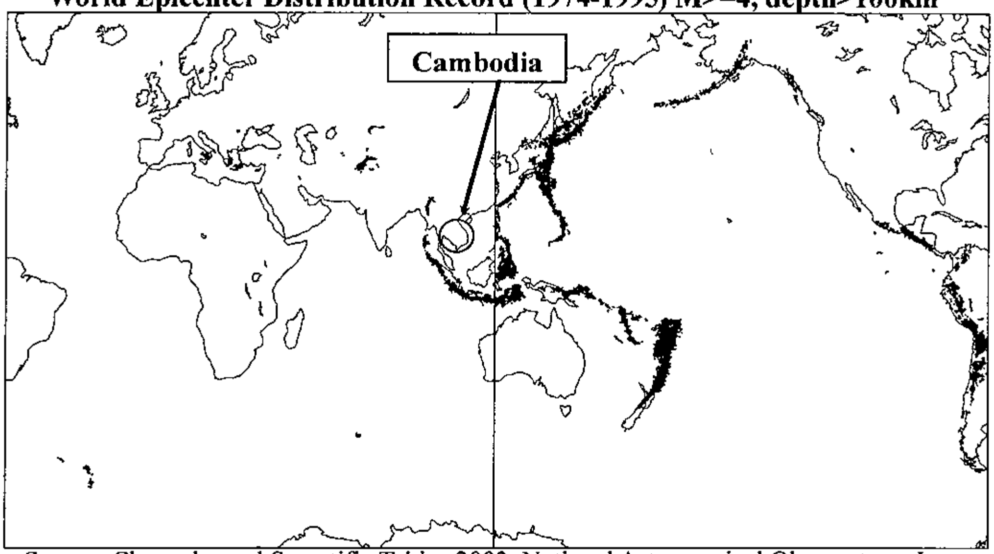
Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD11-4**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Calculations of Loads Acting on Dam Bodies (4)**			

Although no earthquake more than M=4 has been recorded for a long period in and around Cambodia land area and lack of sufficient data for determining the design seismic coefficient in Cambodia, the design seismic coefficient shall be applied for a dam taking account of the conditions such as geology of foundations, its location, and importance from the view point of safety, economy and environment at the downstream.

World Epicenter Distribution Record (1974-1995) M>=4, depth<=100km



World Epicenter Distribution Record (1974-1995) M>=4, depth>100km



Source: Chronological Scientific Tables 2003, National Astronomical Observatory, Japan

Remarks	Revisions	
Chronological Scientific Tables 2003, National Astronomical Observatory, Japan		
	2003/Nov	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD11-5
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	Calculations of Loads Acting on Dam Bodies (5)			

5. Mud pressure

Mud pressure shall be calculated based on the value derived from the following formula:

$P_{ev} = g\, W_1\, d$

$P_{eh} = g\, C_e\, W_1\, d$

Where,

P_{ev}: the vertical component of mud pressure at a random point on the contacting surface with the dam (in units kPa);

P_{eh}: the horizontal component of mud pressure at a random point on the contacting surface with the dam (in units kPa);

g : the gravity per unit mass (9.8 N/kg);

C_e : the mud pressure coefficient;

W_1: the value derived from the following formula (in units t/m^3); and

d: the depth of water between the sedimentation surface and a random point on the contacting surface with the dam

$W_1 = W - (1 - v)\, W_0$

Where,

W: the unit weight of sediment (in units t/m^3);

v: void ratio of sediment; and

W_o: the unit weight of water (in units t/m^3)

For the mud pressure coefficient and so on, the following ranges of values are adopted in Japan.

$C_e = 0.4 \sim 0.6$ $W = 1.6 \sim 1.8$ $v = 0.30 \sim 0.45$

Remarks	Revisions	
Interpretation of Technical Standards for Hydropower Stations, 1998, Japan		
	2003/Nov.	Original

<table>
<tr><td rowspan="3">Category</td><td>Chapter</td><td>2</td><td>Technical Standards of Electric Power Facilities</td><td rowspan="3">Document No.HD11-6</td></tr>
<tr><td>Paragraph</td><td>3</td><td>Generating Facilities (Hydroelectric Power)</td></tr>
<tr><td>Clause</td><td>26</td><td>Dams, Waterways, Powerhouses and Other Facilities</td></tr>
<tr><td>Title</td><td colspan="4">Calculations of Loads Acting on Dam Bodies (6)</td></tr>
</table>

6. Uplift

Uplift for a concrete dam shall be determined by considering the permeability of the foundation after treatments, and drainage.

