UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

INSHP

Technical Guidelines for the Development of Small Hydropower Plants

DESIGN

Part 6-3: Hydro Mechanical Works

SHP/TG 002-6-3: 2019

DISCLAIMER

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ACKNOWLEDGEMENTS

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Foreword

The United Nations Industrial Development Organization（UNIDO）is a specialized agency under the United Nations system to promote globally inclusive and sustainable industrial development（ISID）. The relevance of ISID as an integrated approach to all three pillars of sustainable development is recognized by the 2030 Agenda for Sustainable Development and the related Sustainable Development Goals（SDGs）, which will frame United Nations and country efforts towards sustainable development in the next fifteen years. UNIDO's mandate for ISID covers the need to support the creation of sustainable energy systems as energy is essential to economic and social development and to improving quality of life. International concern and debate over energy have grown increasingly over the past two decades, with the issues of poverty alleviation, environmental risks and climate change now taking centre stage.

INSHP（International Network on Small Hydro Power）is an international coordinating and promoting organization for the global development of small hydropower（SHP）, which is established on the basis of voluntary participation of regional, subregional and national focal points, relevant institutions, utilities and companies, and has social benefit as its major objective. INSHP aims at the promotion of global SHP development through triangle technical and economic cooperation among developing countries, developed countries and international organizations, in order to supply rural areas in developing countries with environmentally sound, affordable and adequate energy, which will lead to the increase of employment opportunities, improvement of ecological environments, poverty alleviation, improvement of local living and cultural standards and economic development.

UNIDO and INSHP have been cooperating on the World Small Hydropower Development Report since year 2010. From the reports, SHP demand and development worldwide were not matched. One of the development barriers in most countries is lack of technologies. UNIDO, in cooperation with INSHP, through global expert cooperation, and based on successful development experiences, decided to develop the SHP TGs to meet demand from Member States.

These TGs were drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2（see www.iso.org/directives）.

Attention is drawn to the possibility that some of the elements of these TGs may be subject to patent rights. UNIDO and INSHP shall not be held responsible for identifying any such patent rights.

Introduction

Small Hydropower（SHP）is increasingly recognized as an important renewable energy solution to the challenge of electrifying remote rural areas. However，while most countries in Europe，North and South America，and China have high degrees of installed capacity，the potential of SHP in many developing countries remains untapped and is hindered by a number of factors including the lack of globally agreed good practices or standards for SHP development.

These Technical Guidelines for the Development of Small Hydropower Plants（TGs）will address the current limitations of the regulations applied to technical guidelines for SHP Plants by applying the expertise and best practices that exist across the globe. It is intended for countries to utilize these agreed upon Guidelines to support their current policy，technology and ecosystems. Countries that have limited institutional and technical capacities，will be able to enhance their knowledge base in developing SHP plants，thereby attracting more investment in SHP projects，encouraging favourable policies and subsequently assisting in economic development at a national level. These TGs will be valuable for all countries，but especially allow for the sharing of experience and best practices between countries that have limited technical know-how.

The TGs can be used as the principles and basis for the planning，design，construction and management of SHP plants up to 30 MW.

- The Terms and Definitions in the TGs specify the professional technical terms and definitions commonly used for SHP Plants.

- The Design Guidelines provide guidelines for basic requirements，methodology and procedure in terms of site selection，hydrology，geology，project layout，configurations，energy calculations，hydraulics，electromechanical equipment selection，construction，project cost estimates，economic appraisal，financing，social and environmental assessments—with the ultimate goal of achieving the best design solutions.

- The Units Guidelines specify the technical requirements on SHP turbines，generators，hydro turbine governing systems，excitation systems，main valves as well as monitoring，control，protection and DC power supply systems.

- The Construction Guidelines can be used as the guiding technical documents for the construction of SHP projects.

- The Management Guidelines provide technical guidance for the management，operation and maintenance，technical renovation and project acceptance of SHP projects.

Technical Guidelines for the Development of Small Hydropower Plants-Design
Part 6-3: Hydro Mechanical Works

1 Scope

This part of the Design Guidelines sets out the contents and requirements for design of hydro mechanical structures in an small hydropower (SHP) station, and provides specific requirements forthe selection and arrangement of hydro mechanical structure, hydraulic design calculations andanti-corrosion measures.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references,the latest edition of the referenced document (including any amendments) applies.

SHP/TG 001, *Technical guidelines for the development of small hydropower plants—Terms and definitions*.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in SHP/TG 001 apply.

4 Design content and requirements

4.1 Hydro mechanical structures include trash racks, gates, trash rack cleaning machine and hoist. During the design of the overall layout, type selection, manufacture and installation of hydro mechanical structure, close coordination with other disciplines and overall analysis shall be carried out, in order to achievean optimal design.

4.2 In the preparation of the design documents for hydro mechanical structures, the project tasks, operating conditions and requirements , water level control requirements, impact of water discharging and leakage, overall project layout and construction schedule, especially the layout and construction arrangement of hydraulic structures shall be understood.

4.3   Basic data of gate design shall include relevant regulations or norms and environmental protection requirements or regulations for project operation. The following relevant information shall also be prepared according to specific circumstances:

a)   Engineering tasks and layout of hydraulic structures;

b)   Gate opening size and operating conditions;

c)   Hydrological data, sediment, water quality, ice conditions, floating matter and meteorological conditions;

d)   Conditions for the materials, manufacture, transportation and installation of the gate;

e)   Earthquake and other special requirements.

5   Selection and layout of equipment

5.1   Generalre quirements

5.1.1   The overall layout of hydro mechanical structures shall be mainly to determine the locationof gates and hoists, orifice size, gate type, number and operation mode and other layout requirements related to operation.

5.1.2   The layout and type of hydro mechanical structures shall be determined through technical and economic comparison in the light of the overall planning of the project and the overall layout of hydraulic structures. A design scheme shall be reliable in quality, safe and applicable, advanced in technology, economical and reasonable.

5.2   Layout of gates

5.2.1   The layout of the gates in the hydraulic structures shall keep the flow smooth and avoid the transverse flow and vortices forming upstream of the gate, and submerged discharge and backflow downstream of the gate. When a gate is set up at an inlet, water shall not be allowed to pass through the bottom and over the top of the gate simultaneously.

5.2.2   For important deep-bottom-orifice gates or hydraulically operated gates, the reasonable layout and shape of the waterway shall be selected to ensure sound hydraulic conditions for gates and gate slots.

5.2.3   When a hydraulic structure is used for flood discharging or power generation and the orifices are arranged at different elevations, they should be staggered and not overlap.

5.2.4 Gates used for water diversion and power generation systems shall be selected in accordance with the protection requirements for turbine-generator units and layout characteristics of waterdiversion and power generation systems，and with overall consideration of the layout，type and operation mode of the gate. In general，on a heavy sediment/silt-carrying river，the sand-discharge bottom holes or sand-discharge corridors shall be set up adjacent to the water intake ofpower station.

