Open Specification for Liquid Cooled Rack Transfer Fluid

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**Open Specification for Liquid Cooled Rack – Transfer Fluid**

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**PROJECT DESCRIPTION [to be removed from specification]:**

The objective of this project is to propose and promote an open specification for the construction of liquid cooled computer racks. This Transfer Fluid specification below would be one section of a comprehensive Specification for the overall Liquid Cooled Rack System. The other sections of the Specification would include Wetted Materials, Quick Connects, In-rack Manifold Design, Tubing (flex hoses), Piping, Instrumentation and Controls, Operating conditions including Temperature, Pressure, Filtration, and Safety. All sections within this Open Specification for a Liquid Cooled Rack must be mutually compatible. Compatibility is driven by the wetted materials, the transfer fluid, connectors, and operating conditions (e.g., temperatures and pressure). In the case of the transfer fluid, compatibility is particularly important with the wetted materials list.

The transfer fluid would be used in the secondary or closed loop between the heat exchanger (e.g., Cooling Distribution Unit (CDU)) and the cold plates or other heat exchangers within the rack/servers. This loop is designated the technology cooling system (TCS) by the [American Society of Heating, Refrigerating and Air Conditioning Engineers](https://www.ashrae.org/) (ASHRAE).  The overall goal is to encourage multi-vendor solutions for liquid cooled computer racks where the liquid cooling infrastructure can be reused through multiple refreshes of liquid cooled computer hardware. Unlike a homogeneous supercomputer system, a rack meeting this specification may hold disparate information technology hardware from multiple manufacturers.

The primary audiences for the Specification for a Liquid Cooled Rack as well as this particular Transfer Fluid section are design and facility engineers and managers who will be responsible for the design and procurement of the construction. A secondary audience is the liquid cooling equipment suppliers whose products could be evaluated as compliant or non-compliant with this specification.

Salient characteristics of the overall specification include:

1. Water based non-glycol transfer fluid.
2. A limited wetted material list with no aluminum or carbon steel (additional materials require additional care).
3. A closed secondary loop between the CDU (not specified) and the servers (not specified). A closed loop reduces the complexity of water treatment with very limited oxygen or new sources of contaminants. Both the CDU and the servers must be compatible with this specification (e.g., wetted material list).
4. The initial fill will be with clean and sterile water, treated to assure high quality.
5. The operating temperature will be low (not expected to go over 150°F, and generally under 120°F).
6. The specification does not address the “facility” side of the CDU (although there is an Open Compute Project (OCP) group working on that, and ASHRAE provides guidance).

There are multiple options for liquid cooling of IT racks, including options for the transfer fluid. For example, OCP has developed a specification for a transfer fluid using water and 25% propylene glycol (PG25). The owner and design team will need to assess the specific needs of the project including potential water sources to determine the suitability of this specification, and modify it accordingly. Further the construction contractor, IT system supplier, and water treatment company should agree on the suitability and may propose alternatives (subject to approval) via the treatment plan to be submitted. It is important that the transfer fluid water treatment as well as the allowed wetted materials be thoroughly documented and maintained through refresh cycles and other future changes/additions to the system.

This work is being coordinated with other industry organizations including [American Society of Heating, Refrigerating and Air Conditioning Engineers](https://www.ashrae.org/) (ASHRAE), and the [Open Compute Project](https://www.opencompute.org/) (OCP). Other specifications are being developed by OCP for other liquid cooling solutions such as immersion cooling and rear door heat exchangers.

This specification generally follows the Construction Specifications Institute (CSI) three-part format including General Requirements, Products and Execution.

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**INSTRUCTIONS:**

Edit this specification for project specific requirements by adding, deleting, or revising text. Remove information and specifications not required. For bracketed items [example], choose applicable item(s) or insert appropriate information. Some specifications contained herein will need to be adjusted relative to the scale or size of the project. The rigor of some specifications may be reduced for small or less critical systems and increased for larger ones based on relative risk. For example, the frequency of fluid testing will likely be higher for larger or more critical systems, as would the use of automated monitoring. Each project will require customization of the specifications.