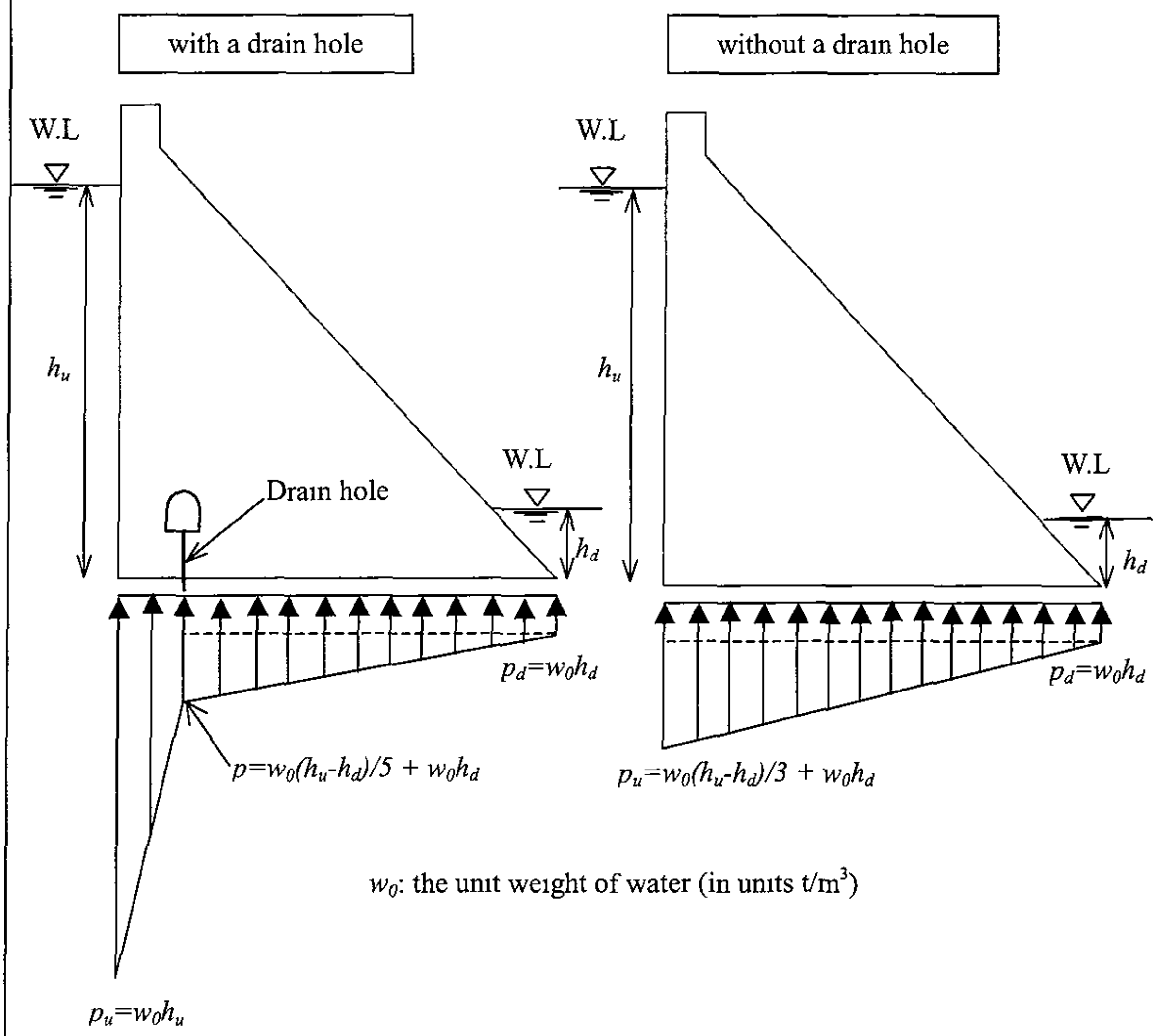
Example of uplift calculation in Japan

<table>
<tr><td colspan="2" rowspan="2">Type of dam</td><td colspan="3">Uplift</td></tr>
<tr><td>At upstream end</td><td>At a drainage hole or at joint between the head and web</td><td>At downstream end</td></tr>
<tr><td rowspan="2">Concrete gravity dam and arch dam</td><td>At horizontal cross section with a drain hole</td><td>Water pressure caused by depth of water between the water level at the upstream end of the dam and the horizontal cross section</td><td>1/5th of the difference in water pressure between at the upstream end and at the downstream end, plus the water pressure at the downstream end</td><td rowspan="3">Water pressure caused by depth of water between the water level at the downstream end of the dam and the horizontal cross section</td></tr>
<tr><td>At horizontal cross section without a drain hole</td><td>1/3rd of the difference in water pressure between at the upstream end, that is caused by depth of water between the water level at the upstream end the dam and the horizontal cross section, and at the downstream end, plus the water pressure at the downstream end</td><td></td></tr>
<tr><td colspan="2">Concrete hollow gravity dam</td><td>Water pressure caused by depth of water between the water level at the upstream end of the dam and the horizontal cross section</td><td>1/10th of the difference in water pressure between at the upstream end and the downstream end, plus the water pressure at the downstream end</td></tr>
</table>

<table>
<tr><td rowspan="4">Remarks
Interpretation of Technical Standards for Hydropower Stations, 1998, Japan</td><td colspan="2">Revisions</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>2003/Nov.</td><td>Original</td></tr>
</table>

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD11-7
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Calculations of Loads Acting on Dam Bodies (7)**			

Uplift distribution for cross section of concrete gravity dam and arch dam



w_0: the unit weight of water (in units t/m^3)

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.HD11-8
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	Calculations of Loads Acting on Dam Bodies (8)			

7. Temperature loads

Temperature loads shall be calculated according to the difference between the temperature inside the dam at contraction joint grouting and the highest and the lowest temperatures inside the dam after grouting.

8. Pore pressure

(1) Pore pressure shall be calculated based on the penetration flow.

(2) Pore pressure for a fill dam shall be determined by considering the permeability of the materials used for the dam body, and drainage, and based on calculations, tests and experience through actual measurements of seepage flow.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD12
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	***Combination of Loads Acting on Dam Bodies***			

Example in Japan

Type of dam		Gravity dam and hollow gravity dam	Arch dam	Fill dam
Loads	When the water level at the upstream end of a dam is at normal water level or at surcharge water level.	- Self weight - Hydrostatic pressure - Hydrodynamic pressure - Mud pressure - Seismic forces - Uplift	- Self weight - Hydrostatic pressure - Hydrodynamic pressure - Mud pressure - Seismic forces - Uplift - Temperature loads	- Self weight - Hydrostatic pressure - Seismic forces - Pore pressure
	When the water level at the upstream end of a dam is at design flood water level.	- Self weight - Hydrostatic pressure - Mud pressure - Uplift	- Self weight - Hydrostatic pressure - Mud pressure - Uplift - Temperature loads	- Self weight - Hydrostatic pressure - Pore pressure
	When the water is empty at the upstream end of a dam	- Self weight - Seismic forces		
	When the water level at the upstream of a dam decreases quickly from the normal water level to the low water level.			- Self weight - Hydrostatic pressure - Seismic forces - Pore pressure

Remarks	Revisions	
Interpretation of Technical Standards for Hydropower Stations, 1998, Japan		
	2003/Nov.	Original

Category				Document No.HD13
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Dam Foundations**			

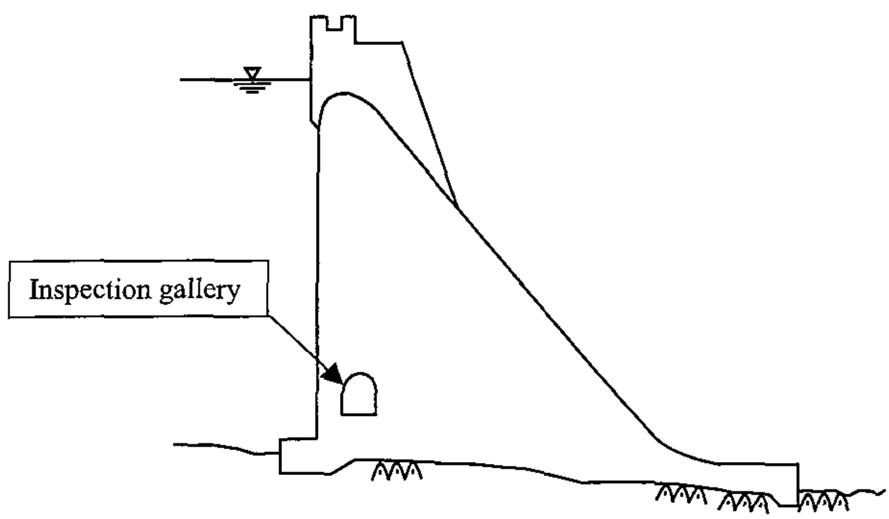
Dam foundations shall meet the following:

1. Dam foundations shall be properly investigated about their geology, permeability, and physical and mechanical properties, taking into account whether the dam is crucial for human safety, properties, economy, and environment, in order to properly evaluate dam stability and seepage properties;
2. Dam foundations shall have a required bearing capacity and a shear strength, and not result in serious settlements, deformations, cracks, sliding failure, or serious erosion;
3. Proper treatments such as grouting or drainage shall be taken at dam foundations in order to protect the dams from excessive uplift, serious water leakage, or seepage failure;
4. Proper treatments shall be taken to any faults or other weak strata in dam foundations, which may harm dam stability and seepage failure, so that the foundations have required strength and water-tightness; and
5. Proper treatments shall be taken to any faults or other weak strata, which may cause harmful settlements, in the dam foundations

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.HD14
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Monitoring and Inspections**			

1. Monitoring equipment shall be equipped and periodical monitoring shall be done corresponding to soundness of a dam body and progress of sedimentation in a reservoir, in order to confirm the safety and proper functions of the dam body, and the proper functions of the reservoir, in such cases that:
   - The dam is crucial for human safety, properties, economy, and environment;
   - The type of the dam is unique;
   - High permeability in the dam foundations before taking foundation treatments; and
   - Existence of a large weak stratum with insufficient strength in the foundations before taking foundation treatments.
2. In case of unusual loads such as earthquake and flood, an inspection shall be immediately done in order to confirm the safety and proper functions of the dam.
3. It is desirable that a dam such as mentioned in Section 1 shall have inspection galleries according to needs for inspections and repairs.



Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.HD15
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Equipment for Inspection of Dam Soundness**			

1. Concrete dam
Volume of water leakage, Uplift, Deformation and Sedimentation

2. Fill dam
Volume of water leakage, Deformation, Permeation line (for homogeneous type) and Sedimentation

Dam Monitoring Items (Example in Japan)

Type of dam and its height	Concrete gravity dam and hollow gravity dam		Arch dam		Fill dam	
	under 50m	50m and more	under 30m	30m and more	Material used for the dam is almost homogeneous	Others
Monitoring items	Volume of the water leakage and Uplift	Volume of the water leakage, Uplift, and Deformation	Volume of the water leakage and Deformation	Volume of the water leakage, Uplift, and Deformation	Volume of the water leakage, Deformation, and Permeation line	Volume of the water leakage and Deformation

Remarks	Revisions	
Interpretation of Technical Standards for Hydropower Stations, 1998, Japan		
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD16**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Emergency Inspection Items in Case the Abnormal Loads are Acted**			

1. Volume of water leakage through a dam body
2. Volume of water leakage through surrounding grounds of a dam
3. Uplift of a concrete dam body
4. Deformation and permeation line of a fill dam body
5. Proper function of a spillway gate

etc.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD17**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Concrete Materials**			

Concrete materials for dams shall be confirmed whether they meet the following requirements through the tests that are specified in a standard such as ISO (the International Organization for Standardization), or be such materials that are specified in a standard for example ISO, which meets the following requirements:

1. Cement shall be capable of adequately cementing and solidifying corresponding to its quality;
2. Aggregates shall be adequately strong and durable;
3. Aggregates, water, and admixtures shall be free of acid, salt, organic substances, and mud, which prevent concrete from cementing, seriously rusts reinforcements, or prevent adhesion between concrete and reinforcements; and
4. Properties of concrete such as unit weight, strength, deformation modulus and the Poisson's ratio shall be determined by testing the materials to be used.

References

(Cements)
- ISO679: 1989/ Method of testing cements- Determination of strength
- ISO9597: 1989/ Cements- Test methods- Determination of setting times and soundness
- ISO680: 1990/ Cements- Test methods- Chemical analysis
- ISO863: 1990/ Cements-Test methods- Pozzolanicity test for pozzolanic cements
- ISO3048: 1974/ Gypsum plasters- General test conditions
- ISO3049: 1974/ Gypsum plasters- Determination of physical properties of powder

(Concrete)
- ISO4012/ Concrete- Determination of compressive strength of test specimens
- ISO4108/ Concrete- Determination of tensile splitting strength of test specimens
- ISO4013: 1978/ Concrete- Determination of flexural strength of test specimens
- ISO6784: 1982/ Concrete- Determination of static modulus of elasticity in compression
- ISO6275: 1982/ Concrete, hardened- Determination of density

(Aggregate)
- ISO6274: 1982/ Concrete- Sieve analysis of aggregates
- ISO6783: 1982/ Coarse aggregates for concrete- Determination of particle density and water adsorption- Hydrostatic balance method
- ISO6782: 1982/ Aggregates for concrete- Determination of bulk density

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD18
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Foundations of Concrete Dams**			

Foundations of concrete dams shall meet the following:

1. In case the dam safety and stability is crucial for human safety, properties, economy, and environment, properties of dam foundations such as strength and deformation shall be determined in consideration of the geology of the foundations based on the results of in-situ tests. In case that, in principle, the dam is not crucial for human safety, properties, economy, and environment, and the geology of the dam site to be built is similar to that of existing neighbor dams, the foundation properties may be determined in consideration of both the actual results of the existing dams and the geology of the dam to be built; and
2. When an in situ test is conducted, test points that are typical and proper for determining properties of the dam foundations shall be deliberately selected in consideration of the geology of the foundations.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.HD19
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Examples of In Situ Test for Dam Foundations**			

Method of test and evaluation for dam foundations

	Method of test	Evaluation parameter
Strength	- In situ block (rock) shear test - Triaxial test - Box shear test	- Shear strength τ - Coefficient of internal friction f
Deformability	- In situ load test - Triaxial test	- Elastic modulus E - Modulus of deformation D
Permeability	- Lugeon test - Permeability test	- Lugeon value Lu - Coefficient of permeability k

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.HD20-1
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	

Title **Stability of Concrete Gravity Dams (1)**

Example of stability criteria for concrete gravity dams (based on the draft Electric Power Technical Standards in Lao)

Concrete gravity dams shall meet the following:

1. Dam bodies shall be stable for overturning due to cracking.
   (1) Under conditions of a normal dam operation, a resultant force consolidated both anticipated external forces and a self-weight shall be within the center one-third (1/3) (so called, the middle third) of the horizontal section of the dam body.
   (2) Under earthquake or flood conditions, the resultant force shall be within the center one-second (1/2) (so called, the middle half) of the horizontal section of the body.

2. Dam bodies, the contact areas between the dam bodies and their foundations, and any weak strata in the foundations shall be stable for sliding.
   (1) The safety factor for sliding calculated by the following formula shall be three (3) or more under normal conditions (the water level of the reservoir is between the Normal Water Level and the Low Water Level, and the downstream water level of the dam is equal to or lower than the water level when the maximum design discharge flows). It shall be two (2) or more under earthquake or flood conditions.

$$n = (f \times V + \tau \times L) / H$$

Where,

n: Shear friction safety factor
f: Internal friction coefficient
τ: Shear strength
V: Total vertical force acting on the shear plane per unit width
H: Total horizontal force acting on the shear plane per unit width
L: Area resisting against the shear force per unit width

   (2) In case the dam is not crucial for human safety, properties, economy, and environment, and the shear strength of the foundations is not taken into account, the shear friction safety factor defined by the above formula shall be at 1.5 or more under normal conditions and 1.2 or more under earthquake or flood conditions.

