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INDUSTRIAL DEVELOPMENT ORGANIZATION



Technical Guidelines for the
Development of Small Hydropower Plants
CONSTRUCTION

**Part 2: Installation of
Electromechanical Equipment**

SHP/TG 004-2: 2019



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Further recommendations and suggestions for application for the update would be highly welcome.

Table of Contents

| | |
|---|-----|
| Foreword | VI |
| Introduction | VII |
| 1 Scope | 1 |
| 2 Normative references | 1 |
| 3 Terms and definitions | 1 |
| 4 Installation of turbine generator units and hydraulic machinery auxiliary equipment | 1 |
| 4.1 Basic requirements | 1 |
| 4.2 Turbine | 3 |
| 4.3 Generator | 18 |
| 4.4 Hydraulic machinery auxiliary equipment | 30 |
| 4.5 System pipelines | 38 |
| 5 Electrical equipment installation | 42 |
| 5.1 Basic provisions | 42 |
| 5.2 Switchboard outfit, complete cubicle and secondary circuit | 43 |
| 5.3 Transformers | 46 |
| 5.4 High-voltage electrical equipment | 49 |
| 5.5 Enclosed bus bar and the bus duct | 53 |
| 5.6 Cable laying | 55 |
| 5.7 Auxiliary system motors | 58 |
| 5.8 Computer monitoring system | 59 |
| 5.9 Video monitoring system | 60 |
| 5.10 Lightning protection grounding | 61 |
| 6 Installation of the automatic hydrological forecasting and reporting system | 65 |
| 7 Installation of Safety Monitoring Equipment | 67 |

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 30MW.

- 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 **CONSTRUCTION**

Part 2: Installation of Electromechanical Equipment

1 Scope

According to the construction characteristics of small hydropower (SHP) projects, this part of the Construction Guidelines stipulates the basic regulations and technical requirements for the installation of electromechanical equipment.

This document includes only technical guidance on engineering construction and excludes construction organization management.

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 Installation of turbine generator units and hydraulic machinery auxiliary equipment

4.1 Basic requirements

4.1.1 These installation requirements are applicable within the following range:

- a) They are applicable to the installation and acceptance of the hydroelectric generating units under the following conditions:
 - 1) The unit capacity is less than 10MW.
 - 2) For Francis and Pelton turbines, the nominal runner diameter is less than 1.0m.
 - 3) For axial-flow, diagonal and tubular turbines, the nominal runner diameter is less than 3.3m.
- b) For hydroelectric generating units and their main auxiliary equipment, and complete unit components transported to the construction site by the equipment manufacturer, such as the spiral case, bearings, generator, governor, main valve, the installation and acceptance of the equipment shall be carried out according to the requirements of this document.
- c) The combined installation of hydroelectric generating units and main auxiliary equipment at the power station shall be carried out according to the installation drawings approved by the manufacturer, the requirements of the corresponding technical documents and this document.

4.1.2 Installation of hydroelectric generating units shall meet the following requirements:

- a) Hydroelectric generating unit equipment shall meet the requirements of the relevant technological

standards and the contract order for the goods, and shall possess ex-factory inspection records and qualification documents. After the equipment has been transported to the receiving site, the acceptor shall organize the relevant people for the unpacking, tally and inspection of the supply list and packing list before the deadline agreed with the manufacturer.

- b) All the material employed in the installation of hydroelectric generating units shall meet the design requirements. The main material of the main parts shall possess inspection or ex-factory certificates of conformance.
- c) Detailed regulations for safety and environmental protection shall be established according to the actual situation.
- d) The installation site shall be protected against wind, rain, dust, fire, and possess enough lighting facilities and construction safeguards according to requirements. The temperature of the installation site should not be less than 5°C, and the relative air humidity should be less than 85%. Installation of equipment and components that require temperature, humidity and other special factors shall be carried out according to the design requirements.
- e) Before being installed, the equipment shall be entirely swept clean and inspected. The major size and fit tolerance of important components shall be checked, and complete sets of equipment with manufacturer's guarantee may not be disassembled.
- f) For embedding the equipment foundation baseplate, the elevation deviation should not be greater than -5mm to 0mm, the centre and distribution position deviation should not be greater than 10mm, and the horizontal deviation should not be greater than 1mm/m.
- g) Embedded components shall be reinforced and strengthened after installation. Foundation bolts, lifting jacks, strainers, wedges and foundation boards shall be fixed by spot welding. The interface between an embedded component and the concrete shall not have any oil stains or serious corrosion.
- h) Wedges for adjusting shall be used in pairs, and the overlapping length shall be greater than 2/3. After installation, the contact condition of a wedge that bears important components shall be inspected with a 0.05mm feeler gauge, and the length of contact on each side shall be greater than 70%.
- i) Equipment installation shall be carried out after the foundation concrete strength has reached at least 70% of its design value. Secondary concrete of the foundation board shall be grouted to compaction and micro-expansive cement should be used.
- j) Any equipment jointing surface shall be bright and clean without burrs. A 0.05mm feeler gauge should be used for inspection, and it shall not pass through any joint gap. If localised gaps are permitted, a 0.1mm feeler gauge shall be employed for inspection, and the depth shall not be greater than 1/3 of the combination width, and the total length shall not be greater than 20% of the perimeter. There shall be no gaps in the vicinity of assembly bolts and dowels. Any misalignment of the installation surface at the joint should not be greater than 0.10mm.
- k) Attention shall be paid to match marks during component assembly. If many generator units are installed together, each turbine generator unit shall be assembled with components from the same number series. Components or measuring points of the same type shall be numbered in order in the installation list. For fixed components, the numbering shall start from +Y and go in a clockwise direction, as seen from the generator end, similarly from below. The rotating components shall be numbered starting from the position corresponding to the middle of the two leads of the rotor poles, and going clockwise, except for the barring gear measuring points on the axis which shall be numbered anti-clockwise. Installation personnel shall pay attention to whether the manufacturers' numbering procedures are consistent with the above. If inconsistent, then these manufacturers' numbering should be clearly marked.

- l) For closely-pitched connecting bolt installation, lubricant shall be applied. Connecting bolts shall be uniformly fastened in a series of steps. For connecting bolts with pre-tightened force requirements, the pre-stress deviation shall not be greater than $\pm 10\%$ of the required value. For bolts that need to be screwed in a heated state, the degree of pre-tightening of about 20% of the bolts shall be selectively checked at room temperature after fastening. As each component is installed, location pin holes shall be drilled and pins shall be assembled according to the design requirements. All bolts, nuts, and pins shall be firmly locked in place or spot welded according to the design requirements.
- m) For the datum line and elevation points for installation of the hydro turbine generator units, the measurement error shall not be greater than $\pm 1\text{mm}$. The measurement error of height difference for all parts shall not exceed $\pm 0.5\text{mm}$; the error of horizontal measurement shall not exceed 0.02mm/m . The wire diameter for core measurement should be 0.3mm to 0.4mm , and the yield strength shall be no less than $1\ 200\ \text{MPa}$.
- n) For the strength withstanding pressure testing of pressure-bearing equipment and connecting pieces made in the field, the test pressure shall be 1.5 times the nominal working pressure, while the lowest pressure shall not be less than 0.4MPa . After maintaining the test pressure for 10min, there shall not be any unusual phenomena such as leakages or fissures. For rigorous withstanding pressure tests of equipment and their connecting pieces, the test pressure shall be 1.25 times the nominal working pressure. After 30min, no leakage shall occur. Withstanding pressure testing of coolers shall be carried out according to the design requirements. If there are no design requirements, the test pressure shall be 2 times the working pressure, at the same time it shall not be less than 0.40MPa . After 30min, no leakage shall occur.
- o) Kerosene leakage tests of equipment containers shall last for at least 4h and there shall be no leakage. Generally, the containers should not be dismantled after the test. Kerosene leakage tests of valves shall last for at least 5min and there shall be no leakage.
- p) Single keys shall be checked together with the key slots and the tolerance shall meet the design requirements. The parallelism of paired keys shall meet the design requirements.
- q) After installation of the bearing, when welding the rotating parts, the electric welder's ground wiring shall be connected directly to the part which is to be welded. Protective measures shall be taken as well to ensure that any splattered weld material will not drop into the bearing.
- r) Hydro turbine generator units shall be kept clean during and after component assembly and final assembly. The interior and exterior of hydro turbine generator units shall be carefully cleaned and checked after the installation. There shall be no sundry materials or dirt.
- s) Each component of the hydro turbine generator units shall be protected by a coating according to the relevant requirements.

4.2 Turbine

4.2.1 Vertical reaction turbine installation shall meet the following requirements:

- a) Installation of embedded parts shall meet the following requirements:
 - 1) Allowable installation error for the draft tube lining shall meet the requirements of Table 1.
 - 2) Allowable installation error for the runner chamber, foundation ring and stay ring shall meet the requirements of Table 2.

- 3) Spiral case installation and welding shall meet the design requirements.
- 4) There shall be a smooth transition between the embedded parts and concrete flow passage surfaces.
- 5) Allowable installation error of the turbine pit lining and servomotor foundation shall meet the requirements of Table 3.

Table 1 Allowable error of draft tube lining installation
Unit: mm

| No. | Items | Allowable error | Explanation |
|-----|---|-----------------|---|
| 1 | Pipe orifice diameter | $\pm 0.0015D$ | D—pipe orifice design diameter, which is measured at 8 equal-part points of the circle. |
| 2 | Difference between the inner perimeters of adjacent pipe orifices | 0.001L | L—Pipe orifice perimeter |
| 3 | Centre and position of the upper pipe orifice | 4 | Measure the distance between the X, Y mark points of the pipe orifice and the hydro turbine generator unit's X, Y datum lines |
| 4 | Upper pipe orifice elevation | 0~+8 | — |
| 5 | Lower pipe orifice centre | 10 | Measure by a hanging hammer |

Table 2 Allowable installation error of runner chamber, foundation ring and stay ring

| No. | Items | Allowable error | Explanation |
|-----|--|--|--|
| 1 | Centre and position | 2mm | Measure the distance between embedded part's X, Y mark points and hydro turbine generator unit's X, Y datum lines |
| 2 | Elevation | ± 3 mm | — |
| 3 | Level | 0.05 mm/m in radial measurement; maximum value shall be no larger than 0.6 mm | Elevation difference between the highest and lowest points |
| 4 | Circularity of the runner chamber | Difference between each radius and average radius shall be no larger than $\pm 10\%$ of the design average gap | For axial-flow type, measure the upper, middle and lower sections; for diagonal flow type, measure the upper and lower spigots at least 8 equidistant points. |
| 5 | Circularity of the foundation ring and stay ring | 1.0 mm | Measure at least 8 equidistant points. For mixed-flow type, the measurement is based on the centre of the lower fixed sealing ring; for the axial-flow type, the measurement is based on the centre of the runner chamber. |

b) Runner installation shall meet the following requirements:

- 1) The runner shall have no fissures. If necessary, it shall be checked by ultrasound. The blade profile shall meet the design requirements.
- 2) When connected together, there shall be no gap between the main shaft and the runner. The axiality and circularity of each part of the runner shall be checked taking the main shaft as the centre. The difference between each radius and the average radius shall meet the requirements of Table 4.

c) Installation of the guide mechanism and servomotor shall meet the following requirements:

- 1) Before the pre-installation of the guide mechanism, recheck the stay ring's upper surface elevation, level and circularity of the bore opening; they shall meet the requirements of Table 2.
- 2) The allowable installation error for the guide vane mechanism shall meet the requirements of Table 5.
- 3) When the guide mechanism has been assembled, it shall be able to move steadily and freely.
- 4) The servomotor shall be disassembled and cleaned, and each part's fitting clearance and stroke shall be checked to meet the design requirements. The piston shall move steadily and freely. After assembly, tightness and pressure tests shall be done according of 4.1.2. The horizontal deviation of the servomotor's installation shall be no greater than 0.10mm/m. The compacting stroke shall meet the manufacturer's requirements. If the manufacturer has no requirements, it shall be in the range of 3mm to 6mm.
- 5) The vertical deviation of the speed controlling shaft shall be no larger than 1mm/m. The fitting clearance between the upper and lower shaft neck and the shaft sleeve shall meet the design requirements. The speed controlling shaft shall rotate freely.

Table 3 Allowable installation error of the turbine pit lining and servomotor foundation

| No. | Items | Allowable error | Explanation |
|-----|---|-----------------|---|
| 1 | Centre of the turbine pit lining | 5 mm | Measure the distance between the lining flange and the bore opening of the stay ring upper flange at 8 equidistant points |
| 2 | The upper opening diameter of the turbine pit lining | ±5 mm | Measure at 8 equidistant points |
| 3 | Elevation of the turbine pit lining's upper opening | ±3 mm | Measure at 8 equidistant points |
| 4 | Level of the turbine pit lining's upper opening | 6 mm | Measure at 8 equidistant points |
| 5 | Verticality of the servomotor foundation flanges | 0.30 mm/m | — |
| 6 | Centre and elevation of the servomotor's foundation | ±1.0 mm | Measure from the upper flange surface of the stay ring |
| 7 | Parallelism between the servomotor foundation and the hydro turbine generator unit's coordinate datum line. | 1.0 mm | — |
| 8 | Distance from the servomotor foundation to the hydro turbine generator unit's datum line. | ±3 mm | Deviation from the design value |

Table 4 Allowable error in the axiality and circularity of the runner parts

| Working water head | Part | Allowable error | Explanation |
|--------------------|--|--------------------|--|
| <200m | Sealing ring | ±10% of design gap | — |
| | Blade's outer edge | ±10% of design gap | — |
| | Diversion plate's sealing ring | ±15% of design gap | — |
| | Flange shelter concurrently used as maintenance seal | ±15% of design gap | — |
| ≥200m | Outer edge of upper and lower crown | ±5% of design gap | Corresponding fixed parts are head cover and bottom ring |
| | Sealing ring | ±0.10 mm | — |

Table 5 Allowable installation error of the guide mechanism

Unit: mm

| No. | Items | Allowable error | | Explanation | |
|-----|---|---|------|-----------------|---|
| 1 | Each composite joint gap | Meet requirements of 4.1.2 | | — | |
| 2 | Each sealing ring's circularity and axiality | Meet requirements of 4.2.1 | | — | |
| 3 | Axiality of the lower cone's flange spigot and the runner chamber | 0.25 | | — | |
| 4 | Total gap of guide vane's end face | No larger than the design gap | | — | |
| 5 | Guide vane's local vertical gap | Guide vane height | ≤600 | >600 and ≤1 200 | Gap's total length shall be no larger than 25% of the guide vane's height |
| | | Guide vane without sealing strips | 0.05 | 0.10 | — |
| | | Guide vane with sealing strip (uninstalled) | 0.15 | | There shall be no gap after the installation of the sealing strip |

d) Installation of rotating parts shall meet the following requirements:

- 1) Generally the hoisting elevation of the main shaft or runner shall be slightly lower than the design elevation and there shall be a 2mm to 6mm gap between the main shaft's top surface and the lower flange spigot sub-face of the generator shaft after being hoisted. For a hydro turbine generator unit whose thrust block is installed on the turbine shaft, the elevation shall be slightly higher than the design elevation to make sure there is a 2mm to 5mm gap between the thrust block and mirror plate after installation. Generally, the main shaft's deviation from verticality shall be no larger than 0.05mm/m. If the hydraulic turbine or generator is centred according to the actual units themselves, then the runner centre and main shaft verticality shall be adjusted so that the sealing ring gap meets the requirements of Table 6. The main shaft's deviation from verticality shall be no larger than 0.02mm/m.
- 2) The final installation elevation of the runner and the allowable error of the gap between sealing rings or the gap between the vane and runner chamber shall meet the requirements of Table 6 if the manufacturer has no requirements.

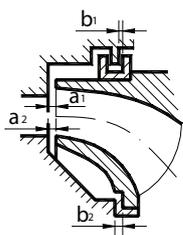
- 3) After the hydro turbine generator unit’s coupling, there shall be no gap at the composite joint of the two flanges. Check the joint with a 0.03mm feeler gauge, which shall not be able to be inserted.
- e) Installation of the turbine guide bearing and main shaft seal shall meet the following requirements:
 - 1) The bearing liner shall meet the following requirements:

The rubber bearing liner’s surface shall be flat and smooth and have no flaws such as fissure or exfoliation. Babbitt bearing liners shall have no flaws such as dense pores, fissures, hard spots and exfoliation. The liner’s roughness shall be less than 0.8μm.

Trial assembly of the rubber liner and cylindrical liner with the shaft shall be done and the total gap shall meet the design requirements. Both the difference between the maximum and minimum gap at each end and the difference between the upper and lower end gap at the same position shall be no greater than 10% of the actual measured average total gap.

Table 6 Allowable error of runner installation elevation and gap

Unit: mm

| No | Items | | Allowable error | Explanation | |
|----------------|-----------|--------------------|---|--|---|
| 1 | Elevation | Mixed-flow type | ±1.5 | Measure the uneven misalignment between the fixed and rotating sealing rings. | |
| | | Axial-flow type | 0~+2.0 | Measure the distance from the bottom ring to the runner’s top surface. | |
| | | Diagonal flow type | 0~+0.8 | Measure the gap between the vane and the runner chamber. | |
| 2 | Gap | Rated head <200m | The difference between each gap and the actual average gap shall be no larger than ±20% of the average gap. | Means the gap between the vane and the runner chamber. Measure at the inlet, outlet and the middle when the runner is totally closed. | |
| | | Rated head ≥200m | a ₁ | The difference between each gap and the actual average gap shall be no larger than ±10% of the design gap. |  |
| | | | a ₂ | | |
| | | Rated head ≥200m | b ₁ | The difference between each gap and the actual average gap shall be no larger than ±10% of the design average gap. | |
| b ₂ | | | | | |

When the cylindrical liner meets the two requirements above, it shall not be scraped any more. Determine whether the segmented bearing liner shall be scraped according to the design requirements. When the bearing liner has been scraped, there should be uniform contact with the liner surface and there shall be at least one contact point per square centimetre. Each block’s non-contact area shall be no larger than 5% of its surface area and the total non-contact area shall be no larger than 15% of the bearing liner’s total surface area.

There should be close contact between the weight resisting cushion blocks and the back cushion seat of the bearing liner, and between the weight resisting screw nut and the screw nut seat.

- 2) Bearing liner installation shall meet the following requirements:

The bearing liner shall be installed under the condition that the hydro turbine generator unit shaft and thrust pad have been properly adjusted to meet load-carrying requirements, and that the gap between the hydraulic turbine's sealing ring and the generator is able to meet the relevant requirements.

Generally, during bearing liner installation, the gap shall be adjusted according to the main shaft's centre position and the value and position of the barring gear's runout. The total installation gap shall meet the design requirements. However, for hydro turbine generator units with only two guide bearings, the gap can be adjusted without considering the runout.

The allowable error of the segmented guide bearing liner gap shall be no larger than $\pm 0.02\text{mm}$. The allowable error of the cylindrical guide bearing liner gap shall be $\pm 20\%$ of the distributed gap value and the liner surface shall be vertical. The allowable deviation of cylinder guide bearing shoe clearance shall be within 10% of the clearance value, and the bearing shoe surface shall be vertical.

3) Bearing installation shall meet the following requirements:

The bearing sump/tank which contains thin oil shall have no oil leakage. Generally, a kerosene penetration test shall be done according to the requirements of 4.1.2.