**SECTION 23 25 00 – WATER BASED TRANSFER FLUID - TREATMENT FOR CLOSED-LOOP HYDRONIC SYSTEMS**

**PART 1 - GENERAL**

**1.1 GENERAL REQUIREMENTS**

1. [Reference Contract conditions, including General Conditions and Supplementary Conditions applying to this this work].
2. References: The publications listed below form a part of this specification to the extent referenced. [List publications cited in the specification. Consider governmental and other regulatory agencies that may vary based on geographical location of the site.]
3. OCP
   1. [add titles and links as they become available]
4. ASHRAE
   1. Water-Cooled servers, common designs, components, and processes, White Paper. ASHRAE 2019. <https://www.ashrae.org/File%20Library/Technical%20Resources/Bookstore/WhitePaper_TC099-WaterCooledServers.pdf>
   2. Liquid cooling guidelines for datacom equipment centers, second edition. ASHRAE 2014 [or latest edition].
5. [ISO 9001: 2015 Quality management systems — Requirements](https://www.iso.org/standard/62085.html)
6. American Society for Testing and Materials (ASTM):
   1. “Standard Test Methods for Corrosivity of Water in the Absence of Heat Transfer (Weight Loss Method),” ASTM D2688-94 (West Conshohocken, PA, ASTM, 1996).
   2. “Standard Guide for Conducting Corrosion Coupon Tests in Field Applications,” ASTM G4- 95 (West Conshohocken, PA, ASTM, 1996).
   3. “Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens,” ASTM G1-90 (West Conshohocken, PA, ASTM, 1996).
7. Association of Water Technologies (AWT). <https://www.awt.org/>
8. CSI. <https://www.csiresources.org/standards/sectionformat-pageformat>
9. Compatibility: The materials that touch the fluid are collectively referred to as the wetted materials. Contractor shall certify compatibility of the transfer fluid with liquid cooled rack system including all wetted components (including but not limited to pump seals, heat exchangers and quick connect seals) and the wetted material list at maximum operating temperatures as specified below. The transfer fluid specification is tied closely to the wetted material list. Any additions to the wetted material list will require (re)evaluation of the transfer fluid.
10. Wetted material list [Note this is a draft list and requires vetting. It may include spelling and other errors. It will be removed and referenced once the wetted materials specification section is developed. Consider adding details on unified numbering system (UNS) and alloy composition as well as address plating and other issues]:

Metals

Copper, copper alloys <15% zinc and lead free

Copper Brazing Filler

316 and 316L Stainless Steels (other SS alloys need to be evaluated relative to corrosion and water treatment, e.g., 304 and 321 require very low chloride in the water. Avoid 303.)

Stainless Welding Filler

Titanium

Chrome and Chrome plated materials (requires special attention to integrity of plating).

Nickel and Electroless nickel plated (ENP) materials (requires special attention to integrity of plating).

Brazes and Brazing Filler(s)??

Mechanical Seals and Bearings (Ceramics)

Aluminum Oxide

Graphite Loaded Silicon Carbide

Polymers

Polysulfone (PSU)

Ethylene Propylene Diene Monomer (EPDM)

Polytetrafluoroethylene polypropylene copolymer (AFLAS)

Vinylidene fluoride hexafluoropropylene (Viton A)

Vinylidene fluoride hexafluoropropylene tetrafluoroethylene (Viton GF)

Ethylene, tetrafluoroethylene (TFE), perfluoromethylvinylether (PMVE) (Viton ETP)

Acrylonitrile butadiene rubber (NBR, Buna-N, Nitrile)

Ethylene propylene rubber (EPR)

Fluorinated Ethylene Propylene (FEP)

Polytetrafluoroethylene (PTFE) – e.g., Teflon based Thread Sealant

Perfluoropolyether (PFPE)/Polytetrafluoroethylene (PTFE) grease

Polypropylene (PP)

Polypropylene Random Copolymer (PP-R)

Polyethylene (PE), including extruded cross-linked polyethylene (PEX), ultrahigh molecular weight polyethylene (UHMW PE), and high Density Polyethylene (HDPE)

Polyvinylidene fluoride or polyvinylidene difluoride (PVDF)

Polyether ether ketone (PEEK)

Perfluoro alkoxy alkanes (PFA, D3307)

[Proposed additions from Ecolab and Nvidia]

CPVC

Hypalon

Vinyl

Neoprene

Plasite 6000

Plasite 7122

Brass  <15% zinc

Polyphenylene Sulfide (PPS)

Polyphenylene Oxide (PPO)

PTFE – convoluted hoses

Nylon 6

Polyphenylsulfone (PPSU)

pipe sealants [What other than Teflon above?]

