Community Specification

Secondary-side Pipeline Process Specification (Version 1.0)

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Change History

Version	Description	Contributor
V0.8	Initial release.	Guangdong Shenling Environmental Systems Co., Ltd. Huawei Technologies Co., Ltd. Shenzhen Envicool Technology Co., Ltd. Sugon Data Infrastructure Innovation Technology (Beijing) Co., Ltd. Hebei Jingmai Technology Co., Ltd.
V1.0	1. Added requirements for the depth, width, and quantity of galls on the appearance of raw materials. 2. Added comparison images of qualified and unqualified blue dot detection results. 3. Added test solutions for stainless steel hoses and rubber hoses.	Guangdong Shenling Environmental Systems Co., Ltd. Huawei Technologies Co., Ltd. Sugon Data Infrastructure Innovation Technology (Beijing) Co., Ltd. Hebei Jingmai Technology Co., Ltd.

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Secondary-side Pipeline Process Specification

1 Scope

This document specifies the key process requirements for the entire prefabricated production process of the secondary-side pipeline in the liquid cooling system, including material supply, processing and assembly, inspection, packaging, and transportation. This ensures that the production process of the secondary-side pipeline is standardized and the prefabricated product quality is controllable.

This document is applicable to the secondary-side pipeline in the liquid cooling equipment room of a newly built, reconstructed, or expanded data center. It does not involve the primary-side pipeline system of the liquid cooling equipment room, such as the external cooling system (e.g., cooling tower and chiller), manifold, and liquid cooling heat dissipation components inside the server.

2 Terms and Definitions

2.1 Secondary-side Pipeline

The pipeline from the outlet of the indoor coolant distribution unit (CDU) to the inlet of the liquid-cooled rack manifold is defined as the secondary-side pipeline system, including the CDU branch pipeline, main pipeline, branch pipeline, and auxiliary valves.

2.2 Austenitic Stainless Steel

A type of stainless steel whose matrix is primarily composed of an austenitic structure with a face-centered cubic crystal lattice, and is strengthened mainly through cold working or nitrogen alloying.

2.3 Acid Cleaning

The process of cleaning a surface with an acid solution to remove foreign materials such as oxide scale, water scale, and grease.

2.4 Passivating

A chemical treatment applied to stainless steel to prevent an increase in surface thickness caused by the natural formation of a chromium-rich oxide film.

2.5 Flatness

Flatness refers to the allowable variation of the actual measured surface relative to an ideal plane, reflecting the degree of evenness of the surface.

2.6 Surface Roughness

Surface roughness refers to the micro-geometric characteristics of a workpiece surface, composed of small spacing, peaks, and valleys. It is a core indicator for evaluating the quality of metal surface finishing.

2.7 Gall Depth

Gall depth refers to the vertical distance from the deepest point of a groove-shaped defect, formed on the stainless steel surface by external forces such as mechanical friction, impact, or tool scratches, to the reference surface of the base material.

2.8 Sand Inclusion

A cavity containing sand particles found inside or on the surface of a casting.

2.9 Shrinkage

Holes generated in the casting during solidification due to poor feeding.

2.10 Passive Film

A passive film is an oxidation protective film formed on the surface of austenitic stainless steel through chemical methods.

2.11 Blue Dot Liquid

Blue dot liquid is a test liquid used to test the quality of the passive film on the surface of austenitic stainless steel. The liquid is brownish yellow. After the passive film is damaged, blue spots are formed.

3 Incoming Material Control and Inspection Requirements

3.1 Stainless Steel Material Requirements

For the metal raw materials in the secondary-side liquid cooling system, such as pipes, elbows, stainless steel hoses, valves, and flanges, it is recommended that austenitic stainless steel of 06Cr19Ni10 or higher grades be used.

3.1.1 Material Certification and Identification Requirements

The supplier of raw materials or components shall provide a material certification report with legal effect. The report shall contain key information such as the grade, material number, chemical composition test result, and mechanical performance indicators. The data in the report shall comply with the national standards of the corresponding stainless steel grade, as specified in GB/T 20878.

3.1.2 Chemical Composition Spot Check Requirements

It is recommended that the direct reading spectrometer be used to spot check raw materials in each lot. The spot check proportion is recommended to be S-1 (special inspection level) in GB/T 2828, and the "0-reject-1-accept" standard be used. If the spot check fails, all materials shall be rejected to prevent the material from failing to meet the requirements of corrosion resistance and mechanical strength.

Lot	Special Inspection Level				Normal Inspection Level		
	S-1	S-2	S-3	S-4	I	II	III
2～8	A	A	A	A	A	A	B
9～15	A	A	A	A	A	B	C
16～25	A	A	B	B	B	C	D
26～50	A	B	B	C	C	D	E
51～90	B	B	C	C	C	E	F
91～150	B	B	C	D	D	F	G
151～280	B	C	D	E	E	G	H
281～500	B	C	D	E	F	H	J
501～1 200	C	C	E	F	G	J	K
1 201～3 200	C	D	E	G	H	K	L
3 201～10 000	C	D	F	G	J	L	M
10 001～35 000	C	D	F	H	K	M	N
35 001～150 000	D	E	G	J	L	N	P
150 001～500 000	D	E	G	J	M	P	Q
500 001 and above	D	E	H	K	N	Q	R

Figure 1 Lot size code

Note: A = 2; B = 3; C = 5; D = 8; E = 13.

3.2 Appearance Requirements for Stainless Steel Raw Materials

1. Cracks, dents, folds, wrinkles, delamination, and scars are not allowed. These defects shall be completely eliminated, and the elimination depth shall not exceed 1% of the wall thickness. The actual wall thickness after defect elimination shall not be less than the minimum value allowed by the wall thickness.
2. The raw materials of pipes and the outer surface of metal corrugated pipes shall be visually inspected, and the inner surface shall be inspected using an endoscope. Bends, valves, and flanges shall be visually inspected. The key positions shall meet the following requirements:
   (1) The depth of a single gall shall not be greater than 0.2 mm, the length shall not be greater than 20 mm, and the width shall not be greater than 2 mm. A maximum of two unqualified gall marks are allowed on the same cross section. Galls are not allowed on the inner surface where measurement cannot be performed.
   (2) Sand inclusion and shrinkage on the surface shall comply with the national standard GB/T 39428. In key areas, sand inclusion of level Z1 or higher and shrinkage of level QK1 or higher are not allowed. The bottom of the holes shall be visible to the naked eye. Holes whose depth cannot be evaluated or even through holes are not allowed.

Casting Appearance	Defect Type	Good ⟺			Poor	Figure
Surface appearance	Surface roughness	BM1	BM2	BM3	BM4	Figure C.1
	Mechanically treated surface	XM1	XM2	XM3	XM4	Figure C.2
Surface discontinuity	Non-metallic inclusion	Z1	Z2	Z3	-	Figure C.3
	Pores	QK1	QK2	QK3		Figure C.4
	Welds	HF1	HF2	HF3		Figure C.5
Note: The letter and number together represent the specific level of a certain type of surface defect. For example, "BM1" indicates level 1 of surface roughness.						

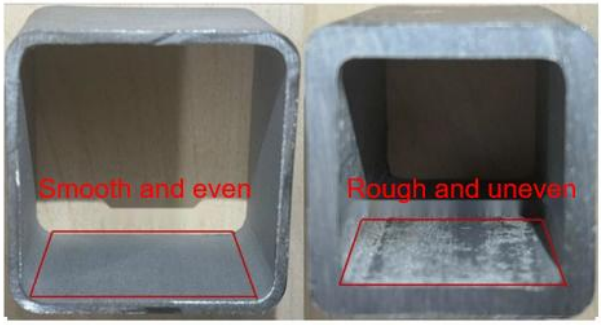
Figure 2 Classification of surface quality defects of castings

Note: For details about the definitions and figures, see Appendix C.3 and C.4 in GB/T 39428.

(3) The processing deformation shall meet the tolerance requirements specified in the design drawing.

(4) Corrosion, yellow rust, and sanding on the pipe wall are not allowed.





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3.3 Dimensions of Stainless Steel Pipe Raw Materials

The nominal outer diameter and nominal wall thickness of stainless steel pipe raw materials shall meet the requirements specified in GB/T 17395. If there are special requirements, the requirements specified in the drawing shall prevail.