For the bearing cooler, pressure tests shall be done according to the requirements of 4.1.2.

The oil shall be qualified and the oil level shall meet the design requirements. Generally, the deviation shall be no greater than $\pm 10\text{mm}$.

4) The main shaft standby seal shall meet the following requirements:

Before the assembly of the air shroud, an underwater air leakage test shall be done by pumping in compressed air at 0.05MPa . There shall be no air leakage during the test.

After installation, the radial gap shall meet the design requirements and the deviation shall be no greater than $\pm 20\%$ of the design gap value.

5) Installation of the main shaft's working seal shall meet the following requirements:

The working seal's axial and radial gaps shall meet the design requirements and the allowable error shall be no greater than $\pm 20\%$ of the actual average gap.

The seals shall be able to move up and down freely and they shall make proper contact with the swivel's sealing surface. The pipelines used for water supply and drainage shall be unblocked.

f) Installation of accessories shall meet the following requirements:

1) Movement and leakage tests shall be done for the vacuum breaking valves and gulp valves. The initial pressure and maximum opening value of the movement tests shall meet the design requirements.

2) The installation of the valve seats of the drainage valve or disc valves of the spiral cases and draft tubes shall have a horizontal deviation no larger than 0.2mm/m . After the disc valve installation, the sealing surface shall be checked to make sure that there is no gap and the valve group can move freely.

4.2.2 Installation of horizontal turbines shall meet the following requirements:

a) Before installation, the first-stage concrete shall be checked to see that the position, elevation and size of the foundation's preformed holes meet the design requirements.

b) The equipment installation shall meet the following requirements:

1) The deviation of the spiral case's verticality shall be no larger than 0.06mm/m and the deflection shall be less than 0.5mm/m .

- 2) The allowable error in the levelness of the hydraulic turbine main shaft shall be no larger than 0.02mm/m. The amount of bounce of the runner's end surfaces shall be no larger than 0.05mm/m.
 - 3) The gap between the runner and the runner chamber shall meet the design requirements and the deviation shall be no greater than 10% of the design gap.
 - 4) When the guide mechanism has been totally closed, the local gap between the guide vane's sealing surfaces shall be no larger than 0.08mm.
 - 5) The end clearance between the guide vane's seals and front and back cover plates shall be no larger than 0.25mm.
- c) The checking and scraping of the bearing liner shall meet the requirements of 4.3.2.
 - d) The fitting between the bearing liner and the bearing shell shall meet the requirements of 4.3.2.
 - e) The bearing liner's gap shall meet design requirements and shall be closely sealed up. The oil shall be able to recycle smoothly.

4.2.3 Installation of tubular turbines with shaft-extensions shall meet the following requirements:

- a) For parts which need to be preassembled on site, when being hoisted and turned over by 90°, measures shall be taken to prevent deformation and overturning. The embedded parts shall be reinforced after the installation and adjustment. The concrete shall be cast layer by layer and the rising speed shall be controlled to prevent the deformation of the parts.
- b) Fitted components shall be preassembled and the fit size shall be checked before hoisting. Any deviation which exceeds the allowable error shall be corrected before installation.
- c) The draft tube's allowable installation error shall meet the requirements of Table 7.
- d) The stay ring's (tubular shell) allowable installation error shall meet the requirements of Table 8.
- e) The allowable installation error of the bearing shall meet the requirements of Table 9.

Table 7 Draft tube's allowable installation error

| No. | Items | Allowable error | Explanation |
|-----|--|-----------------|---|
| 1 | The difference between the maximum and minimum diameters of the pipe orifice flanges | 3.0 mm | For structures with a foundation ring, it means the foundation ring's upper flange |
| 2 | Centre and elevation | ±1.5 mm | Measure the elevation of the pipe orifice's horizontal marks and the horizontal deviation of the vertical marks |
| 3 | Distance between the pipe orifice flange and the runner's centre line | ±2.0 mm | (1) If the stay ring is installed first, its flange surface shall be taken as the datum plane. (2) Measure the upper, lower, left and right points |
| 4 | Verticality of the flange's surfaces | 0.4 mm/m | — |
| 5 | Inside wall perimeters of two adjacent pipe orifices | ≤10 mm | — |
| 6 | Concentricity of each segment unit | 0.002D | D is the design inner diameter of the pipe |

Table 8 Stay ring's (tubular shell) allowable installation error

| No. | Items | Allowable error | Explanation |
|-----|--|-----------------|--|
| 1 | Centre and position | ±2.0 mm | (1) Measure the elevation of the upstream and downstream flanges' horizontal marks (2) Measure the distance between X, Y marks on the component and corresponding datum lines |
| 2 | Distance between the flange and the runner centre line | ±2.0 mm | (1) If the draft tubes or foundation ring are installed first, their flange surfaces shall be taken as the datum planes (2) Measure the upper, lower, left and right points |
| 3 | Verticality of the pre-centrum flanges | 0.8 mm/m | — |
| 4 | Flange's degree of circularity | 1.0 mm | — |
| 5 | Inner tubular shell's composite surface elevation | ±0.8 mm | — |
| 6 | The distance between the foundation frame centre of the flow passage cover plate and the hydro turbine generator unit's centre | ±2 mm | — |
| 7 | The distance between the servomotor foundation and the datum line | ±3 mm | — |

f) Guide mechanism installation shall meet the following requirements:

- 1) The distance between the interior admission water ring (bottom ring) and the main shaft shall be determined by considering the main bearing's deformation caused by the runner weight. Generally, the distance at the upper part is less than that at the lower part, and the distances on the two sides are equal.
- 2) The guide vane's end clearance shall be adjusted and measured in the closed position. The distribution of the interior and exterior end clearances shall meet the design requirement. At each end of the guide vane, the gap should be equal on both sides. The guide vane shall be able to move freely.

Table 9 Bearing's allowable installation error

Unit: mm

| No. | Items | Allowable error | Explanation |
|-----|--|--|---|
| 1 | Verticality of mirror plate and main shaft | 0.05 | — |
| 2 | Split thrust collar's composite joint | Local gaps shall be no larger than 0.05; any misalignment shall be no larger than 0.02 | Check following the hydro turbine generator unit's rotation direction |
| 3 | Degree of fit of the load-bearing surfaces of the bearing liner and bearing seat | Area in contact to be greater than 60% | — |
| 4 | End clearance between bearing liner and shaft neck | Meet the design requirements | — |
| 5 | Bearing liner gap | Meet the design requirements | — |
| 6 | Contact angle between the lower bearing liner and the shaft neck | No larger than 60° | — |
| 7 | Contact points between the lower bearing liner and the shaft neck | 1~3 points/100 mm ² | — |
| 8 | Composite joint gap of the bearing body | Meet the requirements of 4.1.2 | — |
| 9 | Bearing body's ground insulation resistance | No lower than 1 MΩ | — |

3) The maximum value of the guide vane's vertical local gap shall be no larger than 0.25mm and the total length shall be no greater than 25% of the guide vane height.

g) Installation of the main shaft and runner shall meet the following requirements:

- 1) The allowable installation error of the main shaft and the runner shall meet the requirements of Table 10.
- 2) The main shaft's deviation from levelness shall be no greater than 0.04mm/m.

Table 10 Allowable installation error for the main shaft and runner

| No. | Items | Allowable error | Explanation |
|-----|---|--------------------------------|-------------|
| 1 | Runner and main shaft flange's composite joints | No gap | — |
| 2 | The gap between the runner and the runner chamber | Meet the design requirements | — |
| 3 | Main shaft's sealing gap | Meet the requirements of 4.2.3 | — |

4.2.4 Installation of impulse turbines shall meet the following requirements:

a) The deviation of the distance between the diversion pipeline's inlet centre line and the hydro turbine generator unit's coordinate lines shall be no greater than $\pm 2\%$.

b) Casing installation shall meet the following requirements:

1) Casings with split assemblies shall meet the requirements of 4.1.2. Composite surfaces which have no sealing or cushion shall be coated with sealant.

2) When installing the casing, the distance deviation to the hydro turbine generator unit's X, Y datum lines shall be no larger than 1mm and the elevation deviation shall be no larger than ± 2 mm. The horizontal deviation of the casing's upper flange surface shall be no larger than 0.04mm/m. For vertical type hydro turbine generator units, the elevation of each nozzle flange which is welded to the casing shall be the same, and the deviation shall be no larger than 1.0mm. Each flange's verticality deviation shall be no larger than 0.30mm/m and the distance between each flange and the hydro turbine generator unit's coordinate datum line shall meet the design requirements.

c) Bearing assembly shall meet the following requirements:

1) Vertical type turbine bearing assembly shall meet the following requirements:

Check the bearing flange elevation and levelness. The elevation deviation shall be no larger than 2mm and the horizontal deviation shall be no larger than 0.04mm/m.

Turbine guide bearings and their supports shall be preassembled. The centre deviation of bearing supports and the hydro turbine generator unit shall be no larger than 0.40mm. After the preassembly positioning, positioning holes shall be drilled and positioning pins shall be assembled.

The turbine guide bearing can be installed only when the hydro turbine generator unit's axis has passed inspection. During installation, leakage and pressure tests shall be done according to the requirements of 4.1.2, and shall meet the design requirements.

2) Horizontal type turbine bearing assembly shall meet the requirements of 4.3.2.

d) Installation of the turbine shaft shall meet the following requirements:

1) Before the installation of the turbine shaft, composite flanges' degree of flatness and finish shall be checked.

2) For vertical type hydro turbine generator units, the installation of the turbine shaft's upper flange surface shall be lower than the design elevation by 20mm to 25mm. If the turbine shaft connects with the generator rotor directly, not only the axiality and parallelism of the generator rotor flange and the turbine shaft flange, but also the elevation of the generator rotor flange relative to the nozzle axis shall be aligned.

- 3) The main shaft's horizontal or vertical deviation shall be no larger than 0.02mm/m.
 - 4) Before installation of the turbine guide bearing, the hydro turbine generator unit axis shall be checked and shall meet the design requirements.
- e) Installation of the nozzle and its servomotor shall meet the following requirements:
- 1) For the nozzle and its servomotor, tightness and pressure tests shall be done before the installation according to the manufacturer's requirements.
 - 2) After assembly of the nozzle and servomotor, the jet needle and servomotor shall be able to move freely under 16% of the rated working pressure. Pump oil into the servomotor's closing cavity under rated pressure and there shall be no gap between the jet needle's head and the opening.
 - 3) Nozzle installation shall meet the following requirements:
The nozzle's centre line shall be tangential to the runner's pitch circle. The radial deviation shall be no greater than $\pm 2\%d_1$ (d_1 is the runner pitch's diameter). The axial deviation compared with the bucket's water dividing blade shall be no greater than $\pm 0.5\%W$ (W is the bucket's maximum inner width).
Generally, the deviation of the deflector centre and nozzle centre shall be no greater than 4mm.
The deviation between the buffer spring's compression length and the design value shall be no larger than ± 1 mm.
The synchronous deviation of each jet nozzle through the stroke shall be no greater than 2% of the design stroke.
The axial and radial deviations of the reversed braking nozzle's centre line shall be no greater than ± 5 mm.
- f) Runner installation shall meet the following requirements:
- 1) The rotating surface of the runner bucket's water dividing blade shall pass the nozzle flange's centre on the casing and the deviation shall be no greater than $\pm 0.5\%W$.
 - 2) The amount of bouncing of the runner end face shall be no larger than 0.05mm/m.
 - 3) The gap between the runner and water flap shall meet the design requirements.
- g) Main shaft sealing shall meet the requirements of 4.2.1.
- h) Control mechanism installation and adjustment shall meet the following requirements:
- 1) The centre deviation of each component of the control mechanism shall be no greater than 2mm and the elevation deviation shall be no greater than ± 1.5 mm. Horizontal or vertical deviation shall be no greater than 0.10mm/m. The mechanism shall move freely after installation.
 - 2) The deflector opening shall be 3mm larger than the radius of the jet during this opening stroke but shall be no larger than 6mm. Each deflector shall move synchronously and the deviation shall be no greater than 2% of the design value.

4.2.5 Installation of the hydraulic turbine governing system shall meet the following requirements:

- a) The allowable installation error of the oil pressure device shall meet the requirements of Table 11. Leakage testing and pressure testing of the pressure tank's tightness shall comply with the provisions of 4.1.2.

Table 11 Allowable installation error for the return oil tank (governor’s tank) and the pressure tank

| No. | Item | Allowable error | Explanation |
|-----|---|--------------------------|--|
| 1 | Centre | No greater than 5.0 mm | Measure the distance between the equipment marks and the hydro turbine generator unit’s X, Y datum lines |
| 2 | Elevation | ±5 mm | — |
| 3 | Level deviation | No greater than 1.0 mm/m | Measure the four corners’ elevation of the return oil tank (governor tank) |
| 4 | Pressure oil tank’s verticality deviation | No greater than 1.0 mm/m | Measure by hanging plumb lines in X, Y direction |

- b) When installing and aligning the elastic couplings of the oil pumps and electric motors, the eccentricity and gradient shall be no greater than 0.08mm. If the oil pump axial electric motor has no lateral movement, there shall be a 1mm to 3mm gap between couplings. When all the pins have been installed, the couplings shall be able to rotate slightly relative to each other. The oil pump cavity shall be filled with qualified steam turbine oil.
- c) The brands and quality of the turbine oils used in the hydraulic turbine governing system shall meet the design requirements. The oil indices shall meet the relevant requirements and the oil temperature shall be kept in the range of 10°C to 50°C during operation.
- d) Test running of the oil pump electric motor shall meet the following requirements:
- 1) Electric motor inspections and tests shall meet the relevant requirements.
 - 2) Keep the oil pump running under zero-load for 1h, if there is no abnormal phenomenon, keep the oil pump running under 25%, 50%, 75%, 100% of rated pressure for 15min respectively; there shall be no abnormal phenomena.
 - 3) When running, the oil temperature shall be no higher than 50°C and the bearing temperature shall be no higher than 60°C. The shell’s bi-directional amplitude shall be no greater than 0.05mm and shall have no abnormal noise.
 - 4) Under rated pressure, the measured oil output of the oil pump shall be no less than the design value.
- e) The adjustment of the hydraulic device’s components shall meet the following requirements:
- 1) If there are no design requirements, the adjustment of the safety valve and pressure annunciator shall meet the requirements of Table 12. The pressure annunciator’s movement deviation shall be no greater than ±1% of the setting value and the return value shall be no greater than the design value.

Table 12 Setting value for the safety valve and the oil pump pressure annunciator**Unit: MPa**

| Rated oil pressure | Setting value | | | | | | |
|--------------------|----------------------------------|-----------------------|-----------------------|-------------------|--------------------|-------------------|--------------------|
| | Safety valve | | | Working oil pump | | Stand-by oil pump | |
| | Initial pressure of oil-draining | Fully opened pressure | Fully closed pressure | Starting pressure | Resetting pressure | Starting pressure | Resetting pressure |
| 2.50 | ≥.505 | ≤.500 | ≥.500 | 2.20~2.30 | 2.50 | 2.05~2.15 | 2.50 |
| 4.00 | ≥.008 | ≤.004 | ≥.000 | 3.70~3.80 | 4.00 | 3.55~3.65 | 4.00 |
| 6.30 | ≥.303 | ≤.300 | ≥.300 | 6.00~6.10 | 6.30 | 5.85~5.95 | 6.30 |
| 16.00 | ≥6.002 | ≤6.000 | ≥6.000 | 14.00~14.50 | 16.00 | 13.00~13.50 | 16.00 |

- 2) When the safety valve is working, there shall be no severe vibration or noise.
- 3) The setting value for low oil pressure caused by an accident shall meet the design requirements and its movement deviation shall be no greater than $\pm 2\%$ of the setting value.
- 4) For continuously running oil pumps, if there is no design requirement, the flood valve operating pressure shall meet the requirements for the working oil pump's setting value in Table 12.
- 5) The pressure oil tank's automatic air supply device and the return oil tank's oil level annunciator shall be able to work accurately and reliably.
- 6) The starting and stopping of the pressure oil pump and the leakage oil pump shall be correct and reliable, and there shall be no reverse rotation phenomenon.
- f) When the pressure oil tank is under working pressure and the oil level is at its normal position, close each connection valve and keep it that way for 8hours. The decline in oil pressure shall be no greater than 4.0% of the rated working pressure. Drops in oil level should be recorded.
- g) The allowable installation error of the governor's mechanical cabinet, electrical cabinet and emergency distribution valve shall meet the requirements of Table 13.

Table 13 Allowable installation error for the governor’s mechanical cabinet, the electrical cabinet and the emergency distribution valve

| No. | Items | Allowable error | Explanation |
|---|---|-----------------|---|
| 1 | Centre | 5.0 mm | Measure the distance between the equipment marks and the hydro turbine generator units X, Y datum lines |
| 2 | Elevation | ±5.0 mm | — |
| 3 | Mechanical cabinet’s levelness | 0.15 mm/m | For the electro-hydraulic type, measure the base of the electro-hydraulic conversion device; for the mechanical hydraulic type, measure the bottom plate of the pendulum electric motor (the upper diaphragm) |
| 4 | Emergency distribution valve’s verticality or levelness | 0.15 mm/m | Measure the foundation plate of the emergency distribution valve. |
| 5 | Electrical cabinet’s verticality | 1.0 mm/m | Measure by hanging plumb lines in the X and Y directions |
| NOTE During the installation of combined governors, the supports for the speed controlling shaft’s transmission mechanism shall be taken as datum and the deviation shall meet the design requirements. | | | |

h) Governors which need to be dismantled shall meet the following requirements:

- 1) For mechanical hydraulic parts which need to be dismantled in the electro-hydraulic governor, the component cleaning, assembly and adjustment shall meet the requirements of the manufacturer’s drawings.
- 2) Each indicator and lever in the governor cabinet shall be adjusted according to the drawings and each mechanism’s position error shall not be more than 1mm.
- 3) When the guide vane and the runner servomotor are in the middle (have reached 50% of the total opening), the position of the reciprocating mechanism’s crank arms and connecting rods shall meet the design requirements and the vertical and horizontal deviations shall not be more than 1mm/m. The connection of the reciprocating mechanism shall be firm and load tests shall be done according to the design requirements.

i) The turbine governing system’s adjustment test with oil shall meet the following requirements:

- 1) Switch on the oscillating current and check the oscillation value of the electro-hydraulic conversion device. The value shall meet the design requirements.
- 2) Check the zero bias and pressure zero drift of the electro-hydraulic conversion device. The zero bias shall be no greater than 5% of the rated output value (current, voltage). The pressure zero drift shall not cause obvious movement of the servomotor within the range of the working oil pressure.
- 3) Record the static characteristic curve between the input frequency and the electro-hydraulic or electro-mechanical conversion device’s output displacement. Both the dead zone and the amplification coefficient shall meet the design requirements.
- 4) Measure and plot the curve showing the relationship between the feedback transducer’s output voltage (current) and the servomotor’s route. It shall be linear throughout the servomotor’s entire stroke and its characteristics shall meet the design requirements.

