Guidelines For Using Propylene Glycol-Based Heat Transfer Fluids In Liquid Cooled Racks

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Executive Summary

The objective of this project is to propose and promote open specifications for the construction and operation of liquid cooled computer racks. This document discusses guidelines and recommendations for the use of propylene glycol-based heat transfer fluids.

The heat transfer fluid would be used in the secondary or closed loop between the heat exchanger (e.g., Coolant Distribution Unit (CDU)) and the cold plates within the IT server racks. This loop is designated the technology cooling system (TCS) by the American Society of Heating, Refrigerating and Air Conditioning Engineers (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 whitepaper may hold disparate information technology hardware from multiple suppliers.

This work is being coordinated with other industry organizations including American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), and the Energy Efficient High Performance Computing Working Group. Other whitepapers are being developed by Open Compute Project (OCP) for other liquid cooling solutions such as immersion cooling and rear door heat exchangers. OCP is a collaborative community focused on redesigning hardware technology to efficiently support the

growing demands on compute infrastructure. The community provides a structure in which individuals and organizations can share their intellectual property with others and encourage the IT industry to evolve.

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Introduction

The primary audiences for this whitepaper are design and facility engineers, managers and operational personnel who will be responsible for the design, procurement, setup and operation of the TCS loop. A secondary audience is the liquid cooling equipment suppliers and heat transfer fluid vendors whose products could be utilized. The operating temperature of the heat transfer fluid is not expected to exceed 66°C (150°F).

This whitepaper does not address the Facility Water System (FWS). It addresses the closed loop between the CDU and the IT server racks containing copper cold plates for direct-to-chip liquid cooling. A closed loop reduces the complexity of heat transfer fluid maintenance with very limited oxygen or new sources of contaminants. The wetted materials in the CDU and the servers must be compatible with the heat transfer fluids as discussed in this whitepaper (see the wetted material list).

Major components of this whitepaper include:

1. Propylene glycol- based heat transfer fluid typical properties.
2. An acceptable wetted material list (additional materials require further consideration) and guidance on performing material compatibility testing. This includes both metal and non-metallic materials.
3. Overview of proper cleaning, flushing and commissioning procedures prior to installation of the heat transfer fluid.
4. Monitoring, analysis and maintenance of the heat transfer fluid to ensure product integrity and lifetime.

There are multiple options for liquid cooling of IT racks, including options for the heat transfer fluid. For example, OCP has developed whitepapers for heat transfer fluids including treated water and dielectric fluids. The owner and design team will need to assess the specific needs of the project to determine the suitability of this whitepaper and modify it accordingly. Further, the construction contractor, IT system supplier, and heat transfer fluid supplier should agree on the suitability of all wetted materials and may propose alternatives (refer to section 4.1 for additional details).

1 Heat Transfer Fluid Typical Properties

1.1 APPROVED GLYCOL-BASED HEAT TRANSFER FLUIDS

Acceptable heat transfer fluids must contain propylene glycol, for its biostatic properties, as well as an inhibitor package which is designed for the metals present in the TCS loop. The selected heat transfer fluid must be appropriate for the type of metallurgy that the cold plate and all other system components are composed of.

Table 1 lists typical properties of inhibited propylene glycol-based heat transfer fluids at either a 25% (PG 25) or 55% (PG 55) propylene glycol concentration. Approved fluids, when used at these concentrations, should exhibit the properties below. However, users may choose to use a fluid with a different propylene glycol concentration.

Table 1: Typical Properties of New PG 25 and PG 55 Heat Transfer Fluids

Characteristic	Typical Property	Test Method
Appearance	Clear and particulate free *(visual inspection, free of cloudiness)*	**Visual**
Propylene Glycol, volume %	**PG25:** 24.5 - 27.5% *Inhibitors + water should make-up ~75% of formulation* **PG55:** 53.0 - 57.5% *Inhibitors + water should make-up ~45% of formulation* *Biocides are not recommended. PG25 fluids maintained within acceptable glycol ranges are considered bio-static.*	**ASTM D3321**
Freeze Point	**PG25:** 9 to 14°F (-13 to -10 °C) **PG55:** -37 to -51 °F (-38 to -46°C)	**Based on results for ASTM D3321**
Fluid pH	8.0 - 10.5 *Fluid pH is dependent on corrosion inhibitor formulation*	**ASTM D1287**
Reserve Alkalinity *Measure of the buffering capacity of the fluid. Test should be performed on pre-diluted fluid.*	> 6 mL, for conventional technologies For OAT-based technologies, reserve alkalinity is 'to report' *Reserve alkalinity is dependent on corrosion inhibitor formulation*	**ASTM D1121** *Based on a 10 mL sample of ready-to-use fluid*
Total Hardness (as $CaCO_3$)	<25 ppm **High hardness values indicate the use of poor-quality water*	**ASTM D6130**
Sulfate	< 10 ppm *High sulfate values indicate the use of poor-quality water*	**ASTM D5827**

Chloride	< 10 ppm *High chloride values indicate the use of poor-quality water*	**ASTM D5827**
Corrosion Rates	Approved fluids should meet the corrosion rate criteria as outlined in section 4.3	

1.2 INHIBITORS AND ADDITIVES

Heat transfer fluids for liquid cooled computer racks contain corrosion inhibitors and, generally, antifoam and dye that are designed for this application. Over time, it may be necessary to boost the corrosion inhibitor concentrations as determined by the fluid supplier's analyses. Only use additives specified by the fluid supplier to ensure compatibility with the fluid. Do not overdose with the additives as this may lead to negative consequences with the heat transfer fluid. All additions or changes to the system should be documented (see Section 9.1).