3.4 Quality Requirements for Sealing Surfaces

The processing quality of the sealing surfaces of all stainless steel components that need to be equipped with sealing rings (such as the sealing surfaces of pipe flanges, connector adapters, clamps, rubber hoses, and stainless steel hoses for external connections) shall meet the following requirements:

Flatness tolerance: ≤ 0.2 mm

Surface roughness: Ra ≤ 1.6 μm

3.5 Requirements for Non-metallic Materials

Non-metallic sealing kits in pipelines and valves must be made of materials compatible with the solution used in the project. It is recommended that a compatibility testing report issued by a CNAS-certified organization be provided. For specific test requirements and standards, refer to the GCC community standards: *Technical Requirements and Test Methods for Glycol-based Coolant of Cold Plate Liquid Cooling*, *Technical Requirements and Testing Methods for Coolant of Cold Plate Liquid Cooling (Applicable to Deionized Water Coolant)*, and *Testing Method of Compatibility Between Working Fluid and Materials for Cold-plate Liquid Cooling*.

3.6 Requirements for Stainless Steel Hoses and Rubber Hoses

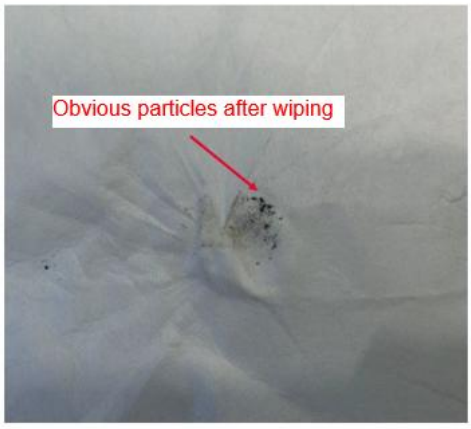
If stainless steel hoses or rubber hoses are used in the secondary-side loop system, it is recommended that samples from the supplier be tested and verified before use to ensure system reliability and stability. For specific test schemes, refer to Appendix A1 and Appendix A2.

EPDM materials are recommended for rubber hoses. EPDM typically offers a small bending radius and good material compatibility. In the data center liquid cooling field, peroxide-cured EPDM is recommended. During the hose assembly process, pipeline cleaning is required after pipe cutting, after joint crimping, and before inspection, packaging, and shipment. The recommended process flow is as follows:

(1) Cutting hoses; (2) Flushing with high-pressure water guns; (3) Ultrasonic cleaning; (4) Cleaning with sponge balls; (5) Flushing with pure water; (6) Blowing dry; (7) Crimping; (8) Ultrasonic cleaning; (9) Blowing dry; (10) Acceptance.

The acceptance method is as follows: Wipe an area of 30–50 cm^2 on the inner wall of the tested pipe with a constant pressure (1–2 N is recommended) in one direction.

The acceptance criteria are as follows: Slight black marks are allowed, but black particles are not allowed. For details, see the figure below.

Qualified (for reference): Slight black marks, no black particles	Unqualified (for reference): Obvious particles
	

4 Requirements for Stainless Steel Pipeline Processing Techniques

4.1 Material Cutting

4.1.1 Requirements for Control of Material Cutting Dimensions

Before cutting the material, accurately determine the weld shrinkage based on the welding procedure qualification data. The shrinkage must be determined based on the pipe wall thickness and welding method.

For pipelines connected using flat welding flanges or socket welding, the socket length must be included in the material cutting dimension. The calculation formula is as follows: Total material cutting length = Design length + Weld shrinkage + Socket length

4.1.2 Pipe Cutting Requirements

Plasma cutting (laser cutting) is preferred. Before cutting, the oxide layer, oil stains, and impurities on the pipe surface must be removed. After cutting, the cut shall be polished to remove oxide scale and burrs, ensuring a smooth and burr-free cut.

The cut surface shall be flat, with correct dimensions, and free from cracks, overlapping, burrs, bulges, shrinkage, slag, oxides, iron chips, and other defects.

4.1.3 Technical Requirements for Groove Processing

1. For a connector or saddle with a wall thickness greater than 2.5 mm, an internal groove should be prepared. The internal groove angle shall be adjusted according to the actual conditions.
2. For pipes with a wall thickness greater than 2.5 mm, an external groove should be prepared for straight seam welding. If the welding tolerance needs to be strictly controlled, a chamfered groove can be processed to facilitate alignment and prevent the butterfly valve, pipe elbow, and other fittings from being deformed due to heat during welding.
3. Groove processing requirements:
    a. Material protection

        When preparing the groove, use stainless steel-specific tools and grinding tools (such as stainless steel-specific grinding wheels and stainless steel wire brushes). Do not use carbon steel tools to contact the pipe surface; otherwise, iron ion contamination may cause electrochemical corrosion.

    b. Surface cleaning

        After the groove is machined, it must be polished and cleaned to remove oxide scale, burrs, oil stains, dust, and other impurities. The surface roughness Ra of the processed groove should not be greater than 3.2 μm.

    c. Dimensional precision control

        The deviation of key dimensions of the groove shall meet the tolerance requirements of Class B in GB/T 19804.

4.2 Welding

4.2.1 Preparations Before Welding

1. Material check: Before welding, check the stainless steel grade (e.g., 06Cr19Ni10) of pipes and fittings to ensure consistency with the design documents.
2. Pipe alignment requirements: When aligning pipes, use a fixture or positioning plate to secure them. Do not forcibly align the pipes to avoid residual welding stress in the pipeline.

4.2.2 Welding Material Requirements

1. Welding wire selection: The grade of the welding wire must match the base metal or offer superior performance. The recommended welding wires are listed in the table below for reference. The welding wire must be sealed and clean, free from defects such as oil stains, rust, and bending. Before use, dry the welding wire (to remove surface moisture).

Base Metal Grade	**Recommended Welding Wire and Grade**	
304 stainless steel	ER308L	H03Cr21Ni10, C ≤ 0.03%, Cr 19.0-21.0%, Ni 10.0-12.5%.
316L stainless steel	ER316L	H02Cr19Ni12Mo2, C ≤ 0.03%, Cr 18.0-20.0%, Ni 11.0-14.0%, Mo 2.0-3.0%

2. Shielding gas requirements: Argon is recommended as the shielding gas for welding. High-purity argon with a purity of 99.99% or higher is recommended. It is recommended that the oxygen content in the gas be tested and kept below 10 PPM before welding. The water and oxygen content in the gas must be controlled at extremely low levels to prevent porosity and oxidation defects in the weld.
3. Tungsten electrode selection and processing: Cerium tungsten or lanthanum tungsten electrodes are preferred. The diameter of the tungsten electrode must match the welding current. Before use, grind the tip of the tungsten electrode into a smooth, concentric cone shape to avoid an irregular tip, which may cause an unstable arc and contamination of the weld pool.

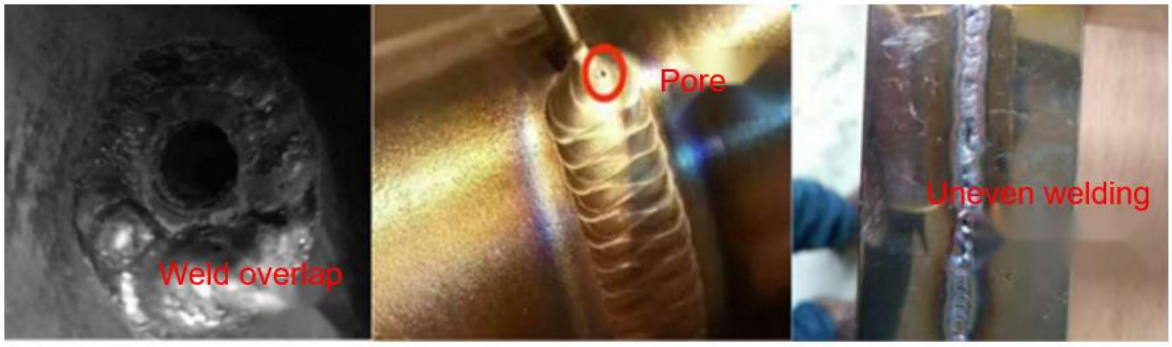
4.2.3 Welding Gas Protection Requirements

Gas protection is the core of austenitic stainless steel welding and directly determines the corrosion resistance of the weld root. It is recommended that the following requirements be met:

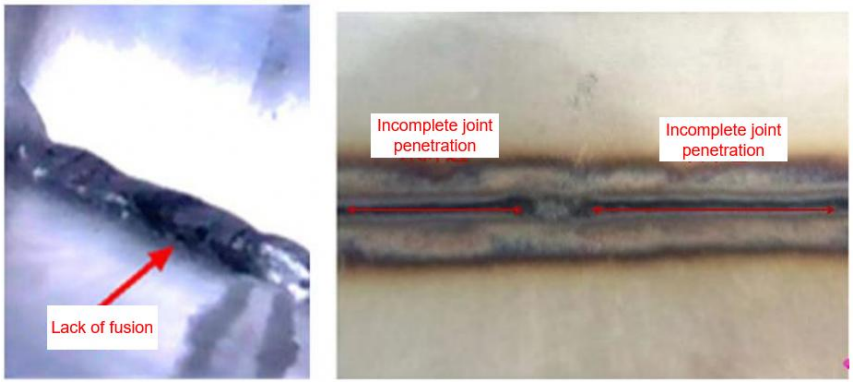
1. When the main shielding gas is used to control welding, the programs for early gas supply and delayed gas cut-off must be set.
2. Argon gas must be filled inside the pipe to prevent the weld root from being oxidized (blackened). The specific requirements are as follows:
    a. Argon filling mode: Partial argon filling (using soluble paper or plugs to seal both ends of the welding area) or overall argon filling can be used. Partial argon filling is preferred to save gas.
    b. Flow control: The argon filling flow rate is determined by the air in the pipe being exhausted. During welding, the optimal condition is that the back of the weld appears silver-white or light golden.