- 5) When filling the turbine governing system with oil for the first time, the filling shall be done slowly and the pressure shall not be more than 50% of the servomotor's rated pressure. Operate the governor over the entire stroke several times and there shall be no abnormal phenomena. Switching tests between different controlling methods, such as manual operation and automatic operation, shall be done for the governors. During the tests, the movement shall be normal and the servomotor shall have no abnormal swinging. For oil pipelines and pressure-bearing components, tightness tests shall be done according to the requirements of 4.1.2.
- 6) Operate the guide vane servomotor manually to check the opening limit. Check the indicated value on the indicator on the mechanical cabinet and the value shall be in accordance with the stroke of the guide vane servomotor and paddle servomotor. The deviation from the former shall be no greater than 1% of the piston's entire stroke, while the deviation from the latter shall not be more than 0.5°.
- 7) The deviation between the guide vane and the paddle's emergency closing time, opening time, the guide vane's sequence closing stroke and the sequence closing time and their design value shall be no greater than $\pm 5\%$ of the design value. Finally, the deviation shall be adjusted to meet the calculation requirements. Generally, the closing and opening times should be expected to be twice the time required for an opening between 25% and 75%.
- 8) The deviation between the closing time of the emergency distribution valve's guide vane and its design value shall be no greater than $\pm 5\%$ of the design value. Finally, the deviation shall be adjusted to meet the calculation requirements.
- 9) Check the reciprocating mechanism's dead stroke and the value shall not be more than 0.2% of the servomotor's whole stroke.
- 10) From the opening and closing directions, plot the curve showing the relationship between the stroke of the guide vane servomotor and the guide vane opening values. Measure the opening value of 4 to 8 guide vanes at each point and take the average of these values. When the guide vanes are totally open, the opening values of all the guide vanes shall be measured. Generally, the deviation shall not be more than $\pm 2\%$ of the design value.
- 11) From the opening and closing directions, plot the curve between the guide vane's servomotor stroke and the paddle's servomotor stroke under the combination relationship of different water heads, and deduce the rules determining the opening and closing. The curve and the rules shall meet the design requirements. The inaccuracy of the paddle's servo system shall be less than 1.5% of the entire stroke.
- 12) The setting of the servo system's practical open loop gain: The servomotor's opening and closing times shall have been adjusted and shall meet the design requirements. Set the amplification coefficient and lever ratio to the maximum value in design, and then input a step signal which amounts to 10% of servomotor's entire stroke into the servo system. Watch the servomotor's movement. The maximum amplification coefficient or lever ratio which can keep the servo system steady and avoid overshoots is the practical open loop gain.
- 13) Record the static characteristic curve of the turbine governing system when the permanent speed droop $b_p = 6\%$. The static characteristic curve shall be approximately a straight line. The rotational speed dead zone rotational speed shall be no greater than 0.04%. For a Kaplan turbine governing system, the inaccuracy of the paddle servo system shall be no greater than 1.5%.
- 14) When there is no water in the spiral case, the pressure tank's pressure and the decreased oil level shall be recorded when it is powered off under emergency low oil pressure.

15) When there is no water in the spiral case, measure the operating mechanism's lowest oil pressure for the guide vane and the paddle; the pressure should be no greater than 16% of the rated oil pressure.

j) Inspection and adjustment of the governor's electrical parts shall meet the following requirements:

- 1) Check the electrical part's circuit wiring in the system; they shall meet the design requirements.
- 2) The output voltage of the regulated power supply in the electrical parts shall meet the design requirements and the fluctuation of the output voltage should not exceed $\pm 1\%$ of the design value.
- 3) Check the properties of each circuit unit of the electrical parts and the adjustable range of the circuit's adjustable parameters, such as the permanent speed droop b_p , slip ratio e_p , proportional gain K_p , integral gain K_i , differential gain K_d (or temporary speed droop b_p , buffer time constant T_d , derivative time constant T_n). All these parameters and adjustable ranges shall meet the design requirements.
- 4) Check the adjustable range of the opening, the frequency and the power. They shall meet the design requirements.
- 5) Record the curve showing the relationship between the speed measuring equipment's input signal and the output (current, voltage). Within $\pm 10\%$ of the rated rotational speed, the static characteristic curve shall be approximately a straight line and the dead zone of the rotational speed shall meet the design requirements. Within $\pm 2\%$ of the rated rotational speed, the deviation of the measured amplification coefficient shall be no greater than $\pm 5\%$ of the design value.

k) The turbine governing system's simulation tests shall meet the following requirements:

- 1) Simulate all kinds of faults of the turbine governing system, and the protection devices shall be able to work reliably and send warning signals correctly.
- 2) Operate the hydro turbine generator units manually or automatically to simulate starting up, shutting down and emergency shutdown. The turbine governing system shall be able to work reliably and send warning signals correctly.

4.3 Generator

4.3.1 Installation of the vertical generators shall meet the following requirements:

a) The scraping of the bearing liner shall meet the following requirements:

- 1) The thrust pad shall have no flaws such as fissures, slag inclusions or dense pores. The total area of localised exfoliation of the bearing liner's surface material and metal base shall be no greater than 5% of the liner's surface area. If necessary, ultrasonic inspection may be used to check the thrust pad. The working surface of the mirror plates shall have no scars or rust. The roughness and rigidity shall meet the design requirements. If necessary, the parallelism between the two surfaces and the working surface's flatness tolerance shall be checked according to the drawing requirements.
- 2) Thrust pads which the manufacturer requires to be scraped on the worksite shall meet the following requirements after scraping:

There shall be 1 to 3 contact points per square centimetre on the liner surface.

On the liner surface, the surface area of each local non-contacting part shall not be more than 2% of the bearing liner's total surface area and the total non-contact area shall be no greater than 5% of the bearing liner total area.

The inlet shall be scraped according to the manufacturer’s requirements.

For supporting screw type thrust bearings without trays, only when its liner has met the requirements above can the middle of part of the liner surface be scraped. In the vicinity of the supporting screw in a circular section whose diameter is 2/3 of the bearing pad length, first remove any contact points (light contact points can be preserved) and cut the bearing pad once with a gang cutter. Secondly, cut the bearing pad in a smaller range, again with a gang cutter, in the vicinity of the supporting screw in a circular section whose diameter is 1/3 of the bearing pad length and in a direction perpendicular to the previous cut.

After rotation of the hydro turbine generator unit at slow speed, the thrust pad shall be extracted to check the degree of contact. If the liner has been rubbed down or there are high points, the liner shall be scraped again until it is qualified.

- 3) The scraping of the guide bearing liner shall meet the requirements of 4.2.1.
- b) The stator’s allowable installation error shall meet the requirements of Table 14.

Table 14 Stator’s allowable installation error

Unit: mm

| No. | Item | Allowable error |
|-----|--|--|
| 1 | Overall joint gap between the stator and the unit base | No greater than 0.10 locally No greater than 0.05 around the bolts. |
| 2 | Overall joint gap between the stator and the iron core | Shall have no gap if adding cushion. Radial mismatch shall be no greater than 0.30 at the bottom of the slots. Groove width shall meet design requirements. |
| 3 | Overall joint between the rack and the foundation plate | Meet requirements of 4.1.2 |
| 4 | Stator circularity (the difference between each radius and the average radius) | ±4% of design air gap |
| 5 | Centre elevation of the stator’s iron core | 0~+0.4% of the iron core’s effective length and shall be no greater than 6.0 |

- c) Measurement of the stator winding’s insulation resistance to the ground and the insulation resistance between the windings shall meet the following requirements:

- 1) When converting the temperature to 100°C, each stator winding’s insulation resistance shall be no less than R, which is calculated by the Formula (1):

$$R = \frac{U_N}{1000 + \frac{S_N}{100}} \dots\dots\dots(1)$$

where

- U_N is the generator’s rated line voltage, in V;
- S_N is the generator’s rated capacity, in kVA

For dry and clean generators, when the room temperature is $t(^{\circ}\text{C})$, the stator winding’s insulation resistance $R_t(\text{M}\Omega)$ shall be revised according to the Formula (2):

$$R_t = R \times 1.6(100 - t) / 10 \dots\dots\dots (2)$$

where

R is the winding’s calculated hot insulation resistance when the temperature is 100°C , in $\text{M}\Omega$.

- 2) When the temperature is lower than 40°C , the epoxy-mica paper’s insulation resistance absorptivity R_{60}/R_{15} shall be no less than 1.6 or the polarization index $R_{10\text{min}}/R_{1\text{min}}$ shall be no less than 2.0.
- d) Rotor assembly shall meet the design requirements. Check the rotor’s circularity and the difference between each radius and the average radius. They shall be no greater than $\pm 4\%$ of the design air gap. Before the rotor has been hoisted into the turbine pit, all the test items listed in 4.4.1 shall be checked one by one.
- e) The allowable installation error of the upper and lower racks shall meet the requirements of Table 15.
- f) The brake’s allowable installation error shall meet the requirements of Table 16.

Table 15 Allowable installation error of the upper and lower racks

Unit: mm

| No. | Items | Allowable error | Explanation |
|-----|--|--------------------------------|-------------|
| 1 | Overall joint gap | Meet the requirements of 4.1.2 | — |
| 2 | Distance between wind shields and fire protection water pipes, and the stators windings and the rotor fans | 0~+20% of the design value | — |
| 3 | Rack’s centre | 0.5 | — |
| 4 | Rack’s levelness | No greater than 0.10mm/m | — |
| 5 | Rack’s elevation | ± 1.5 | — |
| 6 | Overall joint between the rack and the foundation plates | Meet the requirements of 4.1.2 | — |

Table 16 The brake’s allowable installation error

Unit: mm

| No. | Items | Allowable error | Explanation |
|-----|--|--|-------------|
| 1 | Brake tightness and pressure tests | When they last for 30min, decreased pressure shall not exceed 3% | — |
| 2 | Elevation of brake’s top surface | ± 1.0 | — |
| 3 | Gap between the brake and the rotor’s annular braking plate | $\pm 20\%$ of the design value | — |
| 4 | Radial position of the brake | ± 3.0 | — |
| 5 | Tightness and pressure tests of the braking system’s pipelines | No leakage | — |

g) The rotor's allowable installation error shall meet the requirements of Table 17.

Table 17 Rotor's allowable installation error

Unit: mm

| No. | Items | Allowable error | Explanation |
|-----|---------------------------------------|------------------------------|--|
| 1 | Mirror plate's levelness | To be no more than 0.02 mm/m | — |
| 2 | Axial gap of thrust block's snap ring | To be less than 0.02 | Check when the snap ring is load bearing |
| 3 | Air gap | ±8% of the average gap | — |

h) Check the adjustment of the hydro turbine generator unit's shaft to ensure that it shall meet the following requirements:

- 1) Unit's barring shall be used to check the shaft's alignment. Before the unit's barring, the hydro turbine generator unit's rotating parts shall be in the central position and the main shaft shall be free and vertical.
- 2) For rigid barring of the thrust bearings, the load borne by each bearing liner shall be adjusted to be uniform and the deviation of the mirror plate's levelness shall be less than 0.02mm/m. Adjust the guide bearing liner gap on the side of the thrust block; the gap shall be between 0.03mm to 0.05mm. At the same time, other radial guide bearings shall not be in contact with the main shaft. After the shaft's alignment, the runout of the axial line of the hydro turbine generator unit shall not be more than the requirements of Table 18.

Table 18 Allowable runout of the hydro turbine generator unit's axial line (double-amplitude)

| Shaft | Measuring items | Runout type | Shaft rotational speed (n) rpm | | | | |
|-----------------|--|----------------------|--------------------------------|-----------|-----------|-----------|-------|
| | | | n<150 | 150≤n<300 | 300≤n<500 | 500≤n<750 | n≥750 |
| Generator shaft | Shaft neck and flanges of the upper and lower bearings | Relative runout mm/m | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 |
| Turbine shaft | Shaft neck of the guide bearing | Relative runout mm/m | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 |
| Generator shaft | Collecting ring | Absolute runout mm | 0.50 | 0.40 | 0.30 | 0.20 | 0.10 |

NOTE 1 Absolute runout: Actual measured runout.
 NOTE 2 Relative runout: The ratio between the absolute runout (mm) and the distance from the measuring part to the mirror plate (m).
 NOTE 3 The runout above means the hydro turbine generator unit's barring, rather than the operational runout.

- 3) At all events, the absolute runout of the hydraulic turbine's guide bearing shall meet the requirements of Table 19.

Table 19 Allowable absolute runout of the hydraulic turbine guide bearing

| Shaft rotational speed (rpm) | $n < 250$ | $250 \leq n < 600$ | $n \geq 600$ |
|--------------------------------|-----------|--------------------|--------------|
| Allowable absolute runout (mm) | 0.35 | 0.25 | 0.20 |

- i) When the shaft runout has been adjusted to be qualified, the mirror plate's levelness shall be rechecked and the load carried by the thrust pad, the stator and rotor circularity and the air gap shall meet the relevant requirements.
- j) The installation of the thrust bearing's oil groove shall meet the following requirements:
- 1) For the thrust bearing oil groove, kerosene leakage tests shall be done according to the requirements of 4.1.2.
 - 2) For the oil groove cooler, pressure withstanding tests shall be done according to the requirements of 4.1.2.
 - 3) The axial gap between the rotating and fixed parts in the oil groove shall meet the requirements of the jacking rotor and the radial gap shall meet the design requirements. When putting the groove-type sealing felt into the oil groove, it shall be compressed by about 1mm and the contact between the sealing felt and the shaft shall not be too tight.
 - 4) The oil retaining ring's outer circle shall be concentric with the hydro turbine generator unit and the centre's deviation shall not be more than 1.0mm. The deviation between the radial distance from the oil retaining ring's outer circle to the shaft neck's inner circle and the average distance shall be no greater than $\pm 10\%$.
 - 5) The height of the oil surface in the oil groove shall meet the design requirements and the deviation should be no greater than $\pm 5\text{mm}$. The brand of lubricant oil shall meet the design requirements. Oil quality shall be properly checked before filling and it shall meet the design requirements.
 - 6) Allowable insulation resistance of each part of a suspended hydro turbine generator unit's thrust bearing shall meet the requirements of Table 20.
- k) Guide bearing installation shall meet the following requirements:
- 1) The load-bearing conditions of the hydro turbine generator unit's shaft and thrust pads shall be adjusted to be qualified.
 - 2) The hydraulic turbine's sealing ring gap and the generator's air gap shall be qualified.
 - 3) During the final installation of a segmented guide bearing liner which has insulation requirements, the insulation resistance shall be greater than $50\text{M}\Omega$.
 - 4) During installation, the bearing liner gap shall be adjusted according to the main shaft's centre position and consider the direction and size of the barring. The total installation gap shall meet the design requirements.
 - 5) The allowable error for the segmented guide bearing liner gap shall be no larger than $\pm 0.02\text{mm}$. The deviation between two adjacent liner's actual gap and the required value shall be no greater than 0.02mm . When the gap has been adjusted, it shall be reliably locked.

Table 20 Allowable insulation resistance for each part of a suspended hydro turbine generator unit's thrust bearing

| No. | Thrust bearing components | Insulation resistance (MΩ) | Equipment for measuring insulation resistance | Explanation |
|-----|----------------------------------|----------------------------|---|---|
| 1 | Thrust bearing seat and supports | 5 | 500 V | Measure after the installation of the seats and supports |
| 2 | Thrust bearing | 1 | 500 V | Measure when the bearing has been totally assembled and the rotor has been installed Measure before filling with lubricant oil and the temperature shall be between 10 and 30° C |
| 3 | Embedded thermometer | 50 | 250 V | Before filling with lubricant oil, measure the insulation resistance of the thrust pad from each thermometer's core wire |

l) Installation of the generator's temperature measuring devices shall meet the following requirements:

- 1) The temperature measuring device's total insulation resistance shall be no less than 0.5MΩ. For a bearing which is required to be insulated, when all the thermometers have been installed, the insulation resistance of the bearing liner shall meet the requirements of Table 20.
- 2) For the terminal blocks of the stator winding temperature measuring device, if there is a discharge gap, the gap shall be between 0.3mm to 0.5mm.
- 3) Before sealing off the bearing's oil groove, the temperature measuring device shall be checked and the difference between each resistance thermometer's resistances shall be no greater than 1.5%. The device shall be well insulated to ground. The indicated value of the signal thermometer shall approach the bearing liner's actual temperature. The lead wires used in measuring the temperature shall be firmly fixed.
- 4) The mark number of the thermometers and temperature measuring switches shall be in accordance with the number of lines and coolers and the slot number of the windings.

m) Installation of the excitation systems and devices shall meet the following requirements:

- 1) The excitation system and devices shall only be installed when all interior construction has been completed and the indoor humidity has met the relevant requirements.
- 2) For the excitation system plate or cabinet, the plug-in contacts of plug-in type drawers shall be checked according to the design requirements.
- 3) Field discharge switch installation shall meet the following requirements:

The opening/closing coils and locking devices of the switch's transmission mechanism shall each be checked separately and operational tests shall be also done. The reliability and time of the operations shall comply with the relevant product standards.

Check that the action sequence of the arc extinction contacts and main contacts are all correct. The normally closed contacts shall act before the normally open contacts and the spacing time after the breaking of the normally closed contacts shall meet the design requirements.

When using a DM type field discharge switch, the amount, arrangement, shape and installation position of the arc extinction grid's plates, the shunt resistor's connection and resistance and the arc extinction contact's spacing shall be checked. All of them shall meet the product and ordering requirements.

4) The laying and wiring of the excitation system cable shall meet the following requirements:

The lengths of the three phase power cable which connects the excitation transformer to the power cabinet shall be equal.

Cable laying and internal wiring shall meet the design requirements.

4.3.2 Horizontal generator installation shall meet the following requirements:

a) Bearing liner scraping shall meet the following requirements:

1) The bearing liner and mirror plate shall be checked according to the requirements of 4.3.1. The bearing liners which the manufacturer requires be scraped on the worksite shall be processed in two steps, initial scraping and then fine scraping. The initial scraping shall be done before putting the rotor onto the stator and the fine scraping shall be conducted after centring the rotor.

2) The scraping of the pedestal bearing liner shall meet the following requirements:

The gap between the bearing liner and the shaft neck shall meet the design requirements. The gaps on both sides shall be one half of the top gap, and the difference between the gaps on the two sides shall be no greater than 10% of the gap.

The contact angle between the bearing liner bottom and the shaft neck shall meet the design requirements and shall not be more than 60°. The bearing liner shall make total and uniform contact along the direction of its length. There shall be 1 to 3 contact points per square centimetre in the contact area.

For bearings which adopt pressure oil circulating lubrication systems, the oil gallery size shall meet the design requirements and the head's length on both ends of the lengthwise oil gallery at the joint shall be no less than 15mm.

3) Scraping of the thrust pads shall meet the following requirements:

The contact area between the thrust pad and the thrust collar shall reach 75% of the total surface area and there shall be 1 to 3 contact points per square centimetre.

The thickness of the thrust pads without adjusting devices shall be equal. The thickness difference between each thrust pad in the same group shall be no greater than 0.02mm.

b) The allowable installation error for the bearing seat shall meet the requirements of Table 21.