1.3 WATER SPECIFICATIONS

Any water that is used in flushing or cleaning processes should be high purity and meet the requirements below. This is important as impurities such as calcium and magnesium can precipitate out and lead to scale formation on heat exchanger and cold plates surfaces. Impurities such as chloride and sulfate can lead to corrosion. Table 2, below, lists the criteria for water to be used in data center applications. Distilled, deionized or reverse osmosis water will likely meet these requirements. Softened water removes calcium and magnesium but not necessarily chloride and sulfate.

Table 2: Water Requirements

Component	Acceptable Level
Chloride (Cl)	<25 ppm
Sulfate SO_4	<25 ppm
Calcium ($CaCO_3$)	<25 ppm
Magnesium ($CaCO_3$)	<25 ppm
Total Hardness ($CaCO_3$)	<50 ppm

2 Safety

2.1 SAFETY CONSIDERATIONS

Follow the guidance below when handling propylene glycol-based heat transfer fluids:

1. Refer to heat transfer fluid SDS before beginning any work. Wear appropriate PPE such as safety glasses or goggles, nitrile or other impervious gloves and suitable clothing when handling the fluid.
2. Using appropriate safety equipment, small spills may be soaked up with common absorbent material. For large spills, the fluid should be pumped into suitable containers. Residual material should be cleaned up with water.
3. Flush eyes or skin if exposed to the heat transfer fluid.
4. Avoid exposure to glycol mists.

3 Submittals

3.1 RECORDS

1. Maintain a file for each system with the identity and source of the heat transfer fluid, copies of all fluid analyses and a history of cooling system components that were replaced.
2. Maintain a file that documents the volume for each system on-site, which is critical for inhibitor addition.
3. Maintain a file that documents any adjustments that were made to each system, including the date, amount and type of inhibitor added.
4. Maintain a record of the materials of construction of each system (metals, elastomers, etc.) as well as confirmation of compatibility.
5.

4 System Design Considerations

4.1 WETTED MATERIALS

The materials that come into contact with the heat transfer fluid are collectively referred to as wetted materials. The data center operator should verify compatibility of the heat transfer fluid with all wetted materials present in the liquid cooled rack system (including but not limited to cold plates, CDU, hoses, piping, pump seals, heat exchangers and quick disconnect seals). Compatibility for use should be verified at the maximum operating temperature. For any future changes made to the wetted materials used in the system(s), compatibility should be verified. Compatibility testing can be performed by the material supplier, component supplier, heat transfer fluid supplier, data center operator or outsourced to a trusted testing lab. Section 4 describes testing procedures.

Tables 2 and 3 present a list of materials expected to be compatible with propylene glycol-based heat transfer fluids that do not use organic acid technology (OAT) corrosion inhibitors. This list may be different for heat transfer fluids utilizing OAT corrosion inhibitors. The elastomers and plastics shown in Table 3 are available in many different formulations utilizing different catalysts, curing agents, copolymers, plasticizers, molecular weight distributions and potentially other additives. It is not possible to provide guidance on every possible permutation so it is advisable to work with the material supplier(s) to confirm acceptability for use. Table 3 is intended to be as specific as possible for providing guidance but should be used as a starting point for selecting the actual materials intended for the wetted materials. There may also be other materials found to be compatible and acceptable for service and should not be excluded for consideration even though they are not currently included in Table 3.

Table 3: Acceptable Metals and Metal Alloys

Materials	Details	Comments
Copper	CDA110, CDA1020, CDA1220, CDA1100	
Brass		**Brass with <15% zinc is preferred** as concentrations >15% zinc are more prone to dezincification of the alloy. If using an alloy with >15% zinc it should be verified that the material is dezincification resistant by performing ISO 6509, as a first pass, and consulting the material manufacturer to confirm acceptability for use.
Stainless Steel	304L, 316L or higher grades preferred	Most SS alloys should be acceptable, including 303 and 410.
Nickel, high nickel alloys	Avoid Hastelloy B and other alloys designed for reducing environments	**See note below
Chromium	Plated corrosion resistant materials	**See note below
Titanium	Grade 2 (UNS R50400)	
B-Ni-6	88.9% Ni + 11% P	Brazing material in copper cold plate
BCuP-1	95% Cu + 5% P	
BCuP-2	93% Cu + 7% P	

***Quick disconnects made of stainless steel are preferred. Exercise caution when using nickel plated and chromium plated quick disconnects. Life cycle testing may be performed to assess the risk level of plated quick disconnects.*

Table 4: Acceptable Elastomers, Plastics and Other Materials

Materials	Details	Comments
EPDM	Ethylene propylene diene monomer	Peroxide cured EPDM is recommended. Sulfur-cured EPDM can introduce sulfate into the heat transfer fluid over time, leading to issues with corrosion and should be used with caution.
Viton		
FEP	Fluorinated ethylene propylene polymer	
PTFE	Polytetrafluoroethylene polymer	TeflonTM
PP	Polypropylene	
HDPE	High density polyethylene	
PEEK	Poly ether ether ketone	
Loctite 567 (should Loctite 564, Permabond A131 and Permabond MH052 be added??)	Thread sealant	Other thread sealants might be acceptable but should be verified; avoid anything that can introduce particles into the fluid

Note: Polyamide 11 and 12 (unplasticized) is currently under evaluation for inclusion in Table 4, as of 9/15/2025. A decision is expected to be made by January 2025 – currently, results are favorable.