5.2.5 The minimum net distance between two gates，or between the gate and the trash rack，shall meet the requirements of the concrete strength and impermeability of the gate groove，the layout and operation of the hoist，the installation and maintenance of the gate and hydraulic conditions，and should not be less than 1.50 m.

5.2.6 The top of an open-top gate shall be over 0.3 m to 0.5 m above the possible maximum retaining water level.

5.2.7 The hoist for the working gate of the discharge and sluice system with flood control function shall be equipped with a standby power supply.

5.2.8 If adequate ventilation cannot be provided behind a submerged gate of a permanent structure，an air vent shall be installed at the top of the orifice closest to the downstreamof the gate. The open end of the vent shall be separate from the hoist room，and protective facilities shall be provided.

5.2.9 The pressure equilibrium facilities of the gate should use the filling valve that is set on the door body，also may use internode water filling，small opening water filling or other effective facilities. The operation of the pressure equilibrium facilities shall be linked with the opening and closing of the gate，and a small opening travel switch should be installed on the hoist. The pressure equilibriumfacilities for the tailgate of the unit should be filled with water from the downstream end using the unit drainage system.

5.3 Type of gate and size of orifice

5.3.1 The type of the gate shall be selected through technical and economic comparison in the light of the operation requirements of the gate，the working conditions of the gate and the type of the hoist. The characteristics of various types of the gates shall also be considered.

5.3.2 The size of the gate orifice shall meet the requirements ofthe flow rate，the total water pressure undertaken by the gate，the operating conditions and the requirements for the manufacture and installation of the gate and the hoist.

5.3.3 When the water head is high，an orifice with a relatively small width-to-height ratio should be adopted；when the water head is low，an orifice with a relatively large width-to-height ratio should be used.

5.4 Hoist

5.4.1 In the overall arrangement，the advantages and disadvantages of various types of hoists shall be compared to analyze the operation mode of the gate hoist. In addition to considering the function of hoist itself，the possibility and/or necessity of other applicationsshall also be considered.

5.4.2 The type of hoist may be selected in accordance with the following requirements，in the light of the gate type，size，number of orifices and operating conditions：

a) Fixed winch hoist or ahydraulic hoist should be selected for the gate that is closed by deadweight or added weight and requires to be fully opened within a short time.

b) Hydraulic hoist should be selected for the gate that needs to be fully opened within a short time or has the requirements of downward-pressing.

c) Movable hoist should be selected for the plane gate with multiple orifices which are not required to be opened uniformly at the same time. The number of hoists shall be determined in light of the requirements for the opening times of the gate，and an appropriate number of backup hoists shall be considered. When a gantry hoist is set up，the maintenance for the hydro mechanical structure on top of a dam and for the dam itself shall be considered.

d) Screw hoist should be selected for the small gate that has downward-pressing requirements.

e) The opening/closing capacity of the selected hoist shall not be less than the calculated hoisting capacityand a margin of safety shall be reserved.

5.4.3 The lift of a hoist may be decided in light of the operating conditions，and shall meet the following requirements：

a) The overflow gate may be lifted to 1 m to 2 m above the water surface.

b) The quick shut-off gate may be lifted to 0.5 m to 1.0 m above the orifice.

c) The gate may be lifted to 0.5 m to 1.0 m above the maintenance platform for inspection，repair or replacement.

5.4.4 If a movable hoist is used to operate a multi-orifice gate，or the boom is loaded and unloaded frequently during the operation，an automatic hanging beam should be adopted. Mechanical or hydraulic type may be selected in light of the operating conditions. When the gate is equipped with an automatic hanging beam，the following requirements shall be satisfied：

a) The upstream waterstop should be set up for the gate. If the gate is equipped with a downstream waterstop，attention shall be paid to the reliability of the underwater operation of an au-

tomatic hanging beam.

b） During the underwater operation of an automatic hanging beam，attention shall be paid to the impact of flow disturbance on its stability.

c） The construction and installation precision of the gate slot can ensure that the automatic hanging beam can be used in multi-orifice slots.

d） The automatic hanging beam shall be equipped with a guide，positioning and safety devices，as well as gas/water drainage holes.

e） The automatic hanging beam shall be tested for static balance. and there shall be no inclining，blocking or sticking before entering the slot.

f） When the operating temperature is lower than 0 ℃，measures shall be taken to prevent the disassembly parts from freezing during operation or under water.

5.5 Manufacture，transportation and other considerations

5.5.1   In the overall layout of the gate，the manufacturing materials of the gate and the spare parts required for shaping the gate shall be as few as possible. The standardized and typed products should be adopted.

5.5.2   Special devices and equipment should be avoided in the process of gate manufacture and assembly and welding during installation.

5.5.3   Aplane gate shall be tested for static balance. When the tilt value of the gate exceeds the design requirements，the weight should be counterbalanced.

5.5.4   In the transportation of equipment，it is advisable to adopt the gate types or materials that are easy to be divided into parts，small and light pieces and large stiffness，to avoid the situation that the equipment size exceeds the limit or is overweight.

5.5.5   During the construction or operation period，the storage，assembly，maintenance and locking places of the gates and their components shall be designed and arranged in a general way so as to facilitate operation，maintenance and safety.

5.5.6   According to the local climate conditions such as sunshine，temperature，rainfall，thunder，hail，sand，etc.，the necessity of setting up a hoist room and the type of hoist，operation and maintenance conditions，as well as the assembly，storage and maintenance places of the above gate components shall be comprehensively considered. The hoist room and assembly site shall be designed with due consideration to the safety and convenience of operating personnel. Structural measures shall be set at the edge of the gate well to prevent sundries from falling into the well.

5.5.7　The location of backup power shall be reasonably arranged.

5.5.8　In coldand frozen regions, anti-freezing measures shall be taken according to local conditions for the gate structure and the gate slot with operation requirements in winter.

5.6　Arrangement of hydro mechanical structure for surface spillways

5.6.1　The bulkhead gate and hoisting equipment shall be designed in accordance with the following requirements:

a)　The bulkhead gate should be installed upstream of the service gate of the spillway. The type of bulkhead gate may be plane sliding gate, or stoplog, floating stoplog or floating bulkhead gate based on the actual situation of the project.

b)　When the reservoir water level is below the bottom threshold of the gate for enough continuous time each year and can meet the maintenance requirements of the service gate, the bulkhead gate may not be set. However, if the period is not suitable for maintenance due to cold weather and other reasons, the bulkhead gate shall be installed.

c)　In general, emergency gate may not be installed in front of the gate for emersed discharge orifice. However, for some projects, or for the service gate of a spillway where there is a wood-passing requirement, an emergency gate may be installed.

d)　When the spillway is operated by a plane service gate and a movable hoist, the maintenance of the service gate and its gate slot may be solved by adding 1 or 2 backup service gate (s).

e)　When a multi-orifice service gate in a water discharging system is operated by a movable hoist, the bulkhead gate may be used by multiple orifices, and the specific number of gates required shall be determined based on factors such as the number of orifices, the importance of the project and the applicable conditions and maintenance requirements of the service gate.