Table 21 Allowable installation error of the bearing seat for the horizontal generator

| No. | Item | Allowable error | Explanation |
|-----|--|---|-------------|
| 1 | Kerosene leakage tests done for bearing seat's oil cavity | Meet relevant requirements of 4.1.2 | — |
| 2 | Bearing seat's centre axiality | 0.10 | — |
| 3 | Bearing seat cross-wise levelness | No greater than 0.20 mm/m | — |
| 4 | Bearing seat's axial levelness | No greater than 0.10 mm/m | — |
| 5 | Composite joint of the bearing seat and the foundation plate | Meet the relevant requirements of 4.1.2 | — |

- c) If the turbine and generator are coaxial, the main shaft shall be aligned at one time. If both the turbine and generator have their own shafts, the generator rotor's main shaft flange shall be aligned according to the turbine's main shaft flange. For rigid connections, the axiality deviation shall be no greater than 0.04mm and the tilt of the two flange faces shall not be more than 0.02mm; for the gear connection, the co-axiality deviation shall not be greater than 0.08mm; for the elastic connection, the deviation of the radial and axial co-axiality shall not be greater than 0.05mm, and the clearance between the two flanges shall be 3mm to 5mm.
- d) The air gap between the stator and the rotor shall be uniform and the gap of each magnetic pole shall be calculated from the arithmetic mean value of four measured values (rotating the rotor by 90° each time). The difference between each magnetic pole's gap and the average gap shall be no greater than ±8% of the average gap.
- e) The axial centre adjustment of the stator and the rotor shall make the stator shift towards the back of the bearing relative to the rotor and the shift value shall meet the manufacturer's requirements. The value should be between 1.0mm and 1.5mm, or one half of the generator shaft's thermal elongation when the generator is operated at full load can be taken into consideration.
- f) When the main shaft has been connected, each part's runout shall be checked by barring and the runout shall meet the requirements of Table 22.

Table 22 Each part's runout**Unit: mm**

| No. | Item | Allowable error | Explanation |
|-----|--|-----------------|-------------|
| 1 | Shaft neck | 0.03 | — |
| 2 | Amount of jump of the thrust collar's end face | 0.02 | — |
| 3 | Coupling flange | 0.10 | — |
| 4 | Slip ring | 0.20 | — |

- g) Inspection of the bearing parts and the adjustment of the gap shall meet the following requirements:
- 1) After shaft adjustment, the contact conditions of the contact surface between the main shaft and the lower bearing liner, and the contact surface between the thrust pad and the thrust collar shall be checked by barring. The contact conditions shall meet the requirements of Item a) in this paragraph.
 - 2) When determining the axial gap between the bearing liner's two ends and the shaft shoulder, the main shaft's expansion at a speed of $0.011 \text{ mm}/(\text{m}\cdot^{\circ}\text{C})$ when the rotor is running under the highest temperature rise shall be taken into consideration. The gap shall be enough to ensure the rotor's free expansion when running.
 - 3) The thrust bearing axial gap (main shaft movement) should be between 0.3 mm and 0.6 mm (the larger value applies to larger shafts).
 - 4) The fitting between the bearing liner and the shell shall meet the following requirements:
 For cylindrical bearing liners, there shall be no gap between the upper bearing liner and bearing cover, and there shall be 0.05 mm of compression. The lower bearing liner and the bearing seat shall be in close contact and the load-bearing surface shall be more than 60% of the total surface.
 For spherical bearing liners, the contact area between the spherical surface and the spherical bearing seat shall be about 75% of the total spherical surface and the contact shall be uniform. When the bearing cover has been tightened, the gap between the liner and the spherical bearing seat shall meet the manufacturer's requirements.
 - 5) The gap between the sealing ring and the shaft shall meet the drawing requirements and shall be about 0.2mm. During installation, the gap between the opposing halves shall be no larger than 0.1mm and there shall be no misalignment.
- h) Fan installation shall meet the following requirements:
- 1) The fan's surface shall be smooth and clean and have no fissures and other mechanical damage.
 - 2) For fans which are installed on site, the bolts shall be tightened according to the manufacturer's requirements and shall be locked. Spring washers shall not be used and gas cutting and electric welding on the fan shall be avoided.
 - 3) The gap between the fan blade and the air ducting device shall be uniform and the deviation shall be no greater than $\pm 20\%$ of the actual average gap.
 - 4) The distance between the fan's end face and the air ducting device's end face shall meet the design requirements. If there is no requirement, the gap should not be less than 5mm.

4.3.3 Installation of shaft extension tubular turbine generators shall meet the following requirements:

- a) Allowable combination error for the main parts shall meet the requirements of Table 23.

Table 23 Allowable overall error for the main parts**Unit: mm**

| No. | Items | Allowable error | Explanation |
|-----|--|--|-------------|
| 1 | Overall joint gap between the stator and the iron core | There shall be no gap when cushioned Radial misalignment at the bottom of the iron core slot shall be no greater than 0.3 | — |
| 2 | Overall joint gap between the stator and the unit base | Not more than 0.10 in local parts; no more than 0.05 around the bolts | — |
| 3 | Circularity of the stator's iron core | ±4% of the design air gap | — |
| 4 | Circularity of the main case and top cowl flanges | ±0.1% of the design diameter and the maximum value shall not be more than 5.0 | — |
| 5 | Top cowl's overall joint gap | Meet the requirements of 4.1.2 | — |

b) The generator final assembly shall meet the following requirements:

- 1) Bearing assembly shall meet the requirements of Table 21.
- 2) After coupling the main shaft, each part's runout shall be checked by the barring gear and shall meet the following requirements: each shaft neck's runout shall be less than 0.03mm. The jumping value of the mirror plate's end face shall be no greater than 0.05mm. The shaft coupling flange runout shall be no greater than 0.10mm. The slip ring's runout shall be no greater than 0.20mm.
- 3) When installing the stator, the composite surface of the stator and the foundation base shall be carefully cleaned. Packing seals shall be installed in strict compliance with the design requirements. The air gap between the stator and the rotor shall be properly adjusted. The difference between each gap and the average gap shall be no greater than ±8% of the average gap.

4.3.4 Installation of the pipes and accessories shall meet the following requirements:

a) Pipe quality after bending shall meet the following requirements:

- 1) There shall be no flaws such as fissures, delamination and over-burning.
- 2) The difference between the maximum and minimum external diameters of the pipe should not be greater than 8% of the pipe diameter.
- 3) The angle of bending shall be in accordance with the sample plate.
- 4) The height of corrugated folds inside of the elbow pipe should not be more than 3% of the pipe diameter. The spacing of the folds should not be less than 4 times the fold height.
- 5) The ring pipe shall be preassembled after bending and the radius deviation shall be no more than 2% of the design value. The pipes shall be on the same surface and the deviation shall be no more than 40mm.

b) Vertical deviation of welded three way pipes shall be no more than 2% of the height.

c) When installing the pipes, the position of the weld joints shall meet the following requirements:

- 1) The spacing between two circular seams in the straight segment shall be no less than 100mm and shall be more than twice the pipe's external diameter.
 - 2) The distance between butt weld joints and the bending point of the elbow pipes shall be no less than 100mm and shall be no less than the pipe's external diameter.
 - 3) The clear distance between the weld joints and supporting or hanging brackets shall be no less than 50mm; pipes which pass through the partition wall and the floor shall have no welded junctions in the wall and the floor.
 - 4) There shall be no pores at the pipe weld joints; if the pores have to be opened, the weld joints shall pass non-destructive inspection.
- d) A welded elbow pipe's bend radius shall be no less than 1.5 times the pipe diameter. There should be no fewer than four sections in a 90° elbow. The angle of the elbow's axis shall be in accordance with the sample plate after welding.
- e) Pipeline embedding shall meet the following requirements:
- 1) Pipelines should not be connected by screw threads or flanges.
 - 2) For oil or gas pipelines, the method of embedded adapter sleeves shall be used.
 - 3) If the pipeline passes through an expansion joint, the measures which are taken to protect the pipes shall meet the design requirements.
- f) An exposed pipe's installation position shall meet the following requirements:
- 1) The deviation of the installation position (coordinates or elevation) should not be more than 10mm.
 - 2) Horizontal pipe bending and the horizontal deviation should not be more than 0.15% and shall be no more than 20mm. The stand pipe's verticality deviation should not be more than 0.2% and shall be no greater than 15mm.
 - 3) Rack pipes shall be in the same surface and the deviation shall be no greater than 5mm. The deviation of the distance between pipes shall be between 0mm and +5mm.
 - 4) The gradient of gravity and oil drain pipes shall be in accordance with the direction of liquid flow and shall be between 0.2% and 0.3%.
- g) The material of the flange sealing gaskets shall be in accordance with the working medium and the pressure requirements.
- h) Before using oil, water, gas and the turbine governing system, the pipes shall be treated, washed and checked according to the design requirements and relevant standards.
- i) Pipe and fitting tests shall meet the following requirements:
- 1) The pressure vessels self-machined on site and fittings with working pressure of 1MPa or above shall be tested for strength and pressure resistance in accordance with the requirements of 4.1.2. Pressure-free containers manufactured on site shall be tested according to 4.1.2.
 - 2) Valves with a working pressure of 1MPa and above and valves with a working pressure lower than 1MPa at important parts shall be tested for tightness and pressure tolerance according to the requirements in 4.1.2.
 - 3) Before concrete pouring, buried pressure pipes and fittings shall be subjected to rigorous compression tests as required by 4.1.2.

- 4) After the installation of air, water and oil pipe systems and accessories, tests shall be done by pumping the air, water and oil into the pipes. The pressure shall be gradually raised to the rated working pressure during the tests. There shall be no leakage.

4.3.5 Installation of butterfly valves, spherical valves and expansion joints shall meet the following requirements:

- a) Butterfly valve installation shall meet the following requirements:
- 1) For penstocks or the spiral case upstream or downstream of the butterfly valves, the length of opening left outside of the concrete wall shall be long enough to ensure sufficient working space for component assembly and welding.
 - 2) When the butterfly valve has been installed, the centre line in the flow direction shall be determined according to the actual centre of the spiral cases and penstocks. The deviation between the actual and design positions should not be more than 3mm. The deviation between the crosswise centre line (upstream or downstream) and the design centre line should not be more than 10mm. The butterfly valve's horizontal and vertical deviations shall be no greater than 1mm/m when measured after flange welding. For butterfly valves of diameter greater than 4.0m, the deviation shall be no greater than 0.5mm/m.
 - 3) For convenience in moving the butterfly valve towards the expansion joint when overhauling, enough distance shall be left between the foundation bolts and the bolt holes. The distance shall be no less than the diameter of the rubber packing between the flanges.
 - 4) The butterfly valve's allowable assembly error shall meet the requirements of Table 24.

Table 24 Allowable assembly error for butterfly valves

Unit: mm

| No. | Item | | Allowable error | Explanation |
|-----|--|------------------------|--|-------------|
| 1 | Composite joints between the valve seat and the foundation plate | | Meet the requirements of 4.1.2 | — |
| 2 | Valve casing's composite joints | | Meet the requirements of 4.1.2 | — |
| 3 | Rubber seal air tests | | No leakage under 0.05MPa pressurised air | — |
| 4 | Gap when the valves are closed | Aerated water seals | No gap | — |
| | | Un-aerated water seals | ±20% of the design value | — |
| 5 | Tightness tests in still water | | The water leakage after 30 min shall not be more than the design value | — |

- b) Spherical valve installation shall meet the following requirements:
- 1) Allowable installation error of the spherical valves shall meet the requirements of Table 25.
 - 2) Spherical valves shall be able to move freely. A large enough gap shall be left between the spherical valves and the fixed parts. The gap should not be less than 2mm.

Table 25 Allowable installation error for spherical valves

| No. | Item | Allowable error | Explanation |
|-----|--|--|-------------|
| 1 | Composite joints between valve seats and foundation plates | Meet relevant requirements of 4.1.2 | — |
| 2 | Valve body's centre | ±5 mm | — |
| 3 | Valve body's crosswise centre | 15 mm | — |
| 4 | Valve body's levelness and verticality | 1.0 mm/m | — |
| 5 | Valve body's composite joints | Meet the requirements of 4.1.2 | — |
| 6 | Gap between the valve and the valve body | Meet the design requirements | — |
| 7 | Gap between working and maintenance seals | Not more than 0.05 mm | — |
| 8 | Sealed cap's stroke | No less than 80% of the design value, the movement shall be flexible | — |
| 9 | Tightness tests in still water | The water leakage after 30 min shall be no greater than the design value | — |

c) Expansion joint installation shall meet the following requirements:

- 1) The gap between an expansion joint's inner and outer casing shall be adjusted to be uniform and shall have no blockage.
- 2) The expansion distance of expansion joints and the inner and outer casings shall meet the design requirements. The deviation should not be more than ±6mm and shall consider the amount of the pipe union's welding shrinkage.
- 3) Bellows pieces shall be inspected according to design requirements before bellows-type expansion joints are installed; after the adjuster of the steel pipe is welded, check the distance between the bellows, the roundness of the pipe mouths on both ends and the teeth, which shall meet the design requirement.
- 4) After the adjuster of the steel pipe and the bellows are welded, non-destructive flaw detection shall be carried out according to the design requirements.

4.4 Hydraulic machinery auxiliary equipment

4.4.1 Installation of auxiliary equipment shall meet the following requirements:

- a) The quality of the auxiliary equipment's foundations shall meet the design requirements.
- b) Before the equipment is in position, any soiling such as oil stains or mud on the seating plane shall be cleaned up.
- c) The size of the anchor bolt's preformed holes shall meet the design requirements. There shall be no crosswise steel bars and remnants. When casting the foundation's second-stage concrete, the surface of the first-stage concrete shall be scabbled and cleaned. Second-stage casting should use fine stone concrete or cement mortar. The strength grade shall be higher than the foundation concrete's strength by one grade. If the requirements are higher than normal, concrete mixed by expansive cement (or cement mortar) shall be used.

- d) Anchor bolts and grouting shall meet the following requirements:
- 1) Anchor bolt non-perpendicularity shall be less than 1/100.
 - 2) The distance between the anchor bolt and the hole wall shall be greater than 15mm.
 - 3) Oil and dirt on the anchor bolts shall be cleaned off, but the screw threads shall be coated with grease.
 - 4) There shall be close contact between the screw nuts and the gaskets and between the gaskets and the equipment base.
 - 5) The anchor bolts shall be tightened when the concrete has reached 80% of the required strength. When the screw nuts have been tightened, the screw shall be exposed by 2 to 5 threads.
 - 6) The allowable error for the auxiliary equipment's installation position shall meet the requirements of Table 26.

4.4.2 Air compressor installation shall meet the following requirements:

- a) Before installing, the compressor shall be checked and the lubricant oil shall be replaced. If necessary, the compressor shall be disassembled for checking.
- b) The allowable error for integrally installed air compressors shall meet the requirements of Table 27.
- c) Before the air compressor's auxiliary equipment such as the cooler, gas-water separator and gasholder are in position, the positions of the pipe orifices, anchor bolt holes and foundation shall be verified to conform to the construction drawings and the design requirements.

Table 26 Allowable error of auxiliary equipment's installation position

Unit: mm

| No. | Item | Allowable error | Explanation |
|-----|----------------------------------|-----------------|-------------|
| 1 | Equipment's planimetric position | ±10 | |
| 2 | Elevation | -10~+20 | |

Table 27 Allowable error for integrally installed air compressors

| No. | Item | Allowable error | Explanation |
|-----|---|-----------------|-------------|
| 1 | Compressor's lengthwise and crosswise levelness | 0.1 mm/m | |
| 2 | Verticality of the belt pulley's end face | 0.5 mm/m | |
| 3 | End faces of two belt pulleys in the same surface | 0.50 mm | |

- d) For auxiliary equipment under pressure, the strength and tightness tests shall be done under the pressure required by the equipment drawings or technical documents. If there is no requirement, the strength and tightness tests shall be done according to the requirements of 4.1.2.
- e) Before test running, the air compressor shall meet the following requirements:
 - 1) The fasteners for the cylinder head, cylinder, compressor body, crosshead, connecting rod and bearing cover shall be checked that they are tight and firm.
 - 2) Instruments and electrical equipment shall be correctly adjusted. The electric motor's direction of

rotation shall meet the requirements of the air compressor.

- 3) Lubricant oil specification and amount shall meet the requirements of the equipment's technical documents and the oil supply condition shall be normal.
 - 4) Intake and vent pipelines shall be clean.
 - 5) Water inlet and outlet pipelines shall be opened.
 - 6) Turn the compressor through several turns. The turning shall be free and without blockage.
 - 7) Each level's safety valves shall be in working order.
- f) The air compressor's zero-load test running shall last for 4 to 8hrs and shall meet the following requirements:
- 1) The lubricant oil pressure shall be no lower than 0.1MPa.
 - 2) The crankcase oil temperature shall not be more than 70° C.
 - 3) The sound of running parts shall be normal and without obvious vibration.
 - 4) The connecting parts shall not be loose.
- g) The air compressor's on-load test running shall last for 1hr under 25% of rated pressure, 2 hours under 50% or 75% of rated pressure and 3 hours under 100% of rated pressure. The test running shall not only meet the requirements for zero load running, but also the following requirements:
- 1) There shall be no oil leakage, air leakage or water leakage.
 - 2) The drainage temperature of the cooling water shall be no higher than 40°C.
 - 3) Each level's venting temperature and pressure shall meet the design requirements.
 - 4) The safety valve's operating pressure at each level shall be correct and the operation shall be sensitive.
 - 5) Automatic control devices shall be sensitive and reliable.
- h) When the air compressor has been tested to be qualified, the lubricant oil shall be replaced.

4.4.3 Water pump installation shall meet the following requirements:

- a) Water pumps shall be complete and have no missing parts, damage or rust. The pipe orifice protection cover shall be undamaged.
- b) The allowable error for centrifugal pumps shall meet the requirements of Table 28.
- c) The allowable error for deep well pumps shall meet the requirements of Table 29.

Table 28 Allowable error of centrifugal pumps

| No. | Item | Allowable error | Explanation |
|-----|--|---|-------------|
| 1 | Pump's lengthwise and crosswise levelness | 0.1 mm/m | — |
| 2 | Gap between impeller and sealing ring | Meet design requirements | — |
| 3 | Impeller's axial gap of the multilevel pump | Greater than the thrust block's axial gap | — |
| 4 | Centre of driving and driven shafts | 0.10 mm | — |
| 5 | Tilt degree of the driving and driven shafts | 0.2 mm/m | — |

Table 29 Allowable error for deep well pumps

| No. | Item | Allowable error | Explanation |
|-----|---|------------------------------|-------------|
| 1 | Gap between the impellers and the sealing rings at each level | Meet design requirements | — |
| 2 | Impeller's axial gap | Meet design requirements | — |
| 3 | Pump shaft's lifting capacity | Meet the design requirements | — |
| 4 | Eccentricity between the pump shaft and the electric motor shaft | 0.15 mm | — |
| 5 | The inclination between the pump shaft and the electric motor shaft | 0.5 mm/m | — |
| 6 | Pump seat's levelness | 0.1 mm/m | — |

d) The installation of centrifugal water pumps shall meet the following requirements:

- 1) Before connecting the electric motor to the pump, the motor's direction of rotation shall be tested separately. Connect them when the direction has been confirmed.
- 2) When the driving shaft and the driven shaft have been centred and connected, they shall be able to turn freely.
- 3) When connecting the pipeline with the pump, the flanges shall be well centred. The surface of the flange joint shall be parallel and perpendicular to the pipeline's centre line.

e) The installation of deep well pumps shall be checked according to the following requirements:

- 1) The well pipe's inner diameter and non-perpendicularity shall meet the size requirements for pump parts in the well. The well pipe's inner diameter shall be larger than the external diameter of the pump's in-well part by about 50mm to ensure the pump can move freely up and down in the well.
- 2) The well pipe orifice shall be higher than the foundation surface by at least 25mm. Soft isolation layers shall be set between the well pipe and the foundation.
- 3) There shall be no exposed steel pipe ends and sundry materials in the well pipe.
- 4) The end faces of the pump drive shaft shall be flat and smooth. When supported at both ends, the radial jumping value at the middle of the transmission shaft shall be no greater than 0.2mm. Screw threads shall be clean and undamaged.

