Community Specification

Cold Plate Liquid Cooling System Intelligent Operation and Maintenance Specification (Version 1.0)

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Version Change History

Version	Description	Contributor
V0.8	Public release.	Authors of this Specification.
V1.0	1. Updated installation requirements and offline testing details for each indicator type in the section detailing the secondary-side online/offline test method classification. 2. Added coolant degradation trends into the radar chart to enable timely assessment of deterioration severity. 3. Defined sensor installation methods and redundancy configuration rules. 4. Updated the titles of referenced GCC standards.	Authors of this Specification.

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Cold Plate Liquid Cooling System Intelligent Operation and Maintenance Specification

1 Scope

This Specification specifies the requirements for routine monitoring, measurement point calibration, operation and maintenance (O&M) system establishment, emergency handling, tools and instruments, and document management for single-phase cold plate liquid cooling systems and closed cooling distribution unit (CDU) secondary-side piping systems.

This Specification applies to the routine operation and maintenance of single-phase cold plate liquid cooling systems, including but not limited to CDUs, coolants, secondary-side piping, manifolds, quick disconnects (QDs), liquid-cooling cabinets, coolant storage tanks, and the storage and handling of coolants.

2 Terms and Definitions

2.1 Total Suspended Solids (TSS)

All solid particles suspended in a water sample that are retained by a standard filter membrane. The common unit of measurement is mg/L.

2.2 Total Dissolved Solids (TDS)

All dissolved substances in a water sample that pass through a standard filter membrane, typically including ionic salts, inorganic minerals, and small organic molecules. The common unit of measurement is mg/L.

2.3 Wetted Materials

All materials that come into direct contact with the coolant, including but not limited to CDU heat exchangers, secondary-side piping, circulating pump seals, quick disconnects, and manifolds.

2.4 Quick Disconnect

A coupling device used to enable rapid, leak-free, and dry-break connection and disconnection between coolant lines, facilitating online server maintenance and replacement without shutting down the system. Selection depends primarily on flow rate and sizing, and shall be based on the system's design flow rate, operating pressure, and pipe diameter. Quick disconnects include two primary types: manual couplings and blind-mate couplings.

2.5 Colony Forming Unit (CFU)

A standardized unit used to quantify the number of viable, cultivable microorganisms (such as bacteria and fungi) in a sample.

2.6 Chemical Compatibility

As defined in this specification, the property of a coolant and wetted materials remaining free from harmful chemical reactions or physical changes during long-term contact under specified conditions (such as temperature and pressure), thereby maintaining their respective performance stability.

2.7 Ethylene Propylene Diene Monomer (EPDM)

A critical material used in manufacturing key components such as cooling lines, O-rings, and gaskets. Its saturated main-chain chemical structure imparts excellent resistance to heat, water, steam, and chemicals (demonstrating particularly good compatibility with polar media such as water and glycol/propylene glycol coolants), making it highly suitable for long-term use in liquid cooling environments. However, its resistance to mineral oils, greases, and hydrocarbon solvents is poor; therefore, chemical compatibility with the selected coolant must be verified during material selection.

2.8 pH Value

Defined as the negative logarithm of hydrogen ion activity in a solution, representing its acidity or alkalinity. A pH value of 7 indicates a neutral solution, a pH less than 7 indicates an acidic solution, and a pH greater than 7 indicates an alkaline solution. The unit is dimensionless.

2.9 Electrical Conductivity (EC)

An indicator of a solution's ability to conduct an electric current. Higher values indicate a greater concentration of ions, impurities, and dissolved salts in the fluid. The common unit of measurement is μS/cm.

2.10 Turbidity (NTU)

A measure of the cloudiness or haziness of a liquid, reflecting the content of insoluble substances such as suspended particles, colloids, rust products, and other impurities. It serves a similar diagnostic purpose to TSS. The common unit of measurement is NTU.

2.11 Corrosion Rate (CR)

An indicator representing the corrosion speed of metallic materials in a coolant, used to provide early warnings of corrosion, perforation, and leakage risks in piping and cold plates. The common unit of measurement is mm/a.

2.12 Copper Corrosion Inhibitor (CCI)

A water treatment chemical specifically formulated to inhibit the corrosion of copper and copper alloys, ensuring the long-term, reliable operation of cold plates and copper components.

2.13 Total Hardness

The sum of calcium and magnesium hardness in water, representing the total concentration of scale-forming cations.

2.14 Total Alkalinity (TA)

The sum of bicarbonate, carbonate, and hydroxide ions in water, reflecting its pH buffering capacity; often used interchangeably with alkalinity. The common unit of measurement is mg/L.

2.15 Reserve Alkalinity (RA)

The alkaline reserve in a fluid system available to neutralize acidic substances, measuring the system's capacity to resist a decrease in pH. The common unit of measurement is mL.

2.16 Iron Ion (Fe)

The concentration of iron ions in a solution, used to measure corrosion products from steel and iron materials. The common unit of measurement is mg/L.

2.17 Copper Ion (Cu)

The concentration of copper ions in a solution, used to measure corrosion products from copper materials. The common unit of measurement is mg/L.

2.18 Zinc Ion (Zn)

The concentration of zinc ions in a solution, typically serving as a component of corrosion inhibitors that forms a protective film on metal surfaces. The common unit of measurement is mg/L.

2.19 Chloride Ion (Cl-)

The concentration of chloride ions in a solution, which are strongly corrosive anions. The common unit of measurement is mg/L.

2.20 Sulfide (S2-)

The concentration of sulfide ions in a solution, which act as strongly corrosive anions and reducing pollutants. The common unit of measurement is mg/L.

2.21 Sulfate (SO42-)

The concentration of sulfate ions in a solution, which act as corrosive anions that accelerate corrosion at high concentrations. The common unit of measurement is mg/L.

2.22 Dissolved Oxygen (DO)

The concentration of oxygen dissolved in water in molecular form. The common unit of measurement is mg/L.

2.23 Chemical Oxygen Demand (COD)

The mass concentration of oxygen equivalent to the amount of oxidant consumed when organic matter and certain reducing inorganic substances in water are oxidized by a strong chemical oxidant under specified conditions, reflecting the degree of organic pollution in the fluid. The common unit of measurement is mg/L.

2.24 Deionized Water (DI Water / DI)

High-purity water obtained by removing ionic impurities (such as sodium, calcium, iron, and chloride) through processes including ion exchange, reverse osmosis, or electrodialysis.

2.25 Liquid-Borne Particle Counter (LPC)

An instrument used to measure the size distribution and numerical concentration of particles suspended in a liquid, applied to evaluate the cleanliness of pure water and chemical reagents. The common unit of measurement is CNT/mL.

2.26 Temperature Sensor

In liquid cooling systems, temperature measurement is commonly based on platinum resistance thermometers (RTDs), whose operation relies on the variation of platinum's electrical resistance with temperature. Within a specific temperature range, the resistance of a platinum RTD exhibits a near-linear relationship with temperature. Platinum RTDs provide high accuracy, excellent long-term stability, and high repeatability, making them ideal for high-precision, high-reliability temperature measurement.

2.27 Pressure Transmitter

An instrument whose operating principle relies primarily on piezoresistive or piezoelectric effects to measure fluid pressure. Piezoresistive pressure sensors determine pressure by detecting changes in electrical resistance under strain, whereas piezoelectric sensors utilize the direct piezoelectric effect to

convert applied pressure into an electrical signal. Alternatively, ceramic pressure transmitters employ dry/media-isolated sensing, where pressure acts directly on a ceramic diaphragm to generate a voltage signal via minor deformation, offering high linearity and superior thermal and temporal stability.

2.28 Flowmeter

An instrument used to measure the flow rate of a fluid in a closed pipe or open channel, essential for process control and energy metering. Flowmeters are categorized by operating principle into types such as ultrasonic and electromagnetic flowmeters. For example, an electromagnetic flowmeter operates on Faraday's law of electromagnetic induction to measure the volumetric flow rate of conductive liquids: field coils generate a magnetic field inside the flow tube, and as the conductive fluid cuts through the magnetic lines of force, an induced electromotive force (EMF) proportional to the average flow velocity is generated and detected by a pair of electrodes to determine the volumetric flow rate.

2.29 Non-Volatile Residue (NVR)

The total mass of solid residue remaining after a liquid sample has undergone thermal evaporation, serving as a critical metric for evaluating fluid purity and contaminant levels. The common unit of measurement is mg/L.

2.30 Chronic Toxicity

The long-term adverse health or biological effects induced in an organism following repeated or continuous exposure to a chemical substance, typically at dosage levels below those causing acute toxicity, characterized by cumulative and latent effects.

2.31 Permissible Concentration - Time Weighted Average (PC-TWA)

The time-weighted average concentration of a chemical substance permitted for a standard 8-hour workday and 40-hour workweek, to which nearly all workers may be repeatedly exposed day after day without adverse health effects. It serves as a core occupational health standard for chemical exposure limits.

2.32 Bioaccumulation

The net accumulation of a chemical substance over time in the tissues or organs of an organism resulting from all routes of exposure (including inhalation, ingestion, and dermal contact), where the internal concentration exceeds that in the surrounding environmental media (water, soil, air). Quantified by the Bioaccumulation Factor (BAF) or Bioconcentration Factor (BCF), where a higher factor denotes greater bioaccumulation potential.

2.33 Accuracy

The closeness of agreement between a measured value and a true or accepted reference value, typically quantified by measurement error.

2.34 Resolution

The smallest change in a measured quantity that causes a detectable, displayable, or output change in the response of an instrument.

2.35 Manifold

A critical fluid-distribution component used in a liquid cooling system to uniformly distribute and collect coolant, also referred to as a liquid cooling manifold. Widely deployed in data centers, high-performance computing (HPC), and AI server infrastructure, it primarily serves to connect the main CDU supply and return lines of a liquid cooling cabinet to individual cold plates.

2.36 EG25 and PG25

EG25: 25% (v/v or w/w) ethylene glycol aqueous solution (Ethylene Glycol 25%).

PG25: 25% (v/v or w/w) propylene glycol aqueous solution (Propylene Glycol 25%).

2.37 Polytetrafluoroethylene (PTFE)

A fluoropolymer resistant to acids, alkalis, and various organic solvents, virtually insoluble in all solvents. Its unit cost is higher than that of EPDM.

3 Online Monitoring and Automatic Control

3.1 General Provisions

Routine operation and maintenance (O&M) of liquid cooling systems relies primarily on three measures: online monitoring, routine inspection and maintenance, and laboratory testing.

The online monitoring and control framework comprises the upper-level monitoring platform, CDU control system, liquid cooling primary-side control system, liquid cooling secondary-side control system, and leakage detection and control system.

The liquid cooling primary-side control system pertains to the facility-level chilled water system and falls outside the scope of this Specification.

The CDU control system is also outside the scope of this Specification; however, the interfaces it provides to the upper-level platform are addressed herein.

3.2 Monitoring Platform

The liquid cooling monitoring platform mainly covers the secondary-side piping and auxiliary facilities from the CDU to the server cabinets. It is recommended to integrate this platform with the Building Management System (BMS) or Data Center Infrastructure Management (DCIM) system to enable unified monitoring and optimized control of facility operations.

When operations are limited to CDU control and secondary-side operational monitoring, optimization and control shall preferably be managed by the internal CDU controller and its optimized operating logic. The CDU controller interfaces with upper-level platforms (such as BMS/DCIM) using standard protocols including Modbus-TCP, SNMP, and MQTT.

When secondary-side leakage control is required, an independent control system shall be implemented to monitor all secondary-side facilities external to the CDU. This control system shall utilize a Direct Digital Controller (DDC) or Programmable Logic Controller (PLC) that interfaces with upper-level platforms via standard protocols such as Modbus-TCP and SNMP.

The upper-level monitoring platform shall integrate data from the liquid cooling primary-side control system, the air cooling system in the equipment room, the CDU, and the liquid cooling secondary-side system. It shall leverage intelligent algorithms to implement routine monitoring, preventive monitoring, operation optimization, emergency handling, and O&M management.

The upper-level monitoring platform should incorporate O&M management functions: including maintaining an up-to-date wetted materials inventory and enforcing an operation permit ("work ticket") protocol during fluid or component replacements to prevent the introduction of incompatible fluids into the secondary-side pipes. The platform manages full-lifecycle coolant monitoring, tracking spare fluid quality, monitoring waste fluid disposal, and recording and graphically rendering operational fluid parameters to detect and provide early warnings for coolant degradation.

For basic measurement points and alarm thresholds of the liquid cooling monitoring platform, refer to section 3.7.

3.3 CDU Operational Monitoring

The CDU control system comprises integrated controllers that form a group control network via a ring bus or dual-upstream network topology. The core objective of the CDU control system is to satisfy server cooling demand while supporting routine monitoring of coolant chemical properties based on prevailing industry practices.

Variable Frequency Drives (VFDs) paired with the CDU shall maintain their current operating frequency upon loss of control system power. The VFDs shall support Modbus-RTU or Modbus-TCP communication protocols. Monitored CDU parameters shall include supply fluid temperature, fluid level, electrical conductivity, pump status, fluid supply pressure, flow rate, as well as primary-side supply water temperature, differential pressure, and control valve position. The VFDs shall feature automatic fault reset upon power restoration following an outage. All local operational data shall be transmitted to the power and environmental monitoring system in real time. The latency between an end-device action and data acquisition by the monitoring system shall be less than 3 seconds. The PLC shall not reboot during active/standby failover under group control mode. CDU controllers should utilize a 32-bit PLC powered by a 24 V DC power supply.

Specific technical parameters and requirements beyond these baseline clauses may be further detailed and supplemented based on project-specific requirements.

3.4 Liquid Cooling Secondary-Side Monitoring

Secondary-side monitoring encompasses the secondary-side piping facilities and the circulating coolant. When dedicated leakage control is not required, the secondary-side system should be integrated with the CDU system, where all secondary-side pipe sensors connect directly to the CDU controller for optimized logic control by the liquid cooling vendor.

If data center environmental conditions are incorporated into the CDU operating logic, a dedicated monitoring system with an independent controller shall be deployed.

Secondary-side monitoring parameters shall include, but are not limited to: motorized secondary-side piping valves, coolant temperature, flow rate, supply and return differential pressure, and leakage detection. Based on the selected coolant, additional sensors may be deployed as needed, including electrical conductivity, pH, metal ion concentration, turbidity, Oxidation-Reduction Potential (ORP), Chemical Oxygen Demand (COD), alcohol concentration, and liquid-borne particle counts. Control-loop sensors (such as pressure and flow sensors) shall be configured with 2N redundancy. Sensors used solely for operational monitoring shall incorporate data freeze/stuck-value detection and self-diagnostics, implemented via deviation alerts and heartbeat monitoring.