Remarks	Revisions	
Laotian Electric Power Technical Standards (Draft), April 2002, Ministry of Industry and Handicrafts, Lao P.D.R. and JICA		
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD20-2
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Stability of Concrete Gravity Dams (2)**			

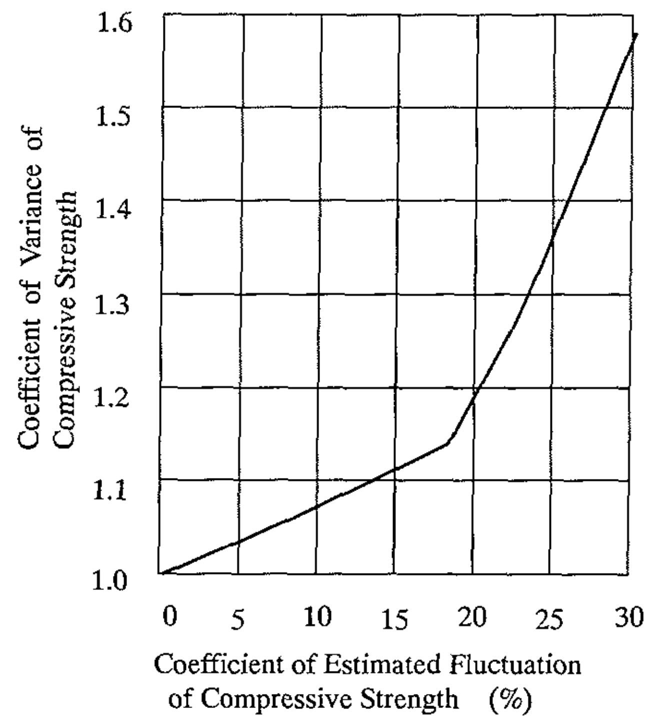
3. The inside stresses of dam bodies shall not exceed the allowable stress as described below:
   (1) The allowable compressive stress of concrete shall be one-third (1/3) of its compressive strength. It shall be one-half (1/2) of its compressive strength under earthquake or flood conditions;
   (2) The allowable tensile stress of concrete shall be one-fortieth (1/40) of its compressive strength;
   (3) The specific age of the concrete for the strength test shall be in principle 91 days. It shall be determined in consideration of the period between the time of concrete placing and that of being loaded; and
   (4) The proportioning strength of concrete shall be determined with the additional rate in consideration of variance of compressive strength to the required compressive strength as follows:

   (The proportioning strength) = (The required compressive strength) x (The coefficient of the variance of compressive strength)

4. The static analyses with a proper design seismic coefficient (so called, the Seismic Coefficient Analysis) shall be applied in principle for stability analyses under earthquake conditions.

Remarks	Revisions	
Laotian Electric Power Technical Standards (Draft), April 2002, Ministry of Industry and Handicrafts, Lao P.D.R. and JICA		
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD21**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Coefficient of Estimated Fluctuation of Compressive Strength**			



Coefficient of Variance of Compressive Strength

Remarks	Revisions	
Standard Specifications for Concrete Structures-2002, Dam Concrete, Japan Society of Civil Engineers		
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD22**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Strength of a Concrete Dam Body**			

1. Compressive stresses caused by the loads acting on the gravity dam or a hollow gravity dam and compressive stresses caused by loads except for hydrodynamic pressure and seismic forces shall not exceed the maximum allowable compressive stress level for each type of concrete to be used.
2. Tensile stresses caused by the loads acting on the gravity dam or the hollow gravity dam shall not exceed the allowable tensile stress level for each type of concrete to be used, except for cases stipulated in below sentences.
3. The gravity dam or the hollow gravity dam shall not generate a vertical tensile stress at its upstream end.
4. At the portion near an overflow section of the dam which is reinforced with reinforcing bars for the tensile stress, the previous two sentences shall not be applied.

Remarks	Revisions	
	2003/Nov	Original

Category				Document No.HD23
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	Stability of Arch Dams			

Example of stability criteria for arch dams (based on the draft Electric Power Technical Standards in Lao)

Arch dams shall meet the following:

1. The contact areas between the dam bodies and the foundations, and any part of the foundations shall be stable for sliding.

   The safety factor for sliding calculated by the following formula shall be four (4) or more under normal conditions (the water level of the reservoir is between the Normal Water Level and the Low Water Level, and the water level of the dam downstream is equal to or lower than the water level when the maximum design discharge flows). It shall be 2.7 or more under earthquake or flood conditions.

   $$n = (f \times V + \tau \times L) / H$$

   Where,

   n : Shear friction safety factor;
   f : Internal friction coefficient;
   τ : Shear strength;
   V : Total vertical force acting on the shear plane per unit width;
   H : Total horizontal force acting on the shear plane per unit width; and
   L : Area resisting against the shear force per unit width

2. The inside stresses of dam bodies shall not exceed the allowable stress as described below:
   (1) The allowable compressive stress of concrete shall be one-third (1/3) of its compressive strength. It shall be one-half (1/2) of its compressive strength under earthquake or flood conditions;
   (2) The allowable tensile stress of concrete shall be one-fortieth (1/40) of its compressive strength;
   (3) The specific age of the concrete for the strength test shall be in principle 91 days. It shall be determined in consideration of the period between the time of concrete placing and that of being loaded; and
   (4) The proportioning strength of concrete shall be determined with the additional rate in consideration of the variance of compressive strength to the required compressive strength as follows:
   (The proportioning strength) = (The required compressive strength) x (The coefficient of variance of compressive strength)

3. The static analyses with a proper design seismic coefficient (so called, the Seismic Coefficient Analysis) shall be applied in principle for stability analyses under earthquake conditions. The dynamic analysis based on a proper evaluation of earthquake motions, the dynamic physical and mechanical properties of the foundations and the materials of the dam body, and reliable methods for analysis, is desirable to be applied.