- 5) Bearing supports and rubber bearings shall be undamaged. Rubber bearings shall not be contaminated by grease.
- f) Before test running, the water pump shall be checked according to the following requirements:
 - 1) The electric motor's direction of rotation shall meet the pump's requirements.
 - 2) All fastening and connecting parts shall not be loose.
 - 3) The lubricant oil's specification, quality and amount shall meet the requirements of the equipment's technical documents.
 - 4) Rubber bearings shall be pre-lubricated with water according to the requirements of the equipment's technical documents.
 - 5) Pipelines shall be washed clean and have no blockage.
 - 6) Safety and protection devices shall be sensitive and reliable.
 - 7) For deep well pumps, the axial gap between the impeller and the discharge bowl shall be adjusted according to the equipment's technical documents.
 - 8) The deep well pump's thrust mechanism shall operate freely and reliably.
 - 9) The water pump's outlet valve shall be in the open position. (For centrifugal water pumps, the outlet is in the closed position, so fill the water to exceed the top of the pump casing first.).
 - 10) The barring gear shall operate freely and be normal.
 - 11) Water pump tests shall be run when each individual auxiliary system has been able to operate normally.
- g) Water pump testing runs under rated load shall last for at least 2hrs and shall meet the following requirements:
 - 1) The stuffing box gland's tightness shall be as appropriate. The leakage shall be in drops.
 - 2) There shall be no abnormal vibration or sound during operation. Each connection shall have no looseness or leakage.
 - 3) The temperature of the rolling bearings and sliding bearings shall be no higher than 70° C. The rolling bearing temperature is not higher than 70°C, and the sliding bearing temperature does not exceed 80°C.
 - 4) Electric motor current shall be no greater than the rated value.
 - 5) Water pump pressure and flow quantity shall meet design requirements.
 - 6) The water pump shaft's radial vibration amplitude shall be no greater than the values listed in Table 30.
- h) Deep well pumps shall be stopped when the test has been run for 20min to again adjust the axial gap between the impeller and the discharge bowl.
- i) Centrifugal water pumps shall not be operated for a long term with the outlet valves all fully closed.
- j) After the test running of the pump, the following work shall be properly done:
 - 1) Close the outlet valves.

- 2) Drain off the water in the pump completely to prevent rusting and frost cracking.

Table 30 Allowable values for the water pump's radial vibration

| Rotational speed (rpm) | >750~1 000 | >1 000~1 500 | >1 500~3 000 |
|---|----------------------|----------------------|----------------------|
| Radial amplitude (double direction) (mm) | No greater than 0.10 | No greater than 0.08 | No greater than 0.06 |

4.4.4 Gear oil pump installation shall meet the following requirements:

- a) The gear oil pump's allowable installation error shall meet the requirements of Table 31.

Table 31 Gear oil pump's allowable installation error

| No. | Item | Allowable error | Explanation |
|-----|---|-----------------|-------------|
| 1 | Pump body's levelness | 0.20 mm/m | |
| 2 | Radial gap between the gear and the pump body | 0.13~0.16 mm | |
| 3 | Axial gap between the gear and the pump body | 0.02~0.03 mm | |
| 4 | Centre of the driving and driven shafts | 0.10 mm | |
| 5 | Centre's inclination of the driving and driven shafts | 0.20 mm/m | |

- b) The gear oil pump shall be kept running for 1hr under zero load and for 30min under 25%,50%,75% and 100% of rated load. The operation shall meet the following requirements:

- 1) There shall be no abnormal vibration and sound during operation. Each connection shall have no looseness and leakage.
- 2) The vibration of the gear oil pump's shell shall be no more than 0.05mm. The shell temperature at the position of the oil pump bearings shall be no higher than 60°C. The shell vibration of the gear oil pump is not more than 0.05mm, and temperature rise of the shell at the bearing part of the oil pump shall not be more than 35°C or 20°C higher than the oil temperature.
- 3) The gear oil pump's pressure fluctuations shall be less than $\pm 1.5\%$ of the design value.
- 4) The gear oil pump's output amount shall be no less than the design value.
- 5) The gear oil pump's electric motor current shall be no greater than the rated value.

4.4.5 Allowable installation error for the hydraulic measurement instruments shall meet the requirements of Table 32.

4.4.6 Installation of containers such as oil or gas tanks shall meet the following requirements:

- a) Container accessories such as cases and tanks shall be complete and their type and specifications shall meet the design requirements.
- b) For containers such as cases and tanks, the specification and position of the inlets and outlets shall meet the design requirements.

- c) Before the tank leaves the factory, leakage tests shall be done and quality certification shall be provided.
- d) Before the gas tank leaves the factory, leakage and pressure withstanding tests shall be performed according to the equipment's technical requirements and quality certification shall be provided.
- e) Before containers such as cases and tanks are placed in position, the container's inner walls shall be cleaned and have no sundry materials.
- f) The allowable installation error for containers such as cases and tanks shall meet the requirements of Table 33.

Table 32 Allowable installation error for hydraulic measurement instruments

| No. | Item | Allowable error | Explanation |
|-----|--|-----------------|-------------|
| 1 | Instrument's installation position | 10 mm | — |
| 2 | Instrument panel's installation position | 20 mm | — |
| 3 | Instrument panel's verticality | 3 mm/m | — |
| 4 | Instrument panel's levelness | 3 mm/m | — |
| 5 | Instrument panel's elevation | ±5 mm | — |
| 6 | Pressure line's position | ±10 mm | — |

Table 33 Allowable installation error for containers such as cases and tanks

Unit: mm

| No. | Item | Allowable error | Explanation |
|-----|----------------------------------|-------------------------------------|-----------------------|
| 1 | Horizontal container's levelness | $\leq 1/1000L$ | L: Container's length |
| 2 | Vertical container's verticality | $\leq 1/1000H$, no greater than 10 | H: Container's height |
| 3 | Elevation | ±10 | — |
| 4 | Centre line's position | 10 | — |

4.4.7 Ventilator installation shall meet the following requirements:

- a) Ventilators shall be checked according to the following requirements before installation:
 - 1) Verify the main installation dimensions of the impeller casing and other parts, such as the anchor hole's centre spacing, inlet/outlet flange's bore diameter, position and centre spacing, shaft's centre and elevation. These dimensions shall be in accordance with the design.
 - 2) Air inlets and outlets shall be tightly covered by cover plates to prevent dust and sundries from entering.
 - 3) The impeller's direction of rotation shall meet the requirements of the equipment's technical documents.
 - 4) Check the ventilator's rotor; there shall be no obvious deformation, serious rusting or damage. If there is any, discuss this with the relevant organizations to find the appropriate treatment.
- b) A centrifugal ventilator's allowable installation error shall meet the requirements of Table 34.
- c) The allowable installation error for axial-flow ventilators shall meet the requirements of Table 35.

Table 34 Centrifugal ventilator's allowable installation error

| No. | Item | Allowable error | Explanation |
|-----|---|--|-----------------------|
| 1 | Bearing's lengthwise and crosswise levelness | 0.20 mm/m | — |
| 2 | Axiality of the casing and the rotor | 2 mm | D - Impeller diameter |
| 3 | Axial gap between the impeller and the casing | Meet the design requirements or 1/100D | — |
| 4 | Radial gap between the impeller and the casing | Meet the design requirements or 1.5~3/100D | — |
| 5 | Centre of the driving and driven shafts | 0.05 mm | — |
| 6 | Centre's inclination of the driving and driven shafts | 0.20 mm/m | — |
| 7 | Verticality of the belt pulley's end face | 0.50 mm/m | — |
| 8 | Two belt pulley's end faces on the same surface | 0.50 mm | — |

Table 35 Allowable installation error of axial-flow type ventilators

| No. | Item | Allowable error | Explanation |
|-----|---|--|---------------------|
| 1 | Ventilator's lengthwise and crosswise levelness | 0.20 mm/m | — |
| 2 | Gap between the impeller and the main air duct or the difference between the gaps on both sides | Meet the design requirements. If $D \leq 600$ mm, no more than ± 0.5 mm If $D > 600 \sim 1\ 200$ mm, no more than ± 1.0 mm | D—impeller diameter |

- d) After installation, the ventilator shall be checked according to the following requirements:
- 1) Ventilator intake and vent pipelines, and valves and adjusting devices shall all be separately supported and firmly connected to the foundation or other buildings. The flange joint faces shall be parallel to each other and be perpendicular to the pipeline's centre line.
 - 2) The ventilator casing shall not bear the weight of other machine components to prevent casing deformation.
- e) Ventilator test runs shall last for no less than 2hrs and shall meet the following requirements:
- 1) The impeller's direction of rotation shall be correct. The ventilator shall operate steadily. There shall be no sound of friction between the rotor and the casing.
 - 2) The rotating parts radial vibration shall be no greater than the values in Table 36.
 - 3) The temperature of sliding bearings shall be no higher than 60°C while that of rolling bearings shall be no higher than 80°C. During the trial run, the sliding bearing temperature of the centrifugal fan does not exceed 65°C and the rolling bearing temperature shall not be 40°C higher than the ambient temperature. Normal working temperature of rolling bearing of the axial flow fan is no more than 70°C, the instantaneous maximum temperature is no more than 95°C, and the temperature rise is no more than 55°C. The normal working temperature of the sliding bearing is no more than 75°C.
 - 4) Electric motor current shall be no greater than the rated current.

Table 36 Allowable values for ventilator radial vibration

| Rotational speed (rpm) | >750~1 000 | >1 000~1 450 | >1 450~3 000 |
|---|---------------------|---------------------|---------------------|
| Radial amplitude (double direction)(mm) | No larger than 0.10 | No larger than 0.08 | No larger than 0.05 |

4.4.8 Installation of firefighting pipes

- a) The distance between the firefighting pipe and the stator coil and rotating parts shall not be less than the design size, generally no more than 20% of the design value.
- b) The direction of the fire pipe spray hole (water spray or CO₂ gas) shall be correct, and the inspection shall be conducted according to the manufacturer's requirements and different structural types. If necessary, use the ventilation method to check this.

4.5 System pipelines

4.5.1 Pipeline materials shall meet the design requirements. If there is no requirement, pipelines whose working pressure is above 1.6 MPa shall be made of seamless steel tubes.

4.5.2 Pipeline fabrication shall meet the following requirements:

- a) The allowable fabrication error for the system pipeline's pipe fittings shall meet the requirements of Table 37.

Table 37 Allowable fabrication error for pipe fittings
Unit: mm

| No. | Item | Allowable error | Explanation |
|-----|---|---------------------------|---|
| 1 | Difference between the maximum and minimum pipe diameters | ≤8% | — |
| 2 | Angle of bending | ±3 mm/m; Total length ≤10 | — |
| 3 | Unevenness of puckering | ≤3%D | D- Nominal diameter of the tubes or cone-shaped tubes |
| 4 | Ring pipe radius | ≤±2%R | R- Ring pipe's curvature radius |
| 5 | Ring pipe's flatness tolerance | ≤±20 | — |
| 6 | Size of Ω shaped expansion joints | ±10 | — |
| 7 | Flatness of Ω shaped expansion joints | 3 mm/m; Total length≤10 | — |
| 8 | Verticality of three-way main pipes and branch pipes | ≤2%H | H-Height of three-way branch pipes |
| 9 | Cone-shaped tube diameters at two ends | ≤±1% D ≤±2 mm | D-Cone-shaped tube nominal diameter |
| 10 | Inclination of the brazed tube's end faces | ≤1/1 000 D | D-pipe's nominal diameter |
| 11 | Brazed tube's perimeter | ≤±1/1 000 L | L-Brazed tube's design perimeter |

- b) The bend radius shall be no less than 4 times the pipe diameter for cold bending pipes, and no less than 3.5 times for hot bending pipes. Hot bending pipes shall be heated by charcoal, coke, petroleum or coal gas rather than coal. The heating temperature shall be no higher than 850°C.
- c) The allowable fabrication error for the vent ducts shall meet the requirements of Table 38.

Table 38 Allowable error for venting pipeline fabrication and installation

Unit: mm

| No. | Item | Allowable error | Explanation |
|-----|---|--------------------------|-------------|
| 1 | Diameter or side length of vent pipes | -2 | — |
| 2 | Diameter or side length of vent pipe flanges | +2 | — |
| 3 | Perpendicularity between the vent pipes and the flanges | 2 | — |
| 4 | Horizontal pipe's levelness | 3 mm/m; total length≤20 | — |
| 5 | Verticality of stand pipes | 2 mm/m ; total length≤20 | — |

4.5.3 The welding shall meet the following requirements:

- a) The welding of pipeline and pipe fittings shall meet the requirements of Table 39.
- b) After welding, the flanges shall be perpendicular to the pipe's centre line and the deflection shall be no greater than the requirements of Table 40.

Table 39 Welding requirements for pipeline and pipe fittings

| No. | Item | Allowable error | Explanation |
|-----|--|--|-------------|
| 1 | Visual examination of the weld joints | There shall be no fissures, slag inclusions and pores on the surface | — |
| 2 | Important weld joint's non-destructive inspection (working pressure ≥6MPa) | Meet the requirements of the relevant sections of DL/T 820 | — |

Table 40 Allowable deflection from the perpendicularity between the flanges and the pipe centre line

| Pipe's nominal diameter (mm) | <100 | <250 | <300 | <350 | <400 | <500 |
|--|------|------|------|------|------|------|
| Maximum deflection of the flange's outer edge (mm) | ±1.5 | ±2 | ±2.5 | ±2.5 | ±3 | ±3 |

4.5.4 Pipeline installation shall meet the following requirements:

- a) Before installation of the pipeline and pipe fittings, the interior shall be washed and cleaned.

- b) For pipelines embedded in concrete, the centre position and elevation of the pipe orifice's exposed ends shall meet the design requirements and the pipe orifice shall be blocked by temporary plugs to prevent debris from getting into the pipe during the concrete casting process.
- c) The pipeline's allowable installation error shall meet the requirements of Table 41.
- d) There shall be no sundry materials or blockage in the pipeline after installation.
- e) After installation, pressure tests on embedded pipelines shall be performed according to the relevant requirements. Only when the pipeline is qualified can the concrete be cast.
- f) Water pipelines inside the generator's wind tunnel shall be wrapped with two layers of white cloth tape to prevent condensate and water dripping onto the pipe exterior.

Table 41 Pipeline's allowable installation error

Unit: mm

| No. | Item | Allowable error | Explanation |
|-----|--|-----------------------------------|-------------|
| 1 | Planimetric position of the exposed pipes per 10m | ± 10 ; total length ≤ 20 | — |
| 2 | Elevation of the exposed pipes | ± 5 | — |
| 3 | Verticality of the stand pipes | 2 mm/m; total length ≤ 15 | — |
| 4 | Flatness tolerance of the rack pipes | $\leq r$ | — |
| 5 | Spacing between rack pipes | 0~+5 | — |
| 6 | Outlet position of embedded pipes connected to the equipment | ± 10 | — |

4.5.5 The setting of the pipeline supports. An added support shall be fixed at each turn of the pipeline. At least one added support shall be fixed at each interval between buildings. The spacing of pipeline supports shall be no less than the requirements of Table 42.

4.5.6 Pipe fittings, valves and pipeline system water pressure tests shall meet the requirements of Table 43.

Table 42 Minimum spacing of pipe supports

| | | | | | | | | | | | |
|----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Pipe nominal diameter (mm) | 15 | 20 | 25 | 32 | 40 | 50 | 70 | 80 | 100 | 125 | 150 |
| Support spacing (m) | 2.0 | 2.0 | 2.5 | 2.5 | 3.0 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 6.0 |

Table 43 Standard requirements for water pressure tests

| No. | Test item | Test property | Test pressure (MPa) | Test time (min) | Standard requirements | Note |
|-----|---|-------------------|---------------------------|-----------------|---|--------------------------|
| 1 | Valves above 1.0MPa | Tightness | 1.25P | 10 | No leakage | P-rated working pressure |
| 2 | Self-made pressure containers and pipe fittings | Strength | 1.5P; larger than 0.4 | 10 | No leakage | — |
| 3 | Self-made pressure containers and pipe fittings | Tightness | 1.25P; 1P | 30 12h | No leakage and the pressure drop shall be less than 5%P | — |
| 4 | Zero pressure container | Leakage | Filling water | 24h | No leakage | — |
| 5 | System pipes | Strength | 1.25P greater than 0.4 | 10 | No leakage | — |
| 6 | System pipes | Tightness | 1.25P greater than 0.4 | 30 | No leakage | — |
| 7 | Ventilation system | Air leakage ratio | Rated air pressure | | No greater than 10% of the design air quantity | — |

4.5.7 The pipeline and supports shall be coated with the colours required in Table 44 after installation.

4.5.8 Each pipe length in separate sections of the building and each branch pipe section shall be marked with black enamel to show the medium's flow direction in the pipe. If there are two opposite directions, two opposing arrows shall be marked.

4.5.9 Behind the arrows which show the medium's flow direction there shall be words to indicate the location of the pipeline. The font size shall be 0.6 times the pipe's external diameter. Valve hand wheels shall be marked with the direction for opening/closing.

Table 44 Requirements for coating colours

| No. | Pipeline name | Pipeline colour |
|-----|---|-----------------|
| 1 | Pipeline for pressure oil and clean lubricant oil in the operation system | Red |
| 2 | Pipeline used to discharge oil and used lubricant oil in the operation system | Yellow |
| 3 | Pipeline for clean insulating oil | Red |
| 4 | Pipeline for unclean insulating oil | Yellow |
| 5 | Supply pipeline for technical water use | Blue |
| 6 | Drainage pump pipeline for technical water demand | Green |
| 7 | Shared pipes for technical water demand and fire demand | Blue |
| 8 | Fire main | Orange |
| 9 | Pipes for washing | Silvery |
| 10 | Powerhouse sewer and sewage pump pipeline | Black |
| 11 | Compressed air pipelines and other air pipelines | White |
| 12 | Pipe supports and valves | Light grey |

5 Electrical equipment installation

5.1 Basic provisions

5.1.1 Electrical equipment installation shall be carried out according to the approved design drawings and product technical documents.

5.1.2 Transportation and storage of the electrical equipment shall meet the requirements of this document and the product technical document.

5.1.3 The storage period for equipment and apparatuses before installation shall meet the requirements of the product technical documents, and shall not exceed one year when it is not specified in the product technical documents. When long-term storage is required, the equipment manufacturer shall be informed for suggestions.

5.1.4 Equipment and apparatuses shall meet the requirements of the technical standards, meet the requirements of the technical conditions of the signed orders, and shall be provided with nameplates, instructions for installation and use, factory test reports, and certification documents.