All sensors shall undergo initial and periodic calibration. Initial calibration includes vendor factory calibration reports and site acceptance sampling reports to ensure system verification prior to commissioning. Periodic calibration shall be conducted as full-equipment calibrations according to supplier-specified maintenance intervals, complemented by periodic spot-checks performed by the infrastructure O&M team.

To facilitate ongoing calibration, sensor design and installation shall support online maintainability without system shutdown.

In liquid cooling architectures utilizing secondary-side thermal energy storage (TES) tanks, temperature and leakage monitoring shall be provided for the storage tanks.

Sensors deployed across secondary-side pipes constitute a critical element of the online monitoring system. Key monitoring indicators, measurement methods, and recommended sensor accuracies for the secondary side are detailed in the following table.

Table 1 Secondary-side monitoring items for the cold plate liquid cooling system

Monitoring Item	Applicable Coolant	Detection Method	Detection Frequency	Sensor Type / Principle	Range	Accuracy	Resolution	Main Function	Installation Requirement	Calibration Period
Secondary-side coolant temperature	DI, EG, and PG	Online	Real-time	Temperature sensor / Platinum resistance thermometry	0–70 °C	±0.2 °C	0.1 °C	Monitors system temperature variations and calculates energy exchange efficiency.	G1/4 or G1/2 threaded process connection with a thermowell/mounting sleeve is recommended, utilizing an M12×1 electrical connector and O-ring/gasket sealing. The use of thread seal tape (PTFE tape) or liquid sealants is strictly prohibited. (The mounting sleeve allows online sensor replacement without system shutdown or fluid drainage during maintenance; M12×1 or Hirschmann electrical connectors shall be used.)	Calibration interval: Annually. Online calibration is not supported; third-party calibration is required. Because this sensor participates in logic control, 2N redundancy (one active, one standby) is recommended.
Secondary-side coolant pressure and differential pressure	DI, EG, and PG	Online	Real-time	Pressure sensor / Piezoelectric, piezoresistive, or capacitive sensing	0–10 bar	±0.025 bar	0.01 bar	Monitors system pressure variations to prevent leakage and flow blockage.	7/16-20 UNF internal thread with a Schrader valve pin, or G1/2 or G1/4 threaded process connection is recommended. When G1/2 or G1/4 threads are used, a manual isolation valve shall be installed. Connections shall be sealed with O-rings/gaskets; the use of thread seal tape or liquid sealants is strictly prohibited. The design shall support online sensor replacement	Calibration interval: Annually. Online calibration is not supported; third-party calibration is required. Because this sensor participates in logic control, 2N redundancy (one active, one standby) is recommended.

Monitoring Item	Applicable Coolant	Detection Method	Detection Frequency	Sensor Type / Principle	Range	Accuracy	Resolution	Main Function	Installation Requirement	Calibration Period
									without system shutdown or fluid drainage. The output signal shall be 4–20 mA, utilizing M12×1 or Hirschmann electrical connectors.	
Secondary-side coolant flow rate	DI, EG, and PG	Online	Real-time	Flowmeter / Inline ultrasonic or electromagnetic sensing (full-bore, non-intrusive)	By pipe diameter	Less than or equal to 1% (recommended)	0.1 L	Monitors coolant flow distribution.	Stainless steel tri-clamp or flanged connections are recommended. Select an appropriate connection type based on site conditions while ensuring mechanical strength and sealing integrity, balancing ease of disassembly with O&M efficiency.	Calibration interval: Annually. Online calibration is not supported; third-party calibration is required. Because this sensor participates in logic control, 2N redundancy (one active, one standby) is recommended.
Secondary-side coolant pH	DI, EG, and PG	Online / Offline	Real-time	pH sensor / Glass electrode potentiometry	0–14	±0.02 pH @25 °C	0.01 pH	Evaluates coolant pH levels to prevent corrosion and scaling, protecting server cold plates.	The electrode shall be mounted vertically with the glass bulb facing downward to prevent internal electrolyte tilt and bubble entrapment at the sensing junction, which impairs measurement accuracy. An integrated stainless steel housing with a 50.5 mm (1.5" Tri-Clamp) process connection is recommended. (The integrated design minimizes space	Maintenance interval: Monthly. Calibration interval: Semi-annually. Online calibration is not supported; the sensor must be removed for calibration, which requires a third-party certification report. To prevent calibration from causing a system shutdown and

Monitoring Item	Applicable Coolant	Detection Method	Detection Frequency	Sensor Type / Principle	Range	Accuracy	Resolution	Main Function	Installation Requirement	Calibration Period
									requirements, while the tri-clamp connection facilitates rapid disassembly and recalibration without causing mechanical damage.)	impacting operations, it is recommended to use a 50.5 mm (1.5" Tri-Clamp) stainless steel clamp connection for compact footprint and quick disassembly. The sensor should be installed on a bypass/branch line equipped with isolation valves on both sides; closing both valves allows sensor removal and calibration while the main loop continues normal operation without shutdown.
Secondary-side coolant electrical conductivity	DI, EG, and PG	Online / Offline	Real-time / Sampling	Conductivity sensor / Contacting 2-electrode or 4-electrode sensing	0–10000 µS/cm	±10 µS/cm or ±5% of the reading	1 µS/cm	Monitors operational risks including ionic contamination, leakage, coolant degradation, and corrosion.	The installation location shall prevent bubble accumulation that interferes with measurement. An integrated stainless steel housing with a 50.5 mm (1.5" Tri-Clamp) process connection is recommended. (The integrated design saves space, and the tri-clamp connection allows easy installation and maintenance.)	Maintenance interval: Quarterly. Calibration interval: Semi-annually. Online calibration is not supported; the sensor must be removed for calibration, which requires a third-party certification report. To prevent calibration from causing a

Monitoring Item	Applicable Coolant	Detection Method	Detection Frequency	Sensor Type / Principle	Range	Accuracy	Resolution	Main Function	Installation Requirement	Calibration Period
										system shutdown and impacting operations, it is recommended to use a 50.5 mm (1.5" Tri-Clamp) stainless steel clamp connection for compact footprint and quick disassembly. The sensor should be installed on a bypass/branch line equipped with isolation valves on both sides; closing both valves allows sensor removal and calibration while the main loop continues normal operation without shutdown.
Secondary-side coolant turbidity	DI, EG, and PG	Online / Offline	Real-time / Sampling	Turbidity sensor, scattering method	0–100 NTU	±0.5 NTU or ±2% F.S.	0.1 NTU	Monitors insoluble impurities, suspended particles, rust products, and filter failures to prevent microchannel blockage.	Bubble accumulation shall be avoided at the installation point. For non-colorless coolants (such as EG25/PG25), the turbidity probe shall feature color-interference compensation. An integrated stainless steel housing with a 50.5 mm (1.5" Tri-Clamp) process connection shall be used. (The integrated design	Maintenance interval: Quarterly. Calibration interval: Semi-annually. Online calibration is not supported; the sensor must be removed for calibration, which requires a third-party certification report. To prevent

Monitoring Item	Applicable Coolant	Detection Method	Detection Frequency	Sensor Type / Principle	Range	Accuracy	Resolution	Main Function	Installation Requirement	Calibration Period
									saves space, and the tri-clamp connection enables easy installation and maintenance.)	calibration from causing a system shutdown and impacting operations, it is recommended to use a 50.5 mm (1.5" Tri-Clamp) stainless steel clamp connection for compact footprint and quick disassembly. The sensor should be installed on a bypass/branch line equipped with isolation valves on both sides; closing both valves allows sensor removal and calibration while the main loop continues normal operation without shutdown.
Secondary-side glycol/alcohol-based coolant concentration	EG and PG	Online / Offline	Real-time / Sampling	Glycol refractometer / Refractive index measurement	0–100%	0.01%	0.01%	Ensures anti-freezing, anti-corrosion, and antimicrobial efficacy, preventing performance failure due to insufficient concentration.	Bubble accumulation shall be avoided at the installation point to prevent measurement interference. An integrated stainless steel housing with a 50.5 mm Tri-Clamp process connection shall be used.	Maintenance interval: Quarterly. Calibration interval: Semi-annually. Online calibration is not supported; the sensor must be removed for calibration, which requires a third-party certification

Monitoring Item	Applicable Coolant	Detection Method	Detection Frequency	Sensor Type / Principle	Range	Accuracy	Resolution	Main Function	Installation Requirement	Calibration Period
										report. To prevent calibration from causing a system shutdown and impacting operations, it is recommended to use a 50.5 mm (1.5" Tri-Clamp) stainless steel clamp connection for compact footprint and quick disassembly. The sensor should be installed on a bypass/branch line equipped with isolation valves on both sides; closing both valves allows sensor removal and calibration while the main loop continues normal operation without shutdown.
Secondary-side coolant corrosion rate	DI, EG, and PG	Online	Real-time	Corrosion rate sensor / Linear polarization resistance (LPR)	0–0.254 mm/a	1% of the reading	0.0001 mm/a	Directly measures pipe/cold plate corrosion rates to provide early warnings of perforation and leakage risks.	The coolant flow velocity at the sensor installation point shall match that of the main loop. Avoid installing sensors in areas prone to bubble accumulation or turbulent flow.	Maintenance interval: Quarterly. Calibration interval: Annually. Online calibration is not supported; the sensor must be removed for calibration,

Monitoring Item	Applicable Coolant	Detection Method	Detection Frequency	Sensor Type / Principle	Range	Accuracy	Resolution	Main Function	Installation Requirement	Calibration Period
										which requires a third-party certification report. To prevent calibration from causing a system shutdown and impacting operations, it is recommended to use a 50.5 mm (1.5" Tri-Clamp) stainless steel clamp connection for compact footprint and quick disassembly. The sensor should be installed on a bypass/branch line equipped with isolation valves on both sides; closing both valves allows sensor removal and calibration while the main loop continues normal operation without shutdown.
Secondary-side coolant copper ion concentration	DI, EG, and PG	Online/ Offline	Real-time/ Sampling	Copper inhibitor sensor / UV fluorescence or UV absorption spectrometry	0–300 mg/L	±1 mg/L or ±2% F.S.	0.1 mg/L	Protects copper cold plates against corrosion, preventing accelerated corrosion caused by inhibitor depletion.	The installation location shall avoid areas prone to bubble accumulation to prevent measurement interference.	Maintenance interval: Quarterly. Calibration interval: Semi-annually.

Monitoring Item	Applicable Coolant	Detection Method	Detection Frequency	Sensor Type / Principle	Range	Accuracy	Resolution	Main Function	Installation Requirement	Calibration Period
Secondary-side coolant particle counts	DI, EG, and PG	Online / Offline	Real-time / Sampling	Liquid particle counter / Light obscuration (optical extinction) or resistance method	0–18000 CNT/mL @ 2–200 um	±5 CNT/mL or ±20 % of the reading	1 CNT/mL	Quantifies suspended particles, colloids, and insoluble impurities in the coolant to prevent large particles from clogging microchannels.	The installation location shall avoid areas prone to bubble accumulation to prevent measurement interference.	A sampling skid/device equipped with flow and pressure regulation shall be provided. Annual factory recalibration is recommended.
Secondary-side coolant total bacterial count	DI, EG, and PG	Offline	Sampling	Bacterial analyzer / Plate count method or rapid test strip assay	0–10^6 CFU/mL	/	/	Monitors total bacterial counts in the coolant to control biofouling, water quality degradation, and microbially induced corrosion.	Heterotrophic plate count (HPC) / total bacterial count is a key monitoring parameter for the secondary-side coolant. Periodic sampling for both field testing and laboratory analysis is recommended. The plate count method is suitable for laboratory analysis, whereas rapid bacterial test strips are suitable for field sampling and testing.	
Coolant leakage detection	DI, EG, and PG	Online	Real-time	Leakage detection sensor / Conductive or resistive sensing cable	Positioning accuracy: 1–3 m	Response time ≤ 2–3 s	Triggering volume ≤ 0.1 mL	Detects coolant leakage inside CDU cabinets and at critical secondary-side piping nodes.	The cable leakage detection method is applicable to conductive coolants. A locating leak-detection sensing cable featuring anti-condensation capabilities is recommended to prevent false alarms.	
Secondary-side coolant total alkalinity	DI, EG, and PG	Offline	Sampling	Total alkalinity analyzer / Titration or	0–500 mg/L	±5% of the reading	0.1 mg/L	Measures total alkalinity as a pH buffer to resist acidic or	The titration method is applicable to laboratory analysis,	Annual calibration of the handheld total alkalinity

Monitoring Item	Applicable Coolant	Detection Method	Detection Frequency	Sensor Type / Principle	Range	Accuracy	Resolution	Main Function	Installation Requirement	Calibration Period
				colorimetry				alkaline ingress and prevent severe pH fluctuations.	whereas the colorimetric method is suitable for field sampling and testing.	analyzer is recommended.
Secondary-side coolant total hardness	DI, EG, and PG	Offline	Sampling	Total hardness analyzer / Volumetric titration or colorimetry	0–500 mg/L	±5% of the reading	0.1 mg/L	Evaluates total hardness to prevent scaling, heat exchanger fouling, and thermal resistance buildup on cold plate surfaces.	The titration method is applicable to samples sent to the lab for testing, and the colorimetric method is applicable to onsite sampling and measurement.	Annual calibration of the handheld total hardness analyzer is recommended.
Secondary-side coolant chloride concentration	DI, EG, and PG	Offline	Sampling	Chloride analyzer / Titration or turbidimetry	0–100 mg/L	±5% of the reading	0.1 mg/L	Identifies high chloride levels that induce corrosion in stainless steel and copper, mitigating pitting corrosion risks in stainless steel.	Chloride concentration is a key monitoring parameter for the secondary-side coolant. Periodic sampling for both field testing and laboratory analysis is recommended. The titration method is suitable for laboratory analysis, whereas the colorimetric method is suitable for field sampling and testing.	Annual calibration of the handheld chloride analyzer is recommended.
Secondary-side coolant iron concentration	DI, EG, and PG	Offline	Sampling	Iron analyzer / Colorimetry	0–3 mg/L	±5% of the reading	0.01 mg/L	Identifies elevated iron levels indicating significant corrosion of stainless steel and carbon steel components.	Iron concentration is a key monitoring parameter for the secondary-side coolant. Periodic sampling for both field testing and laboratory analysis is recommended.	Annual calibration of the handheld iron analyzer is recommended.
Secondary-side coolant copper concentration	DI, EG, and PG	Offline	Sampling	Copper analyzer / Atomic absorption spectroscopy (AAS) or	0–0.21 mg/L	±5% of the reading	0.001 mg/L	Identifies elevated copper levels indicating severe corrosion of	Copper concentration is a key monitoring parameter for the secondary-side coolant. Periodic	Annual calibration of the handheld copper analyzer is