Materials to Avoid

Aluminum

Non-stainless steels

Nylon [Conflict with above proposal from Nvidia]

Polyoxymethylene (POM, Delrin, Acetal, Polyformaldehyde) – if used with cold plates, warps with working temperature above 80C.

1. [Specification assumes piping and transfer fluid are not subject to freezing. If freeze protection is required, modification of the specification will be required.]

**1.2 SCOPE**

1. Furnish and install water-based transfer fluid and equipment covered by this Section, including cleaning and treatment of closed loop systems. Demonstrate successful acceptance of the installation and its operation.
2. Products and services shall be from a company regularly engaged in the treatment of water-based heating and cooling systems for mission critical facilities such as data centers and datacom equipment. The company shall maintain the chemical treatment and provide all chemicals required for a period of [1 year] from the date of acceptance (service period).
   1. **DESCRIPTION OF WORK**
3. Perform water analysis and provide all water treatment products, holding reservoirs, equipment and labor for testing, cleaning, flushing, filling, and dispensing products to control water quality for each closed-loop computer cooling system.
4. Chemicals: Provide all testing and treatment chemicals required for startup, and for operation of all water treatment systems prior to owner acceptance and for the remainder of the service period.
5. Service Representative: Furnish the services of a qualified technical service representative to direct preparation and installation of water treatment products for water-based transfer fluid, including flushing, cleaning, pre-treatment, filling, training, debugging, acceptance testing, and monitoring. Service representative shall return to the site as specified below under inspections and tests through the guarantee period. At such time, service representative shall check water quality and system operation, make adjustments, instruct and advise operating personnel, and provide written status reports.
6. Service and maintain transfer fluid treatment during guarantee period (at least one year).

**1.4 WATER QUALITY PERFORMANCE REQUIREMENTS** [confirm parameters and values]

1. Salient characteristics of the overall specification include [to be removed from specification]:

* Water based non-glycol transfer fluid.
* A very limited wetted material list with no aluminum or carbon steel (only copper and SS).
* Filling a closed loop between the cooling distribution Unit (CDU) and the servers.
* The initial fill will be with clean and sterile water, using RO or softened water if required to assure high quality and meet the specifications below.
* The operating temperature will be low (not expected to go over 150°F, and generally under 120°F).

1. Treated water shall minimize corrosion, scale buildup, and microbiological growth for optimum efficiency and reliability without creating hazards to personnel or the environment.
2. Water quality/chemistry: Water quality shall be maintained as specified below.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Performance** | **Notes** |
| Total Suspended Solids (TSS) | <5 ppm | Test in lab. Normally should not be present and ideally should be close to 0. There should be no visible solids. |
| Total Dissolved Solids (TDS) | <650 ppm at fill, then monitor rate of rise | Test in lab. Related to conductivity (tested at site) and may increase with water treatment. Establish baseline after treatment and track changes over time. |
| Conductivity micromhos/cm  (1 mmhos/cm = 1000 µmhos/cm) | < 1,000 µmhos/cm  at fill, then monitor rate of rise. | Related to TDS. Addition of chemicals can affect conductivity. Baseline prior to and after treatment. If conductivity rises during operation, analyze to determine cause, and take corrective action. If conductivity is too low, water can be corrosive. Temperature dependent. |
| Corrosion byproducts/Ions | CU ions:  <0.2 ppm  Fe ions:  <0.1 ppm | Baseline metal ions. ICP-MS Lab test for soluble ions including iron (none expected), and copper should be less than 0.1 at fill. If any metal ions are high in the fill water, consider remediation in the treatment plan. Investigate cause of any metal ion increases over time (e.g., CU ions >0.2 ppm). |
| Corrosion  (Larger systems >250 gal) | <0.1 mils/year (mpy) for copper and SS | Penetration per year using 90-day corrosion coupon test. |
| pH | 9.0 - 10.5 | Metallurgy dependent (assumes no aluminum or carbon steel). Buffer (e.g., with Borate) to above 9.5 for biological control (toxic biocide may be avoided). |
| Total Hardness  Total Ca / Mg as CaCO3 | < 30 ppm | Test at ambient temperature – values increase with temperature. Care should be taken not to increase chloride if water softening used. |
| Filtration  (side-stream) | < 5 µm  (microns) | Confirm filtration requirements with heat exchangers (Information Technology Hardware and CDU) and quick connect suppliers. Filter fill water to 50 µm, then gradually replace side-stream filter cartridges until target filtration achieved (before placing components with microchannels or other narrow flow passages into the system). Check filters frequently for loading including biocontamination, especially during start-up and after any changes. System may also contain less fine (e.g., 50 µm) in-line filters to protect heat exchangers and quick connectors. |
| Turbidity | <5 Nephelometric Turbidity Unit (NTU) | Lab test. The measure of particles in a fluid that affect the clarity of water. Fill should be clean and quality should not deteriorate. There should be no visible discoloration or opacity. |
| Max Temperature | Surface: 250°F Bulk Water: 150°F | Typical water temperature will be < 120°F. Confirm maximum surface temperature (e.g., stagnation inside the cold plate) with supplier. |
| Microbiological Control - Bacteria | Fill: <1 Colony Forming Unit (CFU)/ml,  Operational: <100 CFU/ml | Fill with sterilized water with no detectable bacteria present. Use test methods for detection down to 1 CFU/ml or better. Relative Luminescence Units (RLU) can used for tracking bio activity onsite. |
| Biocide |  | Add nonoxidizing biocide, e.g., Isothiazoline, only if needed (one-time shots). Do not use halogens (e.g. chlorine). Do not use Nitrites/Nitrates (bio food source). |
| Corrosion Inhibitor:  Azoles (e.g., TTA) | 10-50 ppm or per treatment plan | For corrosion protection of copper and yellow metals. |
| Corrosion Inhibitor:  Molybdate |  | Add Molybdate or other corrosion inhibitor only if needed (not expected with no iron/carbon steel or aluminum). If Molybdate is used, check for dissolved oxygen (min. 1 ppm) and chloride (should be low). Do not use Nitrites or Nitrates (supports bio growth). |
| Dispersant: phosphonate | 5-20 ppm (typical if required by treatment plan) | Prevents deposits of corrosion products (e.g., holds calcium in suspension) |
| Chloride | <50 ppm if 304 or 321 stainless steel (SS) present | Confirm Chloride level compatibility with all SS in system. Chloride must be low if 304 or 321 SS is used. Chlorides can concentrate in system. Chloride may also require more Azole and may reduce effectiveness of Molybdate.  May require DI/RO to remove. |