5.1.5 Equipment and apparatuses shall be checked in good time when being delivered to the site.

- a) Packing and sealing shall be good.
- b) Inventory of unpacking. The specifications shall conform to the design requirements, and the accessories and spare parts shall be complete.
- c) Product technical information shall be complete.
- d) Equipment appearance shall be checked according to the requirements in this document.

5.1.6 Architectural engineering construction related to electrical equipment installation shall meet the following requirements:

- a) Design and equipment requirements shall be met.
- b) Architectural engineering quality related to electrical equipment installation shall meet the design requirements. If there is a special requirement for equipment and special design requirements, these requirements shall be met.
- c) Construction project shall meet the following requirements before the equipment is installed:
 - 1) Roof and floor shall be completed and have no leakage.
 - 2) Doors and windows shall be installed; the indoor ground base shall be completed and the ground elevation shall be marked on the wall; and the indoor grounding shall be completed according to the design.
 - 3) Embedded parts and reserved holes shall meet the design requirements, and the embedded parts shall be fixed.
 - 4) Strength and rigidity of the concrete foundation and scaffolding shall be sufficient for installation.
 - 5) Construction facilities and sundry materials shall be cleaned up. There shall be sufficient installation sites. Construction roads shall be unobstructed.
 - 6) Buildings, concrete foundations, and scaffolding shall have been initially approved for acceptance.

5.2 Switchboard outfit, complete cubicle and secondary circuit

5.2.1 Panel, cabinet, and secondary wiring construction shall be carried out in accordance with provisions of this document. In addition, the designer’s and the equipment manufacturer’s installation technical requirements shall be met.

5.2.2 Construction of the switchboard outfit, complete cubicle and secondary circuit shall meet the following requirements:

- a) Installation of the foundation channel steel shall meet the following requirements:
 - 1) Basic structural steel shall be fabricated according to the design drawings or equipment dimensions, which shall be consistent with the dimensions of the panel and the cabinet. The allowable error shall meet the requirements of Table 45.

Table 45 Allowable error for foundation channel steel

| Items | Allowable error | |
|---|-----------------|-----------------|
| | mm/m | mm/total length |
| Non-linearity | <1 | <5 |
| Levelness | <1 | <5 |
| Position error and unbalance degree | / | <5 |
| NOTE For circular arrangements, the allowable error shall meet the design requirements. | | |

- 2) When the foundation sectional steel has been installed, the top should be 10mm higher than the levelled ground. Complete handcart type cubicles shall comply with the products' technical requirements.
- 3) Foundation sectional steel shall have reliable grounding.
- b) Switchboards, cubicles and their internal equipment shall be firmly connected to the other components. The main control panel, relay protection panel and automatic device panel should not be too firmly welded to the foundation sectional steel.
- c) When the switchboard and cubicle are installed separately or in a row, the allowable value for the switchboard and the cubicle's verticality deviation, horizontal deviation, panel surface deviation and joint deviation shall meet the requirements of Table 46.

Table 46 Allowable installation error for the switchboard and cubicle

| Items | | Allowable error (mm) |
|---|----------------------------|----------------------|
| Verticality deviation (1/m) | | <1.5 |
| Horizontal deviation | Top of two adjacent panels | <2 |
| | Top of panels in a row | <5 |
| Panel surface deviation | Two adjacent panels | <1 |
| | Panels in a row | <5 |
| Joint deviation between adjacent panels | - | <2 |

- d) The switchboard, cubicle, console and cabinet grounding wire shall be firmly fixed. An openable door with electrical equipment shall be reliably connected with grounded metal framework by soft bare copper wires. The complete cubicles shall be equipped with a grounding device for use during maintenance.
- e) Complete cubicle installation shall meet the following requirements:
 - 1) Mechanical and electrical blocks shall be able to operate correctly and reliably.
 - 2) The centre line of the moving and fixed contacts shall be in line with each other and the contacts shall be tight.
 - 3) The changeover contacts of the secondary circuit's pilot switch shall be able to operate correctly and make reliable contact.
 - 4) Cabinet lighting equipment shall be complete.
- f) Installation of drawer type power distribution cabinets shall meet the following requirements:
 - 1) Push-and-pull motion of the drawers shall be free and easy and have no blockage or crashing motion. Drawers shall be able to be exchanged with each other.
 - 2) A drawer's mechanical or electrical interlock device shall operate correctly and reliably. Only after opening of the circuit breaker contacts can the isolator contacts be opened.
 - 3) Drawers shall make good contact with the secondary circuit's plug-in components in between the cabinets.

- 4) The drawer shall not be pulled out when the main circuit in the drawer is switched on.
 - 5) The metal shell and frame of the electrical appliance which needs to be grounded in the drawer shall be reliably grounded. The contact between the drawer and the cabinet, and the grounding of the cabinet and the frame shall be good.
- g) Portable type cabinet installation shall meet the following requirements:
- 1) Check whether the interlock devices used to prevent improper electrical operation are complete and whether they are able to operate freely and reliably.
 - 2) The trolley's push-and-pull motion shall be free and easy, and have no blockage or crashing motion. The same type of trolleys shall be inter-changeable with each other.
 - 3) When the trolley has been pushed into the working position, the gap between the top of the moving contacts and the bottom of the fixed contacts shall meet the product requirements.
 - 4) The trolleys shall be in good contact with the secondary circuit's plug-in components in between the cabinets.
 - 5) Safety isolation plates shall be able to open freely and move in accordance with the trolley's movement.
 - 6) The position of the control cables in the cabinet shall not obstruct the trolley's movement and shall be firm.
 - 7) The grounding contacts between the trolley and the cabinet shall make good contact. When pushing the trolley into the cabinet, the grounding contacts shall make contact earlier than the main contacts. While pulling the trolley out of the cabinet, the grounding contacts shall break later than the main contacts.
 - 8) Shockproof measures for secondary components, such as instruments and relays, shall be reliable. Control and signal circuits shall be correct.
- h) The coating layer of the switchboard or cubicle shall be complete and without damage. The supports used to fix electrical equipment shall be painted. The panel surfaces of the switchboard and the cubicles in the same room shall be painted with the same colour.
- i) For electrical equipment whose panels contain equipment fitted with devices or other electrical equipment which is required to be grounded, the outer casing shall be reliably grounded.
- j) Cables which lead into the switchboard or cubicle and the cable's core wire shall meet the following requirements:
- 1) Cables and conductors shall not have intermediate joints. If necessary, the joints shall be well made and firm, not bear mechanical stress, and ensure the original insulation level; shielded cables shall provide the original shielded electrical connections.
 - 2) The cables that lead into the switchboard and the cubicles shall be regularly arranged and clearly numbered. Crossing cables shall be avoided and the cables shall be firmly fixed. The terminal strip which connects with the cables shall have no mechanical stress.
 - 3) When armoured cable leads into the switchboard or cubicle, the steel strip shall be cut off. The ends of the cutting shall be fastened and the steel strip shall be grounded.
 - 4) Shielded cables shall be properly grounded.
 - 5) Cable core wires in panels and cabinets shall be firmly arranged in an orderly manner. Appropriate

margins shall be left; spare core wires shall lead to the top of the panels and cabinets, or the ends of the wire grooves, and be marked with their standby functions and the conductors of the core wires shall not be exposed.

- 6) The same cable shall not be used in both strong and weak circuits, and the cores shall be arranged in bundles.
- 7) Cable wiring and fixing shall ensure that the cable core and insulation are not damaged.
- k) Switchboards or cubicles used in the tropics shall have damp-proof, anti-mildew and heatproof properties.
- l) The switchboard, cubicle and cable pipes shall be well plugged after installation. In freezing areas, measures shall be taken to prevent water from freezing in the pipes.

5.3 Transformers

5.3.1 Transformer installation shall be carried out in accordance with the provisions of this section. In addition, the designer's and the equipment manufacturer's installation technical requirements shall be met.

5.3.2 Transformers shall not be seriously impacted or vibrated during loading, unloading and transportation.

5.3.3 Architectural engineering construction and quality shall meet design the requirements before the transformers are installed.

5.3.4 The transformer is pulled by mechanical force. The traction point shall be under the centre of the equipment gravity and meet the manufacturer's requirements, and the handling inclination shall not exceed 15°. Dedicated force bearing points of the transformers and reactors shall be used during loading, unloading and positioning. Corresponding anti-skid and anti-slip measures shall be taken and the traction speed shall not exceed 2m/min.

5.3.5 When the bell-jar type transformer is hoisted in its entirety, the steel wire rope shall be tied to the lifting lug exclusively for integral lifting.

5.3.6 The transformer body shall meet the following requirement when being positioned:

- a) For a transformer equipped with gas relays, its top cover shall have a 1% to 1.5% rising slope in the relay airflow direction, unless that installation gradient is not required by the manufacturer. When the transformer is connected to the enclosed bus bar, the bushing central line shall be in line with the centre line of the enclosed bus bar.
- b) The track of the transformer foundation shall be horizontal and the track gauge shall be in line with the wheel tread; for the transformer equipped with the idler wheels, the idler wheels shall roll flexibly. When equipment is installed in position, the idler wheels shall be fixed using a detachable brake device.
- c) When the transformer is directly located on the foundation, the design and manufacture requirements shall be met.

5.3.7 Installation of the transformer accessories shall meet the following requirements:

- a) On-load voltage regulation shifter
 - 1) The operating mechanism, motors, gears, and levers of the transmission mechanism shall be firmly

fixed, the connection positions correct, and the operation flexible and unobstructed; the lubrication of the transmission mechanism shall meet the local climate conditions and the requirements of the product technical documents.

- 2) The contacts and the connecting lines of the selector switch shall be intact and reliable, and the current limiting resistor shall be in good condition.
- 3) The working sequence of the switching device shall comply with the product technical requirements; when the switching device is in the limit position, its mechanical interlocking and electrical interlocking with the limit switch shall operate correctly; and the position indicator shall operate reliably and correctly.
- 4) The selector switch oil tank shall be clean, and the oil tank shall be tested to ensure that it is well-sealed. The insulation strength of the oil injected into the oil tank shall meet the product technical requirements.

b) Cooling device

- 1) Prior to installation, a seal test shall be conducted using air pressure or oil pressure according to the pressure values specified in the product technical documents. For the cooler and forced oil circulating air cooler, the test shall be maintained for 30 minutes without leakage occurring; for the forced oil circulating water cooler, the test shall be maintained for one hour without leakage occurring. Leakage of water and the oil systems shall be checked separately.
- 2) The cooling device shall be flushed using qualified insulating oil before being installed, and the residual oil shall be drained off.
- 3) The fan motor and blade shall be firmly installed, the rotation shall be flexible, and the rotation in the correct direction and unblocked. There shall be no vibration, overheating, blade distortion or wind tube friction during trial operation. The steering direction shall be correct. The power supply wiring of the motor shall be with oil-resistant insulated wire.
- 4) The valve in the pipeline shall be operated flexibly and the opening and closing positions shall be correct; the valve flange joint shall be well-sealed.
- 5) Rust on the external oil pipeline shall be removed and the pipeline shall be cleaned before the pipeline is installed; yellow paint shall be applied to the oil pipeline after the water cooling device is installed; black paint shall be applied to the water pipeline, with the flow direction indicated as well.
- 6) The oil pump is well-sealed without oil leakage or air intake; the rotation direction is correct; there is no abnormal noise, vibration or overheating.
- 7) The liquid-flow annunciator and the pressure relay on the oil and water pipes shall be well sealed and reliable.
- 8) Water shall be drained away when the water cooling device is out of service.
- 9) The cooling device shall be filled with oil immediately after being installed.

c) Oil storage tank

- 1) The oil storage tank shall be inspected and installed according to the product technical documents.
- 2) The oil level meter operates flexibly and accurately, and the indication shall be consistent with the actual oil level in the oil storage tank; the position of the signal contact point of the oil level meter is correct and the insulation is intact.

3) The installation direction of the oil storage tank is correct and the location is rechecked.

d) Casing

1) There shall be no cracks or damages in the appearance of the casing when the porcelain jacket is used, and the adhesive parts of the porcelain casing and the metal flange shall be firmly sealed and coated with waterproof glue with high performance; when a silicone rubber jacket is used for the casing, there shall be no cracks, damages or deformation in the appearance; and the metal flange joint surface of the casing shall be smooth, and without damage or cast sand holes.

2) Erection and hoisting of casing shall meet the requirements of technical documents.

3) The gasket in the top structure of the casing shall be correctly installed and well-sealed, and the top connection shall not be loosened when the lead wire is connected.

4) The surface of the pressure equalizing ring shall be smooth and without scratches, and the ring shall be firmly installed and in the right direction. There shall be drainage holes at the lowest point of the part of the pressure equalizing ring where it is prone to water accumulation.

e) Gas relay

1) The gas relay shall be inspected as qualified before being installed, the action setting value shall meet the requirements, and the fixing measures for transportation shall be removed.

2) The relay shall be installed horizontally with a reliable connection and good sealing and the sign above the top cover shall point to the oil storage tank.

3) The gas collecting box shall be filled with insulating oil and tightly sealed.

4) The relay shall be moisture-proof and water-proof, and be equipped with a rainproof cover.

5) The cable leads shall be equipped with a dripping bend at the connecting point of the relay, and the entrance hole is tightly blocked.

6) The observation window baffle shall be at the opening position.

f) The pressure relief valve shall be installed in the correct direction, and tightly sealed. The electrical contact action shall be accurate. Insulation performance and the action pressure value shall meet the requirements of the product technical documentation.

g) The sealing of the connecting pipe between the moisture absorber and the oil storage tank shall be tight, the moisture absorbent shall be dried, and the oil seal level shall be above the oil surface line.

h) Temperature measuring device

1) The thermometer shall be calibrated before being installed and the signal contact action shall be accurate and properly communicated.

2) The thermometer shall be adjusted according to the manufacturer's requirements.

3) The thermometer pedestal on the top cover shall be tightly sealed without oil leakage, and the thermometer pedestal shall be filled with insulation oil; the unused thermometer pedestal shall also be sealed.

4) The thin metal hose of the expansion signal thermometer shall not be flattened or sharply twisted, and its bending radius shall not be less than 50mm.

5.3.8 Transformer oil filling shall meet the following requirements:

- a) The insulation oil shall be inspected as qualified before filling the transformer.
- b) Oil mixing tests shall be conducted before different grades of insulating oil are mixed or new oils of the same brand are mixed with used oils. It is not suitable to use mixed oil for newly installed transformers.
- c) Vacuum oil filling for the transformers should not be carried out on rainy days or foggy days. Oil filling and vacuum treatment shall meet the product technical requirements and conform to the following requirements:
 - 1) The deformation of the oil tank shall be monitored during vacuuming, and the maximum value shall not exceed twice the maximum wall thickness.
 - 2) Vacuum shall be maintained throughout the entire process. The filled oil temperature shall be higher than the tank body temperature. The oil filling speed should not exceed 100L/min.
 - 3) When the transformer is being vacuumed, accessories which cannot bear the mechanical strength under vacuum conditions shall be isolated from the oil tank; parts which can be vacuumed shall be vacuumed simultaneously; and the vacuum pump or vacuum unit and measures shall be taken to prevent sudden shutdown or reverse filling of the vacuum pump oil caused by improper operation.
 - 4) Oil should enter the transformer from the oil valve at the lower part during oil filling. For transformers with directed forced oil circulation, oil filling shall be carried out according to the requirements of the technical documents.
 - 5) The transformer body and its side winding, oil filter and pipeline shall be reliably grounded during oil injection.

5.4 High-voltage electrical equipment

5.4.1 Installation of high voltage electrical equipment shall meet the following requirements:

- a) Installation of high-voltage electrical equipment shall be carried out in accordance with the provisions of this section. In addition, the designer's and the equipment manufacturer's installation technical requirements shall be met.
- b) The commissioning test technical requirements for high-voltage electrical equipment installation shall be consistent with the regulations.

5.4.2 Installation of the SF₆ breakers shall meet the following requirements:

- a) The base or support of an SF₆ breaker shall meet the requirements of the product technical documents and the following requirements:
 - 1) Concrete strength shall meet the equipment installation requirements.
 - 2) The foundation centre distance and height deviation shall not be greater than 10mm.
 - 3) The centre line deviation of the reserved holes or embedded parts shall not be greater than 10mm, and the upper end of the embedded part shall be 1mm to 10mm higher than the concrete surface.
 - 4) The centre line deviation of embedded bolts shall not be greater than 2mm.
- b) SF₆ breakers shall be installed under the guidance of the manufacturer's technical personnel according to the requirements of the product technical documents, and shall meet the following requirements:
 - 1) Meteorological conditions for the installation environment shall meet product the requirements and

the moisture-proof and dustproof measures shall be completed. The installation shall be carried out in weather without wind, sand, rain, and snow. When the arc extinguishing chamber is checked and assembled, the relative humidity of the air shall be less than 80%.

- 2) The lifting equipment, lifting points and lifting procedures shall conform to the requirements of the product technical documents; the installation shall be carried out in accordance with the component numbering provided by the manufacturer and in the prescribed order. Non-sequential assembly is prohibited.
 - 3) Circuit breaker shall be firmly and reliably fixed according to the requirements of the product technical documents, and the bolt fastening torque shall meet the requirements of the product technical documents. The number of gaskets for the bracket, chassis, and foundation should not be more than 3, the total thickness shall not exceed 10mm, the size of each gasket shall be consistent with the base, and all the gaskets shall be firmly connected.
 - 4) Flange faces of the prop porcelain bushing in the same phase should be on the same horizontal plane, the deviation of the distance between the central lines of the props shall not be greater than 5mm, and the deviation of the inter-phase centre distance shall not be greater than 5mm.
 - 5) All the parts shall be installed in the correct position, and their horizontal and vertical degrees shall meet the requirements of the product technical documents.
 - 6) The seal groove surface shall be intact and clean and without scratch marks. The sealing rings shall be new products. The applied stop-leak compound shall not be come into contact with sulphur hexafluoride gas; the adsorbent shall be replaced and waterproof glue shall be coated according to the product technical documents.
 - 7) Bolts in the sealing part shall be fastened using a torque wrench, and the torque value shall conform to the product technical requirements.
- c) The SF₆ breaker shall meet the following requirements after being installed:

- 1) The joint action of the SF₆ breaker and the operating mechanism shall be carried out in accordance with requirements of the product technical documents and meet the following requirements:

Sulphur hexafluoride gas with a rated pressure shall fill in the breaker before joint operation starts; the first joint operation should be conducted under the guidance of technical personnel from the manufacturer.

The position indicator works correctly and reliably, and its off and on positions shall conform to the breaker's actual switched off or on status.

Those equipped with slow-switching-off and slow-switching-on devices shall perform the slow switching-off and switching-on operations before fast switching off and switching on are operated.

- 2) The inspection of the current carrying parts of the equipment and the connection of the downlead shall meet the following requirements:

The flexible connection of the current carrying parts of the equipment shall not be broken, concave or corroded on the surface.

The contact surface of the equipment terminals shall be smooth, clean, and without oxide film. The silver plating part cannot be rubbed.

The connection surfaces of the equipment terminals shall be coated with thin-layer electrical joint compound.

The connecting bolts shall be complete and fastened, and the fastening torque is in conformity with the regulations.

Connections of the down leads shall not cause unacceptable stress to the equipment connection terminals.