4.2 OPERATING TEMPERATURE

The typical operating temperature of closed loop cooling systems is expected to be between 40-60°C (104 -140°F). Operating above this range will require review of the wetted materials list, particularly elastomers and plastics, to ensure compatibility at the new temperature.

4.3 LIQUID ADDITION AND DRAINAGE

Install ports to drain and fill heat transfer fluid and inject chemicals to maintain fluid chemistry while the TCS loop remains operational. The size and complexity of the addition system should be based on local system requirements. All components used for fluid addition and draining should comply with the wetted materials list and any chemicals to be added. The TCS loop should be designed to have complete drainage without any dead leg(s) to trap contaminants.

4.4 FILTRATION

Section is currently under development – additional content to be added once reviews have been completed by sub-team

Overview: Effective filtration is crucial for maintaining the condition of the TCS loop. It helps capture residual suspended solids in the recirculating fluid, ensuring system efficiency and longevity. Two primary filtration methods can be implemented:

- Side Stream Filtration
- Full Flow Filtration

Sidestream Filtration: The more common method is likely to be sidestream filtration as clogging of the filter does not cause back-pressure problems on the TCS closed loop when this method is employed. Filter replacement is often easier as well. Side stream filtration involves diverting a small proportion (typically 5–15%) of the circulating flow through a filter continuously. This ensures the entire water system volume is filtered at least once over a 24-hour period.

Side stream filtration is strongly recommended for systems greater than 250 gallons of heat transfer fluid. Not only is this type of filtration cost effective, but it also does not create back-pressure issues for the main system if clogging of the filter were to occur. Most CDUs may also contain less fine (e.g. 50 micron) inline filter(s) to protect heat

exchangers and quick disconnectors, however, such filtration shall be approved by the component manufacturer and is not a substitute for side stream filtration.

Side stream filter units should be installed across the circulating pump with the inlet accepting flow from the downstream (pressure side) of the pump and outlet returning flow to the upstream (suction side) of the pump. The recirculating heat transfer fluid is then diverted through the side stream filter. Cartridge filters must be periodically inspected and replaced based on pressure drop monitoring of visual inspection.

Disposable filter media with a 5000 absolute beta ratio and 5 to 25 micron filter size (depending on cold plate requirements) are acceptable. If reusable metallic filters are used, include automatic or manual backflush and drain facilities. Precautions should be taken to prevent microbiological contamination. All filter media shall be approved as a wetted material and be compatible with the heat transfer fluid.

For new installations, frequent filter change outs can be anticipated due to debris (e.g. mill scale, metal swarf, etc.) so it is ideal ideal to start with coarser grader filters (e.g. 50 micron) and taper down to the target micron grade.

Full Flow Filtration: Full flow filtration processes 100% of the system flow, making it suitable for applications where comprehensive filtration is required. In this scenario, duplex filters are recommended as they enable filter cleaning or replacement with a system shutdown, leading to quick and precise cleaning. Pressure differential indicators of BMS sensors should be used to monitor filter conditions. Regular maintenance is recommended to prevent bacterial colonization and corrosion.

Disposable filter media with a 5000 absolute beta ratio and 5 to 25 micron filter size (depending on cold plate requirements) are acceptable. If reusable metallic filters are used, include automatic or manual backflush and drain facilities. Precautions should be taken to prevent microbiological contamination. All filter media shall be approved as a wetted material and be compatible with the heat transfer fluid.

For new installations, frequent filter changeouts can be anticipated due to debris (e.g. mill scale, metal swarf, etc.) so it is ideal ideal to start with coarser grader filters (e.g. 50 micron) and taper down to the target micron grade.

Filter cartridges should be inspected before use for damage or degradation (e.g. inspect o-rings and gaskets for cracks, loss of elasticity of dryness). For effective sealing, verify proper o-ring positioning and lubricate o-rings with the heat transfer fluid before installation.

Filter housings should be designed for safety, accessibility, and functionality. Construction with 316L stainless steel and dished ends (to prevent dead zones and allowing for full drainage) is preferred. An auto air vent is recommended for air removal.

During system design, it is important to take into account the minimum clearance that is necessary to guarantee sufficient space during cartridge maintenance operations. Ensure compliance with manufacturer-recommended clearance for maintenance to provide adequate space for safe filter media changes and chemical dosing.

A tundish (a port with a non-return valve) should be installed on the dirty chamber side to allow for addition of dosing chemicals or additives into the TCS loop. Isolation valves on the drains, vents, inlets and outlets are recommended in addition to a single open-ended end fitting.

5 Validation of Wetted Materials

Section is currently under development – additional content to be added once reviews have been completed by sub-team

5.1 OVERVIEW

Confirming that all wetted materials are compatible with the chosen heat transfer fluid is key to ensuring the integrity of all TCS loop components, including the heat transfer fluid. For materials not listed in the acceptable wetted materials list (refer to Table 2, Table 3 or manufacturer specific data), it is recommended to perform the tests outlined in Section 5, which covers elastomers, plastics and metals.