**1.5 QUALITY ASSURANCE**

A. Contractor Qualifications:

1. Laboratory capable of doing water analysis.
2. A service department and qualified technical service representatives located within [one] hour of the project site.
3. Service representatives who are Registered Engineers, Association of Water Technologies (AWT) Certified Water Technologists (CWT), or factory-certified technicians with not less than 5 years of similar water treatment experience.

B. Standard products: Provide materials and equipment which are standard products of a manufacturer regularly engaged in the manufacturing of such products, that are of a similar material, design and workmanship and that have been in satisfactory commercial or industrial use for at least five years prior to delivery.

C. Chemical Standards: Provide chemical products acceptable under governmental or other regulatory agencies.

D. Testing: Testing shall be performed by a qualified technical service representative as specified above.

E. Manufacturer/vendor must have an auditable quality assurance program in place, ISO 9001 or equivalent. Vendor must have a certificate of analysis (COA) available for all manufactured products that demonstrate product quality. COA shall include a list of ingredients and concentrations. Owner may request the COA but it is not a required submittal unless requested.

F. Confirm with the assistance of the installer/fabricator proper handling and cleanliness of all products with water passages including water-cooled servers and datacom equipment:

1. Confirm all products in the cooling loop are in conformance with the wetted material list.
2. Confirm all products with water passages have been handled properly to eliminate the potential for microbiological fouling, general fouling and/or corrosion during the shipping/storage phase. Confirm all components are clean, nitrogen filled, and factory sealed until installation.
3. Ensure that the cooling loop components are clean and dry, free of bacteria and fungi, and free of soldering and/or brazing fluxes.
4. Notify the owner immediately if conditions indicate potential mishandling and cleanliness, and develop a remediation plan to correct such conditions.