Monitoring Item	Applicable Coolant	Detection Method	Detection Frequency	Sensor Type / Principle	Range	Accuracy	Resolution	Main Function	Installation Requirement	Calibration Period
				colorimetry				copper cold plates and copper alloys.	sampling for both field testing and laboratory analysis is recommended. Atomic Absorption Spectroscopy (AAS) is suitable for laboratory analysis, whereas the colorimetric method is suitable for field sampling and testing.	recommended.
Secondary-side coolant aluminum concentration	DI, EG, and PG	Offline	Sampling	Aluminum analyzer / Colorimetry	0–0.8 mg/L	±5% of the reading	0.01 mg/L	Identifies elevated aluminum levels indicating severe corrosion of aluminum cold plates and aluminum alloys.	This method is applicable to aluminum materials on the secondary-side cold plates or wetted components.	Annual calibration of the handheld aluminum analyzer is recommended.
Secondary-side coolant zinc concentration	DI, EG, and PG	Offline	Sampling	Zinc analyzer / Atomic absorption spectroscopy (AAS) or colorimetry	0–3 mg/L	±5% of the reading	0.1 mg/L	Tracks zinc ion fluctuations to evaluate galvanized pipe corrosion or zinc-based corrosion inhibitor consumption.	This method is applicable to the secondary-side systems utilizing galvanized piping or coolants formulated with zinc-based corrosion inhibitors. Atomic Absorption Spectroscopy (AAS) is suitable for laboratory analysis, whereas the colorimetric method is suitable for field sampling and testing.	Annual calibration of the handheld zinc analyzer is recommended.
Secondary-side coolant sulfide concentration	DI, EG, and PG	Offline	Sampling	Sulfide analyzer / Colorimetry	0–0.7 mg/L	±5% of the reading	0.01 mg/L	Prevents excessive sulfide concentrations to mitigate severe corrosion risks.	Sulfide concentration is a key monitoring parameter for the secondary-side coolant. Periodic sampling for both field testing and laboratory analysis	Annual calibration of the handheld sulfide analyzer is recommended.

Monitoring Item	Applicable Coolant	Detection Method	Detection Frequency	Sensor Type / Principle	Range	Accuracy	Resolution	Main Function	Installation Requirement	Calibration Period
									is recommended.	
Secondary-side coolant sulfate concentration	DI, EG, and PG	Offline	Sampling	Sulfate analyzer / Turbidimetry	0–70 mg/L	±5% of the reading	0.1 mg/L	Prevents excessive sulfate concentrations to reduce associated corrosion and scaling risks.	Sulfate concentration is a key monitoring parameter for the secondary-side coolant. Periodic sampling for both field testing and laboratory analysis is recommended.	Annual calibration of the handheld sulfate analyzer is recommended.
Secondary-side coolant molybdate concentration	DI, EG, and PG	Offline	Sampling	Molybdate analyzer / Colorimetry	0–40 mg/L	±5% of the reading	0.1 mg/L	Measures molybdate-based corrosion inhibitor dosing concentration.	This method is applicable to coolants formulated with molybdate-based corrosion inhibitors.	Annual calibration of the handheld molybdate analyzer is recommended.
Secondary-side coolant nitrite concentration	DI, EG, and PG	Offline	Sampling	Nitrite analyzer / Colorimetry	0–150 mg/L	2 mg/L	0.1 mg/L	Measures nitrite-based corrosion inhibitor dosing concentration.	This method is applicable to coolants formulated with nitrite-based corrosion inhibitors.	Annual calibration of the handheld nitrite analyzer is recommended.
Secondary-side coolant silicate concentration	DI, EG, and PG	Offline	Sampling	Silicate analyzer / Colorimetry	0–75 mg/L	1 mg/L	0.1 mg/L	Measures silicate-based corrosion inhibitor dosing concentration.	This method is applicable to coolants formulated with silicate-based corrosion inhibitors.	Annual calibration of the handheld silicate analyzer is recommended.

Note: Alcohol/glycol-based (PG/EG) coolants currently used in the secondary side of cold plate liquid cooling contain colored fluorescent tracers, which severely interfere with colorimetric water quality analysis. Consequently, colorimetric methods featured in handheld analyzers are generally unsuitable for PG/EG coolant analysis. The concentration of metal ions (such as copper and iron ions) in these coolants should be analyzed via Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES); third-party laboratory testing is recommended as needed.

3.5 Secondary-Side and Cabinet Leakage Monitoring and Protection

To avoid server damage caused by leakage, a secondary-side and cabinet leakage protection system can be built or a negative-pressure CDU can be used.

The system can control the impact scope of secondary-side leakage and protect server assets based on three measures: leakage monitoring, fluid supply isolation, and power supply isolation.

Leakage monitoring can be implemented through a leakage monitoring system. The leakage monitoring system can be configured with leakage sensors at different levels, such as secondary-side piping, cold/hot aisle floors, inside cabinets, and inside servers. When a leakage event occurs, the sensor

automatically transmits a signal to the control system. For leakage inside the server, alarms can be generated through the cold plate leakage monitoring system or personnel contact methods, followed by manual control execution.

Fluid supply isolation can be implemented by installing motorized valves on the supply and return branch pipes connecting the secondary piping to the cabinet, with these valves also serving flow control functions. When a cabinet-level leakage is detected, the motorized supply and return valves for the corresponding cabinet can automatically shut down to isolate the cabinet. (Considering that isolation impacts running services, this part should be implemented after reaching an agreement with the customer on emergency technical plans, depending on actual conditions.) Power supply isolation can be implemented by installing electrical trip units on the TOU side of the power distribution cabinet or busway. When a cabinet-level leakage is detected, the power supply loop of the corresponding cabinet is automatically tripped.

Because liquid supply cutoff will instantly increase the temperature inside the computing server, the control logic shall adopt the measure of cutting off power first and then cutting off liquid supply.

The control system should be implemented using a PLC/DDC. As this control system is the final-tier control with an impact scope of single or multiple cabinets, a redundant architecture is not mandatory. At the same time, because liquid cutoff and power cutoff operations are involved, a fail-safe design shall be adopted so that a control system failure will not affect the operation of the liquid cooling system itself.

Interlocking with the algorithm communication model side should be established to implement automatic data and link migration measures, preventing data loss in compute chips caused by rapid power-off and shutdown of all servers in the leaking cabinet.

When adopting a full-rack liquid cooling delivery form, a rack-level controller can be used to implement relevant leakage protection functions, which can execute automatic server shutdown control via out-of-band management ports.

The essence of the leakage control system lies in isolating the coolant and power supply in the leakage area, and its isolation scope depends on the explosion radius design of the secondary-side system. For SuperPoDs or ultra-high-density cabinets, the isolation impact scope is large; therefore, a comprehensive evaluation between shutdown loss and server hardware scrapping loss must be conducted with the service side. Determining the isolation scope of the leakage control system shall comprehensively evaluate service-side downtime losses versus server failure scrapping losses.

For leakage at secondary-side piping (areas outside the cabinet), only alarm handling shall be performed, and no automatic shutdown control should be executed.

3.6 Liquid Cooling Link Anomaly Prediction

The function for liquid cooling link anomaly prediction should be provided, with specific requirements as follows:

(1) Key devices and parameters of the liquid cooling system link should be monitored online. Information such as the quantity of various device types, operating status, bypass valve status, device connection topology, and operating conditions should be dynamically collected to construct prediction models. Models should be further labeled and trained based on preprocessed historical data. The system should support the generation of inference policies for anomaly prediction and push anomaly information output by the models.

(2) Anomaly prediction should be performed based on operational scenarios such as fouling/blockage, leakage, overtemperature, and condensation.

(3) Status management for anomalies in the liquid cooling link should be supported, including states such as pending, in progress, false positive, and resolved.

(4) The full-link operational status may be displayed based on the energy consumption model of the liquid cooling link to evaluate system health, predict operational risks, and diagnose issues.

3.7 Recommended Monitoring Points for Liquid Cooling Systems

The online monitoring points specified in this section refer specifically to data points uploaded by the liquid cooling system to supervisory monitoring platforms such as the BMS. These points are primarily used for O&M alarm notifications, fault diagnostics, and potential optimization and control requirements. Data points required internally for the operation of the liquid cooling system itself—particularly the CDU unit—fall outside the scope of this section; the internal data points of such equipment shall satisfy their own stable operation and control requirements.

The alarm thresholds listed in this section refer specifically to alarm thresholds set on the supervisory monitoring platform. During project implementation, it shall be ensured that alarm settings on the supervisory platform remain consistent with those on the local control panel of the CDU unit, or that alarm bands are defined based on the control panel settings.

CDU monitoring points include, but are not limited to, those listed in the following table.

Table 2 Reference CDU monitoring points for the cold plate liquid cooling system

Monitoring Point	Signal Type	Unit / Enumerated Value	Alarm Threshold	Remarks
CDU cumulative runtime	AI	h		
CDU pump running frequency feedback	AI	Hz		If there are multiple pumps, provide feedback separately
CDU primary-side motorized valve opening feedback	AI	%		
CDU secondary-side motorized valve opening feedback	AI	%		
CDU primary-side max. supply coolant temperature	AI	°C	Determined by design	If the CDU has multiple built-in temperature sensors, the CDU shall provide the highest temperature value
CDU primary-side max. return coolant temperature	AI	°C	Determined by design	If the CDU has multiple built-in temperature sensors, the CDU shall provide the highest temperature value
CDU secondary-side max. supply coolant temperature	AI	°C	Determined by design	If the CDU has multiple built-in temperature sensors, the CDU shall provide the highest temperature value

Monitoring Point	Signal Type	Unit / Enumerated Value	Alarm Threshold	Remarks
CDU secondary-side max. return coolant temperature	AI	°C	Determined by design	If the CDU has multiple built-in temperature sensors, the CDU shall provide the highest temperature value
CDU primary-side Y-strainer differential pressure	AI	bar	Determined by design	
CDU secondary-side Y-strainer differential pressure	AI	bar	Determined by design	
CDU primary-side supply and return differential pressure	AI	bar	Determined by design	If the CDU has multiple built-in differential pressure sensors, the CDU shall provide the lowest differential pressure value
CDU secondary-side supply and return differential pressure	AI	bar	Determined by design	If the CDU has multiple built-in differential pressure sensors, the CDU shall provide the lowest differential pressure value
CDU primary-side flow	AI	m^3/h	Determined by design	
CDU secondary-side flow	AI	m^3/h	Determined by design	
CDU refill tank liquid level	AI	mm	Determined by manufacturer	
CDU secondary-side supply coolant conductivity	AI	μs/cm		
CDU secondary-side supply coolant pH	AI	pH		
CDU secondary-side	AI	NTU		

Monitoring Point	Signal Type	Unit / Enumerated Value	Alarm Threshold	Remarks
supply coolant turbidity				
CDU secondary-side supply coolant concentration	AI	%		Applicable to liquid cooling systems using PG/EG coolant
CDU secondary-side supply coolant corrosion rate	AI	mm/a		
CDU secondary-side supply coolant copper corrosion inhibitor concentration	AI	mg/L		Applicable to liquid cooling systems with copper corrosion inhibitors added
CDU leakage location	AI	m		
CDU secondary-side supply coolant temperature setpoint	AI	°C		
CDU secondary-side supply coolant flow setpoint	AI	m^3/h		
CDU secondary-side differential pressure setpoint	AI	bar		
Communication status	DI	Normal = 0 Communication lost = 1	1	Determined by BMS
CDU heartbeat (optional)	DI	Normal = 0 Fault = 1	1	The CDU should have a built-in heartbeat register bit whose value changes at an agreed period. If the BMS detects no change beyond the agreed time, an alarm is generated.
Overall system operating status	DI	Stopped = 0 Running = 1		
Overall system operating mode	DI	See manufacturer conventions		Applicable if the CDU has different

Monitoring Point	Signal Type	Unit / Enumerated Value	Alarm Threshold	Remarks
				operating modes, such as group control, standalone, differential pressure control, flow control, etc.
Summary alarm	DI	Normal = 0 Alarm = 1	1	Collection of all alarm points
Level-1 alarm (optional)	DI	Normal = 0 Alarm = 1	1	Collection of all points that cause CDU shutdown
Level-2 alarm (optional)	DI	Normal = 0 Alarm = 1	1	Collection of all points that have caused CDU performance degradation
Level-3 alarm (optional)	DI	Normal = 0 Alarm = 1	1	Collection of all points tending toward CDU performance degradation
Overall system non-automatic alarm	DI	Normal = 0 Alarm = 1	1	Collection of points where any CDU component is in manual mode and affects automatic system control
CDU pump fault	DI	Normal = 0 Alarm = 1	1	
CDU water valve fault	DI	Normal = 0 Alarm = 1	1	
CDU DC power supply 1 fault	DI	Normal = 0 Alarm = 1	1	Applicable if the CDU control panel uses a dedicated DC power supply
CDU DC power supply 2 fault	DI	Normal = 0 Alarm = 1	1	Applicable if the CDU control panel uses a dedicated DC power supply
CDU secondary-side condensation	DI	Normal = 0 Alarm = 1	1	
CDU coolant leakage	DI	Normal = 0 Alarm = 1	1	
CDU built-in ATS control	DI	Automatic = 0	1	

Monitoring Point	Signal Type	Unit / Enumerated Value	Alarm Threshold	Remarks
status		Manual = 1		
CDU built-in ATS main line closed	DI	Open = 0 Closed = 1	0	
CDU built-in ATS standby line closed	DI	Open = 0 Closed = 1	1	
CDU remote start	DO			
CDU remote stop	DO			
CDU group control operating mode	DO	Remote = 0 Group control = 1 Standalone = 2		Remote / Group control / Standalone
CDU remote flow setting	AO	bar		
CDU remote differential pressure setting	AO	bar		
Secondary-side system supply coolant temperature	AI	°C	operating status = 1	
Secondary-side system return coolant temperature	AI	°C		
Secondary-side system supply and return differential pressure	AI	bar		Minimum value of all sensors
Secondary-side total supply coolant flow	AI	m^3/h		Minimum value of all sensors
Secondary-side piping drip pan leakage alarm	DI	Normal = 0, Alarm = 1	1	
Secondary-side piping cabinet row leakage alarm	DI	Normal = 0, Alarm = 1	1	
Thermal storage tank temperature	AI	°C		If available
Thermal storage tank leakage alarm	DI	Normal = 0, Alarm = 1	1	If available

The following table provides the recommended monitoring points specific to the leakage protection design (see Section 3.3).