5.2 ELASTOMERS AND PLASTICS

Elastomers are polymers that exhibit high viscosity and elasticity, allowing them to return easily to their original shape once mechanical stress is removed. Elastomers are often used for hoses, seals, and gaskets and may make-up a significant portion of a server rack cooling loop. Therefore, it is of high importance to ensure that all elastomeric materials are compatible with the heat transfer fluid of choice.

Plastics consist of a wide range of synthetic or semi-synthetic materials that use polymers as a main ingredient. They play a crucial role in data center liquid cooling loops due to their durability, flexibility, and resistance to corrosion. Plastics may be used in piping systems, tanks and reservoirs or sealing components and can make-up a significant portion of a server rack cooling loop. Therefore, it is of high importance to ensure that all plastic materials are compatible with the heat transfer fluid of choice.

Test Overview

To confirm wetted material compatibility, it is recommended to perform exposure testing followed by tensile strength, hardness and volume change testing. Elastomeric and plastic coupons should be tested in triplicate before and after exposure to the chosen heat transfer fluid, particularly if test data is not available from either the heat transfer fluid manufacturer or the elastomer manufacturer. Exposure temperature and duration may vary depending on guidance from the material manufacturer so information in this section is meant to serve as a starting point for testing.

It is recommended to evaluate for weight, volume, tensile strength and hardness of coupons before and after exposure to the heat transfer fluid. In addition, fluid purity testing may also be done at the same time.

Referenced Methods - Elastomers

- **ASTM D471** - Standard Test Method for Rubber Property—Effect of Liquids
    - *Procedure for exposure of rubber coupons to heat transfer fluid and volume and hardness measurements*
- **ASTM D412** - Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
    - *Procedure for tensile strength testing of coupons*
- **ASTM D3182** - Standard Practice for Rubber—Materials, Equipment, and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets
    - *Procedure for preparing coupons from sheet material*
- **ASTM D3183** - Standard Practice for Rubber—Preparation of Pieces for Test Purposes from Products
    - *Procedure for preparing coupons from actual products*
- **ASTM D2240 -** Standard Test Method for Rubber Property—Durometer Hardness
    - *Procedure for measuring hardness of coupons with a Type A durometer*

Referenced ASTM Methods - Plastics

- **ASTM D543** - Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents
- **ASTM D638** - Standard Test Method for Tensile Properties of Plastics
- methods for preparing plastic coupons

Test Coupons

Obtain elastomeric or plastic coupons based on desired testing. For example, if weight and volume change and/or hardness measurements will be done, a minimum of 3 rectangular coupons are needed for every variable (duration and temperature combination) as all three of these measurements can be done on the same coupon. If tensile strength testing is done, a minimum of 3 dumbbell-shaped coupons are needed for every variable (duration and temperature combination) in addition to 5 dumbbell-shaped reference/control coupons required for original properties.

Rectangular coupons, for weight/volume change and hardness, should be 1”x2” and should be prepared following ASTM D3182, ASTM D3183 or ASTM D4703. The thickness of coupons should be 2 mm.

For tensile testing of elastomers, dumbbell-shaped coupons should be cut according to ASTM D412 Figure 2 or ASTM DXXX. It is advised to use Die C.

A small hole measuring approximately 2 mm should be punched in each coupon to allow for suspension in the testing medium.

Pre-Cleaning of Coupons

Generally if there is no visible contamination on the coupons, it is not necessary to clean samples in advance for these tests. However, if fluid purity testing will be done, cleaning of coupons is necessary. In this case, all coupons should be cleaned of manufacturing debris or oils with the minimum aggressive method necessary to clean (e.g. nothing, dry cloth, water, soapy water, solvent, etc.). If solvents must be used, select one appropriate for the material. Coupons should be allowed to fully dry before any measurements are performed.

Pre-Exposure Measurements for Rectangular Coupons

Weight Measurements: Once coupons have been cleaned and allowed to thoroughly dry, measure and record the starting weight (grams) for each coupon using a 4-place balance. All measurements should be collected in triplicate. Make sure it is easy to distinguish between coupons as it will be necessary to correlate the post-exposure measurements for each coupon with the pre-exposure measurements.

Volume Measurements: Once coupons have been cleaned and allowed to dry, measure the starting volume for each coupon, in triplicate. If using a micrometer, measure and record the length, width and thickness of each coupon. Refer to ASTM D471/DXXX for guidance on how to perform these measurements. Volume can be calculated using the following equations:

Volume, cm^3 = Length (cm) x Width (cm) x Thickness (cm)
Note: 1 cm^3 = 1 mL, 1 cm = 10 mm

If a density balance is used to measure the volume of each coupon, record the “weight in air” followed by the “weight in water” then allow each coupon to fully dry before attempting to take duplicate and triplicate measurements. According to Archimedes Principle, the weight of a coupon in air (grams) minus the weight of the coupon in water (g) is equal to the volume of each coupon in (mL), assuming the density of water is 1 g/mL.

Hardness Testing

For pre-exposure hardness measurements of elastomers using a Type A durometer, refer to ASTM D2240 and ASTM D471 (section 16) or ASTM DXXX for guidance.

Material	Method/Durometer
Elastomers	Shore A
Thermoplastics	Shore D

Note: There is overlap between these scales…some plastics may use A and some elastomers use D

Pre-Exposure Measurements for Dumbbell Coupons

The original thickness of each dumbbell should be measured with a micrometer and recorded. These values will be used as the sample thickness during post-exposure calculations, per ASTM D412 and ASTM D638. Tensile testing of control (unexposed) coupons can be done at the same time as the post-exposure coupons are tested. At the start of testing, ensure that 5 control dumbbell coupons are maintained. It is best practice to store the control coupons in a desiccator at room temperature to avoid moisture absorbance from the environment. These will not be exposed to the heat transfer fluid but will be tested while exposed coupons are tested.