4.2.4 Quality Inspection Requirements After Welding

1. Visual inspection: The welds should be uniform and dense in appearance, without defects such as pores, overlap, oxidation, or uneven welding.



2. The weld surface should not be lower than the base metal. All welding positions must be fully penetrated. There should be no gaps or incomplete penetration at the weld root.



3. Non-destructive testing: It is recommended that penetrant testing (PT), radiographic testing (RT), or ultrasonic testing (UT) be performed on samples by lot. The sampling ratio should be defined according to Table 42 in GB/T 20801.1, and can be specified based on project requirements. The qualification standard for the welds that pass the sampling or partial penetrant testing should not be lower than Level I specified in NB/T 47013.5. The qualification standard for the welds that pass the sampling or partial radiographic testing should not be lower than Level III specified in NB/T 47013.2. The qualification standard for the welds that pass the sampling or partial ultrasonic testing should not be lower than Level II specified in NB/T 47013.3.

4.3 Air Tightness Test

1. Based on the nominal diameter of the pipe section, select stainless steel or PTFE sealing tools (such as blind flanges, plugs, and flange covers) of the corresponding specifications. Do not use carbon steel tools to prevent iron ions from contaminating the inner wall of the pipe. Before installing the sealing tools, ensure that the connecting threads or bolts of the tools are intact, and tighten the tools symmetrically to the design torque to prevent the tools from loosening and bursting and causing splashing.
2. Perform the hydrostatic test with the pressure 1.5 times the working pressure according to GB 50235 and GB/T 13907. No bubbles should be generated within 1 minute. It is recommended that the pressure be maintained for 30 minutes, during which the pressure drop should be less than or equal to 1%. There should be no visible leakage or structural deformation.

4.4 Acid Cleaning and Passivation

4.4.1 Process Flowchart

Pre-treatment → Acid cleaning → Water washing → Passivation → Post-treatment.

4.4.2 Pre-treatment

Before acid cleaning, degrease the surface to ensure that there is no water or oil on the surface before acid cleaning.

4.4.3 Acid Cleaning: Stripping Away the Oxide Layer and Welding Slag

1. The acid cleaning solution is selected based on the site conditions and environmental protection requirements.
2. During the acid cleaning process, observe the surface status in real time. Stop the acid cleaning immediately when the oxide scale is completely dissolved and the surface is uniformly silver-gray. This prevents surface pitting caused by over-corrosion.

4.4.4 Water Washing: Neutralization After Acid Cleaning

After acid cleaning is complete, it is recommended that the inner and outer surfaces of the pipes be neutralized or rinsed with an alkaline solution until the pH value of the water is stable at 6–7 and no acid solution remains. This prevents the acid solution from being carried into the subsequent passivation process.

4.4.5 Passivation: Forming a Dense Passivation Film

The immersion or cycling method is recommended. For large pipes, the spray or smearing method is recommended to ensure that the inner surface of the pipes is fully covered.

4.4.6 Post-treatment: Three-Stage Water Rinsing and Drying

1. Three-stage water rinsing:
   a. Stage-1 rinsing: Rinse the surface with tap water to remove the residual passivation solution.
   b. Stage-2 rinsing: Rinse the surface with softened water to reduce the chloride ion content in the water.
   c. Stage-3 rinsing: Rinse the surface with deionized water (conductivity ≤ 10 μS/cm) to ensure that the residual chloride ion content on the pipe surface is less than or equal to 25 mg/L, preventing the chloride ions from damaging the passivation film.
2. Drying:

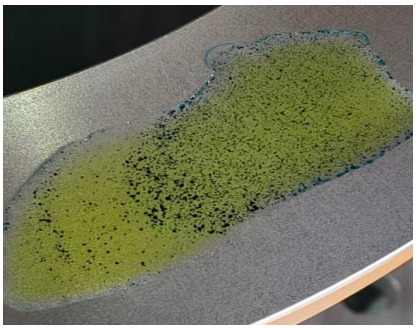
   Clean nitrogen blowing is preferred. Alternatively, hot air drying at approximately 80°C may be used. High-temperature baking is strictly prohibited. After drying, the pipe surface must be free of accumulated water, water stains, and dust.

4.4.7 Quality Control and Inspection Requirements

1. Appearance inspection of the passive film: The surface shall be uniformly silver-gray or light blue, free from defects such as dust, pitting, flow marks, or blackened welds. The passive film on the welds and heat-affected zones shall be completely covered without exposed metal.
2. Blue spot test: Perform the test in accordance with GB/T 25150. Apply blue spot liquid to the pipe surface (focusing on the welds and heat-affected zones). If no blue spot appears within 30 seconds, the result is qualified. If blue spots appear, the affected areas shall undergo acid cleaning and passivation again.



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5 Assembly Requirements for Stainless Steel Pipelines

5.1 Pre-assembly Check

1. The assembly site is clean and tidy.
2. Check whether the dustproof covers on the pipe ports involved in assembly are missing or damaged. Ensure that there is no secondary pollution during transfer and storage.
3. Check whether the valves to be assembled are free of contaminants such as oil stains and impurities inside.
4. Check whether there is residual liquid water inside the pipes and valves involved in assembly.

5.2 Valve Installation

1. Valve and pipe alignment: Ensure that the valve body is aligned with the center of the pipe. Offset installation of the valve body is strictly prohibited.
2. For a three-piece ball valve, the valve body shall be installed with the valve fully closed. Otherwise, uneven compression of the valve seat may occur, leading to internal leakage and damage to the valve.
3. The bolts must be tightened diagonally in three steps, with the tightening torque reaching 50%, 80%, and 100% of the specified torque, respectively.
4. After the valve is installed, rotate the valve to the fully closed and fully open positions. The valve shall rotate smoothly and be capable of being fully closed or opened by 90°.

5.3 Clamp Installation

1. Before installing the clamp, place the clamp washer, squeeze the two ends of the port towards the middle of the washer, and then connect the clamp.

2. Use a torque wrench to tighten the clamp clockwise. The tightening torque shall be applied according to the size of the clamp.
3. All combined washers must be soaked in deionized water. Do not use other substances such as lubricating grease or glue.

5.4 Assembly Requirements

1. Before connecting pipes, seal all pipe ports with dustproof and waterproof dust caps. Remove the dust caps only before connecting pipes. During the connection, only remove the dust cap from the end to be connected and keep the other end sealed to ensure that the pipes that have been installed are always sealed, preventing foreign objects and contaminated gases from entering the pipes.
2. During the pipe connection, chemicals (such as lubricating oil, detergent, soapy water, thread adhesive, foam adhesive, sealant, and raw tape) other than the working medium and deionized water are not allowed to enter the pipes or pipe connection interfaces.

5.5 Air Tightness Test for Trial Assembly

1. Use an air compressor to pressurize the system. Install a filter dryer at the suction port to ensure that the test gas is dry and free of moisture, preventing the inner wall of the pipe from being contaminated or affecting the test precision.
2. Slowly increase the pressure to 0.3 MPa according to the design pressure and check the system. If the pressure does not drop within 10 minutes, continue to increase the pressure. If the pressure cannot be stabilized, use a wet towel with foamed water to check each joint. After the check and repair are completed, increase the pressure to 0.6 MPa and repeat the preceding leakage check. Then, increase the pressure to the strength test pressure (1.5 times the design pressure).
3. Maintain the strength test pressure for 2 hours, during which the pressure change is continuously monitored. The allowed pressure drop should not be greater than 0.02 MPa.