5.6.2　The type and elevation of surface service gates shall be determined by the following factors:

a)　The surface spillway service gate shall be selected based on factors such as the operating requirements of the project, the operating conditions of the gate, the type of hoist, and technical and economic indicators; the plane gate and radial gate may be adopted here.

b)　If the bottom edge of the gate is located on the top of the dam, it should be located slightly downstream of the highest weir crest. If there is bulkhead gate upstream of the service gate, the position of the service gate shall also meet the requirements of the arrangement of the hoist and the installation, operation, maintenance and overhaul of the gate; but its position should not be too low.

5.6.3 The operating equipment of the spillway and service gates shall be provided with not only reliable common power supply but also standby power. A diesel generator unit is usually adopted as the standby power. For hoisting equipment with a relatively small hoisting capacity，a manuallyoperated device shall be used as standby power，but the opening time of the gate shall meet the requirements of flood dispatching.

5.7 Arrangement of hydro mechanical structure for deep-type drainage sluices

5.7.1 The emergency gate，bulkhead gate and hoisting equipment shall be designed in accordance with the following requirements：

a) A deep-type drainage sluice shall be equipped with an emergency gate，which shall not only be able to close the orifice in running water if an accident occurs upstream or downstream of the service gate，but shall also be used to retain water or used as a bulkhead gate in normal operation.

b) The position of a deep-orifice emergency gate，and the shape of the gate slot，shall be favourable for improving the hydraulic conditions of the waterway or inlet section，and shall normally be selected by reference to similar experience of the completed projects or through necessary hydraulic model test.

c) When the deep-type drainage sluice is a non-pressure orifice，and there is a mobile hoist for the operation of the gate，it may be considered that one inlet emergency gate shared by several orifices. However，if the deep-type drainage sluice is a pressure orifice，and the service gate is set up at the outlet，then every orifice may be equipped with a separate emergency gate.

d) If the water level downstream of a deep-type drainage sluice often submerges the bottom sill，a downstream bulkhead gate shall be set up if necessary.

e) A sand-discharging orifice shall be located as close as possible to the areas requiring sand discharge，such as the water inlet for power generation or irrigation，or to the head of ship gate. Usually the inlet section of sand-discharging orifice shall be equipped with an inlet gate. Depending on the specific conditions of a sand-discharging gate，a high-pressure water gun may be set up if necessary.

5.7.2 The type of deep-orifice service gate may be determined in accordance with the following requirements：

a) Radial gate：a radial gate may be preferentially selected as the deep-orifice drainage control equipment. If the size of the gate orifice is relatively large and the operational head of water is more than 50 m，or if the hydraulic conditions of a deep-orifice service gate is improved and the gate is required to be partially open，a radial gate should be selected.

b） Plane gate：the plane gate may be used when the outlet arrangement of the in-dam drainage wa-
terway in the arch dam is improved or when the deep-orifice gate is not partially opened，and
the gate slot is properly designed.

c） Conical valve：when the layout conditions can properly solve the adverse effects of free jets on
the downstream building and equipment of the power station，a conical valve may be adopted
as deep-orifice service gate.

5.7.3 The deep-orifice service gate and hoisting equipment shall be designed in accordance with the
following requirements：

a） The service gate shall be installed at the end of a pressure conduit，and the non-pressure free-
flow section shall be connected behind the gate. The pressure section in front of the gate shall
maintain a certain contraction rate，and the inlet-to-outlet area ratio may be 1.5 to 1.7.

b） The non-pressure free-flow section of a deep-type drainage sluice should be straight. If there are
curves in the discharging conduit，the service gate should be located on the straight section
downstream of the last curve where the water flows smoothly.

c） When the service gate is installed in the middle section of a deep drainage channel，the in-orifice
pressure may be increased，and the pressure distribution condition at the inlet and near the gate
slot can be improved by selecting an appropriate outlet contraction plate and pressure slope line
for the sluice. In the course of opening/closing a gate，the alternative occurrence of pressure
flow and non-pressure flow shall be avoided. When the service gate and hoist are set up at the
outlet of a pressure orifice，a radial gate may be adopted，but attention shall be paid to handle
the supporting structure of the thrust transfer of the radial gate. If a plane gate is selected for
the outlet，the super cavitation jet gate slot may be used to improve the hydraulic conditions.

5.8 Arrangement of hydro mechanical structure for water diversion and power generation systems

5.8.1 The trash rack，trash remover and hoisting equipment at the intake works shall be designed in
accordance with the following requirements：

a） The trash rack shall be designed and installedbased on the importance of the power station and
the nature，and expected quantity，of the trash. In the layout design，conditions such as water
flow direction and favourable topographical location should be utilized so that the accumulation
of trash in front of trash rack is avoided or reduced. The design should also seek to ensure that
the incoming water flow is smooth，the resistance loss is minimized，the racks are easy to
clean，and easy to install，maintain and replace. The arrangement of the trash racks shall meet the
requirements of the water intake of the hydropower station.

b） The design load of the trash rack shall be decided according to the nature，quantity and cleaning

measures of riversewage. The sewage barrier of the water diversion power generation system should be designed with 2 m to 4 m，and the special cases should be analyzed and determined. For rivers with large amount of sewage and poor decontamination conditions，the design head should be raised appropriately.

c） The trash removal from trash racks may include manual mode，mechanical mode and racking-lifting mode.

5.8.2　The bulk head gate and hoisting equipment at the water intake shall be designed in accordance with the following requirements：

a） The bulkhead gate should be set up at the water inlet. As for the type of bulkhead gate，a plane sliding gate may be selected.

b） If the utilization hours of the turbine-generator unit in a power station are relatively small，the stop time is relatively long，the maintenance requirements of an emergency gate or a quick shutoff gate may be satisfied，and the appropriate safety measures are taken for embedded partssuch as gate slots to ensure construction quality，the waterintake bulkhead gate may be omitted.

c） When the water intake bulkhead gate of a power station with several turbine-generator units is operated by a movable hoist/gantry crane，several orifices may share one gate. The number of gates shall be determined based on factors such as the number of orifices，the importance of the project，and the application and maintenance conditions of emergency gates or quick shutoff gates. In general，one intake bulkhead gate may be set up for three to sixturbine-generator units； if there are more than six turbine-generator units，one additional hoist may be set up for every four to six additional turbine-generator units.

d） The bulkhead gate and trash rack may share the same slot. The arrangement of the gate slot and its embedded parts shall meet the opening/closing requirements of the gate and trash rack，and the structural strength shall also be designed in accordance with the bulkhead gate.