Note: For hydroscopic materials, it is recommended to condition the control samples in deionized water for 3-5 days to establish original control sample physical properties.

Exposure Testing

Once initial measurements are taken, obtain clean borosilicate analytical grade glassware or an appropriately temperature rated plastic jar. Suspend coupons from a

stainless steel wire with Teflon spacers or glass beads to separate each coupon. Use a stainless steel holder or other suitable method to hold the wire in place during testing. Make sure you are able to distinguish between coupons as it will be necessary to correlate the post-exposure measurements for each coupon with the pre-exposure measurements. Rectangular and dumbbell-shaped coupons may be placed in the same jar. Fill the jar with heat transfer fluid as the desired concentration (e.g. PG25) until the coupons are covered with some excess.

Note: Test tubes with open condensers are specified by ASTM D471 (section 8) or ASTM DXXX to limit evaporation at typical time and temperature profiles. However, jars are acceptable in this case because pressure build-up is not a concern as the fluid is not being tested near the boiling point.

Once coupons are in place, tightly cap each jar, making sure to properly label with the start date, testing medium, exposure temperature and test duration or end date. Heat each jar at the desired temperature for the length of testing.

Typical Exposure Length: 6 weeks

Typical Exposure Temperature: 65C to 85C

If fluid purity after exposure to elastomers is of concern, it is important to include two control samples. In this case, two glass jars should be filled with the same volume of fluid as all other test variables, but without any elastomers included. One jar is left at room temperature, and the other jar is heated to the same temperature as all other variables for the duration of testing. The room temperature control sample is for a baseline, while the heated control sample is for capturing any effects that the heat might have on the fluid regardless of elastomer.

Ending a Test

At the end of the test period, remove jar(s) from heat (if applicable) and allow to cool to room temperature. Samples should immediately be quenched for 30-60 minutes in room temperature test fluid before any testing is completed. Post-exposure measurements should be done as soon as possible. Remove coupons from the test solution (one variable at a time) and rinse with purified water and blot dry. If dumbbell coupons are in the same jar as the rectangular coupons, do not remove them until you are ready for tensile testing.

Post-Exposure Measurements for Rectangular Coupons

Volume Measurements: Perform volume measurements similar to what was done at the start of testing. Measurements should be taken in triplicate.

Weight Measurements: Perform weight measurements similar to what was done at the start of testing. Measurements should be done in triplicate.

Hardness Testing: Perform hardness measurements similar to what was done at the start of testing. Measurements should be taken in triplicate.

Post-Exposure Measurements for Dumbbell Coupons

Tensile Testing: Refer to ASTM D471 or ASTM DXXX, for guidance on pre and post-exposure tensile testing.

Elongation Testing: Refer to ASTM D471 or ASTM DXXX, for guidance on pre and post-exposure elongation testing.

Calculations

Volume Change, % - Calculate change in volume for each coupon (and for duplicate measurements) and average these values for all measurements of a single material type.

Change in Hardness - Calculate change in hardness for each coupon (and for duplicate measurements) and average these values for all measurements of a single material type.

Change in Tensile Strength - Calculate change in tensile strength and average these values for all measurements of a single material type.

Change in Elongation at Break - Determine elongation at break before and after exposure to any chemical or mechanical stress and calculate the change.

Post-Exposure Fluid Purity Testing

If fluid condition after exposure to wetted materials is of concern, the fluid should be analyzed at the end of the exposure period to determine overall fluid conditions and if any contaminants were introduced from the elastomer. The aged fluid(s) should be compared against the unaged (room temperature), unexposed control sample of the heat transfer fluid from the same batch.

Interpreting Results

Although the heat transfer fluid supplier may be able to provide input on acceptable values for changes in weight, volume, hardness and tensile strength, it is recommended to consult the component manufacturer for guidance on acceptable maximum values as these may differ by material, exposure temperature, test duration and the application (dynamic versus static).

In general, values below those listed below would be generally considered acceptable. For values higher than this, consult the component manufacturer for additional guidance.

1. **Volume Change, %:** -5% to +10%
2. **Hardness Change, %:** -10 to +10 durometer change
3. **Tensile Strength Change, %:** >-20%
4. **Elongation Change, %:** >-25%

5.3 METALS

Referenced ASTM Methods

- **ASTM D8040-18(2023)** - Standard Test Method for Corrosion Test for Heat Transfer Fluids in Glassware
- **ASTM G1-03(2017)e1** - Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens
- **D3306-21 -** Standard Specification for Glycol Base Engine Coolant for Automobile and Light-Duty Service

Various metal alloys may be used in a liquid cooling loop for heat exchangers, piping or fittings. For materials that have not been approved for use by the heat transfer fluid manufacturer or other industry sources, it is advised to perform ASTM D8040-18 corrosion testing of those alloys, with some modifications. Pre-diluted (ready-to-use) heat transfer fluids should be used as-is instead of following dilution guidance in D8040. Corrosive salts should be added as instructed in D8040-18, **section 8.1.1.** Concentrated fluids, or fluids designed to be diluted prior to use, should be diluted to the intended usage concentration and the corrosive salts (sodium sulfate, sodium chloride, sodium bicarbonate) added according to D8040-18 **section 8.1.2**.