6 Packing and Transportation Requirements for Pipes

6.1 General Requirements

The pipes should be packed in sturdy packaging, such as wooden cases or racks. The cases should be lined with buffer materials or moisture-proof film to prevent squeezing and moisture. Each stainless steel pipe inside the case should be individually wrapped with a moisture-proof and dust-proof film and packaged separately with buffer materials (the entire pipe must be completely wrapped). Gaps can be filled with buffer materials if necessary to ensure the pipes are securely fixed, with no risk of collision or scratching caused by shaking or rolling during transportation. The exterior of the case should be reinforced with packing straps.

6.2 Packing Case Identification and Records

1. The exterior of the case should include orientation markings, internal and external dimensions, operation warnings, environmental protection markings, packaging and storage markings, label positioning markings, logistics information markings, orientation information markings, and packing list information markings. The packing list should specify the model, specifications, material, quantity, quality, manufacturer, and related markings or identifiers of the pipes, or provide

corresponding labels, markings, and packing list as per customer requirements. Additionally, packing and transportation records should be prepared.

2. Each finished pipe welding piece and part inside the case should have a separate label to match the packing list.

6.3 Stacking and Handling Safety

The stacking area should be flat and dry. The pipes should not be stacked too high to avoid collapse or rolling due to an unstable center of gravity. When handling manually, operators should wear protective equipment such as anti-slip gloves and safety shoes, and adopt the correct posture (e.g., bending knees and squatting) to prevent physical injury. The transport vehicle should be driven on a smooth route, avoiding rough roads, and the load should comply with road transportation regulations.

6.4 Loading, Unloading, and Transfer Requirements

1. The base of the packing case should be designed with a forklift entry for easy on-site loading and unloading with a forklift (common handling forklifts include manual forklifts, electric counterbalanced forklifts, and pneumatic forklifts).
2. Before transportation, the steel pipes should be carefully inspected, and defects such as scratches, dents, and deformation on the surface should be marked. During loading and unloading, avoid excessive throwing and vertical transportation, and take protective measures.

7 Re-work Methods for Common Problems

No.	Nonconformity	Involved Process	Re-work Method
1	Incorrect spot welding position, direction, or soldering	Welding	Grind and cut the solder joints, and then solder them again.
2	Overlap and internal defects after full welding, oxidation, and blackening	Welding	Grind and polish the internal and external welds, and use an endoscope to check whether the repaired weld is fully penetrated. If not, perform a self-fusion welding repair once, and then grind and polish the weld.
3	Welding with pores or incomplete penetration	Welding	Grind the area with pores first, and then perform additional welding after the surface is smoothed. For incomplete penetration, if the wall thickness is ≤ 2 mm, perform self-fusion welding in one pass; if the wall thickness is > 2.5 mm, cut the joint with a wire cutter, grind the welding joint flat, re-groove the joint, and then weld it again.

No.	Nonconformity	Involved Process	Re-work Method
4	Leakage found in air pressure test, and pores or sand inclusion found on pipes or welding joints	Pipe air tightness test	Grind and clean the sand inclusion or pores, then perform repair welding. After the repair welding is complete, grind and polish the joint.
5	Yellowing or blackening after acid cleaning and passivation	Acid cleaning and passivation	Perform acid cleaning and rinsing again, then use a cleaning cloth to wipe the yellowed or blackened areas. After wiping, perform fuel-free ultrasonic treatment, and then re-passivate.

Appendix A

A.1 Stainless Steel Hose Test Schemes

Case Name	0001 Stainless steel grade and material test scheme
Design Description	Test objective: Stainless steel grade identification
Prerequisites	1. Several stainless steel samples to be tested are available. The samples can be processed into clean chips without oxidation, oil stains, or inclusions. 2. A high-frequency infrared carbon and sulfur analyzer that has passed the calibration and meets the following requirements: carbon and sulfur detection limit ≤ 0.0001% (in accordance with GB/T 20123 testing standard), along with a ceramic crucible, tungsten granules as fluxing agent, and a high-purity oxygen source. 3. An inductively coupled plasma optical emission spectrometer (ICP-OES) that has passed the calibration and meets the following requirements: a ten-thousandth electronic analytical balance, an electric heating digestion device, an ultrapure water machine, and high-purity nitric acid, hydrochloric acid, and hydrofluoric acid, as well as multi-element certified reference solutions. 4. National/Industry standard materials (such as GBW series stainless steel spectral reference materials and carbon and sulfur reference materials) are used for instrument calibration and drift correction. 5. The product specifications or technical agreement clearly specifies the required grade and the mass fraction range of each element (based on GB/T 20878 or ASTM standards).

Test Procedure	1. Sample preparation: Remove the oxide layer and oil stains from the sample surface. Use clean processing tools to prepare uniform chip samples. Divide the chips into two portions for carbon and sulfur detection and ICP digestion detection, respectively. Ensure that the sample is not contaminated during the entire process. 2. Carbon and sulfur content detection: Start the carbon and sulfur analyzer, preheat it, and introduce gas. Use stainless steel reference materials to verify the calibration curve. Accurately weigh a quantitative sample and place it in a ceramic crucible. Add the fluxing agent and send the sample into the high-frequency induction furnace for combustion. Determine the carbon and sulfur content by the infrared absorption method. Perform the test three times in parallel and record the data. 3. Multi-element ICP-OES detection: Accurately weigh a quantitative sample and place it in the digestion container. Add high-purity mixed acids and heat the sample for digestion. After the sample is completely dissolved, dilute the solution to a fixed volume and prepare the reagent blank simultaneously. Prepare multi-element gradient standard solutions to establish the calibration curve. Introduce the sample solution into the ICP-OES instrument to determine the content of characteristic elements such as Cr, Ni, Mn, Si, and Mo. Perform the test three times in parallel and record the data. 4. Result determination: Summarize the average value of each element, exclude abnormal data, and compare the result with the specified composition range of the corresponding national standard of the grade to determine whether the material grade meets the requirements.
Expected Result	The average content of all detected elements is within the composition tolerance range specified in the corresponding stainless steel grade standard, and the material grade is deemed qualified, meeting the product specifications.

Case Name	0002 Inner/Outer diameter test scheme
Design Description	Test objective: Inner/Outer diameter test
Prerequisites	1. Several stainless steel hose test samples are available. 2. An electronic digital caliper with a precision of 0.02 mm, an inner diameter go/no-go gauge that meets the specifications, or an optical measuring instrument with a precision of at least 0.01 mm is available. 3. Product specification (clearly indicating the tolerance range of the inner and outer diameters).
Test Procedure	1. Clean the inner and outer surfaces of the hose to ensure that there is no impurity. 2. Use the measuring tool to measure at least three cross sections at the two ends and the middle of the hose. 3. Record the measurement data of each position and compare the data with the requirements specified in the product specifications.
Expected Result	The inner and outer diameters of all measurement points are within the tolerance range specified in the product specifications.

Case Name	0003 Flow resistance test scheme
Design Description	Test objective: Flow resistance test
Prerequisites	1. Hose samples with a length of 0.8 m, 1.2 m, or 1.6 m 2. A flow resistance test bench with a flow control function and high-precision pressure sensor 3. A dedicated fixture that can fix the hose. Ensure that the hose is in a straight line. 4. Test medium: deionized water
Test Procedure	1. Install the test sample in a straight line or in a 90° bending state on the test bench, and ensure that the joints are sealed properly. 2. Start the test bench and adjust the medium to the specified test flow rate. 3. After the flow rate and pressure stabilize, record the pressure values at the inlet and outlet of the test bench. 4. Calculate the pressure difference between the two ends to obtain the flow resistance value.
Expected Result	Under the specified flow rate, the flow resistance value of the test sample meets the design expectation.