Remarks	Revisions	
Laotian Electric Power Technical Standards (Draft), April 2002, Ministry of Industry and Handicrafts, Lao P.D.R. and JICA		
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD24**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Details of Concrete Dam Bodies**			

Concrete dam bodies shall meet the following:

1. Proper expansion joints shall be installed in order to prevent detrimental cracks;
2. Drain holes shall be installed as necessary from the inspection galleries to the foundations to prevent excessive uplift that acts on the dam body itself, the contact areas between the dam body and its foundations, and the inside of the foundations;
3. The portions around openings of the dam such as inspection galleries, water discharge equipment, and penstocks installed inside of the dam body, shall be structurally safe for the concentrated stresses and the stresses due to temperature change;
4. Waterstops shall be watertight and durable, and be flexible for expanding and contracting of the joints. They shall be installed in transverse joints near the upstream surface of the dam; and
5. The maximum temperature rise of the placed concrete in the dam body shall be controlled or taken countermeasures as necessary in order to protect the dam body from detrimental cracks caused by temperature rise.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD25
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Embankment Materials for Fill Dam Bodies**			

Example of criteria for embankment materials for fill dam bodies (based on the draft Electric Power Technical Standards in Lao)

Embankment materials for fill dam bodies shall meet the following:

1. Materials with properties conforming to the respective purposes shall be used as dam body materials.
   (1) Soil materials of the impervious ones shall meet the following:
      a. Soil materials shall have required strength and water-tightness for dam stability;
      b. Soil materials shall be easily compacted and subject to little deformation;
      c. Soil materials shall be free of such expandability and contractibility that may cause difficulties in dam stability;
      d. Soil materials shall not be subject to softening;
      e. Soil materials shall not contain organic substances and not be water-soluble; and
      f. The Coefficient of Permeability, strength, and compaction properties shall be determined with materials to be used.
   (2) Impervious materials except for soil ones shall be identified to have required water-tightness, properties of strength and compaction, and durability with materials to be used.
   (3) Semi-pervious materials shall meet the following:
      a. Semi-pervious materials shall have required strength and drainage properties for dam stability;
      b. Semi-pervious materials shall have required grain size distribution;
      c. Semi-pervious materials shall be easily compacted and subject to little deformation; and
      d. The Coefficient of Permeability, strength, and unit weight shall be determined with materials to be used.
   (4) Pervious materials shall meet the following:
      a. Pervious materials shall have required strength and drainage properties for dam stability;
      b. Pervious materials shall be hard and durable;
      c. Pervious materials shall be easily compacted and subject to little deformation; and
      d. The Coefficient of Permeability, strength, unit weight, and durability shall be determined with materials to be used.
   (5) Materials for the surfaces of the dam bodies shall not be seriously eroded by waves and rainfall.

2. When materials are selected, they shall be tested properly to identify their properties with materials to be used. When the strength of any selected material is identified at a process of the stability analysis, its consolidation and drainage conditions shall be considered in setting the strength property.

Remarks	Revisions	
Laotian Electric Power Technical Standards (Draft), April 2002, Ministry of Industry and Handicrafts, Lao P.D.R. and JICA		
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD26**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Foundations for Fill Dams**			

Dam foundations of fill dams shall meet the following:

1. Foundations at impervious zones are desirable to be hard rock foundations and shall have required water-tightness and shear strength;
2. In case the dam foundations are not rock ones, the water-tightness, strength and deformation properties shall be tested through in situ and/or laboratory tests in order to identify the foundation properties. Safety for liquefaction under earthquake conditions shall also be secured;
3. Sand-gravel foundations shall require countermeasures against seepage as necessary in order to secure adequate stability; and
4. Soil foundations shall require countermeasures against sliding and deformation as necessary in order to secure adequate stability.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD27
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Stability of Fill Dams**			

Example of stability criteria for fill dams (based on the draft Electric Power Technical Standards in Lao)

Fill dams shall meet the following:

1. Dam bodies and their foundations shall be stable for sliding. Reliable circular arc methods shall be applied as an analysis for sliding. In case sliding lines are anticipated to include the foundations, the calculations shall be done along not only arc lines but also anticipated sliding lines.
   Required safety factors shall be:
   (1) 1.5 or more under normal conditions (the water level of the reservoir is between the Normal Water Level and the Low Water Level, and the seepage flow in the dam body is in steady state);
   (2) 1.4 or more under flood conditions;
   (3) 1.4 or more under the conditions of at the time being just after completion of dam building and before filling the reservoir;
   (4) 1.1 or more under earthquake conditions; and
   (5) 1.3 or more under the conditions of at the time of rapid drawdown in the reservoir water level in case the drawdown is frequent.

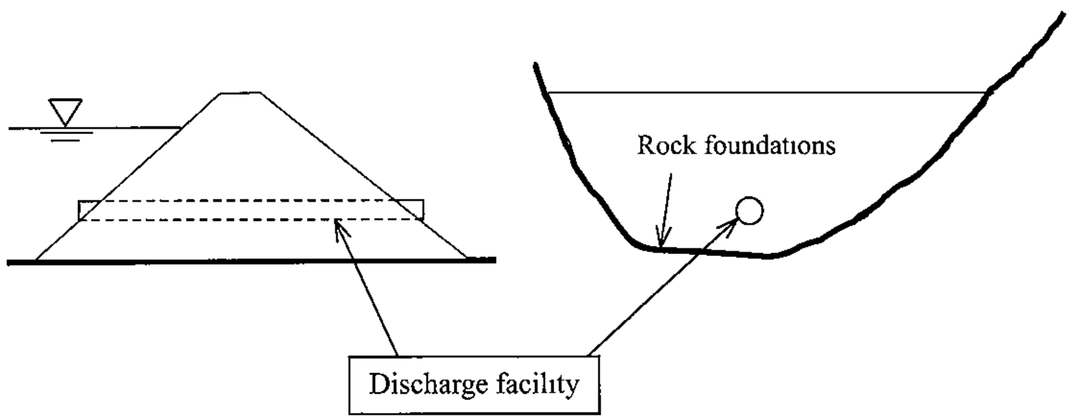
2. Static analyses (so called, the Seismic Coefficient Analysis) with a proper design seismic coefficient shall be applied in principle for stability analyses under earthquake conditions.

Remarks	Revisions	
Laotian Electric Power Technical Standards (Draft), April 2002, Ministry of Industry and Handicrafts, Lao P.D.R. and JICA		
	2003/Nov.	Original

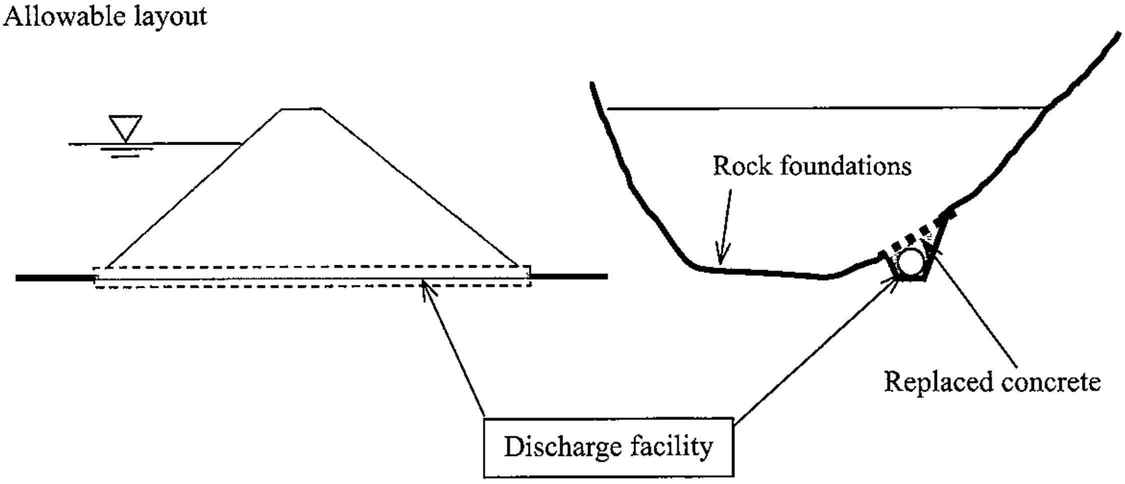
Category				Document No.HD28
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Restrictions on Facilities such as Discharge Facilities of Fill Dams**			