Coupons should be 50.8 mm by 25.4 mm by 1.59 mm (3.18 mm may also be acceptable). Each coupon should have a drilled hole and should be arranged following guidance in 6.2.1. Please note, for plated or chemically treated alloys, the hole should be drilled in the coupon prior to plating or treatment to eliminate any risk of galvanic corrosion. Use insulating spacers of polytetrafluoroethylene (PTFE, Teflon™) in between all coupons and between the coupons and the bundle legs so that the coupons will be non-galvanically coupled.
Each alloy should be tested in triplicate and should be prepared according to guidance from the alloy manufacturer.

Perform corrosion testing according to ASTM D8040-18 with the following modifications:

Testing should be completed with materials of concern (e.g. copper, brass) unless the component manufacturer or heat transfer fluid manufacturer or component has provided corrosion data for these or similar materials. Use insulating spacers of polytetrafluoroethylene (PTFE, Teflon™) in between all coupons and between the coupons and the coupon bundle legs so that the coupons will be non-galvanically coupled.

Pre-diluted fluids (for example, PG25 and PG55) should be tested without further dilution. Corrosive salts should be added as instructed in D8040-18, section **8.1.1**. Perform testing in three separate beakers Additional coupons of each alloy can also be included in each beaker.

Concentrated fluids, or fluids designed to be diluted prior to use, should be diluted to the intended usage concentration and the corrosive salts (sodium sulfate, sodium chloride, sodium bicarbonate) added according to D8040-18 section **8.1.2**.

- 110 mg sodium chloride per liter of test solution
- 99 mg sodium sulfate per liter of test solution
- 92 mg sodium bicarbonate per liter of test solution

All other steps should be followed according to ASTM D8040-18. Testing should be done at 88C for 2 weeks (336 hours) with continuous aeration.

Refer to ASTM G1-03, see section **11**, for guidance on calculating corrosion rates for each coupon. Maximum allowable corrosion rates are as follows:

1. Copper: 0.2 mpy (5 mg/coupon)
2. Brass: 0.2 mpy (5 mg/coupon) - Use caution if a change in color is noted, such as a copper appearance that indicates dezincification corrosion. Also, use caution if pitting corrosion is evident as this could indicate dezincification corrosion.

Note: These values are conservative in comparison to ASTM D3306, which indicates acceptable weight loss values. While even lower corrosion rates than 0.2 mpy for copper are desirable, the limitations of the D8040 coupon corrosion test should be taken into account. There can be variations in coupon mass loss results both within a given lab and in comparing results from different labs. The authors consider the 0.2 mpy (5 mg/coupon mass loss) values to be the limits of the test's ability to discriminate results. That is, it cannot differentiate adequately between 0.1 mpy and 0.2 mpy. For details, see Appendix X1 in the ASTM D8040 document.

5.4 LONG-TERM PERFORMANCE

The guidance provided in Section 4 calls for short-term materials testing for metals and non-metals exposed to PG-based data center heat transfer fluids. Past experience has indicated that these methods are useful in evaluating the different materials and can, to a degree, predict long-term performance. However, there are many variables that are not included in these tests. Changes to the fluid and/or operating conditions can change over time. Also, metal alloy and elastomer compositions can differ from those mentioned in the tests. It is recommended to carry out inspections of equipment after a period of time in service to better anticipate long-term performance of any component or material. We suggest the data center manager, working with the heat transfer fluid and component suppliers, perform these inspections at time periods of their choosing.

6 Fluid Installation and System Operation

6.1 OVERVIEW

1. Provide all chemicals, equipment, filters and labor necessary to bring heat transfer fluid in conformance with the specified requirements. Perform all work in accordance with the supplier's published recommendations and warranty requirements.
2. The heat transfer fluid shall be used from an unopened, or an opened container that has been properly sealed and stored and meets the supplier's shelf-life recommendations, to ensure no debris is introduced into the system.
3. Coordinate with all those supplying wetted materials and confirm compatibility. Submit written certification as specified in Submittals (section 8).
4. Provide secondary containment for all hazardous chemicals.
5. Follow the guidelines, below, for fluid installation and start-up procedures. Collect a sample from each system and retain at least until the CDU fluid is replaced.

6.2 START-UP

Certificate of Analysis
Vendors may supply a certificate of analysis (COA) available for manufactured products that demonstrates product quality. Maintain a copy of COA for your records, as specified in Submittals (section 8).

Cleanliness

Confirm, with the assistance of the installer/fabricator, proper handling and cleanliness of all products with fluid passages including propylene glycol-cooled servers and datacom equipment:

1. Confirm all products in the cooling loop are in conformance with the wetted material list.
2. Confirm all components are clean and factory sealed until installation.
3. Ensure that the cooling loop components are clean 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.

Compatibility

Fluids and components shall be as recommended by the heat transfer fluid supplier for compatibility with the TCS loop's wetted materials and operating conditions and shall also meet required governmental and local environmental regulations for the treatment of hydronic systems.