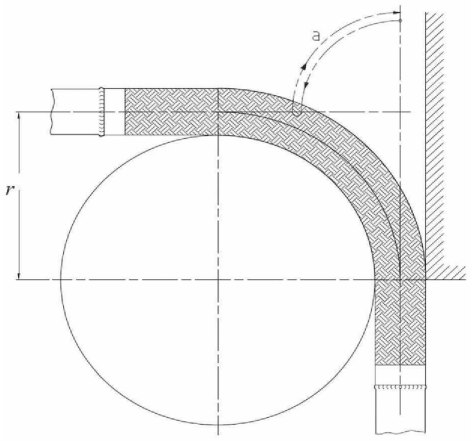
Case Name	004 Pressure resistance test scheme
Design Description	Test objective: Pressure resistance test
Prerequisites	1. Hydraulic test pump (pressure range at least 0–10 MPa, accuracy not lower than ±1%) 2. Vacuum extraction equipment (absolute pressure ≤ 0.2 kPa) 3. Test medium: deionized water
Test Procedure	1. Pressure resistance test: Apply 1.5 MPa hydraulic pressure to the hose, hold the pressure for 1 minute, and check for leakage, plastic deformation, or other failures. 2. Negative pressure test: Reduce the internal pressure of the hose to an absolute pressure of ≤ 0.2 kPa, hold the pressure for 1 minute, and check for failures such as collapse.
Expected Result	1. The test sample does not leak, crack, or undergo plastic deformation under a pressure of 1.5 MPa. 2. The test sample can withstand a negative pressure of ≤ 0.2 kPa (absolute pressure) without cracking or plastic deformation during the test.

Case Name	005 Air tightness test scheme
Design Description	Test objective: Air tightness test
Prerequisites	1. Clean and dry compressed air source (such as an air compressor or high-pressure gas cylinder) 2. Pressure adjustment and display device 3. A water tank that can accommodate the test sample and has good visibility
Test Procedure	1. Connect the test sample to the air source and pressure adjustment device, and fully immerse the test sample in the water tank. 2. Inject clean and dry air or inert gas into the hose, and slowly increase the pressure to 0.6 MPa. 3. Maintain the pressure for 2 minutes, while carefully observing the hose body and the joints.
Expected Result	During the pressure hold at 0.6 MPa, no bubbles are generated on the hose or at any connection point.

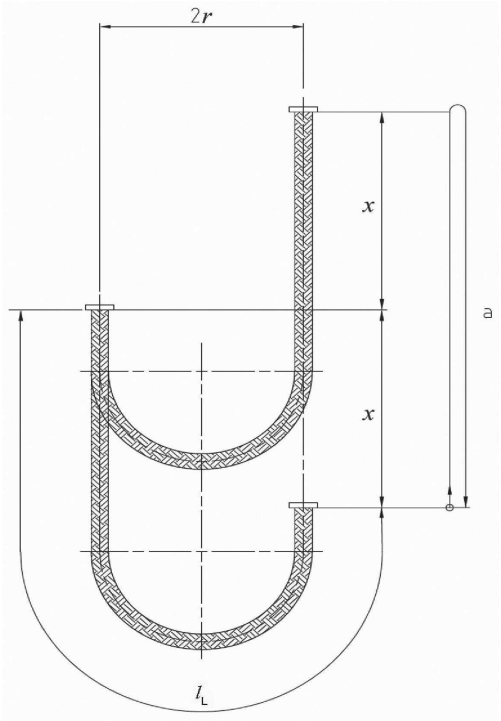
Case Name	006 Elongation test scheme
Design Description	Test objective: Elongation test
Prerequisites	1. A hydraulic test pump (pressure range: at least 0–10 MPa, accuracy: not lower than ±1%) 2. A micrometer or laser length measuring instrument with a precision of 0.01 mm, used to measure the length change
Test Procedure	1. Before applying a pressure of 1.5 MPa, measure and record the initial length L0. 2. Perform the pressure resistance test (1.5 MPa, maintain pressure for 1 minute). 3. After releasing the pressure, measure the length L1 at the marked point again. 4. Calculate the permanent elongation rate: (L1 – L0)/L0 × 100%.
Expected Result	The permanent elongation rate of the test sample does not exceed 1% of the initial length.

Case Name	007 Burst test scheme
Design Description	Test objective: Burst test
Prerequisites	1. An ultra-high pressure hydraulic pump (the pressure range must cover at least 1.5 times the expected burst pressure) 2. A safety shield that can completely enclose the test area
Test Procedure	1. Install the hose on the test device and ensure safety. 2. Slowly increase the pressure to 1.5 times the design pressure (design pressure: 1 MPa) and hold for 1 minute. 3. Continue to increase the pressure to 4 times the design pressure in at least 10 increments (i.e., each increment ≤ 0.25 times the design pressure). Hold the pressure for 1 minute and observe for leakage or damage. 4. If the hose is not damaged, continue to slowly increase the pressure until the hose leaks or is damaged. 5. Record the leakage pressure, final damage pressure, and damage position during the entire process.
Expected Result	1. The hose does not leak or get damaged when the pressure is 1.5 times or 4 times the design pressure for 1 minute. 2. Record the actual burst pressure value to provide data support for the design.

Case Name	008 Static bending test scheme
Design Description	Test objective: Static bending Test
Prerequisites	1. Compressed air source, pressure regulating device, and water tank (used for subsequent air tightness test) 2. Product specifications (used to determine the specified static bending radius and design pressure)

Test Procedure	1. Secure one end of the hose and move the other end around the mandrel in an arc motion (as shown in the following figure). The radius of the mandrel should be the same as the minimum bending radius of the hose. Ensure that the hose is in close contact with the mandrel within the arc length of 90°. Note: There should be no excessive horizontal force except the force required to bend the hose around the mandrel.  2. Bend the test sample 10 times at a frequency of 5 to 15 cycles per minute (one cycle includes one bending and returning to the straight position). 3. After the bending test is complete, inject clean air or inert gas into the hose and slowly increase the pressure to 10% of the design pressure. 4. Fully immerse the pressurized hose into the water tank, maintain the pressure for at least 2 minutes, and carefully observe the hose body, especially the bent sections and connectors.
Expected Result	1. The test sample does not leak or undergo plastic deformation under static bending conditions. 2. No bubbles are generated when the test sample is under 10% of the design pressure.

Case Name	009 Dynamic bending test scheme
Design Description	Test objective: Dynamic bending test
Prerequisites	1. Compressed air source, pressure regulating device, and water tank (for subsequent air tightness test) 2. Product specifications (used to determine the specified dynamic bending radius and design pressure)

Test Procedure	1. The test shall be performed using the metal hose assembly shown in the figure below, installed in a vertical loop. The distance between the axes of the end connectors shall be equal to twice the minimum bending radius (fatigue test) specified for the stainless steel hose. The effective active length lL is given by the following formula (1): lL=4r+x (1) Where: r is the minimum bending radius of the hose, in millimeters; x is 4DN, in millimeters, or 125 millimeters, whichever is greater; DN is the nominal dimension, in millimeters. 2. The test sample shall be filled with pure deionized water and pressurized slowly to the design pressure. The metal hose assembly shall be subject to 10,000 repeated sinusoidal bending tests at a frequency of 5 to 30 cycles per minute, with the bending direction parallel to the axis of the hose and a bending amplitude of 2x.  3. After the bending test is completed, the sample shall be dried. The test sample shall be filled with clean, dry air or inert gas and pressurized slowly to the design pressure. 4. After the test is completed, the sample shall be tested for air tightness (the procedure is the same as above).
Expected Result	1. The local radius of the sample does not decrease by more than 50% during the test. 2. The test sample does not leak or undergo plastic deformation under dynamic bending conditions. 3. No bubbles are generated after the test sample is dynamically bent.

Case Name	010 Component pressure cycling test scheme
Design Description	Test objective: Component pressure cycling test
Prerequisites	1. The pipe system has been filled with inert liquid and air has been exhausted. 2. The liquid cooling component has been connected in series to the system, and the valves in the pipe system are installed properly.
Test Procedure	1. The test sample is filled with inert liquid and connected to the pressure drive source. 2. The pipe system has been filled with inert liquid and air has been exhausted. The valves in the pipe system are required to be opened or closed normally. 3. Perform the strength test on the component: Inject inert liquid into the component to be tested, and gradually increase the static pressure to three times the maximum normal operating pressure. Maintain the pressure at the maximum operating pressure for 1 minute. If the component does not burst or leak, or if leakage occurs at the gasket at more than 40% of the test pressure, the component is deemed to have passed the strength test. 4. The test temperature is the specified temperature. 5. Pressure cycling test: (1) The pressure cycles between the maximum abnormal operating pressure (0.35 MPa) and 0 at a frequency of 1 Hz sine wave. (2) The number of cycles is 500,000. 6. After the test is complete, perform the external static pressure (ESP) strength test.
Expected Result	After the specified number of test cycles, the ESP strength test is performed, and no rupture, explosion, or leakage occurs.