Discharge facilities and waterways that may cause detrimental cracks inside of fill dam bodies shall not be installed inside of the bodies

Prohibited layout



Allowable layout



Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD29
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Designs of Fill Dam Bodies**			

1. For homogenous type fill dams composed of impervious materials, the seepage lines shall not appear on the downstream surfaces of the dams. Proper drains shall be installed as necessary to promote reduction of pore pressure.
2. For zoned fill type dams, the zones shall be properly arranged. Every material of these zones in contact with each other shall not make too much difference so that the material particle in each zone does not move.
3. Surface diaphragm type fill dams shall meet the following:
   (1) Surface diaphragm type fill dams shall be designed and installed so that cracks which damage sealing function of the diaphragms may not appear; and
   (2) According to the permeability of the foundations, proper measures for water sealing shall be taken to protect the foundations of the diaphragm from seepage failure.

Remarks	Revisions	
	2003/Nov.	Original

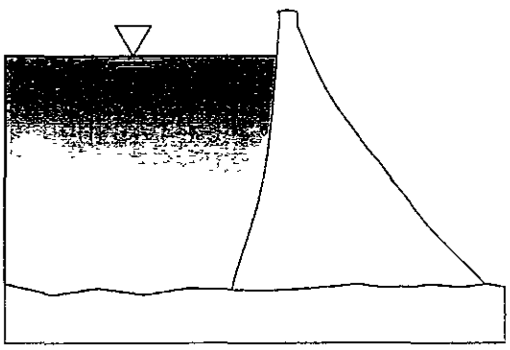
Category				Document No.HD30
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**The Other Types of Dam**			

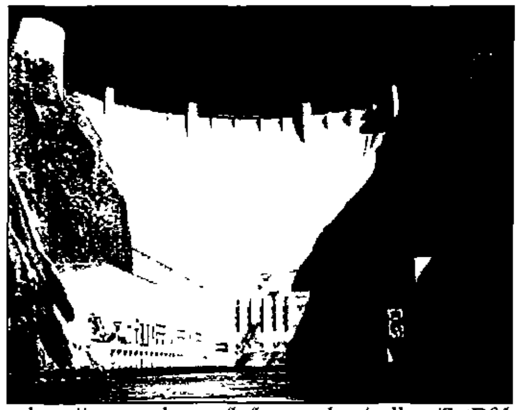
The other type dams such as rubber dams and gabion dams (those dams except for fill dams, concrete dams, and concrete arch dams) shall be installed in accordance with the following:

1. Safety for anticipated conditions such as overturning, sliding, occurrence of excessive stress on materials to be used, cracking, and seepage failure shall be sufficiently considered in designing the dams;
2. Concrete materials shall meet Document No.HD17;
3. Soil and rock materials shall meet Document No.HD25; and
4. In the case that materials except for soil, rock, and concrete are applied, they shall be sufficiently identified by tests on their durability, water-tightness, and strength.

Remarks	Revisions	
	2003/Nov	Original

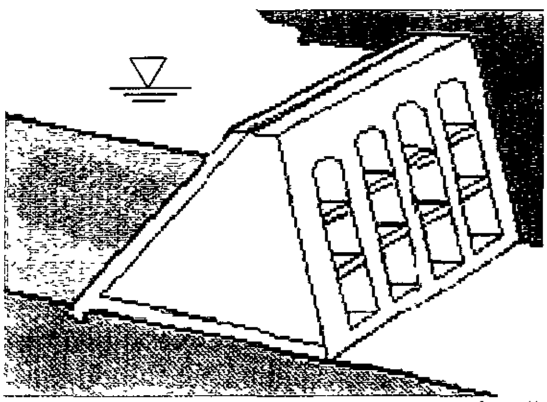
Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD31-1**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Examples of Other Types of Dam (1)**			

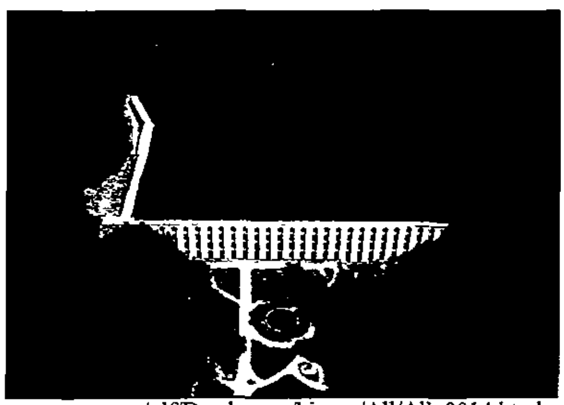




http://www.usbr gov/lc/hooverdam/gallery/SetD01 htm
Hoover Dam (U.S.A)

1. Concrete Gravity Arch Dam



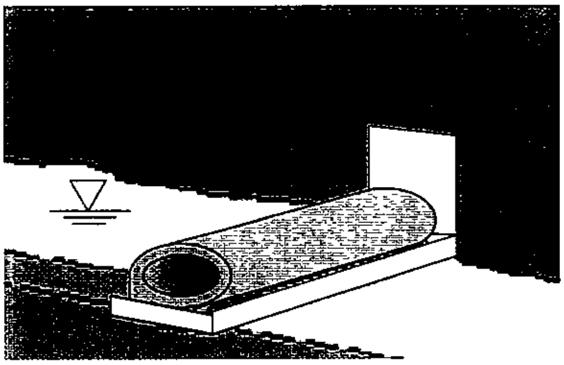


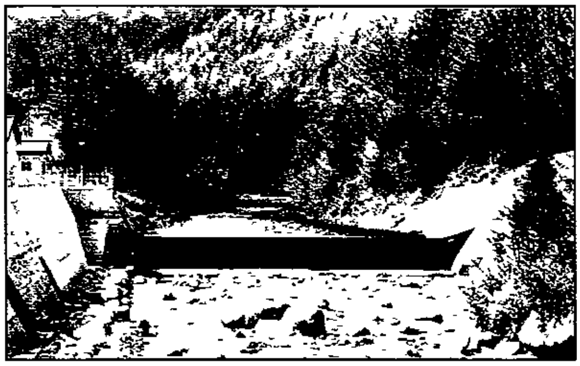
http //wwwsoc.nii ac jp/jdf/Dambinran/binran/All/All_0014 html
Sasanagare Dam (Hakodate, Japan)