5.8.3　The emergency gate and hoisting equipment at the intake shall be designed according to the following requirements：

a） When units or penstocks require accident protection of the gate，quick shutoff gatesand bulkhead gates shall be installed at the intake of the power station at the dam toe. For a diversion power station，the quick shutoff gate should be installed at the head end of the underground buried penstock without a water inlet valve in front of the open penstock and the turbine；and the emergency gate should be installed at the entrance to the long diversion channel. For riverbed hydropower stations，when the unit has a reliable anti-runaway device，its intake should be equipped with an emergency gate and anbulkhead gate. After the demonstration，if the emergency gate has maintenance conditions，it is not necessary to install the bulkhead gate.

For a tubular turbine power station，a trash barrier and abulkhead gate（or emergency gate）shall be installed at the intake，and an emergency gate（or bulkhead gate）shall be installed at the tail water outlet.

b）   The emergency gate shall be installed based on the emergency protection requirements of the turbine-generator units or penstocks. When the unit has an accident and the diversion mechanism fails to close，or when the penstock has an accident，the emergency gate shall be able to close the gate. If the diversion conduit or the turbine-generator unit is under maintenance，the emergency gate may be used to retain water and used as a bulkhead gate.

c）   For diversion-type power stations，the bulkhead gate or emergency gate shall be installed at the inlet of the diversion conduit. The quick shutoff gate or emergency gate should be set up at the inlet of the penstock at the location of the surge shaft within thelong diversion conduit.

d）   If the quick shutoff gate or emergency gate of a hydropower station is located in the surge shaft and often stays in the gate slot，the adverse impact of a surge event in the surge shaft on stopping or lowering of gate shall be considered.

e）   The closing time for a quick shutoff gate shall meet the requirements for runaway prevention of the turbine generator unit and for penstock protection. Its lowering speed when getting close to the sill should not be more than 5 m/min.

f）   The hoisting equipment of a quick shutoff gate shall have both a local operating system and a remote operating system and shall be equipped with a reliable power source.

g）   The emergency（quick shutoff）gate and bulkhead gate at the water intake of a power station should opened in static water. A reliable pressure measuring facility shall be installed at the water intake of the power station.

5.8.4   The tailwater gate and hoisting equipment shall be designed in accordance with the following requirements：

a）   The tailwater bulkhead gate should opened/closed in static water. For a tubular turbine power station with bulkhead gates at the intake，the emergency gate shall be installed at tailwater outlet.

b）   In general，a plane sliding gate shall be adopted as the tailwater bulkhead gate. Two tailwater bulkhead gates may be installed for three to six turbine-generator units；if there are more than six turbine-generator units，one additional hoist may be set up for every four to six additional turbine-generator units.A movable hoist should be installed when gate holes are shared.

c）   To equalize the pressure on the tailwater gate，the water should be diverted from tailwater into the draft tube.

6 Hydraulic design and calculation

6.1 Calculation of load on a gate

6.1.1 The static water pressure applied to a gate may be calculated by the means of formulas in Table 1.
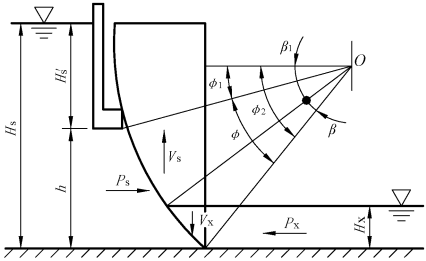
Table 1 Calculation of static water pressure

No.	Diagram of water pressure	Calculation formula
1		Total water pressure: Position of acting point of force P: $H_c = \dfrac{2}{3} H_s$
2		Total water pressure: $P = \dfrac{1}{2} \gamma (H_s^2 - H_x^2) B_{zs}$ Position of acting point of force P: $H_c = \dfrac{1}{3} \left(2H_s - \dfrac{H_x^2}{H_s + H_x} \right)$
3		Total water pressure: $P = \dfrac{1}{2} \gamma (2H_s - h) h B_{zs}$ Position of acting point of force P: $H_c = H_s - \dfrac{h}{3} \cdot \dfrac{3H_s - 2h}{2H_s - h}$
4		Total water pressure: $P = \gamma (H_s - H_x) h B_{zs}$ Position of acting point of force P: $H_c = H_s - \dfrac{1}{2} h$
5		Total water pressure: $P = \dfrac{1}{2} \gamma \left[(2H_s - h)h - H_x^2 \right] B_{zs}$ Position of acting point of force P: $H_c = \dfrac{3H_s H_x^2 - H_x^3 - 6H_s^2 h + 6H_s h^2 - 2h^3}{3H_x^2 - 6H_s h + 3h^2}$

Table 1（*continued*）

No.	Diagram of water pressure	Calculation formula
6		$P = \dfrac{1}{2}\gamma H_s^2 B_{zs}$ $V_s = \dfrac{1}{2}\gamma R^2\left[\dfrac{\pi\phi}{180} + 2\sin\phi_1\cos\phi_2 - \dfrac{1}{2}(\sin2\phi_1 + \sin2\phi_2)\right]B$ $P_x = \dfrac{1}{2}\gamma H_x^2 B$ $V_x = \dfrac{1}{2}\gamma R^2\left[\dfrac{\pi\beta}{180} + 2\sin\beta_1\cos\phi_2 - \dfrac{1}{2}(\sin2\beta_1 + \sin2\phi_2)\right]B$ Total water pressure： $P = \sqrt{(P_s - P_x)^2 + (V_s - V_x)^2}$
7		$\phi_1 < \phi_2$ $P_s = \dfrac{1}{2}\gamma H_s^2 B$ $V_s = \dfrac{1}{2}\gamma R^2\left[\dfrac{\pi\phi}{180} - 2\sin\phi_1\cos\phi_2 - \dfrac{1}{2}(\sin2\phi_2 - \sin2\phi_1)\right]B$ $P_x = \dfrac{1}{2}\gamma H_x^2 B$ $V_x = \dfrac{1}{2}\gamma R^2\left[\dfrac{\pi\beta}{180} + 2\sin\beta_1\cos\phi_2 - \dfrac{1}{2}(\sin2\beta_1 + \sin2\phi_2)\right]B$ Total water pressure： $P = \sqrt{(P_s - P_x)^2 + (V_s - V_x)^2}$
8		$\phi_1 > \phi_2$ $P_s = \dfrac{1}{2}\gamma H_s^2 B$ $V_s = \dfrac{1}{2}\gamma R^2\left[\dfrac{\pi\phi}{180} - \sin2\phi_2 - \sin(\phi_1 - \phi_2) - 2\sin\phi\sin^2\left(\dfrac{\phi_1 - \phi_2}{2}\right)\right]B$ $P_x = \dfrac{1}{2}\gamma H_x^2 B$ $V_x = \dfrac{1}{2}\gamma R^2\left[\dfrac{\pi\phi}{180} + 2\sin\beta_1\cos\phi_2 - \dfrac{1}{2}(\sin2\beta_1 + \sin2\phi_2)\right]B$ Total water pressure：$P = \sqrt{(P_s - P_x)^2 + (V_s - V_x)^2}$