Case Name	011 Scheme for checking the welding quality of connectors
Design Description	Test objective: Checking the welding quality of connectors
Prerequisites	1. The test sample is ready, and the welding parts have been inspected using an endoscope. 2. The inspection tools have been calibrated, and the inspection personnel are qualified.

Test Procedure	1. Use an endoscope to inspect the inner and outer surfaces of the welded joints of the test sample, and record the images. 2. Check whether there are surface cracks, incomplete penetration, incomplete fusion, surface pores, arc pits, unfilled welds, slag inclusions, and spatter on the welding parts. 3. Check whether the welds and the base metal are smoothly transitioned, and whether the external shape of the fillet welds is smoothly transitioned in a concave shape. 4. Perform the air tightness test to further determine whether the welds leak (this test is performed for all products before delivery).
Expected Result	1. The welding part has no surface defects, and the weld transition is smooth. 2. The air tightness test is passed.

Case Name	012 Salt spray test scheme
Design Description	Test objective: Salt spray test
Prerequisites	1. A neutral salt spray test chamber that complies with the GB/T 2423.17 standard 2. A dedicated support (made of corrosion-resistant non-metallic material) for fixing the hose and keeping it in the minimum bending state 3. An industrial endoscope for internal inspection after the test
Test Procedure	1. Fix the test sample on the support to keep it in the minimum bending state. 2. Place the test sample in the salt spray test chamber and perform the neutral salt spray test according to the GB/T 2423.17 standard. Use 5% sodium chloride solution at 35°C for 48 hours. 3. After the test is complete, take out the test sample and carefully inspect the inner wall and connector using the endoscope.
Expected Result	The inner wall of the rubber hose and the welding joints are free from rust and corrosion.

Case Name	013 Guide to testing the cleanliness of liquid-cooled components
Design Description	Test objective: Testing the cleanliness of liquid-cooled components

Prerequisites	1. The supplier has inspected all the components or the entire liquid cooling system before shipment. If components are used, inject the cleaning medium into them for cleaning. The cleaning medium for the flushing and ultrasonic cleaning solutions is pure water, and that for the shaking and flushing solution is the actual working medium used in the liquid-cooled components. (If there are multiple types of working media, the first cleaning should be performed using different media to compare the differences. In subsequent tests, the most stringent working medium should be used.) 2. Calculate the internal volume V and surface area S of the tested component. 3. When the equipment is used for cleaning, the equipment must be cleaned automatically before cleaning. The residual particles of the equipment with a pore size of 10 μm must be less than 0.1 mg. The particle size must be less than or equal to 50 μm.
Test Procedure	Ultrasonic cleaning solution (using the liquid-cooled component cleaning equipment): 1. Prepare at least one piece of 10 μm microporous filter membrane. Before using the filter membrane, store it at 70°C for 30 minutes to remove the internal moisture, and then weigh the filter membrane to obtain M1. Then, install the filter membrane on the vacuum filtration equipment. 2. Seal both ends of the component to be tested, and place it in the ultrasonic cleaning pool. Add pure water to the pool to immerse the component to be tested. Start the ultrasonic cleaning equipment and clean the external impurities of the component for 30 minutes. After the cleaning, the impurities are discharged and are not collected for detection. 3. Then, open the sealing kits on both sides of the component to be tested, place the component into the ultrasonic cleaning pool, and add pure water (at least 500 mL) into the pool to immerse the component. Record the cleaning water volume V1, and ensure the interior of the component to be tested is connected to the outside. Start the ultrasonic cleaning device for 30 minutes (at maximum power) for cleaning. 4. After cleaning, perform suction filtration on the solution using a 10 μm filter membrane. After the filtration is complete, remove the filter membrane from the device, place it in a high-temperature environment at 100°C for 30 minutes to evaporate the moisture on the filter membrane, and weigh it to obtain M2. 5. Collect 500 mL of the solution after suction filtration and test the content of multiple ions, including copper, aluminum, iron, sulfate, calcium, magnesium, and zinc. (Internal testing capability is unavailable; the solution needs to be sent for testing.) 6. Observe the maximum size L of impurities under a microscope after the 10 μm microporous filter membrane is dried. Record the total amount of impurities M = (M2 – M1).

Expected Result	1. Impurity L ≤ 0.1 x 0.1 mm² (maximum projection diameter ≤ 0.1 mm, fiber filament ≤ 0.5 mm); impurity content M2 – M1 ≤ 20 mg/m² x S. 2. The water sample is sent for testing. For the required ions, the ion concentration needs to be calculated using the reduction coefficient, where the reduction coefficient = V / V1. (1) Cl^- ≤ Reduction coefficient x 10 mg/L. Test method: Ion chromatography. Test standard: JT/T 1230-2018; (2) SO_4^{2-} ≤ Reduction coefficient x 10 mg/L. Test method: Ion chromatography. Test standard: JT/T 1230-2018; (3) Cu^+/Cu^{2+} ≤ Reduction coefficient x 0.2 mg/L. Test method: ICP. Test standard: NB/SH/T 0828-2010; (4) Fe^{2+}/Fe^{3+} ≤ Reduction coefficient × 0.5 mg/L. Test method: ICP. Test standard: NB/SH/T 0828-2010; (5) Al^{3+} ≤ Reduction coefficient × 0.5 mg/L. Test method: ICP. Test standard: NB/SH/T 0828-2010; (6) Ca^{2+} ≤ Reduction coefficient × 1 mg/L. Test method: ICP. Test standard: NB/SH/T 0828-2010; (7) Mg^{2+} ≤ Reduction coefficient × 1 mg/L. Test method: ICP. Test standard: NB/SH/T 0828-2010; (8) $Zn^{2+}/^{3}$ + ≤ Reduction coefficient × 1 mg/L. Test method: ICP. Test standard: NB/SH/T 0828-2010. 3. The absolute pH value after the test is greater than 7, and the pH increase is required to be less than 10%. Test equipment: pH meter. Test standard: SH/T 0069.

Case Name	014 Hose anti-trampling test scheme
Design Description	Test objective: Hose anti-trampling test
Prerequisites	1. Before the test, check that the pipe assembly is free of appearance damage, and that the connectors are properly crimped and tightened. 2. The test sample does not need to be injected with pressure or working medium.
Test Procedure	1. Use the bare machine stepping tooling to place a single pipe in the middle of the tooling and perform a 45 kg bearing test (simulating a single foot stepping). Keep the test for 1 minute. 2. Use a new test sample to simulate the scenario of stepping with both feet. The bearing weight is 90 kg and the test duration is 1 minute. 3. Check whether the appearance and functions of the pipe are normal.
Expected Result	1. After the pipe is under 45 kg pressure for 1 minute, there is no visible dent on the pipe surface, and the pipe does not burst or leak when the operating pressure is injected. 2. After the pipe is under 90 kg pressure for 1 minute, visible dents are allowed on the pipe surface, and the pipe does not burst or leak when the operating pressure is injected.

Case Name	015 Reliability test of long-term flushing of hoses
Design Description	Test objective: Determining the long-term reliability of hoses at different flow rates
Prerequisites	1. Hose: three pieces, each with a length of 1 m 2. Working fluid: sufficient 3. Cycling test rig: at least one water pump, one flow meter, one exhaust valve, one temperature sensor, one stainless steel heating module (with PID and temperature control), and one 270-mesh filter 4. Liquid refilling test rig: used to refill liquid into the cycling test rig 5. The test rig and hoses must be clean. Before the test, ensure that there is no ion precipitate or welding debris inside the test rig, which may affect the test result.
Test Procedure	1. Pre-configure the solution. 2. Connect the hose to be tested in series to the cycling test rig. The hose must be bent to the minimum bending radius. Check whether all valves are closed and ensure that the exhaust valve is open. 3. Use the liquid refilling test rig to add working fluid into the system. 4. Start the cycling, ensure that the cycling temperature is 65°C and the flow rate inside the hose is 5 m/s, and run the system for 1000 hours. 5. After the system is shut down, observe the corrosion status of the hose surface. Observe three positions on each hose (water inlet, water outlet, and position with the minimum bending radius). The corrosion depth of the three hoses is the maximum value. Then, calculate the corrosion depth based on the 1000-hour data and the five-year period.