**1.6 SUBMITTALS**

1. Plans:
2. For each plan submit as appropriate: a layout; control scheme; make-up water chemistry, a list of treatment chemicals to be added; the proportion of chemicals to be added; the final treated water control levels; and a description of health, safety and environmental concerns for handling the chemicals plus any special ventilation and disposal requirements.
3. Test Temperature: Test values change with temperature so specify base temperature in treatment and testing plans.
4. Product data sheets for all products including chemicals. Provide Material Safety Data Sheets (MSDSs) and manufacturer’s literature and data for all cleaning and treatment products including procedures for their use.
5. Certification of compatibility: Submit written certification with each plan signed by the Manufacturer and countersigned by the Installer and Contractor that the transfer fluid, treatment chemicals (e.g., corrosion inhibitors and biocide) and all wetted materials are compatible for long term performance/reliability. List any materials that should be avoided.
6. Plans including chemicals to be used shall be approved by the manufacturer and Owner.
7. Equipment data sheets and Shop Drawings: Submit equipment data sheets and shop drawings for all components in each water treatment system. The data shall include a complete list of parts and supplies, with source of supply. Shop drawings shall show wiring, piping and tubing sizes, fittings, accessories, valves and connections, and space required for maintenance and connections as appropriate.
8. Owner’s manual: Submit operation and maintenance manual including field instructions and training materials. Include step-by-step water treatment and testing procedures used in determining and maintaining water quality.
9. Test reports: Submit certified test reports of samples of each treated water system.
10. Guarantee: Submit a written guarantee signed by the Manufacturer and countersigned by the Installer and Contractor, agreeing to adjust or replace the chemicals in the systems as required to achieve the required performance during a 1-year period following the final start-up and acceptance.
11. Proposed Agreement to Maintain: Prior to final acceptance, submit an Agreement for Continued Service for the Owner's possible acceptance. Offer terms and conditions for furnishings chemicals and providing continued testing for a 1-year period beyond the service period included in the contract.

**PART 2 — PRODUCTS**

**2.1 ACCEPTABLE MANUFACTURERS/SERVICE PROVIDERS**

A. NALCO Water, an Ecolab Company, SUEZ-Water Technologies & Solutions, ChemTreat Inc., [others as determined by owner]

**2.2 GENERAL**

1. Governing Laws: Ensure that neither products, waste, blow-down nor other effluents violate governmental or other agency regulations in effect in the project area.

**2.3 CLOSED LOOP COOLING WATER TREATMENT SYSTEM**

1. Water treatment system: Provide a water treatment system capable of feeding chemicals and blowdown to prevent corrosion, scale, and biocontamination within the cooling and piping distribution system. [if water quality on the facility side of the CDU is not assured, consider/add provisions for testing and filtering to protect heat exchangers]
2. Initial fill and make-up water shall be sterile to ensure no microbial contamination from water source. Water shall be treated as described in the approved treatment plan and as required to meet the performance requirements listed above. If treating fill water on-site, comply with all applicable safety and environmental requirements. [For small systems or where water treatment is not routinely done on-site, utilize pre-mixed treated water in proper concentrations and with certificate of analysis.]
3. Chemicals:
4. Chemical specifications below are for guidance. Final chemical specifications shall be determined by the treatment specialist and submitted in the water treatment plan for approval.
5. Chemicals shall meet required governmental and local environmental regulations for the treatment of hydronic systems and discharge to the sanitary sewer. Chemicals shall be as recommended by the treatment system manufacture for compatibility with the cooling system’s wetted materials and operating conditions, and for attaining the water quality performance specified. The water treatment chemicals shall protect against corrosion, scale, and biocontamination (bio-growth or biological propagation). They shall remain stable throughout the operating temperature range of the system and shall be compatible with pump seals and other elements of the system including all materials on the wetted material list.
6. Chemicals shall be nonoxidizing.
7. Cleaning compounds: Assure effectiveness and compatibility with wetted materials and subsequent chemical treatment.
8. Chemical Treatment: Treat water with inhibitors to protect wetted materials, maintain system free of scale, corrosion, and fouling. Treatment shall be maintained at the limits specified above. Treatment shall be stable at equipment surface temperatures and bulk water temperatures specified above.
9. Biocide: Add nonoxidizing biocide, e.g., Isothiazoline, only if needed. Do not use Nitrates or Nitrites.
10. Filtration: Provide side stream filtration with pressure gauges in and out in each system. Provide filtration to achieve < [5 μm]. System shall filter [5%] of the water volume per hour. Filter media shall be approved as a wetted material and be compatible with the water treatment. Certain components such as heat exchangers and quick-connects may call for inline filtration. Such filtration shall be approved by the manufacturers of those components and is not a substitute for the side stream filter(s).
11. Ports: Provide ports to sample and replace fluid for water quality tests.
12. Feeder: Provide bypass feeder, or reservoir tank (or bag on small systems) and injection pump on the water piping. [This may be included with the CDU]. Size and capacity of feeder shall be based on local system requirements. Wetted feeder materials, including reservoir tank or bladder shall comply with the wetted material list. The feeder shall be furnished with an air vent, gauge glass, funnel, valves, fittings, and piping as appropriate to operate and isolate. Install ports to drain and fill water and inject chemicals to maintain fluid chemistry while system remains fully operational. Install to allow bleed and feed for continuous operation during fluid replacement. If the feeder or reservoir is existing or supplied with the CDU, confirm compatibility and functionality with the overall system and transfer fluid.
13. Corrosion Coupon Test Rack [for larger (>250 gal) and more critical systems]: Provide a corrosion coupon test rack per the recommendations of ASTM. Include coupons for each metal contained in the system to verify corrosion control. Testers or coupons are installed in flowing water through a side stream or rack system.
14. Test Kit: Provide test kit(s) and reagents for determining proper water conditions, including test kit for corrosion inhibitors, pH, bacteria count, hardness, conductivity, temperature. Provide one test kit of each type required to determine the water quality as specified, and describe within the operation and maintenance manual.
15. [Automated Monitoring: For larger systems (>250 gallons) or critical systems, consider continuous monitoring of water chemistry, conductivity, pH, corrosion rate and turbidity.]