Table 1（*continued*）

No.	Diagram of water pressure	Calculation formula
9		$P_s = \dfrac{1}{2}\gamma(H_s + H'_s)hB$ $V_s = \dfrac{1}{2}\gamma R^2 \left[\dfrac{\pi\phi}{180} + 2\sin\phi_1\cos\phi_2 - \dfrac{1}{2}(\sin 2\phi_1 + \sin 2\phi_2) + \right.$ $\left. \dfrac{2H'_s}{R}(\cos\phi_1 - \cos\phi_2) \right]B$ The calculation formulas for P_x, V_x and P are the same as those in this Table item 6 Where： P_s —is the upstream horizontal component force，in kN； V_s —is the upstream vertical component force，in kN； P_x —is the downstream horizontal component force，in kN； V_x —is the downstream vertical component force，in kN； H_s —is the upstream water head，in m； H_x —is the downstream water head，in m； R —is the curvature radius of the faceplate of radial gate，in m； γ —is the unit weight of water（In general，10 kN/m³ may be used for fresh water）； B_{zs} —is the interval of waterstops on both sides，in m； B —is the width of the orifice，in m； h —is the height of gate(the height to the top waterstop)，in m.

6.1.2　The dynamic water pressure applied on the gate may be calculated in accordance with the following provisions：

a）　For a service gate that is often operated in dynamic water conditions under a high water head or is often operated partially open，the different dynamic loads undertaken by different components of the gate shall be considered in the design，while the static load on the different components of the gate may be multiplied by different dynamic coefficients in accordance with the type and flow conditions of the gate. The value of the dynamic coefficient should be between 1.0 and 1.2. As for the main beam and supporting arm of anemersed radialgate，the value of the dynamic coefficient should be between 1.1 and 1.2. The dynamic coefficients of important service gates with complicated flow conditions shall be specially studied. The dynamic coefficient shall not be consideredin the calculation of the rigidity of gate.
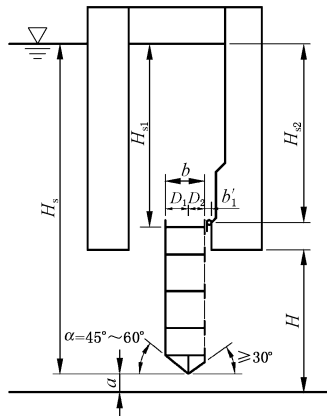
Figure 1—Schematic diagram of bottom edge of gate

b) When the type of bottom edge indicated in Figure 1 is adopted, the uplift force may be calculated by usingthe Formula (1):

$$P_t = \gamma \beta_t H_s D_1 B_{zs} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where

P_t is the uplift force, in kN;

H_s, D_1 see Figure 1, in m;

B_{zs} is the interval of waterstops on both sides, in m;

γ is the unit weight of water, in kN/m³;

β_t is the Up lift force coefficient. In the calculation of the gate closing force, it shall be considered that the gate is fully closed, and $\beta_t = 1.0$; in the calculation of the holding force, it may be considered for different opening positions of the gate, and β_t may be determined by reference to Table 2 and shall be verified through hydraulic model testing for special circumstances; the values of β_t given in Table 2 are applicable to the free-flow state behind the gate, and for sluiceway gates, $0 < a < 0.5\,H$ (where H is the orifice height of diversion channel); for quick shutoff gates for a power station, $0 < a < a_k$ (where a_k is the critical opening for the transition from free to pressurized flow behind the gate when the quick shutoff gate of the power station is closed; this may be calculated based on experience of similar completed projects or by reference to the relevant testing and study reports; it may be determined through hydraulic model testing if necessary. Under normal circumstances, it may be temporarily estimated as $a_k = 0.5H$).

Table 2 Up lift force coefficient β_t

α (°)	a/D_1				
	2	4	8	12	16
60°	0.8	0.7	0.5	0.4	0.25
52.5°	0.7	0.5	0.3	0.15	—
45°	0.6	0.4	0.1	0.05	—

Notes: a — is the opening height of gate, in m;

D_1 — is the distance from bottom waterstop of gate to upstream faceplate, in m;

α — is the upstream inclination of bottom edge of gate (See Figure 1).

c) The downward suction may be calculated by the Formula (2). When the arrangement of the bottom edge of the spillway gate, sluice gate and free flow tunnel gate in the dam meet the requirements of Figure 1, and the downstream flow state is good and the ventilation is sufficient, the calculation of downward suction may be omitted:

$$P_s = p_s D_2 B_{zs} \quad\quad\quad\quad\quad\quad\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(2)$$

where

P_s is the downward suction, in kN;

D_2 is the distance from the waterstop at the bottom edge of gate to the lower edge of the main beam, in m;

p_s is the average downward suction at D_2 section on the bottom edge of gate, to be calculated on the basis of 20 kN/m². When the flow state is good, the gate is well ventilated and the requirements for the arrangement of the bottom edge of the gate in Figure 1 are satisfied, the suction may be decreased appropriately.

6.1.3 The horizontal silt pressure applied on a gate may be calculated in accordance with the Formula (3) and the Formula (4). When the water-retaining face of the gate is tilted, the vertical silt pressure shall be calculated.

$$P_n = \frac{1}{2} \gamma_n h_n^2 \tan^2 \left(45° - \frac{\phi}{2} \right) B \quad\quad\quad\quad\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(3)$$

$$\gamma_n = \gamma_0 - (1 - n) \gamma_w \quad\quad\quad\quad\quad\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(4)$$

where

P_n is the silt pressure, in kN;

γ_n　is the buoyant unit weight of silt, in kN/m³;

γ_0　is the dry unit weight of silt, in kN/m³;

γ_w　is the unit weight of water, in kN/m³;

n　is the porosity of silt;

h_n　is the thickness of silt accumulated in front of the gate, in m;

B　is the width of silt accumulated in front of the gate, in m;

ϕ　is the internal frictional angle of silt, in (°).

6.1.4　The impact force of floating materials may be calculated in accordance with the Formula（5）:

$$P_z = \frac{W_p v}{gt} \qquad\qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots（5）$$

where

P_z　is the impact force of floating material, in kN;

W_p　is the weight of floating material in kN, which is to be determined on the basis of actual survey
　　of floating material in the river;

v　is the flow velocity, in m/s;

g　is the gravitational acceleration;

t　is the impact time to be estimated based on actual data, in s.