Expected Result	The requirements and expected results of the check points are as follows: 1. Function and performance check: (1) The withstand voltage strength meets the strength test requirements. (2) Open the cover for inspection: The corrosion depth after conversion is less than or equal to 10% of the wall thickness. (3) Open the cover for inspection: No obvious sediment or blockage. 2. The working fluid water sample is sent for inspection. The test result is converted into the system specifications and then determined as follows: (1) Impurities: L ≤ 0.1 x 0.1 mm^2 (the maximum projected diameter is less than or equal to 0.1 mm, and the fiber diameter is less than or equal to 500 μm), and M ≤ 20 mg/m2; (2) Cl^- ≤ 10 mg/L; (3) SO_4^{2-} ≤ 10 mg/L; (4) Cu^+/Cu^{2+} ≤ 0.2 mg/L; (5) Fe^{2+}/Fe^{3+} ≤ 0.5 mg/L; (6) Al^{3+} ≤ 0.5 mg/L; (7) Total amount of Ca^{2+} and Mg^{2+} ≤ 5 mg/L; (8) $Zn^{2+/3+}$ ≤ 1 mg/L. 3. Other specifications: (1) The working medium pH is greater than 7. (2) The turbidity is ≤ 5 NTU, and the water is clear and transparent.

A.2 Rubber Hose Test Schemes

Case Name	0001 Inner/Outer diameter test scheme
Design Description	Test objective: Inner/Outer diameter test
Prerequisites	1. Several rubber hose test samples are available. 2. An electronic digital caliper with a precision of 0.02 mm, an inner diameter go/no-go gauge that meets the specifications, or an optical measuring instrument with a precision of at least 0.01 mm is available. 3. Product specification (clearly indicating the tolerance range for the inner and outer diameters)
Test Procedure	1. Clean the inner and outer surfaces of the hose to ensure that there is no impurity. 2. Use the measuring tool to select at least three cross sections at the two ends and the middle of the hose for measurement. 3. Record the measurement data at each position and compare it with the requirements specified in the product specification.
Expected Result	The inner and outer diameters of all measurement points are within the tolerance range specified in the product specification.

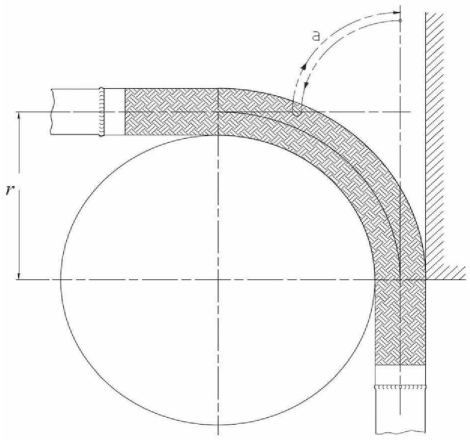
Case Name	0002 Flow resistance test scheme
Design Description	Test objective: Flow resistance Test
Prerequisites	1. Hose test samples with a length of 0.8 m, 1.2 m, or 1.6 m 2. A flow resistance test bench with flow control and a high-precision pressure sensor 3. A dedicated fixture that can fix the hose. Ensure it is in a straight line. 4. Test medium: deionized water
Test Procedure	1. Install the test sample on the test bench in a straight line or at a 90° bending state, and ensure that the joints are properly sealed. 2. Start the test bench and adjust the medium to the specified test flow. 3. After the flow and pressure stabilize, record the pressure values at the inlet and outlet of the test bench. 4. Calculate the pressure difference between the two ends to obtain the flow resistance value.
Expected Result	Under the specified flow rate, the flow resistance of the test sample meets the design expectation.

Case Name	003 Pressure resistance test scheme
Design Description	Test objective: Pressure resistance test
Prerequisites	1. Hydraulic test pump (pressure range at least 0–10 MPa, accuracy not lower than ±1%) 2. Vacuum extraction device (absolute pressure ≤ 0.2 kPa) 3. Test medium: Deionized water
Test Procedure	1. Pressure resistance test: Apply 1.5 MPa hydraulic pressure to the hose, hold the pressure for 1 minute, and observe for leakage, plastic deformation, or other failure modes. 2. Negative pressure test: Reduce the internal pressure of the hose to an absolute pressure of ≤ 0.2 kPa, hold the pressure for 1 minute, and check whether there is no failure such as collapse.
Expected Result	1. The test sample does not leak, crack, or undergo plastic deformation under a pressure of 1.5 MPa. 2. The negative pressure resistance of the test sample is less than or equal to 0.2 kPa (absolute pressure), and the test sample does not crack or undergo plastic deformation during the test.

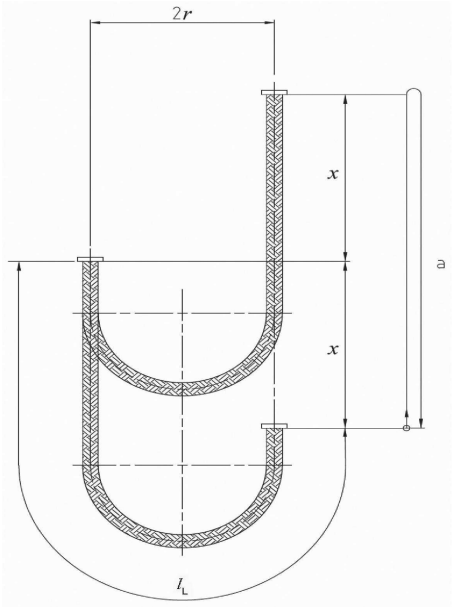
Case Name	004 Air tightness test scheme
Design Description	Test objective: Air tightness test
Prerequisites	1. Clean and dry compressed air source (such as an air compressor or high-pressure gas cylinder) 2. Pressure adjustment and display device 3. A water tank that can accommodate the test sample and has good visibility
Procedure	1. Connect the test sample to the air source and pressure regulator, and fully immerse the test sample in the water tank. 2. Inject clean and dry air or inert gas into the hose and slowly increase the pressure to 0.6 MPa. 3. Maintain the pressure for 2 minutes while carefully observing the hose body and joints.
Expected Result	During the pressure maintained at 0.6 MPa, no bubbles are generated on the hose or at any connection point.

Case Name	005 Burst test scheme
Design Description	Test objective: Burst test
Prerequisites	1. An ultra-high pressure hydraulic pump (the pressure range must cover at least 1.5 times the expected burst pressure) 2. A safety shield that can completely enclose the test area
Test Procedure	1. Install the hose on the test device and ensure safety. 2. Slowly increase the pressure to 1.5 times the design pressure (design pressure: 1 MPa) and hold the pressure for 1 minute. 3. Continue to increase the pressure to 4 times the design pressure in at least 10 increments (each increment ≤ 0.25 times the design pressure). 4. Hold the pressure for 1 minute and observe for leakage or damage. 5. If the hose is not damaged, continue to slowly increase the pressure until the hose leaks or is damaged. 6. Record the leakage pressure, final damage pressure, and damage position during the entire process.
Expected Result	1. The hose does not leak or get damaged when the pressure is 1.5 times or 4 times the design pressure for 1 minute. 2. Record the actual burst pressure value to provide data support for the design.

Case Name	006 Static bending test scheme
Design Description	Test objective: Static bending test

Prerequisites	1. Compressed air source, pressure regulating device, and water tank (used for subsequent air tightness test) 2. Product specifications (used to determine the specified static bending radius and design pressure)
Test Procedure	1. Secure one end of the hose and move the other end around the mandrel in an arc motion (as shown in the following figure). The radius of the mandrel should be the same as the minimum bending radius of the hose. Ensure that the hose is in close contact with the mandrel within the arc length of 90°. Note: There should be no excessive horizontal force except the force required to bend the hose around the mandrel.  2. Bend the test sample 10 times at a frequency of 5 to 15 cycles per minute (one cycle includes one bending and returning to the straight position). 3. After the bending test is complete, inject clean air or inert gas into the hose and slowly increase the pressure to 10% of the design pressure. 4. Fully immerse the pressurized hose in the water tank, maintain the pressure for at least 2 minutes, and carefully observe the hose body, especially the bent areas and connections.
Expected Result	1. The test sample does not leak or undergo plastic deformation under static bending conditions. 2. No bubbles are generated when the test sample is under 10% of the design pressure.