6.3 CLEANING AND COMMISSIONING

For the purposes of cleaning and commissioning new TCS components and infrastructure for use, it is recommended to follow the guidance below which is divided into two sections. The first section, Cleaning of Individual TCS Equipment, addresses the cleaning of individualized components that are used in the TCS loop and would often be cleaned off-site by the component manufacturer, prior to shipment to a datacenter location. The second section, Cleaning of New TCS Piping, addresses the procedure for cleaning of piping once it has been installed and is ready for use. Typically, the IT racks would not be connected to the TCS loop, or would be isolated, during the cleaning of the TCS piping.

Cleaning of Individual TCS Equipment

Flushing and cleaning of TCS connected equipment (e.g. IT racks, CDUs, etc.) is likely to occur separate from that of the larger TCS piping, for liquid-to-liquid cooling loops, and can be done as part of the testing of the rack (e.g. hydrostatic, operational). Flushing and cleaning can be completed in multiple ways, depending on preference and setup. This procedure can also be used with individual components.

When selecting a flushing fluid, take into consideration the level of cleaning that needs to be achieved, based on starting cleanliness of parts/components (e.g. water alone will not remove oils and greases).

With filters in place, flush with either the heat transfer fluid or a cleaning solution, as outlined below. Multiple flushing procedures may be used in sequence, utilizing more than one of the flushing agents listed below:

Heat Transfer Fluid

If using a heat transfer fluid for flushing, fill the IT rack with the selected propylene-glycol based heat transfer fluid and circulate for a minimum of 30 minutes (or a minimum of 4x system volume turnover) at room temperature and at a minimum velocity of 5 ft/sec to ensure thorough mixing and suspension of any manufacturing debris. Hydro-testing may be performed at this time.

Use of ready-to-use fluid is preferred. If the selected PG-based fluid requires dilution, dilute with high purity water meeting the requirements in Table 2, according to the manufacturers recommendations.

After flushing, remove all heat transfer fluid from the system. It may be possible to reuse the heat transfer fluid for multiple flushes but check with the heat transfer fluid supplier to confirm.

If the heat transfer fluid will be reused for additional flushing or testing, filtration should occur with a 5 micron filter after removal before the fluid can be reused. Flushing fluid must be tested to verify that it meets the specifications in Table 4 for fluid pH, reserve alkalinity, glycol concentration and overall appearance. Testing frequency can be determined by the heat transfer fluid supplier, and can be based upon usage.

Once the fluid has been removed from the system, inspect and/or replace all accessible filters in the system (refer to Section 3.3). If the IT server rack will be shipped pre-filled, continue on to System Fill. For systems which will be shipped empty, it is best practice to ship with a nitrogen blanket to reduce the risk of corrosion as it is unlikely that complete removal of the heat transfer fluid can be achieved.

Cleaning Solution

If using a cleaning solution for flushing, fill the IT rack with high purity water, meeting the requirements in Table 2, and a suitable cleaning agent (do not use silicate-based additives). Circulate for a minimum of 30 minutes at room temperature at a minimum velocity of 5 ft/s to ensure thorough mixing and suspension of any manufacturing debris. Hydro-testing may be performed at this time.

<u>Additive Considerations</u>

- **Tolyltriazole/benzotriazole** – used for protection of copper cold plates and other copper-based alloys - typical usage level is 20 - 40 ppm

- **Phosphate (or other suitable additive)** - used as a pH buffer and to protect iron-based alloys – typical usage level is 1000 ppm as orthophosphate
  Note: Some wastewater treatment streams may not allow disposal of phosphate-based additives, when used above certain levels.
- **Surfactant –** typical usage level is to be determined by cleaning company and/or surfactant supplier
  Note: Do NOT use for final flush, prior to installation of PG25 or PG55.
- **Biocide –** typical usage level: To be determined by cleaning company and/or biocide supplier
  Note: Do NOT use for final flush, prior to installation of PG25 or PG 55.
- Fluid pH of the final cleaning solution should be as recommended by the cleaning company, based on the metallurgy present in the system

Additives to Avoid
Avoid using any silicate-based additives

Cautionary Additives
Exercise caution when using the following additives: **chromate, nitrite, nitrate and molybdate** are discouraged from an environmental standpoint (e.g. may cause issues with disposal)

After flushing, remove all of the cleaning solution from the system. Multiple rinses with high purity water may be necessary to ensure that all cleaning chemicals are removed (e.g. surfactants). To ensure complete removal, turbidity and conductivity of the inlet and outlet fluid can be tested to ensure the values are the same. Additionally, a shake test can be performed to check for the presence of surfactants. Complete removal of all flush water may not be possible, resulting in over-dilution of PG25 or PG55 fluid after system fill. For systems that are inadvertently over-diluted due to the presence of residual flush water, a concentrated or PG55 fluid should be on hand to adjust the concentration back to within an acceptable range.

After flushing fluid is removed, replace all accessible filters in the system (refer to section 3.3). **If the IT server rack will be shipped pre-filled**,continue on to **System Fill within 2 hours after removal of the flush water. For systems which will be shipped empty**, it is best practice to ship with a nitrogen blanket to reduce the risk of corrosion as it is unlikely that complete removal of the water can be achieved.

Water
Flushing with uninhibited water is not preferred due to an increased risk of corrosion for certain metallurgy. If this method is utilized, consult a reputable cleaning company to determine if there will be any unintended consequences with using uninhibited

water.Although carbon steel is not recommended for use in this application, if it is present, uninhibited water should **not** be used for cleaning.

Cleaning of New TCS Piping

Once TCS piping has been erected, and before IT server racks are installed, follow the steps below to perform system flushing and cleaning. This is general guidance as various cleaning companies may use different procedures and flushing chemicals based on system design and size.