Table 3 Reference leakage monitoring points for the cold plate liquid cooling system

Monitoring Point	Signal Type	Unit / Enumerated Value	Alarm Threshold	Remarks
Cabinet supply-side motorized valve opening control	AO	%		
Cabinet supply-side motorized valve opening feedback	AI	%		
Cabinet return-side motorized valve opening control	AO	%		
Cabinet return-side motorized valve opening feedback	AI	%		
Cabinet leakage alarm	DI	Normal = 0, Alarm = 1	1	
Cabinet power supply circuit trip control	DO	Trip = 1		
Cabinet power supply circuit status feedback	DI	Tripped = 0, Closed = 1		
Server leakage alarm	DI	Normal = 0, Alarm = 1	1	Server data is generally not directly connected to the infrastructure monitoring platform, so this is for recommendation only

4 Routine Maintenance and Inspection

4.1 General Requirements

The liquid cooling system shall pass a strict air tightness test before delivery. Ease of O&M shall be enhanced through modular product design and specialized maintenance tooling. During routine O&M, core parameters shall be monitored, such as the liquid level in the CDU storage tank and the secondary-side supply/return coolant temperature and pressure. Personnel shall be trained to execute standardized operations.

For liquid leakage faults under extreme conditions, the liquid cooling data center shall establish an efficient emergency response mechanism. O&M personnel shall quickly locate faulty components according to preset operating procedures, and use dedicated tooling to remove and replace cold plates

or blade servers without damage. The entire fault handling process shall be completed within a short time via simple operations, minimizing impact on service operation.

Routine maintenance and inspection primarily comprise planned and unplanned maintenance. The O&M team shall formulate system-level and device-level SOP, MOP, and EOP documentation. For planned maintenance, different components in the liquid cooling system shall have distinct maintenance frequency requirements, generally categorized into routine inspections and periodic testing. Coolant shall undergo regular laboratory testing. If coolant deterioration is detected, unplanned maintenance operations such as refilling or replacement shall be performed in a timely manner.

4.2 O&M OP Document Guidance

4.2.1 SOP Guidance for Cold Plate Liquid Cooling

A series of specific operational guidelines shall be developed for the cold plate liquid cooling system, including but not limited to: *CDU Startup and Shutdown SOP*, *Coolant Water Preparation SOP for Cold Plate Liquid Cooling*, *Power-On and Liquid Filling SOP for Liquid-Cooled Servers*, *Power-Off and Liquid Draining SOP for Liquid-Cooled Servers*, *Primary-Side Cooling System Rotation SOP for Liquid Cooling*, *Secondary-Side Water Quality Sampling SOP for Liquid Cooling*, *Secondary-Side Sensor Calibration SOP for Liquid Cooling*, and *CDU Rotation SOP*. During CDU startup, it shall be verified that the supply chilled water temperature of the BA water system is below 34 °C, the end differential pressure is ≥ 0.7 bar, the CDU in the startup aisle operates stably without alarms, the supply coolant temperature is 35 °C, and the supply coolant differential pressure is 0.8 bar. (For specific parameters, refer to actual design requirements.)

Note: During the installation of new liquid-cooled servers, pressure holding tests and post-filling air bleeding shall be executed as key operations. When withdrawing a server from the rack, it shall be verified that valve isolation is intact with no leakage risk. Relevant operations shall be performed by two persons (one operating and one verifying). SOPs for front-end primary-side cooling source equipment in cold plate liquid cooling systems may refer to traditional water cooling architectures.

4.2.2 EOP Guidance for Cold Plate Liquid Cooling

Emergency response plans shall be formulated for cold plate operations. In addition to executing routine PPM and controlling liquid cooling change management processes, O&M personnel shall strengthen their emergency response capabilities for contingencies. Anomalies during daily O&M of cold plate liquid cooling systems primarily center on coolant leakage (directly threatening IT equipment), CDU circulating pump failure (causing coolant circulation interruption), and coolant medium control anomalies (e.g., contamination or cooling performance degradation); special attention shall be directed to these areas. Liquid cooling systems carry high leakage risks: cold plate liquid cooling systems directly contact IT equipment, and coolant leakage may damage servers or other critical hardware, requiring rapid response. Buffering time is short: cold plate liquid cooling systems lack the thermal air buffering capability of traditional water cooling, and device temperatures may rise rapidly after coolant circulation is interrupted, leaving a short response window for the O&M team (typically measured in seconds), requiring rapid response. The system should be equipped with leakage detection sensors. Upon leakage detection, the faulty pipeline shall be shut down immediately (or the emergency fluid refill cart shall be dispatched for rapid refilling), and the backup cooling path shall be initiated (typically referring to primary-side continuous water makeup and replacement circulation cooling).

The following are common EOP guides for cold-plate liquid cooling faults, for reference only.

Table 4 Reference emergency scenarios for cold plate liquid cooling

Emergency response for liquid cooling	Emergency plan for liquid cooling temperature control unit (CDU) faults	

temperature rise / anomalies	Emergency plan for circulating pump (chilled / cooling) accidents (EOP)	
	Emergency plan for valve leakage in liquid cooling secondary side	
	Emergency plan for emergency water refill in liquid cooling chilled water system	Major leakage on chilled primary side
	Emergency plan for internal leakage in CDU	
	Emergency plan for piping network leakage in liquid cooling secondary side	
	Emergency plan for cabinet hose leakage (minor leakage) in liquid cooling secondary side	Minor leakage
	Emergency plan for cabinet hose leakage (major leakage) in liquid cooling secondary side	Major leakage

4.2.3 MOP Guidance for Cold Plate Liquid Cooling

O&M personnel shall periodically perform PPM on the liquid cooling system. Standard operations and maintenance for specific products shall be performed according to the corresponding O&M manual. Meanwhile, the qualifications and skills of O&M personnel shall be verified to meet mandatory compliance or O&M manual requirements. The following maintenance directions are for reference only, and specific maintenance directions shall be determined based on the secondary-side medium type used in the project:

(1) Check whether there are alarm records on the CDU/CDM alarm display interface and handle them in a timely manner.

(2) Check whether the cooling fans of the CDU/CDM electrical control system operate normally.

(3) Check whether there is any leakage at the rear piping connections of the CDU/CDM.

(4) Check the manual and automatic control functions of the motorized regulating valve.

(5) Verify the functions of the differential pressure bypass valve and safety valve.

(6) Check the manual/automatic control and rotation switching of circulating pumps, and perform timely maintenance if any anomaly occurs.

(7) Perform dust removal and decontamination on the main unit.

(8) Check the pressure difference between the secondary-side return liquid pressure and system pressure, and clean the system filter element if an anomaly occurs.

(9) Testing frequency: The following table lists the testing frequency for glycol/alcohol-based coolants. For deionized water coolants, it is recommended to monitor the secondary-side deionized water coolant once a week after server installation and stable operation. After maintaining stability for 1 month, the monitoring frequency shall change to once a month; after maintaining stability for 3 months, the water quality indicators shall be monitored once every 3 months, continuing throughout the entire service period of the liquid cooling system.

The following table lists the secondary-side MOP items for reference only.

Table 5 Reference secondary-side MOP items for cold plate liquid cooling

No.	Maintenance Item	Frequency	Maintenance Party	Standard	Remarks
1	CDU supply coolant solution pH	Once/quarter	Facility management (FM) team	Deionized water type: 7.5–10.5; Ethylene glycol type: 7.0–10.0; Propylene glycol type: 7.5–10.5	When sampling from the manual drain valve, ensure the stagnant fluid in the pipe is fully drained before taking the test sample. If the initial test fails, a retest is recommended; if there is a significant discrepancy between the two tests, the CNAS laboratory test result shall serve as the basis for disposition.
2	CDU supply ethylene glycol or propylene glycol concentration	Once/quarter	FM team	20% ethylene glycol & 25% ethylene glycol: 15%–25%; 25% propylene glycol: 23%–29%; 55% propylene glycol: 53%–59%	
3	CDU supply coolant solution turbidity	Once/quarter	FM team	≤ 10 NTU (deionized water type)	
4	CDU supply coolant total microbial count	Once/quarter	Third-party lab	≤ 100 CFU/mL (alcohol/glycol type); ≤ 1000 CFU/mL (deionized water type)	Samples shall be collected using sterile sampling bottles or bags and submitted to a professional laboratory for testing.
5	Manifold air vent valve	Once/quarter	FM team	Inspection shows no leakage, dripping, or seepage; regularly verify that the air venting function operates normally	/
6	EPDM hose connection	Once/quarter	FM team	Inspection shows no leakage, dripping, or seepage	Hose clamp connections are particularly prone to leakage.
7	Piping thermal insulation	Once/half a year	FM team	Inspect whether thermal insulation on the unit and connected piping is intact	/
8	Motorized valve check	Once/quarter	FM team	For powered-on equipment, observe that the motorized valve operates normally without sticking; for powered-off equipment, test manual opening and closing to	/

No.	Maintenance Item	Frequency	Maintenance Party	Standard	Remarks
				ensure smooth operation without sticking	
9	Temperature sensor	Once/year	FM team	Verification Regulation for Industrial Platinum and Copper Thermoresistance (JJG 229-2010)	/
10	Pressure sensor	Once/year	FM team	Verification Regulation for Pressure Transmitters (JJG 882-2019)	/
12	Flowmeter	Once/year	FM team	Electromagnetic flowmeter reference: JB/T 9248-2015	/
13	pH sensor	Once/month	FM team	HJ 1147-2020 Water Quality - Determination of pH - Electrode Method	When sending the sensor to a third party for calibration/inspection, ensure the glass probe is protected with KCl solution to avoid dry storage and air exposure.
14	Conductivity sensor	Once/quarter	FM team	JB/T 9366-2017 Laboratory Conductivity Meters	/
15	Turbidity sensor	Once/quarter	FM team	HJ 1075-2019 Water Quality - Determination of Turbidity - Turbidimeter Method	/
16	Alcohol/glycol refractometer	Once/quarter	FM team	GB/T 614-2021 Chemical Reagent - General Method for the Determination of Refractive Index	
17	Corrosion rate sensor	Once/quarter	FM team	ASTM G102-89(2015) Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements	/
18	Copper inhibitor concentration sensor	Once/quarter	FM team		/

No.	Maintenance Item	Frequency	Maintenance Party	Standard	Remarks
19	Butterfly clamp	Once/quarter	FM team		/
20	Pump	Once/quarter	FM team	Noise level at 1 m in front of the pump is below 75 dB; motor temperature is below 80 °C	-
21	Motorized valve	Once/quarter	FM team	Operates normally without sticking	-
22	Automatic air vent valve	Once/quarter	FM team	Vents air normally without water leakage	-
23	Internal piping and drip pan	Once/quarter	FM team	Thermal insulation is intact with no leakage traces	-
24	Display screen	Routine inspection	FM team	Displays normally	-
25	Supply coolant temperature	Routine inspection	FM team	Setpoint ± 1 °C	-
26	Supply coolant differential pressure	Routine inspection	FM team	Setpoint ± 0.1 bar	-
27	Storage tank liquid level	Routine inspection	FM team	Maintained above the low liquid level mark	-
28	Primary-side filter	Routine inspection	FM team	Differential pressure below *x* bar; if exceeded, clean the filter element (refer to filter mesh size for specific values)	Reference value: 0.5 bar
29	Secondary-side filter	Routine inspection	FM team	Differential pressure below *x* bar; if exceeded, clean the filter element (refer to filter mesh size for specific values)	Reference value: 0.5 bar

4.3 Secondary-Side Medium Control for Cold Plate Liquid Cooling

4.3.1 Overview of Secondary-Side Medium Indicators for Cold Plate Liquid Cooling

The cooling liquid used in cold plate liquid cooling systems to implement heat exchange is collectively referred to as the coolant, which flows within the secondary-side circulation system. Common working media are categorized into water-based and non-water-based types. When selecting a coolant, key considerations shall include compatibility with all wetted materials in the secondary-side liquid cooling module, reliability, hazards, cost efficiency, and other factors. Among these, the medium shall possess good heat transfer capacity, with a high product of density and specific heat capacity; it shall possess good environmental adaptability, featuring a lower freezing point and a higher boiling point to facilitate freeze prevention and help reduce system pressure and design complexity. It shall possess good

material compatibility, demonstrating favorable compatibility with piping materials (including metals and non-metals) to ensure long-term operational reliability; it shall possess good environmental protection characteristics, featuring low GWP (Global Warming Potential) and low ODP (Ozone Depletion Potential) to satisfy local environmental regulations.

Meanwhile, the coolant shall possess good low-viscosity performance, maintaining low viscosity and favorable fluidity within the operating temperature range of 10 °C to 45 °C. During the design phase, an appropriate pump and flow rate shall be selected based on the finalized secondary-side coolant type (pure water type, ethylene glycol/propylene glycol type, or other coolant types) to meet heat dissipation requirements.

The following table list the advantages and disadvantages of different cooling media for reference when selecting a coolant.

Table 6 Comparison of different secondary-side media for cold plate liquid cooling

Water-based Cooling Media	**Advantages**	**Disadvantages**
Pure water	1. Stable performance, and simple measurement and evaluation indicators (typically evaluated via conductivity). 2. Low cost and easily accessible, with high cooling efficiency and low viscosity.	1. Maintenance conditions heavily affected by the environment, requiring a secondary-side deionization unit with periodic replacement. 2. Stringent environmental requirements, with impurities dissolving easily and causing increased conductivity, electrical conduction, corrosion, and bacterial growth.
Formulated liquid	Excellent heat transfer, effective prevention of corrosion and microbial growth, and stable performance.	1. Formula dosage (concentration) dissipating over time, resulting in the failure of corrosion inhibition, biocide, and bacteriostatic effects, with quality unassessable visually and requiring external analysis under high periodic monitoring requirements. 2. Electrical conductivity, posing significant hazards to the liquid cooling system upon leakage. 3. Undisclosed formulations preventing the mixing of different formulated liquids, with replacement requiring system flushing and involving a heavy workload.