6.2　Calculation of gate hoisting capacity

6.2.1　The hoisting capacity of a plane vertical gate shall be calculated in accordance with the follow-
ing methods:

a）　The calculation of the gate hoisting capacity in dynamic water shall include the calculation of the
　　gate closing force, the holding force and the gate opening force.

　　1）　The gate closing force shall be calculated in accordance with the Formula（6）. When the cal-
　　　　culation result is a positive value, the 'weight' must be added（the 'weight'elements in-
　　　　clude the weighting block, the water column or the mechanically downward-pressing）;

when the calculation result is a negative value，the gate can be closed by virtue of its dead weight.

$$F_w = n_T (T_{zd} + T_{zs}) - n_G G + P_t \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6)$$

2）The holding force shall be calculated in accordance with the Formula（7）：

$$F_T = n'_G G + G_j + W_s + P_x - (T_{zd} + T_{zs}) \quad \cdots\cdots\cdots\cdots\cdots\cdots (7)$$

3）The gate opening force shall be calculated in accordance with the Formula（8）：

$$F_Q = n_T (T_{zd} + T_{zs}) + P_x + n'_G G + G_j + W_s \quad \cdots\cdots\cdots\cdots\cdots (8)$$

4）The frictional resistance of the roller in the sliding bearing shall be calculated in accordance with the Formula（9）：

$$T_{zd} = \frac{P}{R}(f_1 r + f) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (9)$$

5）The frictional resistance of roll in the rolling bearing shall be calculated in accordance with the Formula（10）：

$$T_{zd} = \frac{Pf}{R}\left(\frac{R_1}{d} + 1\right) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (10)$$

6）The frictional resistance of the sliding support shall be calculated in accordance with the Formula（11）：

$$T_{zd} = f_2 P \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (11)$$

7）The frictional resistance of thewaterstop shall be calculated in accordance with the Formula（12）：

$$T_{zs} = f_3 P_{zs} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (12)$$

where

F_w，F_T，F_Q is the gate closing force，holding force and gate opening force，respectively，in kN；

n_T is the frictional resistance safety coefficient，which shallbe 1.2；

n_G	is the gate dead-weight correction coefficient used for the calculation of gate closing force，which shall be 0.9 to 1.0；
n'_G	is the Gate dead weight correction coefficient used for the calculation of holding force and opening force，which shall be 1.0 to 1.1；
G	is the Gate dead weight，in kN（the weight of the suspender shall be included，if any）；for calculation of gate closing force，the weight of the suspender shall not be included，and the floating weight may be taken as the weight of gate；
W_s	is the water load on gate，in kN；
G_j	is the weight of weighting block，in kN；
P_t	is the up lift force，in kN；including uplift force of bottom edge and uplift force of waterstop. The uplift force of the bottom edge may be calculated in accordance with Formula（1）；
P_x	is the downward suction，in kN，which may be calculated in accordance with the Formula（2）；
T_{zd}	is the frictional resistance of support，in kN；
P	is the total water pressure applied on gate，in kN；
r	is the radius of roller shaft，in mm；
R_1	is the average radius of rolling bearing，in mm；
R	is the radius of the roller，in mm；
d	is the diameter of roller or ball of rolling bearing，in mm；
f	is the rolling frictional arm，in mm，to be determined in accordance with Appendix A；
T_{zs}	is the frictional resistance of waterstop，in kN；
P_{zs}	is the pressure applied on waterstop，in kN；

f_1, f_2, f_3 is the sliding frictional coefficients, to be determined in accordance with Appendix A (the minimum value shall be taken for the calculation of the holding force, and the maximum value shall be taken for the calculation of the gate opening force and gate closing force).

b) For a gate opened in static water, the calculation of its hoisting capacity shall involve the frictional resistance caused by the water level difference, the dead weight of the gate as well as the weight of the weighting block. For emersed gates and tail water gates, the water level difference shall be no more than 1 m; for submerged gates, the water level difference of 1 m to 5 m shall be adopted. In cases of silt or dirt sedimentation, the difference allowed may be increased appropriately based on actual situations.

6.2.2   The radial gate hoisting capacity shall be calculated in accordance with the following methods:

a) The closing force shall be calculated in accordance with the Formula (13). When the calculation result is a positive value, the weight shall be added; when the calculation result is a negative value, the gate can be closed under its own dead weight.

$$F_W = \frac{1}{R_1} [n_T (T_{zd} r_0 + T_{zs} r_1) + P_t r_3 - n_G G r_2] \qquad \cdots\cdots\cdots\cdots\cdots\cdots (13)$$

b) The opening force may be calculated in accordance with the Formula (14):

$$F_Q = \frac{1}{R_2} [n_T (T_{zd} r_0 + T_{zs} r_1) + n'_G G r_2 + G_j R_1 + P_x r_4] \qquad \cdots\cdots\cdots\cdots (14)$$

where:

r_0, r_1, r_2, r_3, r_4 is the acting arm of frictional resistance of the rotating hinge, frictional resistance of the waterstop, dead weight of the gate, uplift force and downward suction inrelation to the moving centre of the radial gate, in m.

R_1, R_2 is the acting arm of the additional weight (or the downward force) and gate opening force relative to the moving centre of the radial gate, in m.

T_{zs} is the Frictional resistance of the waterstop, to be calculated in accordance with the Formula (12).

The meanings of other symbols are the same as above.

c) During the opening/closing of aradial gate, the acting point, direction and arm of force will change as the gate moves. Therefore, if necessary, the curve of opening/closing force may be

drawn to determine the maximum value.

6.2.3 The lifting force of the trash rack shall be calculated in accordance with the following methods:

a) In static water, the lifting force may be calculated in accordance with the Formula (15):

$$F_Q \geqslant n'_G G + n_m m \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(15)$$

where

F_Q is the lifting force of trash rack, in kN;

n_m is the overweight coefficient of trash, which shall be 1.2;

m is the weight of trash, in kN, to be determined on the assumption that the grilles are partially blocked, and the blockage area shall be decided upon relative to the amount of trash;

G is the dead weight of the trash rack, in kN;

n'_G is the dead-weight correction coefficient, which shall be between 1.0 and 1.1.

b) When lifting in dynamic water, the lifting force shall be calculated according to the Formula (15), and the impact of water level difference caused by partial blockage of trash rack shall also be considered, and the water level difference selected shall not be more than 2 m.