2. Buttress Type Dam

Remarks	Revisions	
http://www.usbr.gov/lc/hooverdam/gallery/SetD01.htm		
http://wwwsoc nii.ac.jp/jdf/Dambinran/binran/All/All_0014.html		
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD31-2**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Examples for Other Types of Dam (2)**			





3. Rubber Inflated Dam

http //www matsuikk co jp/product/jakago html

4. Gabion Dam

Remarks
http://www.matsuikk co.jp/product/jakago html

Revisions	
2003/Nov.	Original

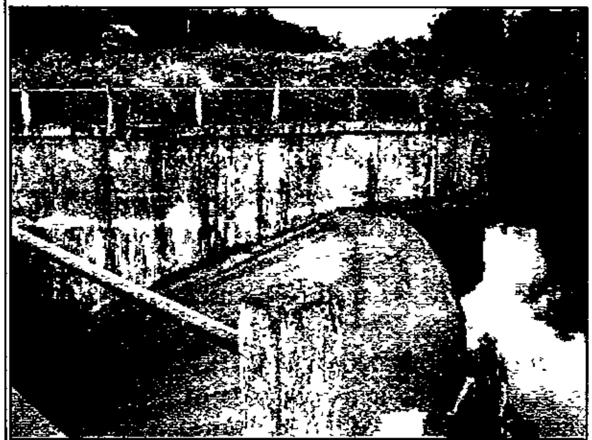
Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD32-1**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Spillways (1)**			

Spillways shall meet the following:

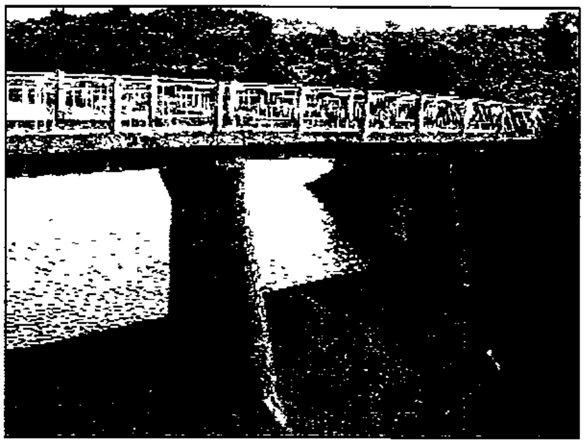
1. All dams shall be equipped with spillways on/in/beside the dams in order to safely discharge the water flow equal to or less than the inflow design flood to the downstream;
2. For fill dams, no spillways shall be equipped on/in the dam bodies themselves;
3. The bottom ends of structures such as bridges and hoisted gate leafs shall be apart enough from the surfaces of the overflowing water discharged through the spillways at the flood water level so that the overflowing water is safely discharged;
4. The forces of a water current discharged through the spillways shall be defused to protect the dam bodies and the downstream areas from harmful impacts;
5. Spillways shall have stability stipulated in Documents No.HD20 or No.HD23 for the loads based on the Documents applied for concrete gravity dams and the loads of a water flow discharged through the spillways at the flood water level;
6. Reliable calculation methods shall be applied in designing spillways and discharge facilities. If it may be difficult to obtain reliable design results for safety through calculations alone, the hydraulic model tests shall be conducted to identify the safety; and
7. No substances that may cause a malfunction to the spillways shall flow into them.

Remarks	Revisions	
	2003/Nov.	Original

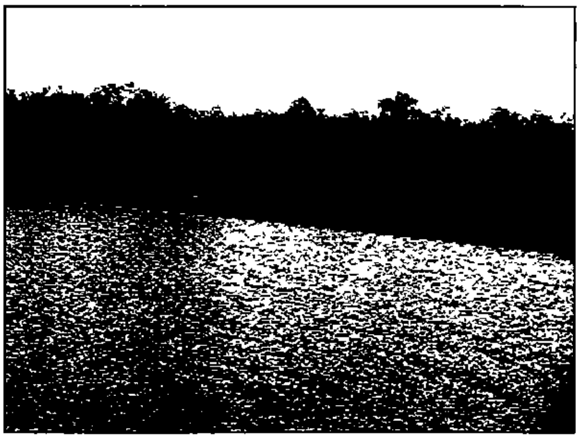
Category				Document No.HD32-2
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	Spillways (2)			



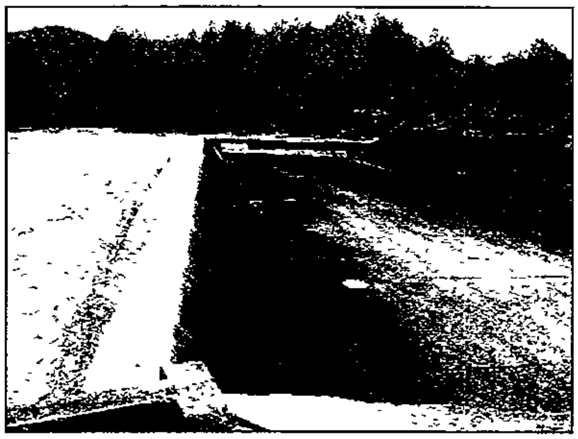
O Chum 1 spillway (no gate)



O Chum 2 spillway (no gate)



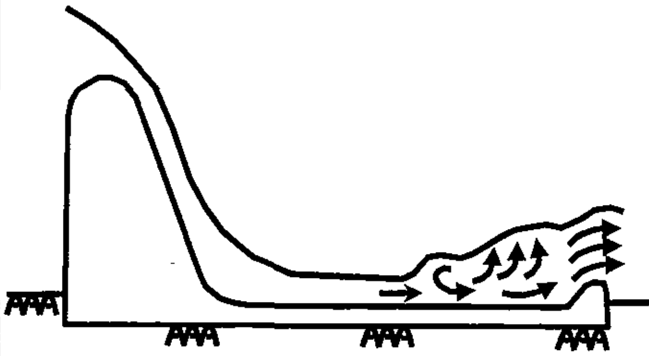
Kirirom 1 spillway (no gate)