- 3) The piezometer ring shall have no scratches and burrs, and its installation shall be firm, flat, and without deformation; the piezometer ring should be drilled with drainage holes at the lowest position.
 - 4) The grounding wire connections of the equipment shall meet the design requirements and product technical documents, and shall be free of corrosion and damage, and shall be reliably connected.
- d) Performance parameters of the SF₆ breaker after being installed and adjusted shall meet the design requirements and meet the requirements of the product technical documents.

5.4.3 Installation of the gas insulated switchgear (GIS) shall meet the following requirements:

- a) Concrete strength of the GIS equipment foundation shall meet the equipment installation requirements and the embedded parts shall be well-grounded and meet the design requirements. The allowable deviation of the GIS equipment foundation and the embedded parts shall meet the requirements of Table 47, in addition to the requirements of the product technical documents.
- b) GIS elements shall be installed under the guidance of the manufacturer's technical personnel according to the requirements of the product technical documents, and meet the following requirements:
 - 1) Meteorological conditions for GIS installation shall meet the product requirements and the moisture-proof and dustproof measures shall be completed.
 - 2) The lifting equipment, lifting points, and lifting procedures shall conform to requirements of the product technical documents; the installation shall be carried out in accordance with the component numbering provided by the manufacturer and in the prescribed order. Non-sequential assembly is not allowed.
 - 3) The pre-charged nitrogen in the box shall be exhausted and then filled with dry air. When the oxygen content in the air in the box is more than 18%, the installation personnel shall be allowed to enter the box for inspection and installation.
 - 4) The contact centre of the connecting plug-in shall be aligned with the socket and be unblocked. The insertion depth shall conform to the requirements of the product technical documents; the contact resistance shall conform to the requirements of the product technical documents and should not exceed 1.1 times the values specified in the product technical documents.
 - 5) All the parts shall be installed in the correct position, and their horizontal and vertical degrees shall meet the requirements of the product technical documents.
 - 6) The seal groove surface shall be intact and clean. The sealing rings shall be new products. The applied stop-leak compound shall not come into contact with sulphur hexafluoride gas; the adsorbent shall be replaced and dust removal and seal waterproofing treatment shall be performed according to the product technical documents.
 - 7) Installation of the expansion joints and bushings shall meet the requirements of the technical documents.
 - 8) The inner part of the gas pipe shall be clean, and the on-site processing technology, curvature radius, and bracket arrangement of the gas pipe shall meet the requirements of the product technical documents; connecting joints between gas pipes shall be located in a place that is convenient for observation and maintenance.

- 9) Equipment grounding wire connections shall conform to the requirements of the product technical documents, and shall be free from corrosion and damage, and shall be reliably connected.

Table 47 Allowable deviation of the GIS equipment foundation and the embedded parts

| Item | Allowable foundation elevation deviation (mm) | | | Allowable deviation of the embedded part (mm) | | | Axis (mm) | | |
|--|---|----------|-------------|---|--------------------|--------------------------|-------------|---------------------------|--------|
| | Foundation elevation | In-phase | Inter-phase | Adjacent embedded parts | All embedded parts | Above foundation surface | Centre line | With other equipment x, y | Axle y |
| Three phases sharing one foundation | ≤2 | — | — | — | — | — | — | — | — |
| One foundation for each phase | — | ≤2 | ≤2 | — | — | — | — | — | — |
| Foundation for every other device | ≤5 | — | — | — | — | — | — | — | — |
| In the same group | — | — | — | — | — | — | ≤1 | — | — |
| Surface elevation of the embedded parts | — | — | — | ≤2 | — | ≤1~10 | — | — | — |
| Embedded bolts | — | — | — | — | — | — | ≤2 | — | — |
| Indoor installation | | | | | | | | | |
| Each phase of the breaker | — | — | — | — | — | — | — | ≤5 | — |
| Indoor and outdoor equipment foundation under a voltage lower than 220kV | ≤5 | — | — | — | — | — | — | — | — |
| Indoor and outdoor equipment foundation | — | — | — | — | — | — | — | — | ≤5 |

5.4.4 Installation of the vacuum circuit breaker and the high-voltage switch cabinet shall meet the following requirements:

- a) The installation and adjustment of the vacuum circuit breaker shall meet the requirements of the product technical documents and the following requirements:
 - 1) The installation shall be vertical and fixed, and the inter-phase support porcelain bushing shall be on the same level.
 - 2) Connecting levers of the three-phase linkage connecting rods shall be on the same level and have consistent angles.
 - 3) Three-phase synchronization, the contact resistance values of conductive circuits, the switching on time, switching on speeds, switching off time, switching off speed, and other performance parameters shall meet the requirements of the product technical documents.
- b) The SF₆ breaker installed in the high-voltage switch cabinet shall be installed and adjusted according to the requirements of 5.4.2.

5.5 Enclosed bus bar and the bus duct

5.5.1 Enclosed bus bar and the bus duct installation shall be carried out in accordance with the provisions of this section. In addition, the designer's and equipment manufacturer's installation technical requirements shall be met.

5.5.2 Installation of the enclosed bus bar and the bus duct shall meet the following requirements:

- a) The bus body, accessories, and fixing components shall be processed or configured according to the requirements of construction and the installation drawings before the enclosed bus bar and the bus duct is installed.
- b) All sections of the enclosed bus bar and the bus duct supplied in a complete set shall be clearly marked, with complete accessories, and without outer casing deformation or internal damages.
- c) The support shall be firmly installed, the bus shall be placed in strict accordance with the installation section diagram, phase sequence, numbering, direction, and sign; the longitudinal clearance shall be evenly distributed. No mechanical stress shall be generated on the bus and the case after the bus is installed.
- d) Installation of the rigid bus shall meet the following requirements:
 - 1) The rigid bus is connected by welding, by through bolts, by plywood or by clamping bolts. The tubular and bar bus shall be connected using a special clamp, and the inner screwed pipe joints or tin soldering cannot be used for the connection.
 - 2) Installation of the bolt joint faces between one bus and another bus, and between the bus and the electric appliance connecting the terminal shall meet the following requirements:

The bus contact surface shall be kept clean after being processed and be coated with the electrical joint compound.

When the bus is placed horizontally, the through bolts shall be installed from bottom to top. In other cases, nuts shall be placed on the maintenance side. 2 to 3 threads of the bolt should be exposed out of the nut.

Both sides of the bus connecting with the through bolts shall be equipped with flat washers. Clearance of

more than 3mm between adjacent bolt washers shall be reserved. A spring washer or a locking nut shall be installed at the nut side.

Stress on the bolts shall be uniform, so no additional stress shall be applied on the connecting terminals of the electrical appliance.

The bus contact surface shall be tightly connected, and the connecting bolts shall be tightened using a torque wrench.

3) When the bus is connected to the screw terminal, the diameter of the bus shall not be 1mm greater than that of the screw terminal. The oxide film of the threads shall be brushed clean, the contact surface of the nuts shall be smooth, a copper tin-lined flat washer shall be added between the nuts and the bus, and a locking nut with no spring pad shall be provided.

4) When the bus is fixed on the post insulator, the following requirements shall be met:

Fixture between the bus support clamp and the post insulator shall be smooth and firm, and additional stress shall not be applied on the bus.

The support clamp or other supporting fittings of the AC bus shall not form a closed magnetic circuit.

When the bus is placed horizontally, the upper pressure plate of the bus bar support splint shall have a 1mm to 1.5mm gap with the bus. When the bus bar is placed vertically, the upper pressure plate shall have a 1.5mm to 2mm gap with the bus.

A fixed dead point shall be set for each section of the bus on the post insulator, which should be set at the midpoint of the full length or at two bus expansion joints.

When the tubular bus is installed on the sliding holder, there shall be a gap of 1mm to 2mm between the shaft seat and the tubular bus.

There shall be no edges and burrs on the fixing device of the bus.

5) Bus expansion joints shall not have cracks, broken strands or wrinkles; their total section shall not be less than 1.2 times the bus section.

e) The insulator and the wall bushing shall meet the following requirements:

1) Insulators and the wall bushing shall be inspected before being installed, the porcelain flanges shall be complete without cracks, the filling in of the glued points is complete, and the bonding is firm.

2) Insulators and the through wall bushing shall be tested as qualified before being installed.

3) Top surfaces of the post insulator or wall bushing installed on the same plane or the vertical plane shall be located on the same plane. The centre line position shall meet the design requirements. Installation centre lines of the post insulators in the straight bus section shall be on the same straight line.

4) When post insulators and wall bushing are installed, the base or flange shall not be embedded in the concrete or plastering layer.

5) Buffer gaskets, such as rubber or asbestos paper, with a thickness not less than 1.5mm shall be padded between the contact surfaces of low-voltage post insulators without base/top caps and the metal fixtures.

6) Installation of the wall bushing shall meet the following requirements:

The bore diameter for installing the wall bushing shall be 5mm larger than that of the bushing insertion part, and the maximum thickness of the concrete installation slab shall not exceed 50mm.

Wall bushing with rated current of 1 500 A or above is directly fixed on the steel plate; no closed magnetic circuits shall be formed around the bushing.

When the wall bushing is installed vertically, the flange shall be upwards; when the wall bushing is installed horizontally, the flange shall be on the outside.

Metal splints (except fasteners) at the end of the bus wall bushing with current of 600A and above shall be made of non-magnetic materials. They shall be metal-connected to the bus, and the contact shall be stable. The thickness of the metal splint shall not be less than 3mm. When the bus includes two or more parts, the bus itself shall be fixed.

Casing grounding terminals and unused voltage extraction terminals shall be reliably grounded.

- f) Uncharged metal components such as the post insulator base, casing flange and the protective net (cover) shall be grounded. Grounding wires should be neatly arranged and in the same direction.
- g) Closed bus shall not be lifted or tied with bare wire ropes to prevent any mechanical damage. During installation and adjustment, it is important to keep the casing clean both inside and outside. Dust and other debris shall be prevented from entering the connections. The inner side of the casing and insulators shall be wiped clean, and there shall not be any remnants in the casing. The assembly and the connection of the equipment connected to the enclosed bus bar shall be carried out after adjustment of the enclosed bus is completed. Metal parts of the casing for the enclosed bus and supporting structure shall be reliably grounded.

5.6 Cable laying

5.6.1 Cable laying shall be carried out in accordance with the provisions of this section. In addition, the designer's and the equipment manufacturer's installation technical requirements shall be met.

5.6.2 Cable laying shall meet the following requirements:

- a) Basic provisions
 - 1) Processing and installation of cable pipes and supports, the placing of cables, and the creation of the cable terminals and joints shall meet the requirements of the construction and installation drawings.
 - 2) Whether the cable type, voltage, and specifications conform to the design shall be checked before the cables are placed. The appearance of the cable shall be non-destructive and well-insulated. The buried cables shall be tested as qualified.
 - 3) The length of each cable shall be calculated according to the design and the actual path, and each cable shall be reasonably arranged to reduce the number of cable connections before the cable is placed.
 - 4) Standby length should be reserved for each cable at the end of the terminal and near the joint.
 - 5) Cables shall be drawn from the upper end of the disc, and the cables shall not be frictionally dragged on the supports and on the ground when cables are laid. There shall be no mechanical damage to cables, such as armour crush, cable twisting, and sheath fracture.
 - 6) The maximum traction strength should meet the requirements in Table 48 when cables are laid through mechanical means.

Table 48 Maximum traction strength of cables
Unit: N/mm²

| Traction method | Traction head | | Wire mesh set | | |
|-----------------------------|---------------|----------------|---------------|------------------|----------------|
| | Copper core | Aluminium core | Lead sleeve | Aluminium sleeve | Plastic sheath |
| Allowable traction strength | 70 | 40 | 10 | 40 | 7 |

7) The mechanical cabling speed should not exceed 15m/min and shall be slowed down when the voltage is 110kV and above or under complex path conditions.

8) Lateral pressure at the turning point shall not exceed 3kN/m when the voltage of the cable is 110kV and above.

b) The distance between the supporting points of the cable shall meet the design requirements. When it is not specified in the design, the values shall not exceed those listed in Table 49.

Table 49 Distance between the supporting points of the cable
Unit: mm

| Cable type Level | | Cabling method | |
|---------------------|--|----------------|-------|
| | | Vertical | |
| Power cable | Whole plastic | 400 | 1 000 |
| | Middle-voltage and low-voltage cables (excluding all-plastic cables) | 800 | 1 500 |
| | High-voltage cables with voltage of 35kV and above | 1 500 | 2 000 |
| Control cable | | 800 | 1 000 |

NOTE When all-plastic power cables can be fixed horizontally along the bracket, the distance between supporting points is allowed to be 800mm. Reliable moisture-proof sealed ends shall be provided after the cables are cut off, and the laying temperature shall be above 0°C.

c) The minimum bending radius of the cable shall meet the requirements in Table 50.

Table 50 Minimum bending radius of the cable

| Cable type | | Multi-core | Single-core |
|---|---|--------------|-------------|
| Control cable | Non-armoured and shielded flexible cables | 6D | --- |
| | Armoured and copper shielded | 12D | |
| | Others | 10D | |
| Rubber insulated power cable | Lead free and steel armour-sheathed | 10D | |
| | Bare lead sheath | 15D | |
| | Steel armour sheath | 20D | |
| Plastic insulated cable | No armoured | 15D | 20D |
| | Armoured | 12D | 15D |
| Oil-paper insulated cable | Aluminium sleeve | | 30D |
| | Lead sleeve | Armoured | 20D |
| | | Not armoured | 20D |
| Self-contained oil filled (lead) cable | | --- | 20D |
| NOTE D refers to the outside diameter of the cable. | | | |

- d) The power cable connection shall meet the following requirements:
- 1) Cables that are laid in parallel should be staggered.
 - 2) Connectors for exposed cables shall be fixed using the supporting plate.
 - 3) The box of the buried cable connector shall be protected with a protection box (except epoxy resin contact box), preventing mechanical damage. The protection box in the frozen soil layer should be filled with asphalt.
- e) Cables shall be neatly laid, uncrossed, fixed and signs shall be installed in good time. Signs shall be installed on the cable terminals and connectors, at the bending position, in the interlayer, at both ends of tunnels and shafts, and in the wells. Circuit numbers shall be marked on the sign. The cable type, specification, and places of origin and destination shall be specified when no serial number is given; the sign shall be corrosion-resistant, uniform in specifications, have clear writing, not fall off easily, and it shall be firmly mounted.
- f) The fixing of the cables shall meet the following requirements:
- 1) For cables to be laid vertically or laid with a gradient steeper than 45°, they shall be fixed on the brackets which are arranged on the cable tray for every 2m.
 - 2) Horizontally laid cables are fixed at both ends of the cable, the bending position and both ends of the cable joints; they are fixed every 5m to 10m when cable spacing is required.
- g) When the cable enters the cable trench, shaft, building, panel (cabinet) and pipe, the entrance and exit shall be closed, and the pipe entrance shall be sealed.
- h) Arrangement of the cables in substations and in the main and auxiliary powerhouses shall meet the following requirements:

- 1) Power cables and control cables shall not be laid on the same layer bracket.
 - 2) High & low voltage power cables and strong & weak power control cables shall be laid in sequence and by layers, which should be laid from high voltage to low voltage and from bottom to top.
 - 3) Control cables should not be more than 1 layer on the common bracket, and not be more than 3 layers on the cable tray.
 - 4) AC three-core power cables should not be more than 1 layer on the common bracket, and not be more than 3 layers on the cable tray.
 - 5) Sundry materials shall be cleaned up promptly and the cover plate shall be covered after the cables are laid. If necessary, the gap of the cover plate shall be sealed.
- i) The following measures shall be taken to prevent fire and flaming:
- 1) Openings for cables passing through the shaft, wall, floor, or entering the electrical panel or cabinet shall be plugged so as to be closed using anti-fire plugs.
 - 2) In important cable trenches, the cables shall be segmented, or fire resisting walls made of soft refractories shall be installed as required.
 - 3) Cables with important circuits can be laid singly in special ditches or in fire-proof enclosed boxes, or have fire-proof coating or fire-proof bandages applied on them.
 - 4) Fire retardant coatings or fire retardant tapes shall be applied on both sides of the power cable joints and on 2m to 3m sections of the adjacent cables.
 - 5) Fireproof coatings shall be applied five times according to the manufacturer's instructions and once every 8 hours. The thickness of the fire-proof coatings is not less than 1.2mm. During construction of the plugging materials, the cables shall be wrapped with organic plugging materials to facilitate cable replacement and heat dissipation, and then inorganic plugging materials shall be filled in around the cables. The thickness of the plugging materials shall not be less than 100mm. For larger cable holes, the middle part of the holes may be plugged with the use of fire protection pillows when the above construction requirements are met.
 - 6) Flame retardant material shall meet the effective self-extinguishment requirement. Refractory products shall meet the requirement that the refractory limit is not less than 1hr when in use and the refractory temperature is not less than 1 000°C.
- j) Cable openings shall be tightly plugged. There shall be no obvious cracks and visible pores. Large openings shall be equipped with a refractory lining and then plugged.

5.7 Auxiliary system motors

5.7.1 Auxiliary system motor installation shall be carried out in accordance with the provisions of this section. In addition, the designer's and the equipment manufacturer's installation technical requirements shall be met.

5.7.2 The position, dimension, and quality of the motor foundation, anchor bolt hole, groove, opening, embedded parts, and cable pipe shall conform to the product technical documents and the design requirements.

5.7.3 The inspection of the motor shall meet the following requirements when the motor is installed:

- a) The disc rotor shall be flexible and without crashing sound.

- b) The grease's condition is normal and has no discoloration, deterioration or hardening. Its performance shall meet the working conditions of the motor.
- c) For motors whose air gap may be measured, the requirement for gap unevenness as specified in the product technical conditions shall be met. The ratio of the difference between the air gap at each point and the average air gap to the average air gap should be $\pm 5\%$, if the value is unspecified.
- d) The incoming/outgoing line of the motor shall have well pressed lugs that have proper clearance and clearly marked numbers conforming to the requirements of the product standards.
- e) The brush lifting device of the wound-type electromotor shall be checked. The lifting device shall have "start" and "run" signs. Actions shall first be in the sequence of the short circuiting collector rings, and then of the lifting brush.

5.7.4 The core-pulling inspection shall be carried out when the motor is in the following circumstances:

- a) The date of production exceeds the manufacturer's warranty period.
- b) The date of production is more than 1 year ago, when the manufacturer has no warranty period.
- c) The quality is not sceptical based on the appearance inspection or electrical test.
- d) The open-type motor is not qualified based on the terminal test.
- e) Abnormal conditions occur during commissioning.

5.7.5 Installation of the multi-speed motor shall meet the following requirements:

- a) The wiring mode and polarity of the motor shall be correct.
- b) The interlocking switch device shall be reliable.
- c) The motor's operating procedure shall conform to the technical specifications for the product.

5.7.6 For motors with fixed steering requirements, the phase sequence of the motor and power source shall be inspected and be consistent before the trial run.

5.8 Computer monitoring system

5.8.1 Computer monitoring system shall be installed out in accordance with the provisions of this section. In addition, the designer's and the equipment manufacturer's installation technical requirements shall be met.