Antifreeze Agent [Alcohol]	**Advantages**	**Disadvantages**
Propylene glycol, ethylene glycol, etc.	1. Concentration adjustable to adapt to specific environments. 2. Bacterial growth suppressible at certain concentrations. 3. Stable performance during long-term use.	1. High susceptibility of ethylene glycol (containing hydroxyl groups) to oxidation, forming aldehydes and acids (corrosive to metals) when two hydrogen atoms are bonded to the α-C atom, and oxidizing to glycolic acid and oxalic acid (toxic) under long-term operation at 80 °C–90 °C. 2. Increased system viscosity and degraded heat dissipation performance caused by

Antifreeze Agent [Alcohol]	Advantages	Disadvantages
		higher ethylene glycol or propylene glycol content. 3. Low toxicity and low irritation of propylene glycol, but subject to cost constraints (implying a relatively high cost).

Design requirements for secondary-side coolant:

The secondary-side coolant is a core material in cold plate liquid cooling systems. Server vendors may select and designate specific coolant types and brands according to their requirements. During O&M, the usage and monitoring of coolant shall strictly follow server vendor specifications. For the core parameter ranges of different secondary-side coolants, refer to the following Green Computing Consortium (GCC) standards:

Technical Requirements and Test Methods for Glycol-Based Cold Plate Coolants

Technical Requirements and Test Methods for Cold Plate Coolants (Applicable to Deionized Water Type)

Wetted Material Compatibility Requirements and Test Methods for Single-Phase Cold Plate Liquid Cooling (Applicable to Glycol-Based Type)

Wetted Material Compatibility Requirements and Test Methods for Single-Phase Cold Plate Liquid Cooling (Applicable to Deionized Water Type)

4.3.2 Secondary-Side Medium Testing for Cold Plate Liquid Cooling

As the component directly contacting the server in a liquid cooling system, the health status of the coolant severely affects the long-term and stable operation of the server itself. Deterioration of the coolant may lead to degraded heat exchange performance of the cold plate, subsequently causing degraded server performance. The O&M team shall understand the characteristic differences among different coolants and the resulting differences in maintenance requirements. For example, deionized water is relatively prone to deterioration and thus requires more frequent testing, while ethylene glycol solution possesses a certain degree of toxicity, requiring proper safety protection during operation, such as wearing gloves and protective masks.

The health status indicators of the coolant shall be determined by comprehensively considering the recommended requirements of all wetted material manufacturers. Because excessive addition of bacteriostatic agents may indirectly lead to organic accumulation and clog the piping of the liquid cooling system and server cold plates, and similar issues exist for other coolant additives, the health status indicators of the coolant shall not fall outside the upper and lower limits of the nominal control range specified for any wetted material.

Table 7 Secondary-side medium testing instructions

Indicator	Applicable GCC Standards	Test Measure	Remarks
Appearance	*Technical Requirements and Testing Methods for Glycol-based Coolant of Cold Plate*	Online monitoring	
EG/PG		Online monitoring + qualified	20% & 25% ethylene glycol: 15%–25%; 25% propylene

Indicator	Applicable GCC Standards	Test Measure	Remarks
concentration	*Liquid Cooling* *Technical Requirements and Testing Methods for Coolant of Cold Plate Liquid Cooling (Applicable to Deionized Water Coolant)* *Testing Method of Compatibility Between Working Fluid and Materials for Cold-plate Liquid Cooling*	laboratory testing	glycol: 23%–29%; 55% propylene glycol: 53%–59%
Conductivity		Online monitoring + qualified laboratory testing	Reported value
pH value		Online monitoring + qualified laboratory testing	Deionized water type: 7.5–10.5 Ethylene glycol type: 7.0–10.0 Propylene glycol type: 7.5–10.5
Turbidity		Online monitoring + qualified laboratory testing	≤ 10 NTU (deionized water type)
Total hardness (as CaCO3)		Qualified laboratory testing	≤ 25 mg/L (alcohol/glycol type); ≤ 25 mg/L (deionized water type)
Bacterial concentration		Qualified laboratory testing	≤ 100 CFU/mL (alcohol/glycol type); ≤ 1000 CFU/mL (deionized water type)
Copper inhibitor concentration		Qualified laboratory testing	Inhibits the corrosion/dissolution of copper and copper-zinc alloys
Filter clogging		Online monitoring; if a differential pressure sensor is not installed, visual inspection can serve as a substitute	0.5 bar, depending on the filter mesh size
Total copper		Online monitoring + qualified laboratory testing	≤ 5 mg/L (alcohol/glycol type); ≤ 0.5 mg/L (deionized water type)
Total iron		Online monitoring + qualified laboratory testing	≤ 5 mg/L (alcohol/glycol type); ≤ 0.5 mg/L (deionized water type)
Total aluminum		Qualified laboratory testing	≤ 5 mg/L (alcohol/glycol type); ≤ 1.0 mg/L (deionized water type)
Total calcium		Qualified laboratory testing	≤ 20 mg/L (alcohol/glycol type)
Total		Qualified laboratory testing	≤ 20 mg/L (alcohol/glycol type)

Indicator	Applicable GCC Standards	Test Measure	Remarks
magnesium			
Total hardness (as CaCO3)		Qualified laboratory testing	≤ 50 mg/L (deionized water type)
Chloride ion		Qualified laboratory testing	≤ 25 mg/L (alcohol/glycol type); ≤ 25 mg/L (deionized water type)
Sulfate ion		Qualified laboratory testing	≤ 25 mg/L (alcohol/glycol type); ≤ 25 mg/L (deionized water type)

Third-party testing shall select laboratories with relevant qualifications such as CMA and CNAS. Test reports shall be stamped with CMA and CNAS seals and bear traceable report numbers. Test methods for each indicator shall execute in accordance with the latest national standards.

Online monitoring data is susceptible to interference factors. When online monitoring data shows anomalies, processing shall follow the workflow below:

1. First verify the accuracy of the online monitoring equipment.
2. Classify and handle the severity levels of adverse indicators according to Section 7.5 "Classification of Handling Levels for Abnormal Media O&M Indicators in Cold Plate Liquid Cooling" of this specification.
3. Complete qualified laboratory testing as soon as possible.
4. Complete the intervention and closed-loop management of abnormal water quality indicators.

4.4 Introduction to Liquid Cooling Piping and Auxiliary Components and Control Guidance

4.4.1 Manifolds and Quick Disconnectors: Common Components in Cold Plate Liquid Cooling

Cold plate liquid cooling may include but is not limited to the following common components:

Manifold: A coolant supply and return device located between the cooling distribution unit and the cold plates, used to distribute water or other cooling media to each cold plate in the cabinet.

Universal Quick Disconnector (UQD): A quick-disconnect assembly that typically comprises a plug and a socket, with both plug and socket featuring fluid shut-off functionality.

Connected system: A collective term for piping or connectors used to achieve interconnections among liquid cooling components.

Metallic materials: Shell components should use stainless steel, and metallic elastic components should use stainless steel materials, with springs required to remain undamaged after 1,000 compressions post-assembly. Surface treatment requirements are as follows:

- Passivation shall be applied when shell components use stainless steel.
- Passivation shall be applied for metallic elastic components.

- No surface treatment shall be applied to non-metallic components.

Sealing performance: During and after testing, the helium mass spectrometer leakage rate of mated and unmated fluid connectors in both connected and disconnected states shall be no greater than 1×10^{-7} Pa·m³/s.

Prior to any operation involving quick disconnectors, key technical indicators of the quick disconnectors shall be verified in advance, including but not limited to: rated flow rate, rated temperature, rated pressure, burst pressure, and coolant loss volume. Properties of the seal ring material shall meet compatibility requirements with the transfer medium. Seal ring material hardness shall be 65–85 Shore A, measured in accordance with GB/T 6031. Seal ring materials, corresponding transfer media, and prohibited media are listed in the following table.

Table 8 Compatibility of selected sealing materials and corresponding media

No.	Sealing Ring Material	Transmission Medium	Prohibited Medium
1	Fluorosilicone rubber	Deionized water, ethylene glycol aqueous solution, aviation kerosene, etc.	Fluorinated liquid media
2	EPDM rubber	Deionized water, alcohol/glycol aqueous solution, fluorinated liquid (specific models)	Mineral oil media
3	Nitrile rubber	Deionized water, mineral oil	Polar solvents ^a

Note: When using each sealing ring material, ensure that it is compatible with the coolant. ^a Polar solvents include ketones, ozone, nitrohydrocarbons, etc.

4.4.2 Technical Description of Key Components and Wetted Materials for Cold Plate Liquid Cooling

Wetted materials refer to all materials in direct contact with the coolant. Generally, chemical compatibility between wetted materials and the coolant shall be fully considered during the design of a newly built liquid cooling system. During the operation and maintenance phase, guidance in this section shall be attended to only when wetted materials are replaced. At the initial O&M stage, a wetted material inventory list shall be prepared to ensure material consistency during any subsequent wetted material replacement. If wetted material types need to be changed, technical reviews with manufacturers of both the coolant and relevant wetted materials shall be organized to ensure chemical compatibility. Wetted materials include but are not limited to those listed in the following table.

Table 9 Technical advantages and disadvantages of key components and wetted materials for cold plate liquid cooling

Component Type	Common Material	Advantages	Disadvantages	Compatibility Description
Cold plate	Copper	Excellent thermal conductivity	Relatively high price, large weight	Applicable to most coolants, but galvanic corrosion must be prevented

Component Type	Common Material	Advantages	Disadvantages	Compatibility Description
	Aluminum	Light weight, relatively low cost	Corrosion resistance inferior to copper	Anodizing treatment required to improve corrosion resistance
Piping	Stainless steel	Strong corrosion resistance, applicable to high pressure	Relatively high cost, complex installation	Applicable to multiple coolants, especially corrosive liquids
	PEX/PVC	Low cost, easy to install	Poor high-temperature resistance	Applicable to low-pressure systems, with attention required for temperature limits
	EPDM (Ethylene Propylene Diene Monomer)	Heat resistance, chemical corrosion resistance	Unsuitable for contact with certain oils	Applicable to most water-based coolants and glycol mixtures
Seals	EPDM (Ethylene Propylene Diene Monomer)	Heat resistance, chemical corrosion resistance	Unsuitable for contact with certain oils	Applicable to most water-based coolants and glycol mixtures
	PTFE (Polytetrafluoroethylene)	High-temperature resistance, excellent chemical stability	Relatively high cost	Applicable to almost all chemical environments, especially high-temperature applications
Connectors and valves	Brass	Good corrosion resistance	Dezincification may occur in certain water qualities	Applicable to most coolants, but attention required for impacts from chlorine-containing water quality
	Stainless steel	High strength, corrosion resistance	Relatively heavy, high cost	Applicable to highly corrosive environments and high-pressure applications
Coolant	Water/ethylene glycol (propylene glycol) mixture	Anti-freezing, anti-corrosion	Regular replacement or monitoring required	Compatible with most metals and seal materials
	Deionized water	Good thermal conductivity, impurity-free	Corrosive to certain metals	Corrosion inhibitors must be added to prevent corrosion
Thermal interface material	Thermal grease	Fills micro-gaps, good thermal conductivity	Regular replacement required	Compatible with most metal surfaces, with attention required for cleanliness
	Thermal pad	Easy to install, high adaptability	Thermal transfer efficiency may be lower than thermal grease	Applicable to multiple surfaces, but attention required for pressure and temperature limits

Component Type	Common Material	Advantages	Disadvantages	Compatibility Description
Temperature sensor	Stainless steel	Strong corrosion resistance, high pressure resistance, long service life	Relatively high cost	Applicable to multiple coolants, especially corrosive liquids
Pressure sensor	Stainless steel	Strong corrosion resistance, high pressure resistance, long service life	Relatively high cost	Applicable to multiple coolants, especially corrosive liquids
Flowmeter	Stainless steel	Strong corrosion resistance, high pressure resistance, long service life	Relatively high cost	Avoid using flowmeters with flow-restricting, loss-inducing, and maintenance-intensive parts (e.g., impellers, turbines) wherever possible.

5 Description of Cold Plate Liquid Coolant Recycling and Waste Liquid Disposal

5.1 Purpose and Scope of Application

This guideline is used to ensure process control over the entire waste liquid disposal process during data center O&M, and to ensure the safety of personnel and property during the transfer, disposal, and recycling of cold plate liquid cooling waste liquid.

5.2 Guidelines on Organizational Responsibility Division

The waste liquid involved in the routine O&M of cold plate liquid cooling systems primarily comprises scrapped ethylene glycol/propylene glycol coolants or chemical waste liquids on the secondary side of liquid cooling systems. The following table provides the responsibility guidance for each party involved in the waste liquid disposal process.

Table 10 Guidelines on responsibilities for waste liquid disposal

Relevant Position	Responsibility and Authority
Project technical owner and EHS specialist	Responsible for the entire onsite management, disposal, and recycling supplier supervision of operational hazardous waste generated by the center; Properly classify the waste liquid generated on the secondary side of liquid cooling, and require coolant vendors to provide recycling and disposal solutions for supplied coolant products; Timely report hazardous waste quantities and transfer applications to the company; Responsible for document record archiving, post-disposal weight verification, and ledger updates during hazardous waste disposal; Organize hazardous waste disposal information forms and submit them to the provincial environmental protection department's hazardous waste disposal system for filing.
Project administration	Responsible for administrative work such as signing, stamping, and seal application for hazardous waste disposal/recycling agreements; responsible for billing settlement and follow-up work after hazardous waste disposal/recycling.

Relevant Position	Responsibility and Authority
Project manager	Responsible for urging and assisting the center to reduce, reuse, and recycle hazardous waste within scope wherever possible; review/supervise the team to comply with relevant procedures; Responsible for investigating hazardous waste-related anomaly events in the center and formulating corrective/preventive measures.
Commercial department	Responsible for commercial work such as bidding and price inquiry for hazardous waste disposal/recycling suppliers; responsible for interfacing with hazardous waste disposal suppliers.
Legal department	Responsible for legal work such as drafting, reviewing, and stamping agreements with hazardous waste disposal/recycling suppliers.
Finance department	Responsible for approving hazardous waste disposal/recycling orders and conducting financial settlements.
Transfer supplier	Settle the disposal/recycling process based on unit prices in the framework agreement according to the project's hazardous waste list; assist in applying for transfer manifests from the local environmental protection bureau, and provide full coordination and support to the enterprise side.

5.3 Coolant Storage, Refilling, and Replacement

When the coolant fails testing or leakage occurs, the coolant shall be replaced or refilled in a timely manner according to the EOP plan. Because the coolant is a hazardous liquid, all operations shall strictly comply with the technical guidance and requirements specified by the manufacturer. During coolant replacement, all materials used (including but not limited to coolant distribution containers, piping of the liquid injection system, piping of the liquid drainage system, and waste liquid collection containers) shall meet the requirements of the coolant manufacturer. The use of any materials that may chemically react with the coolant, such as galvanized steel or distribution containers contaminated with oil stains, is strictly prohibited.