6.3 Calculation of the venthole area

6.3.1 Fora service gate or emergency gate set up in a sluice pipe, the area of theventhole behind the gate may be calculated in accordance with the empirical Formula (16) and Formula (17), ormay be calculated in accordance with the semi-theoretical and semi-empirical Formula (18) , Formula (19) and Formula (16):

$$A_a \geqslant \frac{Q_a}{[v_a]} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(16)$$

$$Q_a = 0.09 v_w A \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(17)$$

$$\beta = \frac{Q_a}{Q_w} = K(F_r - 1)^{[a\ln(F_r-1)+b]} - 1 \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(18)$$

$$F_r = \frac{v}{\sqrt{9.81\,e}} \qquad\qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(\,19\,)$$

where

A_a is the sectional area of vent hole, in m^2;

Q_a is the full ventilation capacity of vent hole, in m^3/s;

$[v_a]$ is the allowable air velocity of vent hole, in m/s, which shall be set as 40 m/s (or 50 m/s for a small gate);

v_w is the flow velocity at gate orifice, in m/s;

A is the area of conduit behind gate, in m^2;

β is the air-water ratio, namely the ratio between flow rate of air and flow rate of water discharged;

Q_w is the flow rate when the gate is at a given opening height, in m^3/s;

F_r is the Froude number of cross-section of gate orifice;

v is the average flow velocity at cross section of gate orifice, in m/s;

e is the opening height of gate, in m;

K、a、b is the coefficient for every section. See Appendix B.
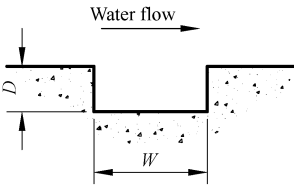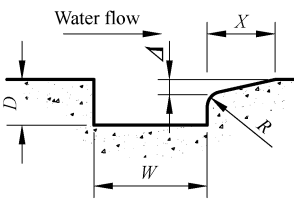
6.3.2   The area of the venthole behind a quick shut off gate in a water diversion and a power generation conduit maybe selected according to 4 per cent to 7 per cent of the area of the power generation conduit; and the area of the venthole of an emergency gate may be reduced as appropriate.

6.3.3   The area of the venthole behind a bulkhead gate may be selected based on the specific situation, and should not be less than the area of the charging conduit.

6.4 Type selection and calculation of the slot of a plane gate

6.4.1   For the type of gate slot for aplane gate in a water discharging system, the Type-I and Type-II gate slots may be selected. Their applicability and shape parameters are detailed in Table 3.

Table 3 Types, shape parameters and applicability of plane gate slots

Type	Diagram	Parameters of geometric shape of gate slot	Applicability
I		① Very good width-depth ratio W/D = 1.6 to 1.8; ② Appropriate width-depth ratio W/D = 1.4 to 2.5; ③ The empirical formula for the initial cavitation number of the gate slot is: $K_i = 0.38$ (W/D) (this formula is applicable to W/D which is 1.4 to 3.5)	① Gate slot of an emergency gate in a drainage sluice, and the gate slot of a bulkhead gate. ② Gate slot of a service gate on top of an overflow dam of which the water head is lower than 12 m. ③ Gate slot of an emergency gate or quick shutoff gate at the water inlet of a power station. ④ Gate slot of a service gate in a drainage sluice, where the flow cavitation number, K, is more than 1.0 (approximately equivalent to the situation when the waterhead is lower than 30 m or the flow velocity is less than 20 m/s).
II		① Appropriate width-depth ratio W/D = 1.5 to 2.0. ② Very good off set ratio $\triangle/W$ = 0.05 to 0.08. ③ Very good slope ratio $\triangle/X$ = 1/10 to 1/12. ④ Very good fillet radius R = 30 mm to 50 mm or rounded corner ratio R/D = 0.10. ⑤ The initial cavitation number of the gate slot is $K_i = 0.4$ to 0.6 (to be selected based on existing research results and experience of similar projects).	① Gate slot of a service gate in a drainage sluice, where the flow cavitation number, K, is more than 0.6 (approximately equivalent to the situation when the waterhead is 30 m to 50 m, or the flow velocity is 20 m/s to 25 m/s). ② Gate slot of an emergency gate with high waterhead and short conduit, of which the flow cavitation number, K, is more than 0.4 and less than 1.0. ③ Gate slot of a service gate which must frequently be opened partially and of which the flow cavitation number, K, is more than 0.8. ④ Gate slot of a service gate on top of an overflow dam of which the water head is lower than 12 m and the flow cavitation number, K, is more than 0.8.

6.4.2 If the structure near the gate slot has a special shape or the flow state is complicated, or if the service gate is required to frequently be partially open and the above-mentioned two types of slots cannot meet the needs, an appropriate type of gate slot may be selected by reference to operational experience from completed projects and through hydraulic model testing; this enables reasonable measures or methods to increase the flow cavitation number, K, in the gate slot to be determined.

6.4.3 When the flow cavitation number, K, is less than 0.6 （approximately equivalent to a situation where the water head is higher than 60 m or the flow velocity is more than 30 m/s）, the Type-IIgate slot or another special type of slot shall be selected. Based on the specific conditions of the project, the lining shall be made of steel plate or low-water-cement-ratio high-strength concrete or other corrosive-resistant materials; these should be applied to areas on the upstream and downstream sides of the gate slot. During construction, the shape shall be maintained accurately and the surface shall be plane.

6.4.4 The flow cavitation number, K, may be calculated by using the Formula （20）:

$$K = \frac{(P_1 + P_a - P_V)/\gamma}{\dfrac{v^2}{(2g)}} \qquad\qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots（20）$$

where

P_1 is the Average pressure on the cross section immediately adjacent to the upstream side of the-gate slot, in kPa;

P_a is the atmospheric pressure, in kPa. See Figure 2;

P_V is the saturated vapour pressure of water, in kPa. See Figure 3;

γ is the unit weight of water, in kN/m^3;

v is the verage flow velocity on the cross section immediately adjacent to the upstream side of thegate slot, in m/s;

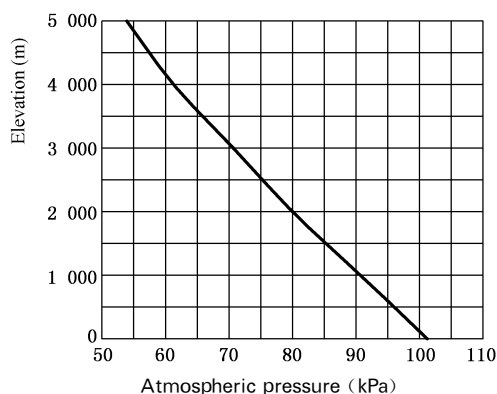g is the gravitational acceleration, in m/s^2.

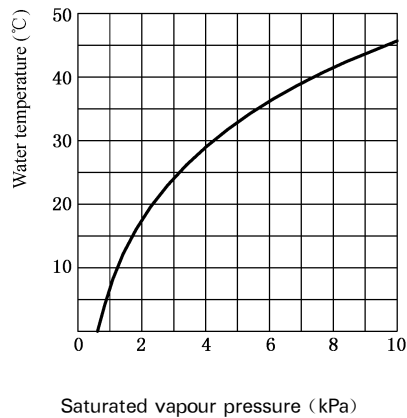Figure 2—Curve for relationship between atmospheric pressure and elevation

Figure 3—Curve for relationship between saturated vapour pressure of water and temperature

6.4.5 Based on the flow cavitation number, K, near the gate slot, the appropriate type of gate slot may be selected. If $K_i < K$, then this type of gate slot will not generally cause cavitation. For a safety allowance for $K > K_i$, the safety coefficient $n = 1.2$ to 1.5 may be selected based on the importance and operating conditions of the gate, so as to ensure that $K \geqslant nK_i$.