5.8.2 Installation of field automation instrumentation shall meet the following requirements:

- a) The installation position of the instrument shall meet the requirements of the design documents. If it is not specified in the design documents, the installation position shall meet the following requirements:
 - 1) The installation position shall be well lighted, and be convenient for operation and maintenance.
 - 2) The height from the instrument centre to the operation ground should be 1.2m to 1.5m.
 - 3) The display instrument shall be installed in a position convenient for observation and indication.
 - 4) Instruments shall not be installed in places where there is vibration, humidity, or is prone to mechanical damage, strong electromagnetic interference, high temperature, drastic temperature changes, and corrosive gases.
 - 5) Detection elements shall be installed in a position that can reflect the input variables truly.

- b) Instruments shall not be knocked or shaken during installation. Instrument installation shall be firm and flat, the connection with the equipment, pipes or components and the fixed parts shall be uniformly stressed and shall not bear abnormal external forces.
- c) Instruments to be directly installed on the pipeline should be installed after the pipeline is cleaned; if installed simultaneously with the pipeline, the instrument shall be removed before the pipeline is cleaned. A pressure test shall be conducted after the instrument is directly installed on the equipment or pipe.
- d) The cover and intake of the instrument junction box in the construction process shall be closed in good time. The cable intake should not face up. Sealing measures shall be taken after the construction is completed.
- e) Measures shall be taken to prevent weak current equipment and electronic components from being damaged when the insulation resistance of the instrument and the instrument power supply equipment is measured.
- f) Field-bus instruments shall be connected parallel to each other. The number of instruments on each bus and the maximum inter-bus distance shall meet the requirement of the design documents.
- g) The installation of the instrument panels, cabinets, and boxes shall meet the requirements.

5.8.3 The installation of local control unit (LCU) screen, the network equipment rack, server rack, central control room console, and the analogue screen shall meet the requirements.

5.9 Video monitoring system

5.9.1 Video monitoring system installation shall be carried out in accordance with the provisions of this section. In addition, the designer's and the equipment manufacturer's installation technical requirements shall be met.

5.9.2 The camera shall be installed near the monitoring area where the camera cannot be easily damaged, is easy to maintain, and can avoid strong electromagnetic interference. The camera installation location shall not affect the operation of the field equipment and the personnel's normal activities, and shall ensure that the camera's field of view meets the monitoring needs.

5.9.3 Camera installation height from the ground should not be less than 2.5m indoors and 3.5m outdoors. If outdoor cameras are installed with vertical poles, the strength and stability of the upright rods shall meet the camera usage requirements.

5.9.4 Camera lens should be installed to align with the monitoring object along the light source direction. Backlighting installation should be prevented; when backlighting installation is necessary, it is advisable to reduce the illumination contrast of the monitoring area or to select cameras with backlighting compensation accessories, such as curtain grids.

5.9.5 When certain illumination is required for monitoring multi-scenes or changing scenes, auxiliary lighting fixtures should be installed at the top of the protective cover of the camera equipped with an electric platform or on other devices rotating in the same direction as the electric platform.

5.9.6 Installation of the console and rack in the main control monitoring centre shall meet the regulations; the screen of the monitoring display shall avoid direct light from outside.

5.10 Lightning protection grounding

5.10.1 Construction of the lightning protection grounding device shall be carried out according to approved design documents.

5.10.2 Installation of the grounding devices shall be in accordance with the construction of the architectural engineering; hidden parts shall be inspected, checked, and accepted by the relevant authorities before being covered and a relevant record shall be created.

5.10.3 The following metal parts of the electrical devices shall be grounded:

- a) Metal base, frame, shell, and transmission device of the electrical equipment
- b) Metal seat and housing for portable or mobile electric appliances
- c) Box-type substation body
- d) Second side winding of the mutual inductor
- e) Metal frame and base of the panels (cabinets, boxes) and the operation tables for the power distribution, protection, and controlling
- f) Metal shield, joint box, terminal head, metal protective pipe of the power cables and the shield layer of secondary cables
- g) Cable tray, bracket, and derrick
- h) Substation structure and support
- i) Overhead power line structures equipped with overhead ground wires or electrical equipment
- j) Metal barriers for distribution devices
- k) Metal case for electric heating equipment
- l) Metal base and housing of the rotary motor
- m) Metal base and housing for the electric hoist, gantry crane, portal crane track and electrical equipment

5.10.4 Grounding wires shall not be used for other purposes.

5.10.5 In addition to the natural grounding electrodes, the power plants and substations shall also be laid out with grounding mats with horizontal artificial grounding electrodes as the main part. The measuring well separating the natural grounding electrodes from the artificial grounding electrodes shall be set.

5.10.6 Grounding device materials shall meet the following requirements:

- a) In addition to temporary grounding devices, hot-dip galvanizing shall be applied for all the steel used in the grounding devices. For horizontally laid devices, hot-dip galvanized round steel and flat steel shall be used; for vertically laid devices, hot-dip galvanized angle steel, steel pipes or round steel shall be used.
- b) When a flat copper strip, copper strand, copper bar, copper coated steel (round wire, strand), zinc clad steel and other materials are used for grounding devices, the selection shall meet the design requirements.
- c) Aluminium conductors shall not be used as the grounding electrode or grounding wire.

5.10.7 For the artificial grounding electrode of the grounding devices, the conductor section shall meet requirements for thermal stability, voltage sharing, mechanical strength, and corrosion resistance; the horizontal grounding electrode section shall not be less than 75% of the grounding wire section connected to

the grounding device; the minimum specifications for the steel grounding electrode and the grounding wire shall not be less than the specifications listed in Table 51 and Table 52; the cross section area of the grounding electrode outgoing line for the overhead line structures shall not be less than 50mm².

Table 51 Minimum specifications for the steel grounding electrode and ground wire

| Type, specifications and unit | | Overground | Underground |
|---|----------------------------|------------|-------------|
| Round steel diameter (mm) | | 8 | 8/10 |
| Flat steel | Section (mm ²) | 48 | 48 |
| | Thickness (mm) | 4 | 4 |
| Angle steel thickness (mm) | | 2.5 | 4 |
| Steel pipe thickness (mm) | | 2.5 | 3.5/2.5 |
| NOTE 1 For the underground round steel diameter, the molecular data and denominator data respectively correspond to the overhead lines and the grounding grid of the power station and substation; | | | |
| NOTE 2 For the wall thickness of the underground steel pipe, the molecular data and the denominator data correspond to the pipes that are buried in the soil and in the indoor concrete floor respectively. | | | |

Table 52 Minimum specifications for the copper and copper coated steel grounding electrodes

| Type, Specifications, and Unit | Overground | Underground |
|---|------------|-------------------------------|
| Copper bar diameter (mm) | 8 | Horizontal ground electrode 8 |
| | | Vertical ground electrode 15 |
| Copper bar section (mm ²) / thickness (mm) | 50/2 | 50/2 |
| Copper pipe thickness (mm) | 2 | 3 |
| Copper stranded wire section (mm ²) | 50 | 50 |
| Diameter of copper coated round steel (mm) | 8 | 10 |
| Diameter of copper coated steel strands (mm) | 8 | 10 |
| Copper coated flat steel section (mm ²) / thickness (mm) | 48/4 | 48/4 |
| NOTE 1 Bare copper strands are not suitable for that grounding electrode of a small grounding device. When copper strands are used as the grounding electrode of the grounding grid, the sectional area shall meet the design requirements. | | |
| NOTE 2 The diameter of one strand of copper strand wire shall not be less than 1.7mm; | | |
| NOTE 3 Copper coated steel specifications indicate the size of the steel, and that the copper layer thickness shall not be less than 0.25mm. | | |

5.10.8 The minimum cross-sectional area of the exposed ground lead that is connected with the grounding electrode or the protective wire (PE) on the ground of the low-voltage electrical equipment shall conform to Table 53.

Table 53 Minimum cross-sectional area of the exposed copper ground lead on the low voltage ground electrical equipment

| Name | Minimum sectional area (mm ²) |
|--|---|
| Exposed bare conductor | 4 |
| Insulated conductor | 1.5 |
| Grounding core of the cable, or the grounding core of multi-core cables wrapped in the same protective enclosure with the phase line | 1 |

5.10.9 It is strictly forbidden to use metal hoses, the metal skin of the pipeline insulation layer, or metal mesh, the lead skin of the conductor for the low-voltage lighting network, and the metal sheath of the cable as grounding wires.

5.10.10 Embedded depth and spacing of the grounding grid shall meet the design requirements. Buried depth of the top surface of the grounding electrode should not be less than 0.8m; the spacing of the horizontal grounding electrode should not be less than 5m; and the spacing of the vertical grounding electrode should not be less than twice its length.

5.10.11 Grounding of the electrical devices shall be connected with the grounding bus or the grounding grid separately. It is strictly prohibited to connect two or more electrical devices that need to be grounded in series with one grounding wire.

5.10.12 Annular grounding buses shall be laid around the communication room, the cross-sectional area of the copper bars shall not be less than 90mm², and the cross-sectional area of galvanized flat steel shall not be less than 120mm². Closed annular grounding devices shall be laid around the communication room.

5.10.13 Uncharged metals exposed in the main control room and the central control room should be in equipotential connection with the building. The minimum cross-sectional area of the equipotential ground terminal boards and the interconnected conductors shall meet the requirements in Table 54 and Table 55, respectively.

Table 54 Minimum cross-sectional area of all kinds of equipotential grounding terminals

| Name | Material | Minimum sectional area (mm ²) |
|---|-------------|---|
| Main equipotential ground terminal board | Copper belt | 150 |
| Floor equipotential ground terminal board | Copper belt | 100 |
| Partial equipotential ground terminal board in the equipment room | Copper belt | 50 |

Table 55 Minimum cross-sectional area of all kinds of equipotential bonding conductors

| Name | Material | Minimum sectional area (mm ²) |
|---|--|---|
| Vertical grounding main lines | Multi-strand copper conductor or copper belt | 50 |
| Bonding conductor between the floor terminal board and the partial terminal board in the equipment room | Multi-strand copper conductor or copper belt | 25 |
| Bonding conductor between partial terminal boards in the equipment room | Multi-strand copper conductor | 16 |
| Bonding conductor between the equipment and the equipotential connection network in the equipment room | Multi-strand copper conductor | 6 |
| Equipment room grids | Copper foil or multi-strand copper conductor | 25 |

5.10.14 The common grounding network shall be used for the grounding of the hydropower plant computer supervisory control system. Grounding of the equipment casing, AC power supply, logic circuit, signal circuit, and the cable shield of equipment shall meet the following requirements:

- a) The equipment casing or exposed non-current carrying metal parts shall be grounded.
- b) The isolated AC and DC power supply shall be grounded when the voltage exceeds 150V.
- c) There should be a grounding point in all the computer DC circuits (including the DC power supply, logic circuit, and signal circuit) that are not isolated.
- d) The difference in ground potential between any two grounding points shall not be greater than the allowable noise of the equipment at any time when there are two or more grounding points in the common ground circuit of all the non-isolated calculation DC circuits.
- e) When all the external interface devices in any cabinet (or a set of devices) are isolated, the cabinet casing, AC power supply, computer DC circuit and cable shielding layer shall be grounded at one point in the cabinet. The computer logic circuit shall have only one point in the cabinet connected with the common grounding point of the cabinet.
- f) There shall not be two separate grounding grids in any device or adjacent equipment.
- g) Grounding points of the corresponding sensors or other connecting devices shall be considered for the grounding of the signal and the cable shield layer to avoid the grounding of two points. One point at the computer monitoring and receiving equipment shall be selected for the grounding by preference.

5.10.15 The power supply line and the surge protector shall be installed at the front end of the power supply line of the protected equipment, and the terminals of the surge protector shall be connected with the terminals of the same names in the distribution box. The grounding end of the surge protector is connected with the PE grounding terminal board of the distribution box. The grounding terminal board of the distribution box shall be connected with the equipotential grounding terminal board in the lightning protection area. Connecting wires of the all-level surge protectors shall be neatly arranged, and their length should not exceed 0.5m.

5.10.16 Surge protectors with connecting terminals shall be crimped when connecting with the wires, and the surge protector with binding posts should be connected to the binding posts using wire lugs.

5.10.17 The minimum cross-sectional area of the connection wires of the surge protectors should meet the requirements in Table 56.

Table 56 Minimum cross-sectional area of the surge protector connection lines

| Protection grade | Surge protector type | Lead section (mm ²) | |
|------------------|--------------------------------------|---|---|
| | | Copper conductor for surge protector phase connecting | Copper conductor for surge protector grounding connecting |
| Grade I | Switch type or voltage limiting type | 16 | 25 |
| Grade II | Voltage limiting type | 10 | 16 |
| Grade III | Voltage limiting type | 6 | 10 |
| Grade IV | Voltage limiting type | 4 | 6 |

NOTE For the combination type surge protector, the cross-sectional area of the lead for the corresponding protection level can be selected.

6 Installation of the automatic hydrological forecasting and reporting system

6.1 Main equipment of the automatic hydrological forecasting and reporting system shall meet the technical standards and product quality requirements of the relevant industries and have a production license for the industrial products.

6.2 The following requirements shall be met before the equipment is installed:

- a) Preliminary inspection of the equipment quantity and quality shall be carried out according to the design and purchase list.
- b) Necessary quality marks for the key equipment shall be checked.
- c) Civil facilities for the equipment installation shall pass the preliminary inspection or the acceptance for the individual works according to the design.
- d) Related telemetry stations and central stations shall be put into operation in advance for the system using the public communication network.
- e) The battery charging and discharging processes shall be completed according to the prescribed procedures and sufficient electricity shall be provided according to the regulations.
- f) Installation and commissioning shall be completed by trained technicians.

6.3 Equipment installation shall meet the following requirements:

- a) Different equipment installation sequences and plans shall be prepared before equipment installation. The system should be installed in the order of the central station, relay station, and telemetry station.
- b) Equipment shall be strictly installed according to the product specifications and design technical documents. Telemetry terminals, sensors, and other equipment shall also be configured according to the design requirements.

- c) For installation processes that require on-site treatment, such as welding and mechanical fixing, the relevant process standards and requirements shall be strictly followed, and the necessary inspection or testing shall be carried out.
- d) Routing and installation methods of the connection lines shall be selected with full consideration given to preventing mechanical damage, water and dampness, electromagnetic interference, animal bites and burglary. Protective measures, such as sheaths, must be taken. When the equipment connection involves the indoor and outdoor interconnection, rainwater shall be prevented from being introduced into the room.

6.4 After the installation and fixing work is completed, the following key inspections and adjustments shall be carried out:

- a) Check whether the connecting line between the equipment is solid and reliable. Check whether equipment that needs to be grounded meets the installation requirements.
- b) Check whether the battery voltage and charging current meet the requirements.
- c) Check whether the open circuit voltage and short-circuit current of the solar panels meet the requirements.
- d) In the range of the design sensor, simulate the actual situation, and check & debug whether all kinds of equipment work as expected, including the normal functions of communication, display, keys and storage.

6.5 After the installation is completed, the basic configuration information for equipment installation and commissioning shall be completely recorded and sorted.

6.6 System integration and testing shall meet the following requirements:

- a) After the central station, telemetry station and other equipment are installed, the overall connection and coordination shall be completed through system integration. According to the system design and software requirements, configure and set the parameters for joint testing of the system functions, and inspect the functions and indicators of the system to achieve the desired results. System integration and testing shall include the following aspects:
 - 1) Simulate the actual operation parameters in the design range of the sensor.
 - 2) Trigger transmission conditions, including time triggering and parameter triggering.
 - 3) Data upload and the response process.
 - 4) Inspection of the data receiving process, including the accuracy of the parameters, transmission speed and time, and the completion time of the collection of all the data from the telemetry stations.
 - 5) The central control instruction is issued to check whether the telemetry station acts according to predetermined requirements, including clock calibration and the telemetry terminal configuration.
 - 6) Other functions of the telemetry station, such as on-site data downloading, manual input and settings.
 - 7) Other functions of the central station, such as graphic display, storage, query, printing.
- b) After the entire system is installed, the correctness of the collected data and the system patency rate shall be checked according to the design requirements.
- c) Problems and processing results during installation shall be recorded in detail for future reference.

7 Installation of safety monitoring equipment

7.1 The purchase of safety monitoring instruments shall meet the following requirements:

- a) Under the pre-condition that the type, specification, range and accuracy can meet the design requirements, and comprehensively considering the product's properties such as performance, quality and durability, select no less than 3 manufacturers to make an instrument purchase plan which shall be submitted for approval.
- b) The purchase of instruments shall comply with the approved purchase plan. If there is any change, the new plan shall be approved again.

7.2 The acceptance of the safety monitoring instruments shall meet the following requirements:

- a) Before the instruments leave the factory, all the instrument equipment shall be checked and quality certifications shall be provided by the manufacturer. If necessary, one shall go to the factory to take part in the main instrument equipment's checking and acceptance.
- b) When the instruments have been transported to the site, check and accept all instruments provided by the manufacturer. Testing, correction and calibration shall be done according to the relevant requirements. Only when the instruments have been accepted as qualified can they be used.
- c) For the qualified instruments, identification records shall be established in good time.

7.3 The installation and embedding of the safety monitoring instruments shall meet the following requirements:

- a) Preparatory work before the installation and embedding shall meet the following requirements:
 - 1) The construction of the preformed holes, grooves, conduits and all kinds of embedded parts shall be finished according to the requirements of the observation design drawings. The measurement and setting out shall be properly done at the embedded points.
 - 2) Cable type shall meet the design requirements and the cable connections shall meet the requirements of the standards.
- b) Installation and embedding shall meet the following requirements:
 - 1) Design number, manufacturing number and measured values in the free state shall be rechecked before installation and embedding.
 - 2) Each kind of instrument shall be installed and embedded according to its own requirements and procedures to ensure that the positions are correct.
 - 3) The outgoing cable shall be wound to leave a certain length around the instrument's embedding point to prevent the instrument's direction and position from being changed when the cable is dragged around during construction.
 - 4) When the instrument is embedded into bedrock, the slots shall be washed clean and backfill mortar should be mixed with micro-expansion cement.
 - 5) Backfill concrete around the instrument shall be manually vibrated and compacted by layers. Concrete shall be more than 1.5m away from the instrument when being placed, and the distance between the vibrator and the instrument shall be greater than the vibration radius and should not be less than 1.0m.

- 6) The instruments shall be marked in a timely manner after the embedding to prevent them from being damaged by people or machines.
- 7) The instrument's working conditions shall be monitored during the embedding. If abnormal conditions are found, take remedial measures or replace the instrument in time.
- 8) The record and research data for monitoring facilities shall be collected to acquire the initial (reference) value in a timely manner.
- 9) As-built drawings shall be made and the completion reports shall be prepared in a timely manner.

7.4 Safety monitoring during the construction period shall meet the following requirements:

- a) The contractor shall appoint special observers to take charge of the construction period's safety monitoring.
- b) The observation instruments shall be regularly observed, and maintained by professional observers according to the approved observation specifications. If abnormal data is noticed, increase the frequency of observation and report it to the relevant department.
- c) The original observation records shall be properly done. The records shall be compiled and analysed in a timely manner and the observation reports shall be made regularly. The dam safety during the construction period shall be evaluated to provide basis for decision-making for the construction.
- d) A special report on the project safety monitoring shall be submitted when the project is completed for acceptance, in order to evaluate whether the safety monitoring system meets the requirements for project completion acceptance.



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