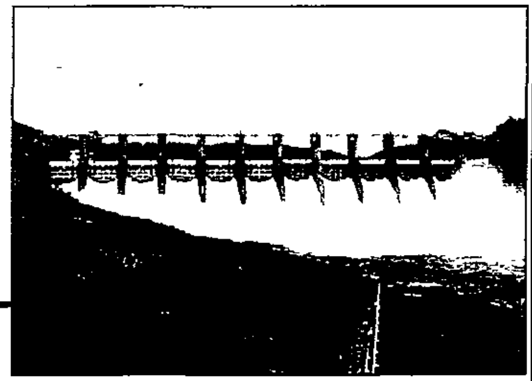


Kirirom 1 spillway (no gate)
- dry season -

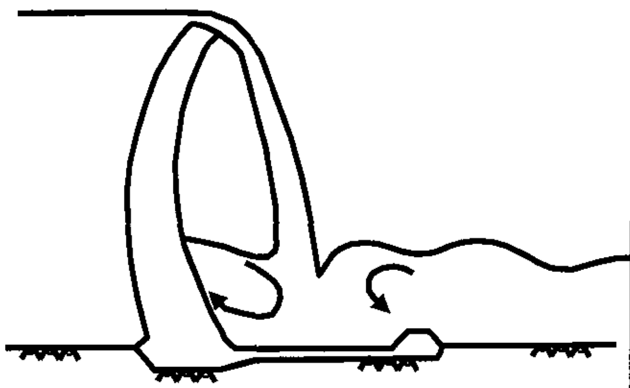
Remarks	Revisions	
	2003/Nov.	Original

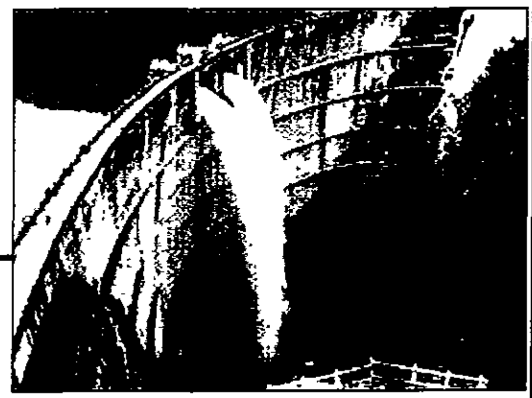
Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD33**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Energy Dissipater**			



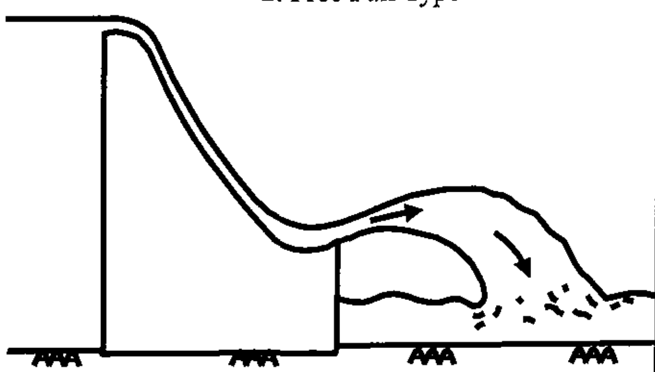


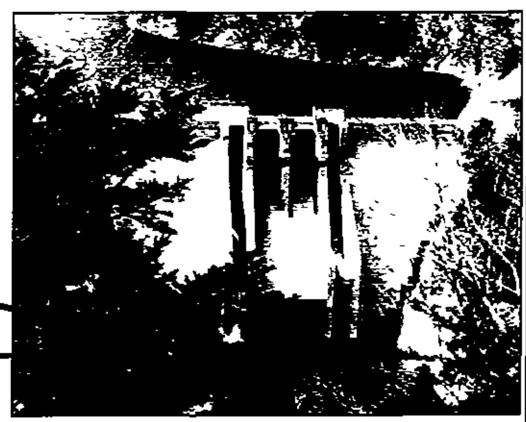
1. Hydraulic jump type





2. Free Fall Type





3. Ski Jump Type

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD34
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Structure to Safely Release the Flow of Water**			

A spillway shall be established so that the water discharged at the design flood water level shall be able to safely flow through it and shall not cause damage to the dam or the dam's surroundings.

Example in Japan,

1. In case the spillway is an overflow type, the lower end of the structure, such as a bridge and a hoisted gate door, shall be at least 1.5 m away from the surface of overflowing water *discharged from the spillway at the design flood water level.*
2. In case the depth of overflowing water is less than 2.5 m for the case in the previous paragraph, the lower end of the structure shall be at least 1 m away from the surface of overflowing water.

Remarks	Revisions	
Interpretation of Technical Standards for Hydropower Stations, 1998, Japan		
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.HD35
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Spillway Gates and their Auxiliaries**			

Spillway gates and their auxiliaries shall meet the following:

1. Spillway gates, as defined herein including valves, shall be sufficiently watertight and durable;
2. Spillway gates shall be easily opened and closed, and their operation shall not cause any harmful vibration;
3. Spillway gates shall be stable for anticipated loads such as self-weight, hydrostatic pressure, hydrodynamic pressure, mud pressure, seismic force, buoyancy, and forces caused by opening and closing of the gates and their auxiliaries. Every material for the spillway gates shall have required strength and durability for the said loads. They shall not result in a buckling against the said loads and shall be such structures that safely convey the said loads to the dam bodies and so on;
4. Materials for spillway gates shall be confirmed whether they have required strength with the tests that are specified in a standard such as ISO, or be such materials that are specified in a standard for example ISO, which meets required strength; and
5. In case power-drive devices are applied to operate spillway gates, the devices shall be equipped with back-up devices such as power source facilities and buck-up power sources to ensure the gates operation.

References

(Steel)

- ISO630/ Structural steels, E275, E355
- ISO4950-2/ High yield strength flat steel products, Part 2: Products supplied in the normalized or controlled condition, E355
- ISO4950-3/ High yield strength flat steel products, Part 3: products supplied in the heat-treated (quenched + tempered) condition, E460

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD36**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Opening and Closing of the Gates**			

The gate shall be able to open and close easily and securely.

That the gate opens and closes easily and securely means that a power-driven device and a backup device (in case such a device is electrically operated, the device means a backup power supply device) shall be installed for a gate where a power-driven device is used to open the gate.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD37**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Power Device and Back-up Power Source**			

In case diesel generators are installed as power devices or back-up power sources, they shall meet technical standards related to thermal power plant.

Remarks	Revisions	
- Draft Electric Power Technical Standards in Cambodia, Chapter 2, Section 2, Thermal Power		
- Guidebook for Power Engineers, Vol. No.2, Thermal Power		
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.HD38**
	Paragraph	3	Generating Facilities (Hydroelectric Power)	
	Clause	26	Dams, Waterways, Powerhouses and Other Facilities	
Title	**Other Discharge Facilities**			

Other discharge facilities shall meet the following:

1. Dams shall be equipped with discharge facilities in order to lower the water levels of reservoirs in case of emergency and to discharge water to the areas affected by river diversion. In case water outlet facilities or spillways meet these requirements, the said discharge facilities are not required; and
2. In case discharge facilities are not usually operated, operational checks for the facilities shall be periodically done to ensure proper gates operation.

Remarks	Revisions	
	2003/Nov.	Original