**PART 3 – EXECUTION**

**3.1 INSTALLATION:**

1. Provide all chemicals, equipment and labor necessary to bring transfer fluid in conformance with the specified requirements. Perform all work in accordance with the manufacturer's published recommendations and warranty requirements.
2. Coordinate compatibility: Coordinate with all those supplying wetted materials and confirm compatibility. Submit written certification as specified under submittals.
3. Confirm proper handling and cleanliness as specified under Quality Assurance. Provide secondary containment for all hazardous chemicals.

**3.2 CLOSED LOOP COOLING WATER TREATMENT SYSTEMS PREPARATION AND FILL:**

1. Analyze water to be used in system and confirm water treatment plan is appropriate to meet water quality requirements. Run Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) test to fully understand and document fill. Adjust plan as appropriate and (re)submit for approval.
2. If SS304 or 321 are included as a wetted material, test Chloride level and reduce to <50 ppm in all water used.
3. Implement preparation treatment, flush, clean, and fill procedures according to the approved plans. Chemicals to be used shall be approved by the manufacturer and Owner and as specified herein and in the plans.
4. Pre-Treatment: After piping systems are erected and proven free of leaks, administer any chemicals required for preparation treatment and flushing. Apply chemicals for the time period and in the concentration recommended by the water treatment manufacturer and in accordance with the approved pre-treatment plan. Generally, pre-treatment should be done before connecting IT equipment to the rack manifolds and bypassing the CDU heat exchanger to avoid dirt and solids from lodging in the heat exchangers.
5. Flushing and Cleaning: Drain preparation products from the system(s). Flush until system tests prove systems are free of preparation products and other contaminants. If contaminants are present, add cleaning compound/dispersant. Avoid strong acid or strong alkaline cleaning that will attack and remove natural oxide film on the soft metals. Utilize clean, sterile water meeting the water quality performance requirements for the final flush before final fill. Replace filter elements.
6. Final fill: Utilize clean, filtered (< 50 μm), and sterile water for the final fill meeting the water quality performance requirements including low TSS, low TDS/Conductivity, low hardness, low turbidity, low chloride, and no detectable bacteria. Utilize premixed inhibitors [especially suitable for small systems] or add to system immediately following final fill.
7. Filter: Utilizing side-stream cartridge filter(s) with pressure gauges, start with 50 µm and progressively replace down until specified filter stays online without blinding.
8. Sterilize: Fill water and initial operation shall demonstrate no perceptible biocontamination (<1 CFU/ml).
9. Test and document water quality prior to adding inhibitors. Confirm suitability of the treatment plan inhibitors and dosing.
10. Add inhibitors soon after filling.
11. [option: Pre-treatment, cleaning and flushing chemicals and inhibitors shall be supplied premixed and ready to use from the manufacturer]
12. Testing: Perform test procedures and submit a written report of test conditions and results to the Owner. If test results are unsatisfactory, repeat preparation treatment as necessary to achieve test results approved by the Owner. See Acceptance Test and Inspections and Tests below.
13. Start-up Procedures: During final hydronic system start-up, with all components in line and specified chemicals in place, operate the water treatment system(s) to maintain the required steady-state characteristics.