7 Anti-corrosion of hydro mechanical structures

7.1 General requirements

7.1.1 During the design of hydro mechanical structure, the anti-corrosion measures shall be selected after technical and economic comparisons have been carried out that consider factors such as operating environment, operating conditions, maintenance and management conditions of the structures.

7.1.2 The following three measures may be adopted for the anti-corrosion of hydromechanical structures:

a) Anti-corrosion coating;

b) Sprayed metal anti-corrosion coating;

c) Sacrificial anode cathodic anti-corrosion protection.

7.1.3 The surface of hydro mechanical structures should be pretreated before coating.

7.1.4 The design document shall specify the surface pretreatment cleanliness and surface roughness level and quality assessment standards.

7.2 Coating protection

7.2.1 The anti-corrosion coating should be composed of primer, intermediate paint and finishing coat. The primer shall have good adhesive force and rust resistance, the intermediate paint shall have shielding performance and good combination with the primer and finishing coat, and the finishing coat shall have weather and water resistance.

7.2.2 The coating system shall be selected based on the surrounding environment.

7.3 Sprayed-metal anti-corrosion coating

7.3.1 The sprayed metal anti-corrosion coating system may include sprayed-metal coating and sealing coating layer. The thermal sprayed metal and coating protection system shall be applied with intermediate paint and finishing coat after the coating is sealed.

7.3.2 The metal wires used for thermal spraying shall be clean and free of rust, oil or fold marks, and the wire diameter should be less than 3.0 mm.

7.3.3 In the sprayed metal coating protection system, the thickness of the metal coating may be determined based on the environmental factors.

7.3.4 The sealing coating shall be compatible with a sprayed metal coating, with relatively low viscosity and certain corrosion resistance.

7.4 Sacrificial anode cathodic anti-corrosion protection

7.4.1 Before design of sacrificial anode cathodic anti-corrosion protection, the following data shall be collected and, if necessary, an on-site survey shall be carried out:

a) Data about the design and construction of the hydromechanical structures;

b) Types, conditions and service life of the coating on the surface of the hydromechanical structures;

c) Electrical continuity of the hydromechanical structures, and electrical insulation from the other hydro mechanical structures under the water;

d) Chemical composition, PH value, resistance rate, contamination degree of the medium and variations of temperature, flow velocity and water level.

7.4.2 The sacrificial anode cathodic anti-corrosion protection shall be used together with coating protection.

7.4.3   The hydro mechanical structures applied with sacrificial anode cathodic protection shall be insulated from the other hydro mechanical structures in the water.

7.4.4   The actual service life of the sacrificial anode cathodic protection system shall be determined based on the design service life or the maintenance period of the metal structure.

8   Workload of hydro mechanical structures

The summary of the workload of hydro mechanical structures shall include：

a） Name，specification，type，orifice size，design water head and weight of the trash rack，trash rack groove，gate and gate slot；

b） Name，specification，type and quantity of trashrack cleaning machine and hoisting equipment，hoisting capacity，delivery head for hoisting operations，distance of the lifting points，and the power and weight of the matching motor.

c） For a gantry hoist or a platform hoist，the span，wheel track，track model and track length of the hoist shall also be stated.

Appendix A
(Informative)
Friction coefficient

Table A.1 Friction coefficient

Type	Material and operating conditions		Coefficient value	
			Maximum	Minimum
Sliding frictional coefficient	Steel vs. steel (dry friction)		0.5～0.6	0.15
	Steel vs. cast iron (dry friction)		0.35	0.16
	Steel vs. wood (with water)		0.65	0.3
	Slideway made of steel-based copper and plastic composite material or slide way made of reinforced polyflu-ortetraethylene plate vs. stainless steel，with the intensity of pressure q in fresh water	Intensity of pressure $q>2.5$ kN/mm	0.09	0.04
		Intensity of pressure $q = 2.5$ kN/mm to 2.0 kN/mm	0.09～0.11	0.05
		Intensity of pressure $q = 2.0$ kN/mm to 1.5 kN/mm	0.11～0.13	0.05
		Intensity of pressure $q = 1.5$ kN/mm to 1.0 kN/mm	0.13～0.15	0.06
		Intensity of pressure $q<1.0$ kN/mm	0.15	0.06
Frictional coefficient of sliding bearing	Steel vs. bronze (dry friction)		0.30	0.16
	Steel vs. bronze (lubricated)		0.25	0.12
	Steel-based copper and plastic composite material vs. chromium-plated steel (stainless steel)		0.12～0.14	0.05
Frictional coefficient in stagnant water	Rubber vs. steel		0.70	0.35
	Rubber vs. stainless steel		0.50	0.20
	Rubber and plastic composite water seal vs. stainless steel		0.20	0.05
Acting arm of rolling friction force	Steel vs. steel		1 mm	
	Steel vs. cast iron		1 mm	
NOTE The roughness R_a of the work face of the track shall be at least 1.6 μm，and the roughness R_a of work face of slideway shall be at least 3.2 μm.				

Appendix B
（Informative）
Semi-theoretical and semi-empirical formula coefficient

Table B.1　Semi-theoretical andsemi-empirical formula coefficient

Type of pipe	Section No.	Length of conduit behind gate Net height of conduit	Scope of F_r	$\beta = K(F_r-1)^{[a\ln(F_r-1)+b]}-1$		
				K	a	b
Pressure conduit equipped with plane gate	Ⅰ	6.10～10.66	3.96～20.30	1.158	0.112	−0.242
			3.87～3.960	1.0154	0	0
	Ⅱ	10.66～27.40	1.94～6.290	1.0150	0.035	0.004
			1.61～1.940	1.0152	0	0
	Ⅲ	27.40～35.78	1.91～17.190	1.042	0.039	0.008
			1.38～1.910	1.0413	0	0
	Ⅳ	35.78～77.00	1.08～15.670	1.1300	0.028	0.144
Non-pressure conduit equipped with radial gate	Ⅴ	6.10～10.66	4.57～32.590	1.342	0.173	−0.438
			3.49～4.570	1.0153	0	0
	Ⅵ	10.66～27.40	1.70～18.06	1.0540	0.019	0.013
			1.56～1.70	1.0515	0	0
	Ⅶ	27.40～35.78	2.45～10.81	1.073	0.053	0.070
	Ⅷ	35.78～77.00	2.33～8.310	1.170	0.182	−0.019

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