Before coolant replacement, check the sealing integrity, shelf life, and test qualification certificates provided with the spare coolant packaging containers. The use of uncertified coolant is prohibited.

During coolant replacement operations, contact contamination related to the coolant shall be strictly controlled.

The addition of chemical agents to the coolant shall comply with the environmental protection requirements of the project location. Waste liquid after replacement shall be recycled by the coolant manufacturer or handled uniformly by a dedicated organization.

If dripping, spillage, or tipping occurs during coolant replacement, absorbent materials shall be used immediately to absorb and collect the liquid into a dedicated container. Residuals on the ground must be cleaned thoroughly with water.

Given the current lack of laboratory data demonstrating compatibility among different coolants, when performing addition operations into the original coolant, it shall be ensured that the chemical properties match those of the original coolant.

If the replacement coolant has chemical properties inconsistent with those of the original coolant,

priority shall be given to draining the original coolant and completing piping flushing in accordance with the process for newly built projects before injecting the coolant. Because this situation rarely occurs, it is beyond the scope of guidance in this manual.

Coolant replacement should obtain approval from the server side (i.e., end user or server manufacturer) to ensure that technical parameters of the new coolant meet the chemical compatibility requirements of cold plates on the server side.

Routine refilling of coolant shall be conducted using products of the same brand and model as the original coolant. Coolants of different brands have different formulation compositions and shall not be interchanged across brands.

When procuring new coolant for storage, it shall be ensured that the coolant manufacturer provides valid product test reports. The storage environment and duration for stored coolant shall strictly comply with the manufacturer's guidance requirements, including ambient temperature, humidity, light, container material, and shelf life. Furthermore, the coolant manufacturer shall have completed storage and near-expiration performance testing of the coolant based on these guidance requirements and provided test reports. Meanwhile, spill prevention measures shall be set up in the coolant storage room. Hazardous waste in liquid cooling systems mainly consists of the coolant and wetted materials contaminated by the coolant. Even intrinsically non-toxic coolants (such as deionized water) can become toxic and harmful liquids due to added chemical agents such as corrosion inhibitors, buffers, scale inhibitors, and bacteriostatic agents, which may cause pollution to O&M personnel and the environment if handled improperly. The coolant manufacturer shall provide the coolant MSDS and onsite user manual.

Before initiating any coolant-related operations, operating personnel shall fully study and understand the operating guidance provided by the manufacturer. Effective personal protective equipment, such as goggles, rubber gloves, and masks, shall be worn during operations.

5.4 Mechanism for Handling Accidental Leakage

Coolant leakage in cold plate liquid cooling systems is a major event during data center O&M. Once it occurs on the server side, it may cause huge data losses and economic losses. To better avoid the hazards brought by accidental coolant leakage, coolant leakage shall be monitored during the data center design and O&M phases. Section 3.5 "Secondary-Side and Cabinet Leakage Monitoring and Protection" of this specification provides a detailed description; this section only introduces the emergency handling mechanism after accidental leakage has occurred.

5.4.1 Mechanism for Handling Accidental Leakage on the Secondary Side and in Cabinets

The handling mechanism should follow the principle of "prevention first, rapid detection, automatic blocking, and emergency isolation." Reference can be made to the following comprehensive handling mechanism based on best practices: Before leakage occurs, system design and hardware structure shall already incorporate multi-layer protection aimed at preventing leakage spread or mitigating damage.

5.4.1.1 Cabinet-Level Drip Pan

Mechanism: A drip pan made of stainless steel or anti-corrosion materials shall be designed at the bottom of all liquid-cooled cabinets, covering the entire bottom surface of the cabinet.

Function: Even if severe leakage occurs (e.g., pipe burst or connector detachment), the coolant will be confined within the drip pan, preventing it from flowing onto the equipment room floor, seeping into lower levels, or contacting non-liquid-cooled equipment.

Drainage port: The drip pan is equipped with a drainage port, which can be connected to a drain pipe to route liquid to a safe area or collection bucket.

5.4.1.2 Quick Disconnectors

Self-sealing function: Blind-mate quick disconnectors used on the secondary side shall possess a "dual self-sealing" function. When a server is pulled out or a connector is accidentally disconnected, the male and female connectors shall automatically and instantly seal to cut off fluid flow, ensuring that leakage volume at the moment of disconnection is extremely small (typically < 10 mL).

Poka-yoke design: The physical structure prevents abnormal disconnection caused by misoperation.

5.4.1.3 Piping Materials and Layout Optimization

Secondary-side hoses should adopt double-layer braided stainless steel pipes, EPDM pipes, or NBR rubber piping, featuring pressure resistance, corrosion resistance, and anti-aging properties.

Piping routing should avoid being directly above electrical components wherever possible, or an insulating protective sleeve should be added.

5.4.2 Proactive Detection and Automatic Response Mechanism

The proactive detection and automatic response mechanism is the core of the handling mechanism, which shall discover and respond within milliseconds to seconds.

5.4.2.1 Deployment of Multi-Level Leakage Detection Sensor Points

Cabinet bottom: A rope-type or point-type leakage detection cable shall be laid inside the drip pan, covering the entire bottom chassis.

Key nodes: Point-type sensors shall be added at high-risk locations such as manifolds, below quick disconnectors, and at pump outlets.

Inside servers: Some high-reliability solutions also deploy sensors at cold plate inlets or inside server chassis.

Detection principle: Liquid conductivity or changes in optical refractive index are utilized to trigger signals.

5.4.2.2 Automated Interlock Control Logic

Audible and visual alarms: Once sensors detect liquid, local audible and visual alarms shall be triggered immediately, and top-level alarms shall pop up in the monitoring system (DCIM/BMS).

Automatic valve shutoff (key step): Installation of cabinet-level motorized ball valves is recommended for all scenarios with high reliability requirements. When major leakage is detected, the system shall immediately interlock to close the corresponding secondary-side motorized ball valve for that cabinet. If leakage occurs on a specific server, the smart manifold may attempt to close only the miniature valve of that branch (if motorized control valves are configured).

Pump group shutdown: Corresponding secondary-side circulating pumps shall be interlocked to stop, reducing loop pressure and decreasing leakage volume from the source.

Server power-off (optional but recommended): When leakage is confirmed and cannot be stopped immediately, power to the cabinet or affected servers shall be remotely cut off via PDUs to prevent

electrical fires or equipment damage caused by coolant (even for non-conductive liquids, long-term immersion may cause short circuits or corrosion).

5.4.3 Emergency Response and Manual Handling Process

After the automatic mechanism is activated, O&M personnel shall intervene according to the following emergency plan:

1) Information reporting and confirmation

- After receiving the alarm, carry protective equipment (insulated gloves, goggles) and quickly arrive at the site.
- Confirm the leakage position, leakage volume, and whether flow shutoff has been automatically executed.

2) Physical isolation and cleaning

- Flow isolation reconfirmation: Manually close relevant valves to ensure that the loop is completely physically isolated.
- Liquid collection: Use absorbent cotton, absorbent pillows, or explosion-proof vacuum cleaners to clean up coolant in the drip pan. If the coolant is an ethylene glycol aqueous solution, it shall be disposed of as chemical waste; if it is a dielectric fluid, it shall be recovered and filtered.
- Drying check: Use heat guns or dryers to thoroughly dry damp areas, and use multimeters to test insulation resistance, ensuring no short-circuit risks exist before considering power restoration.

3) Fault locating and repair

- Inspect leakage points (whether connectors are not tightened, seal rings are aged, or pipes are ruptured).
- Replace damaged parts (O-rings, hoses, or connectors).
- Perform a pressure test to confirm that the repair is correct.

4) System recovery

- Reopen valves, start circulating pumps, and perform air venting operations.
- Observe operating parameters (flow rate, pressure, temperature) to confirm normal status.
- Gradually restore server power supply and service workloads.

For different types of coolant, the following considerations and handling shall be applied:

1) For water/ethylene glycol solution (conductive risk):

- Core risk: short circuits
- Key handling point: Power off the equipment first. After cleaning, insulation must be strictly tested, as residual moisture may cause subsequent corrosion or micro short circuits.

2) For dielectric fluids (e.g., fluorinated liquids, non-conductive):

- Core risk: Although non-conductive, they may cause poor connector contact, reduced heat dissipation efficiency, or environmental pollution
- Key handling point: The priority lies in recycling expensive coolants and cleaning surface oil stains. The priority of powering off is slightly lower than that for water cooling, but powering off remains recommended to prevent other secondary disasters.

Mechanism for handling accidental leakage of liquid media in the storage area:

For leakage of drummed coolant (e.g., 20 L/200 L drums or ton drums) in the storage area, the leakage level is much lower than that in the equipment room. However, the leakage shall still be handled according to the relevant handling mechanism.

Basic protection: Spill containment pallets (secondary containment) serve as the first and most crucial line of defense. All drummed liquids must be placed on leakage prevention trays that meet standards.

Tray capacity standards:

- Single-drum storage: Tray capacity shall be at least 110% of the drum volume (i.e., capable of holding the liquid in the entire drum with some extra capacity).
- Multi-drum storage: If multiple drums are placed on one tray, tray capacity shall be at least 110% of the maximum single-drum volume or 25% of the total volume of all drums (whichever is greater).

Material requirements:

- Water/ethylene glycol solution: High-density polyethylene (HDPE) or galvanized steel (requiring anti-corrosion spray coating).
- Fluorinated liquid/chemical solvent: Tray materials shall be confirmed to be resistant to chemical corrosion (stainless steel 304/316 or specific modified plastics are usually recommended) to prevent trays from being corroded and perforated, which may cause secondary leakage.

Routine inspection: Ensure that the drainage plug of the tray is in the closed position (unless connected to an automatic drainage system). The tray shall be kept dry and free of accumulated water or debris.

Hierarchical handling mechanism based on leakage volume: According to the volume and spread of leaked liquid, different response measures shall be taken:

(1) Minor leakage (< 1 L) scenario: The bucket lid is not tightened, the sampling port leaks, or there are tiny sand holes on the bucket body. Symptom: Liquid only forms a thin layer at the bottom of the leakage tray and does not overflow the tray edge. Handling procedure: Tighten/seal leakage: Wear gloves and try to tighten the bucket lid, or use leakage sealing adhesive or thread seal tape to temporarily seal the leakage point. Absorb and clean up: Use liquid-absorbing cotton or pillows to absorb the liquid in the tray. Transfer: If the bucket body is damaged and cannot be repaired, move the entire bucket to a spare empty bucket for decanting transfer (conducted inside the tray). Record: Record the loss volume and replenish new liquid.

(2) Moderate leakage (1 L to 80% of tray capacity) scenario: The bucket body cracks, the valve breaks, or the bucket is overturned. Symptom: Liquid level in the tray rises significantly and is close to the warning line, but does not overflow to the ground. Handling procedure: Personnel protection: Wear goggles and chemical-resistant gloves (wear gas masks if handling ethylene glycol). Cut off source: If there is remaining liquid, immediately stand the bucket upright or close the valve. If the valve cannot be closed, quickly prepare a spare empty bucket for decanting transfer. Pumping operation: If the tray is equipped with a manual or electric liquid drainage valve, open the valve to drain the liquid into a dedicated waste liquid collection bucket. If there is no drainage valve, use an explosion-proof portable pump or large syringe to extract liquid. Clean thoroughly: Use a large amount of liquid-absorbing cotton to clean up residual liquid, and check whether the tray is corroded or damaged.

(3) Large-scale leakage (> tray capacity or tray failure) scenario: The bucket body bursts, the bucket is broken due to forklift impact, or the tray is broken. Symptom: Liquid overflows the tray and flows to the floor of the storage area, or even to floor drains or power distribution areas. Handling procedure: Emergency alarm and evacuation: Immediately trigger the alarm and evacuate irrelevant personnel. If the liquid is volatile (fluorinated liquid), start forced exhaust ventilation. Containment and interception (most critical): Quickly use liquid-absorbing sandbags, inflatable water barriers, or absorbent strips to build a cofferdam at the entrance of the storage area and around floor drains to prevent liquid from spreading to other areas. Source control: Under safe conditions, attempt to push the damaged bucket into a larger emergency collection pit or cover it with a large leak-proof

cover. If the bucket cannot be moved, directly seal the leakage point (using a quick leakage sealing clamp). Large-scale recovery: Use an explosion-proof industrial vacuum cleaner or a high-power submersible pump to pump accumulated liquid on the ground into an emergency pool or a large waste liquid tank. Lay out a large amount of absorbent cotton or absorbent granules to handle residual thin layers. Follow-up disposal: Detect residual concentration on the ground and clean the ground. All contaminated absorbent materials and sandbags shall be sealed as hazardous waste and handed over to a qualified entity for disposal.

Special note: Ethylene glycol solutions or chemical coolants are strictly prohibited from being directly flushed into the sewer. If leakage occurs at night or in an unattended area, capacity redundancy of the leak-proof tray is the only guarantee to prevent catastrophic consequences; integrity of the tray must be inspected regularly.

5.5 Guidelines for Use of Liquid Cooling Media and Hazardous Waste Storage Management

The following describes the storage of hazardous waste liquid cooling media:

First, hazardous waste generated by each discipline shall be collected and classified. For substances defined as hazardous waste, an application for transfer planning shall be submitted to the responsible person, and the responsible person shall designate a dedicated person to transfer the hazardous waste to the hazardous waste warehouse. (Personnel engaged in hazardous waste collection and transfer operations shall be equipped with necessary personal protective equipment, such as gloves, protective goggles, protective clothing, gas masks, or masks, according to work requirements.) For substances defined as recyclable, the corresponding coolant recycling vendor shall be contacted to recycle such substances in compliance with regulations. Before recycling, necessary measures such as recycling qualification certification, recycling scheme confirmation, recycling substance flow confirmation, and a compliance recycling guarantee shall be completed.

Substances defined as hazardous waste shall be placed in dedicated hazardous waste storage warehouses (including temporary storage areas). Hazardous waste identification signs shall be set in this area according to regulations. All containers storing hazardous waste need to be labeled. The labels provide key information for employees in the workplace, transportation, or storage areas to correctly handle their respective materials to protect themselves and the environment, and to ensure appropriate responses can be made in case of emergencies or accidents. The responsible person shall check hazardous waste identification signs and labels every week.