**3.3 ACCEPTANCE TEST**

1. Execute acceptance test in accordance with the approved acceptance test plan.
2. Water quality to be analyzed by an independent test lab approved by the owner. Run Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) test to fully document baseline conditions. Provide certified test report for each required water performance characteristic. See Laboratory Quality Assurance Testing under Inspections and Tests below.
3. Demonstrate system operation to Owner's operating personnel.

**3.4 OPERATION**

Maintain system in accordance with treatment plan(s) and Owner’s Manual. Monitor system as specified under inspections and tests, and maintain water quality per the performance requirements.

**3.5 PERSONNEL TRAINING:**

Operator Training: Train Owner's personnel in use and operation of water treating systems including preparation of chemical solution reservoir. Training material and a Manual shall be furnished encompassing all systems in this section of the Specifications.

Submit a schedule, at least 2 weeks prior to the date of the proposed training that identifies the date, time, and location for the training. Conduct training for the operating staff as designated by the Owner. The training period shall consist of a total [\_\_\_\_\_] hours of normal working time and start after the system is functionally completed but prior to final acceptance. Submit field instructions, at least 2 weeks prior to training, including equipment layout, wiring and control diagrams, piping, valves, control sequences, and operation instructions. The operation instructions shall include preventative maintenance procedures, methods of checking the system for normal and safe operation, and procedures for safely starting and stopping the system if appropriate. The field instructions shall cover all of the items contained in the Operation and Maintenance Manuals as well as demonstrations of routine maintenance operations.

**3.6 INSPECTIONS AND TESTS**

1. Service representative shall provide inspections and tests in accordance with best industry practices (ASTM). If the water in the cooling system(s) is not in conformance with the specified requirements or in accordance with the manufacturer's recommendations and the treatment plan, the water treatment company shall take corrective action to enable compliance. Inspections and tests shall be performed at frequencies to maintain required control to prevent corrosion, scaling and damage to equipment during operation. Submit test schedules, at least 2 weeks prior to the start of testing. The schedules shall identify the date, time, frequency and collection location for each test. Test values change with temperature so specify (and record) the water temperature.
2. [Confirm/clarify desired service and testing frequency, provide schedule considering a graded approach dependent on system size and criticality. Also consider a gradual reduction of testing frequency as test results stabilize. But reinitiate sequence if 5% or more of the total water volume is replaced].
3. Onsite Testing: Test weekly for a month, monthly for a quarter, and quarterly thereafter, or until test results stabilize (whichever is longer). At a minimum perform the following tests:

|  |  |  |
| --- | --- | --- |
| Conductivity | [\_\_\_\_\_] | micromhos/cm |
| pH | [\_\_\_\_\_] |  |
| Hardness: Total CA / Mg as CaCO3 | [\_\_\_\_\_] | ppm (mg/L) |
| Bacteria: Colony forming unit (CFU) | [\_\_\_\_\_] | CFUs/mL |
| Azoles corrosion inhibitor | [\_\_\_\_\_] | ppm (mg/L) |
| Other corrosion inhibitors if appropriate | [\_\_\_\_\_] | ppm (mg/L) |
| Water appearance (color and opacity) | Investigate if not clear |  |
| Filter Loading | Investigate if high |  |

1. Laboratory Quality Assurance Testing: Conduct QA testing for Acceptance Test and quarterly thereafter for one year by an independent water treatment lab approved by the owner to verify that the mechanical and water treatment systems are being maintained properly. Run Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) test to fully understand and document water quality and changes over time. Reduce frequency to every 6 months after one year if test results are stable. Provide the QA evaluation reports to the owner. In addition to the tests listed above, test the following (as a minimum):

|  |  |  |
| --- | --- | --- |
| Total Suspended Solids (TSS) | [\_\_\_\_\_] | ppm (mg/L)  DM: put under B |
| Total Dissolved Solids (TDS) | [\_\_\_\_\_] | ppm |
| Corrosion byproducts/soluble ions | [\_\_\_\_\_] | ppm |
| Corrosion on each metal (if coupon station installed) \* | [\_\_\_\_\_] | Mils/year |
| Turbidity (Nephelometric) | [\_\_\_\_\_] | NTU |
| Written evaluation summary |  |  |

\* In larger and critical systems, samples of copper and other metals contained in the system shall be tested in a coupon rack or station. Samples are to be replaced and analyzed every [3] months as part of the independent lab quality assurance test program.