Case Name	007 Dynamic bending test scheme
Design Description	Test objective: Dynamic bending test
Prerequisites	1. Compressed air source, pressure regulating device, and water tank (for subsequent air tightness test) 2. Product specifications (used to determine the specified dynamic bending radius and design pressure)

Test Procedure	1. The test shall be performed using the hose assembly shown in the figure below, installed in a vertical loop. The distance between the axes of the end fittings shall be equal to twice the minimum bending radius (fatigue test) specified for the stainless steel hose. The effective active length lL is given by the following formula (1): lL = 4r + x (1) Where: r is the minimum bending radius of the hose, in millimeters; x is 4DN, in millimeters, or 125 millimeters, whichever is greater; DN is the nominal size, in millimeters. 2. The test sample shall be filled with pure deionized water and slowly pressurized to the design pressure. The hose assembly shall be subject to 10,000 repeated sinusoidal bending cycles at a frequency of 5 to 30 cycles per minute, with the bending direction parallel to the axis of the hose and the bending amplitude being 2x.  3. After the bending test is completed, the sample shall be dried. The test sample shall be filled with clean, dry air or inert gas and slowly pressurized to the design pressure. 4. After the test is completed, the sample shall be tested for air tightness (the procedure is the same as above).
Expected Result	1. The local radius of the sample does not decrease by more than 50% during the test. 2. The test sample does not leak or undergo plastic deformation under dynamic bending conditions. 3. No bubbles are generated after the test sample is dynamically bent.

Case Name	008 Component pressure cycling test scheme
Design Description	Test objective: Component pressure cycling test
Prerequisites	1. The pipe system has been injected with inert liquid and air has been exhausted. 2. The liquid cooling component has been connected to the system, and the valves in the pipe system have been installed properly.
Test Procedure	1. Inject the test sample with inert liquid and connect it to the pressure drive source. 2. The inert liquid has been injected into the pipe system and air has been exhausted. The valves in the pipe system are required to be opened or closed normally. 3. Perform the strength test on the component. Inject the inert liquid into the component to be tested, and gradually increase the ESP to three times the maximum normal operating pressure. Maintain the pressure at the maximum operating pressure for 1 minute. If the component does not burst or leak, or if the gasket leaks at more than 40% of the test pressure, the component is qualified in terms of strength. 4. The test temperature is the specified temperature. 5. Pressure cycling test: (a) The pressure cycles between the maximum abnormal operating pressure (0.35 MPa) and 0 at a frequency of 1 Hz with a sine wave. (b) The number of cycles is 500,000. 6. After the test is complete, perform the ESP test.
Expected Result	After the specified number of test cycles, the ESP test is performed, and no rupture, explosion, or leakage occurs.

Case Name	009 Hose anti-stepping test scheme
Design Description	Test objective: Testing the hose anti-stepping performance
Prerequisites	1. Before the test, check that the pipe assembly is free of appearance damage, and the connectors are properly tightened and connected. 2. The test sample does not need to be injected with pressure or working medium.
Test Procedure	1. Use the bare machine stepping test fixture to place a single pipe in the middle of the fixture and perform a 45 kg bearing test (simulating a single-stepping scenario) for 1 minute. 2. Use a new test sample to simulate a double-stepping scenario, with the bearing weight of 90 kg for 1 minute. 3. Check whether the appearance and functions of the pipe are normal.

Expected Result	1. After the pipe is pressurized to 45 kg for 1 minute, there is no visible dent on the pipe surface. After the operating pressure is applied, the pipe does not burst or leak. 2. After the pipe is pressurized to 90 kg for 1 minute, visible dents are allowed on the pipe surface. After the operating pressure is applied, the pipe does not burst or leak.

Case Name	010 Working medium compatibility test
Design Description	1. Test objective: Decouple conditions, and verify whether the pipe is compatible with the working medium, whether any precipitate is generated, and whether the performance deteriorates. 2. Reference: *GB/T 14832-2008 Compatibility of Elastomeric Materials with Hydraulic Fluids.*
Prerequisites	1. Prepare 10 samples for each medium (5 samples for the control group and 5 samples for the test group). 2. Calculate the ratio A of the inner surface area of the hose to the amount of the working medium in the system, in the unit of m^2/L.
Test Procedure	1. Test the function and pressure resistance of the liquid cooling component. 2. Before the test, the tested sample and container must be cleaned to ensure that no external impurities are introduced. 3. Inject the working medium into the tested sample to completely immerse the sample, and reserve a certain amount of gas space to avoid expansion after the liquid cooling temperature rises. Cover the container and seal it. Record the surface area of the sample and the volume of the working medium. The volume ratio A of the working medium to the system is preferred. If the volume ratio is not matched, the test result needs to be converted. 4. Place the container in a 100°C oven for 168 hours. 5. After the temperature and pressure return to normal, take out the sample and perform the function test and withstand voltage test. Open the container and observe the internal and external surfaces to check for any sediment or corrosion marks. 6. Take out the tested working medium. Filter out a portion of it (it is recommended that half of the working medium be filtered) to test the weight of impurities and calculate the total weight of all impurities. Send a portion of the water sample for inspection (it is recommended that more than 200 ml be sent) to test Cl^-/SO_4^{2-}/Cu/Fe/Al/Ca/Mg/Zn, pH value, and turbidity. 7. The preceding compatibility tests are performed to confirm the compatibility between non-metallic materials and all working media.

Expected Result	The requirements and expected results of the check points are as follows: 1. Changes in liquid cooling components: The function meets the requirements, and the withstand voltage meets the requirement of 1.05 MPa (or three times the maximum operating pressure). 2. There is no obvious adhesion or corrosion on the internal and external surfaces. 3. Send the sample for inspection. The test result is converted into the system specifications according to the attached table, and then the result is determined as follows: (1) Impurities: L ≤ 0.1 x 0.1 mm^2 (the maximum projected diameter is less than or equal to 0.1 mm, and the fiber diameter is less than or equal to 500 μm); mass: M ≤ 20 mg/m^2; (2) Cl^- ≤ 10 mg/L; (3) SO_4^{2-} ≤ 10 mg/L; (4) Cu^+/Cu^{2+} ≤ 0.2 mg/L; (5) Fe^{2+}/Fe^{3+} ≤ 0.5 mg/L; (6) Al^{3+} ≤ 0.5 mg/L; (7) Total Ca^{2+} and Mg^{2+} ≤ 5 mg/L; (8) $Zn^{2+/3+}$ ≤ 1 mg/L. 4. Other indicators: (1) The working medium pH is greater than 7; (2) Turbidity ≤ 5 NTU, clear and transparent.

Case Name	011 Reliability test of long-term flushing of rubber hoses
Design Description	Objective: Testing the long-term reliability of rubber hoses under different flow rates
Prerequisites	1. Rubber hoses: three pieces, each with a length of 1 m 2. Working fluid: sufficient 3. Cycling tooling: at least one water pump, one flow meter, one exhaust valve, one temperature sensor, one stainless steel heating module (with PID and temperature control), and one 270-mesh filter 4. Fluid refilling tooling: used to refill fluid into the cycling tooling 5. The tooling and hoses must be clean. Before the test, ensure that there is no ion precipitate or welding debris inside the tooling and hoses, which may affect the test result.

Test Procedure	1. Pre-configure the solution. 2. Connect the hose to be tested in series to the cycling tooling system. The hose must be bent to the minimum bending radius. Check whether all valves are closed and ensure that the exhaust valve is open. 3. Use the fluid refilling tooling to add working fluid into the system. 4. Start the cycling, ensure that the cycling temperature is 65°C and the flow rate inside the hose is 3 m/s, and run the system for 1000 hours. 5. After the system is shut down, observe the corrosion status on the surface of the hoses. Observe three positions on each hose (water inlet, water outlet, and position with the minimum bending radius). The corrosion depth of the three hoses is the maximum value. Then, calculate the corrosion depth based on the 1000-hour data and the five-year period.
Expected Result	The indicators and expected results of the check points are as follows: 1. Function and performance check: (1) The pressure resistance meets the strength test requirements. (2) Check after opening the cover: The corrosion depth after conversion is less than or equal to 10% of the wall thickness. (3) Open the cover and check: No obvious sediment or blockage. 2. Send the working fluid water sample for testing, convert the test results into system indicators, and then make a determination: (1) Impurities: L ≤ 0.1 x 0.1 mm² (maximum projected diameter ≤ 0.1 mm, fiber length ≤ 500 μm); mass M ≤ 20 mg/m²; (2) Cl^- ≤ 10 mg/L; (3) SO_4^{2-} ≤ 10 mg/L; (4) Cu^+/Cu^{2+} ≤ 0.2 mg/L; (5) Fe^{2+}/Fe^{3+} ≤ 0.5 mg/L; (6) Al^{3+} ≤ 0.5 mg/L; (7) Total Ca^{2+} and Mg^{2+} ≤ 5 mg/L; (8) $Zn^{2+/3+}$ ≤ 1 mg/L. 3. Other indicators: (1) Working fluid pH > 7; (2) Turbidity ≤ 5 NTU, clear and transparent.