The hazardous waste storage warehouse (or temporary storage area) shall use clear signs or ground markings to clearly mark locations for waste sorting and collection, avoiding secondary pollution (such as in warehouses or designated locations). Hazardous waste shall be stored in separate zones according to chemical compatibility. Low walls or ground markings with clear intervals (such as aisles) shall be set up between different zones. Acids and alkalis shall not be mixed, oxidants shall not be mixed with organic substances, and cyanides shall not be mixed with acids. Special notice for liquid hazardous waste storage: Containers shall not be filled to the brim. A space of at least 100 mm shall be reserved between the top of the container and the liquid surface. Even if liquid hazardous waste is stored indoors, secondary containment shall always be provided to prevent leakage, and the secondary containment shall be kept in good condition. The responsible person shall inspect the hazardous waste in the hazardous waste storage warehouse (or temporary storage area) every week. The reference diagram for waste liquid labels is shown below:



Figure 1 Reference diagram for waste liquid labels

Generated waste shall be packaged as required and delivered to designated temporary storage points, where the responsible person shall receive and place the waste in a unified planned manner. The responsible person shall be responsible for routine inspections of hazardous waste collection, storage, packaging, and transfer points at the local site, at a frequency of at least once a month, to ensure compliance with regulatory requirements, proper operation of the ventilation system, and regular inspection and maintenance of the system.

The onsite emergency plan shall also include instructions on how to handle hazardous waste generated during emergency or abnormal situations. Onsite emergency response disposal plans shall be placed on site. In the event of a hazardous waste leakage, immediate reporting shall be made to the data center manager and the emergency organization. If possible, the leakage source shall be immediately cut off, the leakage area shall be isolated, and signs stating "Do Not Approach" shall be set up.

Hazardous waste leakage includes but is not limited to the following situations: leakage caused by damage to storage containers; leakage caused during transportation; leakage of hazardous waste caused by operation errors; and leakage of hazardous waste caused by fire or explosion. The maximum storage period of hazardous waste in the warehouse shall not exceed one year. If an extension is indeed necessary, it shall be reported to the higher-level environmental protection department for approval.

5.6 Guidelines for Waste Liquid Disposal

The responsible person for substances defined as hazardous waste shall fill in the Hazardous Waste Handling Application List within 60 days after the hazardous waste is stored in the warehouse, complete internal filing within the company, and apply for hazardous waste disposal. The responsible person shall send a demand email to relevant departments such as corresponding commercial personnel and administrative personnel, and retain email records of the internal hazardous waste transfer process.

The responsible person for substances defined as recyclable materials shall complete the coolant vendor recycling procedure within 60 days after recyclable materials are stored in the warehouse. The coolant vendor shall provide a certificate containing the recycling time, quantity, and coolant type to

relevant departments such as corresponding commercial personnel and administrative personnel to complete closed-loop management.

5.6.1 Guidelines for Waste Liquid Transfer and Disposal of Secondary-Side Liquid Cooling Media

Vehicles transporting hazardous waste must meet Chinese requirements for dangerous goods transport vehicles. The responsible person shall inspect transport vehicles before loading hazardous waste.

The responsible person shall inspect loading, transport, and unloading activities related to hazardous waste, especially hazardous waste packaging and proper labeling.

After onsite hazardous waste transfer is completed, the responsible person shall request the approved weight on the current hazardous waste transfer settlement sheet from the supplier, create transfer manifests for relevant government agencies (within the province or city) on government hazardous waste management system platforms, and archive manifests locally after the overall transfer manifest is completed.

The final responsible person shall hand over settlement sheets related to the current hazardous waste transfer to administrative personnel to enter the settlement phase.

5.6.2 Emergency Response and Rescue

In the event of a general leakage accident, hazardous chemical user units shall handle the accident according to physical and chemical properties specified in safety data sheets of hazardous chemicals, and report to the EHS management responsible person at the same time.

In the event of a severe leakage accident, immediate reporting shall be made to the safety and environmental protection department, and corresponding emergency rescue shall be initiated. Prompt measures such as sealing and isolation shall be taken against hazards and potential hazards caused to human bodies, soil, water sources, and air. If necessary, immediate reporting shall be made to local safety supervision and management departments, public security departments, and environmental protection departments.

6 Description of Cold Plate Liquid Cooling O&M Tools

6.1 Introduction to Tools and Instruments for Cold Plate Liquid Cooling Maintenance Handover

Currently, liquid cooling piping and valves with mature processes should be prefabricated at the factory side, and subjected to pickling and neutralization, passivation, cleaning, and drying [cleaning methods include ultrasonic cleaning, high-pressure water flushing, UV light inspection, etc.]. Then, piping components and valves shall be sealed and packaged, and finally delivered to the construction site.

At the site, a dedicated area shall be demarcated using isolation tape to store the above secondary-side piping components, and plastic film isolation and coverage protection shall be applied to avoid confusion and secondary pollution. During onsite installation operations, torque re-checking shall be strictly performed according to required tightening torques for different models of bolts provided by manufacturers, and lines shall be marked on bolts and nuts using red and blue marker pens. Tools commonly used in this process include ordinary adjustable open-end wrenches and digital torque wrenches required for secondary re-checking.

Note: During the entire process installation, whenever bolt or screw tightening is involved, the use of thread seal tape and liquid adhesive is prohibited to avoid secondary reactions with the medium.

The following table shows a reference check record for bolt torque on liquid cooling piping.

Table 11 Secondary-side piping torque check record

Secondary-side piping Torque Check Record			
Piping Bolt Torque Standards			
Name	**Specifications**	**Bolt (grade 8.8)**	**Recommended Torque (N·m)**
Flange	DN50-DN125	M16	80±5
Flange	DN150-DN200	M20	85±5
Flange	DN250	M24	90±5
Clamp	DN25	\	6-8Nm
Clamp	DN50	\	6-8Nm
Pipe Bolt Torque Table - Recommended Value - ICV Valve			
Name	**Specifications**	**Bolt (grade 8.8)**	**Recommended Torque (N·m)**
Butterfly valve/Filter/Check valve	DN50-DN125	M16	85
Butterfly valve/Filter/Check valve	DN150-DN200	M20	163
Butterfly valve/Filter/Check valve	DN250	M24	288

Equipment Room Location	**Data Center *** Equipment Room**				**Engineering Quality Inspection**	**Other Issues**	**Remarks**
CDU01	Supply		Return				
CDU02	Supply		Return				
CDU03	Supply		Return				
CDU04	Supply		Return				
Column-01	Supply		Return				
Column-02	Supply		Return				
Column-03	Supply		Return				
Column-04	Supply		Return				
Column-05	Supply		Return				

After the pipes are installed and secured, check whether the onsite process meets the requirements for flushing and pressure testing.

Note: Rotate the valve on the secondary side to fully closed and fully open, and confirm that the valve operates smoothly over its full range and can be fully closed/opened at 90°. The other end of the ball valve is equipped with a dustproof cap. The pipe labels (main pipe and branch pipe) and valve labels are complete. Prepare one or two external circulating pumps (20–40 m³/h) in advance. Based on the number of servers and the distance between the servers, prepare an appropriate number of EPDM short pipes (rubber hoses) in advance. In addition, prepare an appropriate number of floor suction devices to check whether there is leakage under the raised floor during the flushing and pressure testing. Also, prepare soap water, PH detector, conductivity meter, turbidity meter, portable bacterial detector, digital pressure gauge (precision: 0.1 kPa), and other instruments in advance for real-time detection during the flushing and pressure testing. Some of the tools are as follows:



Figure 2 Digital pressure gauge (precision: 0.1 kPa)



Figure 3 Digital torque wrench

6.2 Tools for Routine O&M of Cold Plate Liquid Cooling

During the routine use of cold plate liquid cooling, various types of tools are involved. The following tools can be used as a reference: an external liquid refill pump, a liquid refill needle, a liquid refill hose, and intact spare barrels of glycol stored onsite for routine liquid refill. The torque wrench is used to tighten the butterfly buckles on the secondary side of the CDU and check the torque of the bolts on the liquid cooling pipes. The small oil-free air compressor and air pressure gauge are used to preserve the pressure of the liquid-cooled cabinet when a new cabinet is installed. The waste liquid collection bucket, protective face shield, goggles, and gloves are used to collect leaked liquid and protect the personnel from the leakage. The floor suction device is used to open and move the raised floor during the installation of the cold plate liquid cooling system.

The following table lists the common operation tools.

Table 12 Tools for routine O&M of cold plate liquid cooling

Tool Description	Remarks
Liquid refill needle	External liquid refill on the secondary side of the CDU
Liquid refill pump	Quick liquid refill for the CDU liquid storage tank
Barrel of glycol/pure water	External flexible storage unit for the secondary coolant of the CDU
Torque wrench	Standard test tool for tightening butterfly buckles on the CDU secondary side
Caliper	Pipe tightening
Small oil-free air compressor	Pressure preservation for the liquid-cooled cabinet
Gas pressure gauge	Pressure measurement for the liquid-cooled cabinet
Waste liquid container	Liquid collection at leakage points
Rubber gloves	Work use
Goggles	Protection against liquid splashing into eyes
Diagonal pliers	Cutting of cable ties
Hex key	Securing the butterfly buckle cover
Screwdriver	Securing of the butterfly buckle
Floor suction	Opening and moving of raised floors

During daily use of cold plate liquid cooling, monitoring the coolant is also a key part of O&M work. To better monitor water quality on the secondary side and prevent potential risks, vendors may require some simple onsite water quality test items to be completed at the O&M site and some periodic water quality indicators to be completed in qualified laboratories.

The following table lists the test items that can be quickly completed onsite.

Table 13 Reference quick water quality test items for the secondary side of cold plate liquid cooling

Item	Unit	Applicable GCC Standards	Testing Device	Recommended Brands (Equivalent Brands Allowed)
Appearance		Clear solution without impurities, sediment, or suspended particles	Visual inspection	None
Glycol concentration/Propylene glycol Concentration	%	*Technical Requirements and Test Methods for Glycol-based Cold Plate Coolant* *Technical Requirements and Test Methods for Cold Plate Coolant (Applicable to Deionized Water)*	Portable freezing point tester	1. Brand: Delixi; Product name: Handheld freezing point tester; Model: DLX-ARF102 2. Brand: Pyxis; Product name: Handheld freezing point tester; Model: SP-230R
Conductivity	μS/cm		Conductivity	1. Brand: Lichen; Product name:

Item	Unit	Applicable GCC Standards	Testing Device	Recommended Brands (Equivalent Brands Allowed)
(25 °C)	(25 °C)	*Compatibility Requirements and Test Methods for Wetted Materials in Single-Phase Cold Plate Liquid Cooling (Applicable to Glycol-based)* *Compatibility Requirements and Test Methods for Wetted Materials in Single-Phase Cold Plate Liquid Cooling (Applicable to Deionized Water)*	measuring instrument	Pen-type conductivity meter; Model: CT-2 2. Brand: Pyxis; Product name: Handheld multi-parameter meter; Model: SP-505 3. Brand: Leici; Product name: Benchtop conductivity meter; Model: DDS-11A
Total bacterial count	CFU/ml		Bacterial test strip	1. Brand: Pyxis; Product name: Bacterial test strip; Model: AB-T&YM-R 2. Brand: 3M; Product name: Total bacterial count test strip; Model: 6406
Turbidity	NTU		Turbidity measurement instrument	1. Brand: Lichen; Product name: Portable turbidity meter; Model: WGZ-1B 2. Brand: Pyxis; Product name: Handheld multi-parameter meter; Model: SP-505 3. Brand: Hach; Product name: Portable turbidity meter; Model: 2100Q
pH value	/		pH meter	1. Brand: Lichen; Product name: Pen-type pH meter; Model: PH-100 2. Brand: Pyxis; Product name: Handheld multi-parameter meter; Model: SP-505 3. Brand: Mettler; Product name: Benchtop pH meter; Model: FE28

The following table lists some periodic water quality indicators that need to be tested by qualified laboratories.

Table 14 Reference periodic sampling water quality test items for the secondary side of cold plate liquid cooling

Test Item	Unit	Normal O&M Range	Test Method and Basis
Appearance	/	Clear solution, without impurities, sediment, or suspended particles	References: *Technical Requirements and Test Methods for Glycol-based Cold Plate*
Freezing point (Ethylene glycol	%	Provided by the implementer before delivery	

Test Item	Unit	Normal O&M Range	Test Method and Basis
concentration/Propylene glycol concentration)			*Coolant* *Technical Requirements and Test Methods for Cold Plate Coolant (Applicable to Deionized Water)* *Compatibility Requirements and Test Methods for Wetted Materials in Single-Phase Cold Plate Liquid Cooling (Applicable to Glycol-based)* *Compatibility Requirements and Test Methods for Wetted Materials in Single-Phase Cold Plate Liquid Cooling (Applicable to Deionized Water)*
Conductivity (25 °C)	μS/cm	Provided by the implementer before delivery	
Total bacterial count	CFU/ml	Provided by the implementer before delivery	
pH Value	/	Provided by the implementer before delivery	
Turbidity	NTU	Provided by the implementer before delivery	
Total hardness (as CaCO3)	mg/L	Provided by the implementer before delivery	
Total iron	mg/L	Provided by the implementer before delivery	
Total copper	mg/L	Provided by the implementer before delivery	
Chloride ion content	mg/L	Provided by the implementer before delivery	
Sulfate content	mg/L	Provided by the implementer before delivery	

All water quality test data shall be subject to test data from qualified laboratories. When onsite test data is non-compliant or abnormal, test items from qualified laboratories shall be completed as soon as possible, and non-compliant water quality items shall be handled in a closed-loop manner.

7 Document Recording and Management

7.1 Guidelines for Main Equipment Ledger of Cold Plate Liquid Cooling

The main equipment ledger of cold plate liquid cooling shall record the model, specifications, manufacturer, installation date, maintenance period, and other key parameters of equipment, effectively monitor the health status of the system, prevent potential faults, and ensure timely maintenance and updates.

The following table provides a reference ledger.

Table 15 Reference main equipment ledger of cold plate liquid cooling

Main Equipment	Main Equipment Type	Warranty Status	Main Equipment Qt	Spare Parts Description	Spare Parts Type	Detailed Position Explanation	Supplier/ Manufacture	Vendor No. / Manufacturer	Unit	Quantity Used
Main equipment name	Main equipment model	Out of warranty	Quantity of main equipment of the same model	Spare parts description	Spare parts model	Additional description	Supplier / Manufacturer	Supplier / Manufacturer serial number	Unit	Inventory quantity
XX	XX	XX	XX	CDU control cable	/		/		PCS	X

7.2 Guidelines for Registration and Use Records of Cold Plate Liquid Cooling Tools and Media

A management and use registration system for tools and instruments as well as secondary media usage records shall be established. By documenting the usage of each tool and instrument and the requisition and usage records of secondary media in detail, the operations team can effectively monitor equipment status, optimize resource allocation, and reduce the risks of fault occurrence and resource misallocation or waste.

The following table is an example of registration form for the media requisition.

Table 16 Requisition registration form for cold plate liquid cooling media

No.	Requisition Date	Recipient	Media Type	Requisition Quantity (L)	Purpose Description	Remaining Inventory (L)	Remarks
1	2025-12-01	Zhang San	Ethylene glycol mixture	50	New equipment filling	200	None
2	2025-12-05	Li Si	Ethylene glycol mixture	30	System replenishment	170	None
3	2025-12-10	Wang Wu	Deionized water	40	Equipment cleaning	160	Pay attention to safe operation.
4	2025-12-15	Zhao Liu	Ethylene glycol mixture	20	Leakage replenishment	140	Inspect leakage points.

The following table is an example of registration form for daily tool and instrument requisition.

Table 17 Requisition registration form for daily tools and instruments of cold plate liquid cooling

No.	Tool / Instrument Name	Tool / Instrument No.	Recipient	Dept.	Requisition Time	Purpose of Use	Return Time	Tool / Instrument Status	Remarks
1									
2									
3									
4									

7.3 Guidelines for Cold Plate Liquid Cooling Inspection Records

Table 18 Inspection record for cold plate liquid cooling

Inspection Module	Inspection Item	Inspection Content	Status (Normal / Abnormal)	Inspector	Inspection Time
CDU system	Water quality test	Appearance, pH, conductivity, turbidity, bacterial content, and other items required by vendors			
	Circulating pump check	Vibration, abnormal noise, and temperature			
	Liquid refill tank	Liquid level height			
	Piping	Air release valve and thermal insulation			
	Filter	Differential pressure across the filter			
	Leakage check	Obvious leakage at the bottom of the CDU (minor leakage of circulating water pump)			
Water pump	Check valve after pump	No abnormal sticking of check valve			
	Water pump connection piping	Good thermal insulation, without condensation or dripping			
	Water pump seal	No water dripping or leakage risks			
	Vibration and abnormal noise	No abnormal vibration or noise			

Inspection Module	Inspection Item	Inspection Content	Status (Normal / Abnormal)	Inspector	Inspection Time
	Temperature	Risks exist if pump body temperature exceeds 85 °C or motor temperature exceeds 95 °C			
	Lubrication	Lubricating oil shall be injected if operating time exceeds 3,000 hours			
Cooling tower system	Cooling tower valves	Inlet and outlet valves open and close normally			
	Float valve	Manually check whether float valve moves freely without damage			
	Blockage check	Overflow pipe and water refill pipe blocked or not			
	Cleaning and decontamination	Packing cleaning and water pan cleaning			
	Component check	Motor belt, bearing oiling, fan, and electric heater			
	Power distribution	Cable check and current check			

7.4 Guidelines for Cold Plate Liquid Cooling Media Test Records

Routine operation and maintenance of the liquid cooling system, especially content related to coolants, shall be supported by long-term and sound document recording, management, and data analysis measures. Document recording and management shall be completed using information technology, such as a traditional DCIM platform combined with locally deployed AI inference tools (for information security reasons, cloud-based AI tools are not recommended). Daily operation records, inspection records, test records, and laboratory test results shall all be uploaded to the DCIM platform, which shall automatically extract relevant information from each file to generate trend records, comparisons, and analyses.

Relevant data will provide guidance and tracking for spare parts replacement, liquid storage management, coolant dosing, waste liquid management, and other activities.

The following table provides an example of the sampling and test record form.

Table 19 Test record form for cold plate liquid cooling media

No.	Equipment Room and Smart Module	Conductivity	Turbidity	pH Value	Ethylene Glycol Concentration	Remarks	Inspector
1	XX Module Room-01 Smart Module	3620	0	8.8	22.2	Normal	XX

No.	Equipment Room and Smart Module	Conductivity	Turbidity	pH Value	Ethylene Glycol Concentration	Remarks	Inspector
2	XX Module Room-02 Smart Module	3680	0	8.67	15.0	Abnormal: notify vendor, send to testing agency, and wait for disposal scheme.	XX
3	XX Module Room-03 Smart Module	3700	0	8.77	22.2	Normal	XX

7.5 Classification of Handling Levels for Abnormal Indicators of Cold Plate Liquid Cooling Media Operation and Maintenance

Stable and real-time monitoring of liquid cooling media water quality indicators shall be ensured to detect water quality changes. O&M monitoring personnel shall respond quickly to each abnormal water quality indicator to ensure the safety and reliability of the entire liquid cooling system. Refer to the following classification of abnormal water quality indicators to improve O&M efficiency and reduce the probability of liquid cooling system risks.

Table 20 Classification of exception handling levels for cold plate liquid cooling media

Test Item	O&M Indicator	Impact / Handling Level	Emergency Intervention Suggestion
Appearance (If CDU has a sight glass, refer to sight glass)	Clear solution, without impurities, sediment, or suspended particles	Very severe/Level I	If visible sediment, precipitates, or suspended solids are found, retain system liquid and urgently replenish deionized water to flush the liquid cooling system, preventing sediment from blocking cold plates and affecting system heat dissipation. After emergency handling, contact the coolant vendor and equipment vendor to analyze the coolant fault and perform subsequent handling.
pH value (20 °C)	7.5-10.5	Very severe/Level I	pH represents acidity or alkalinity of coolant. If pH is lower than 7.0, system corrosion risk increases exponentially, sharply increasing risk to liquid cooling system reliability. Contact the coolant supplier immediately to handle the coolant. In an emergency, deionized water or original brand coolant may be injected to replace system coolant to reduce system corrosion risk.
Turbidity	≤10 NTU	Very severe/Level I	Increased turbidity is related to appearance. If visible sediment, precipitates, or suspended solids appear, retain system liquid and urgently replenish deionized water to flush the liquid cooling system, preventing sediment from blocking cold plates and affecting system heat dissipation. After emergency handling, contact the coolant

Test Item	O&M Indicator	Impact / Handling Level	Emergency Intervention Suggestion
			vendor and equipment vendor to analyze the coolant fault and perform subsequent handling.
Total bacterial count	<1000 CFU/ml	Very severe/Level I	Total bacterial count is generally required to be lower than 100 CFU/ml. If detected bacteria exceed 1000 CFU/ml, a bacterial outbreak risk exists. Bacterial proliferation in the system affects coolant appearance and increases under-deposit corrosion risk, posing huge risks to liquid cooling system safety. If total bacterial count exceeds standards, contact the coolant vendor immediately to handle the coolant. In an emergency, deionized water may be injected for replacement handling; however, after emergency handling, contact the coolant vendor and equipment vendor to analyze the coolant fault and perform subsequent handling.
Alcohol content (Refractive index)	>20%	Severe/Level II	If alcohol content drops below 20%, risks exist in bactericidal capability and stability of liquid. Contact the coolant vendor as soon as possible for evaluation and handling. Handling suggestions include replenishing high-concentration EG/PG containing inhibitors or completely replacing secondary-side coolant of the system.
Total iron	≤5 ppm	Severe/Level II	Increases in total iron and total copper indicate corrosion. If continuous increases occur, contact the coolant vendor as soon as possible for evaluation and handling. If corrosion is caused by corrosion inhibitor failure or bacterial growth, perform timely handling and conduct a risk assessment on existing system corrosion to ensure liquid cooling system stability.
Total copper	≤5 ppm	Severe/Level II	
Conductivity (25 °C)	Initial value ±50%	Intervention required/Level III	Conductivity represents chemical content in coolant on one hand, and degree of corrosion or bacterial growth on the other. Generally, system conductivity remains stable without large fluctuations. If conductivity fluctuates by ±50% in a short period, it indicates intensified chemical concentration or corrosion degree in the system. Contact the coolant vendor as soon as possible for evaluation and handling. Identifying the cause before handling is recommended.

Test Item	O&M Indicator	Impact / Handling Level	Emergency Intervention Suggestion
Total hardness (as CaCO3)	≤50 ppm	Intervention required/Level III	Increased total hardness affects system scaling risk. Hardness increase is generally a gradual process, and its growth value can be paid attention to during long-term water quality monitoring. When exceeding or approaching recommended O&M indicators, contact the coolant vendor and equipment vendor in a timely manner to perform intervention and handling regarding hardness increase causes and disposal schemes.
Chloride ion	≤25 ppm	Intervention required/Level III	Increased chloride ions increase system corrosion risk. Avoiding chlorine-containing biocides is recommended. If content increases due to improper chemical use by the coolant vendor, timely intervention and handling shall be performed on the system.
Sulfate (as SO42-)	<50 ppm	Intervention required/Level III	Increased sulfate increases system corrosion risk, and its increase is generally a gradual process. Its growth value can be paid attention to during long-term water quality monitoring. When exceeding or approaching recommended O&M indicators, contact the coolant vendor and equipment vendor in a timely manner to perform intervention and handling regarding increase causes and disposal schemes.

1. Level I: Very severe, belonging to "urgent intervention" level indicators. Immediate intervention and handling shall be performed within 30 minutes.
2. Level II: Severe, belonging to "intervention as soon as possible" level indicators. Intervention and handling shall be performed within 48 hours.
3. Level III: Intervention required, belonging to "preventive intervention" level indicators. Causes shall be identified and intervention plans formulated within 7 days, with handling completed within 1 month.

Note: The above urgency definitions are for reference only. Actual core indicators strictly controlled by users during operation shall serve as benchmarks to define urgency.

The above suggestions and schemes for handling abnormal O&M indicators are limited to protection schemes for liquid cooling systems under emergency states. The final coolant handling scheme after emergency handling shall strictly follow vendor technical requirements and comprehensive solutions provided by coolant vendors.

Appendix A

A.1 Checklist for Formal Operation

To ensure a solid operation foundation, the liquid cooling system O&M team should get involved in the test and acceptance process in advance to familiarize themselves with the system design, operating principles, and key test results. The checklist includes but is not limited to the following:

No.	Documentation	Remarks
Design		
1	As-built drawings: including but not limited to floor plans/professional system diagrams/installation detail drawings	
2	HVAC BA system control description	
3	HVAC system control communication point table	
4	CDU control logic description	
5	HVAC load calculation report/Hydraulic balance calculation report	
6	Test report on compatibility between secondary-side media and wetted materials	
7	Secondary-side media selection description	
8	Technical description of waterproof design for liquid cooling equipment rooms	
Product		
1	Product brochure/User manual/Factory quality inspection report	
2	Equipment list/Product manual, etc.	
3	Equipment selection report (consistent with final equipment procurement)	
4	Equipment contract (warranty/maintenance/spare parts clauses in the contract)	
5	Description of secondary-side filter mesh count and rating adaptability	
6	List of core spare parts related to liquid cooling	
7	Piping materials: secondary-side piping material qualification certificates (including manifolds and valves)/description of deionized water materials/description of ethylene & propylene glycol materials/clamps/description of stainless steel flange materials/raised floor load-bearing description	
8	Supplier/Installer contact list	
Test		
1	Technical documents for CDU test scheme, system joint commissioning test scheme	
2	Heat load test report	
3	Joint commissioning test report	

No.	Documentation	Remarks
4	Water quality test report	
5	Stainless steel flaw test report	
6	Pickling report/Flushing report	
7	Description of torque standards for secondary-side piping valve flanges/and torque checklist	
8	Primary-side/Secondary-side pressure test report	
9	Completion sign-off report	
10	Initialization-related items [Valve tightness re-check/Piping filter dirt and clogging re-check/Equipment parameter setting re-check/Alarm threshold initialization for each discipline/Parameter setting initialization for each discipline]	
11	Description of liquid cooling piping acceptance criteria	

A.2 List of Reference Specifications

1. ASTM D15.30: Sub-committee on Industrial Heat Transfer Fluids/HVAC
2. ASTM D8040: Standard Test Method for Corrosion Test for Heat Transfer Fluids in Glassware
3. ASTM D8039: Standard Specification for Heat Transfer Fluids (HTF) for Heating and Air Conditioning (HVAC) Systems
4. YD/T 3980-2021 Data center cold plate liquid cooling server system technical requirements and test methods
5. T/CIE 088-2020 Code for Design of Non-Water Cold Plate Indirect Liquid Cooling Equipment Room

   Applicable provisions for fluid connectors and connection assemblies of server and storage equipment in cold plate liquid cooling information equipment are as follows. Among them, for dated reference documents, only the version corresponding to that date applies to this Specification; for undated reference documents, the latest version (including all amendments) applies to this Specification.
6. GB/T 1690-2010 Rubber, vulcanized or thermoplastic—Determination of the effect of liquids
7. GB/T 2423.16 Environmental testing—Part 2: Test methods—Test J and guidance: Mold growth
8. GB/T 2828.1 Sampling procedures for inspection by attributes—Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection
9. GB/T 2941 Rubber—General procedures for preparing and conditioning test pieces for physical test methods
10. GB/T 5861 Hydraulic fluid power—Quick action couplings—Test methods
11. GB/T 5095.2 Electromechanical components for electronic equipment—Basic testing procedures and measuring methods—Part 2: General examination, electrical continuity and contact resistance tests, insulation tests and voltage stress tests
12. GB/T 5568 Rubber or plastics hoses and hose assemblies—Hydraulic-pressure impulse test without flexing

13. GB/T 6031 Rubber, vulcanized or thermoplastic—Determination of hardness
14. GB/T 10125 Corrosion tests in artificial atmospheres—Salt spray tests
15. GB/T 11547 Plastic—Methods of test for the determination of the effects of immersion in liquid chemicals
16. GB/T 36176 Vacuum technology—Vacuum leak testing method by helium mass spectrometer
17. GJB 420B-2015 Solid particle contamination classes for fluid of aviation
18. Reference regulations for hazardous waste of cold plate liquid cooling
19. Environmental Protection Law of the People's Republic of China
20. Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste
21. National Directory of Hazardous Wastes [B1]
22. GB 18597-2023 Standard for pollution control on hazardous waste storage
23. Measures for the Administration of Hazardous Waste Transfer Manifests [B2]
24. HJ 1259-2022 Technical guideline for deriving hazardous waste management plans and records
25. National Directory of Hazardous Wastes (2025 Edition)