Please note: Cleaning & commissioning of TCS pipe systems is also addressed in Modular TCS Workstream - Commissioning Considerations

Fill system piping with inhibited water/cleaning solution made from purified water (e.g. reverse osmosis, deionized, distilled, etc.) meeting the requirements below. Additives to consider for use are also listed below. Chemical composition of the inhibited water will depend on the metallurgy present in the system.

Water Requirements

- Chloride (as Cl) < 25 ppm
- Sulfate (as SO_4) < 25 ppm
- Calcium (as $CaCO_3$) < 25 ppm
- Magnesium (as $CaCO_3$) < 25 ppm
- Total Hardness (as $CaCO_3$) < 50 ppm

Note: *Softened water likely will not meet these requirements.*

Additive Considerations

- **Tolyltriazole/Benzotriazole** - used for protection of copper cold plates and other copper-based alloys – typical usage level is 20 - 40 ppm
- **Phosphate (or other suitable additive)** - used as a pH buffer and to protect iron-based alloys – typical usage level is 1000 ppm as orthophosphate
  Note: Phosphate should be used if carbon steel is present in the system, although carbon steel is not recommended for use in this application
  Note: Some wastewater treatment streams may not allow disposal of phosphate-based additives, when used above certain levels.
- **Surfactant –** typical usage level is to be determined by cleaning company and/or surfactant supplier
  Note: Do NOT use surfactants for final flush, prior to installation of the heat transfer fluid
- **Biocide –** typical usage level is to be determined by the cleaning company and/or biocide supplier. Non-oxidizing biocides (e.g. isothiazolones) should be used (non-quaternary compounds) to reduce the risk of interfering with the passivation layer.

Note: Do NOT use for final flush, prior to installation of the heat transfer fluid

Additives to Avoid
Avoid using any silicate-based additives

Cautionary Additives
Exercise caution when using the following additives: **chromate, nitrite, nitrate and molybdate** are discouraged from an environmental standpoint (e.g. may cause issues with disposal)

For systems with a minimal risk of contaminants and without the presence of carbon steel (e.g. systems with stainless steel), it is acceptable to use purified water (without additives or inhibitors, meeting water requirements listed above) for flushing. However, in this scenario, the flush water should remain in the system no longer than 24 hours before removal.

With filters in place, filter the system by starting with a larger filter size, for example 50 micron, and work down to a 5 micron filter. If using inline filtration, flushing for 2 hours with each micron grade is sufficient. If using side stream filtration, it is recommended to consider the flow rate and pass the total system volume through the filter 4-6x which, based on flow rates, may take up to 24 hours. Fluid velocity should be a minimum of 5 ft/sec (verify turbulent flow at chosen velocity, which is typically defined by a Reynolds number > 4000). Multiple system flushes may be completed, using the procedure above, to achieve the desired results.
Note: If the system will **not** be filled immediately with the heat transfer fluid, leave the flushing fluid (containing inhibitors, biocides and surfactants) in the system until ready for system fill.

Once the desired level of cleaning has been achieved, remove the cleaning solution from the system by flushing with purified water (meeting specifications above) through the piping until the conductivity, fluid pH and turbidity values for both the inlet and outlet water are the same, to ensure that all biocides and surfactants are no longer present.

The final flush can be done with inhibited water as long as it contains additives which are compatible with the heat transfer fluid that will be used and does not contain biocides and surfactants. If surfactants remain in the system once the heat transfer fluid is added, this can lead to foaming issues. If biocides remain in the system, this can interfere with the corrosion inhibitors in the heat transfer fluid and diminish corrosion protection.

After flushing, drain all water out of the piping via valves located in all the low spots. Blow compressed air through the system to help remove any remaining water (ensure contaminants are removed from compressed air). Replace filters with new filters which are the appropriate micron size for operation with the chosen heat transfer fluid.

Note: Any remaining flush water will inadvertently dilute the PG25 or PG55 heat transfer fluid. It is possible to dilute the glycol concentration below the lower limits set in place by the fluid manufacturer. In this case, it is important to have a way to increase the glycol concentration to within acceptable limits, such as via addition of PG55 heat transfer fluid or a more concentrated blend from the manufacturer.

If passivation of the stainless steel piping will be performed, refer to "Passivation of New TCS Piping" below. Otherwise, install the heat transfer fluid as soon as possible, as outlined in System Fill, following the final flush, or at least within 24 hours. This is important to avoid bacterial growth. If the system will not be filled for 24 hours or greater, purge with nitrogen and seal the system. For systems containing only stainless steel, elastomers and/or plastic components, exposure to air is acceptable for up to 72 hours. If the storage will last beyond 72 hours, use nitrogen gas to purge the system as described above.

Passivation of New TCS Piping

Passivation is a chemical treatment process that restores the corrosion resistance of stainless steel (e.g. 300 series) and other metal surfaces and is recommended after welding, hot work or corrosion but may be optional for modular pipe systems. The process involves applying an acid solution, typically nitric acid or citric acid, to remove contaminants like free iron and scale that can cause rust or localized corrosion. Passivation allows the natural chromium oxide layer on stainless steel to form or regenerate, which provides protection against oxidation.

Please note: Cleaning & commissioning of TCS pipe systems is also addressed in Modular TCS Workstream - Commissioning Considerations

Materials & Tools:

To complete the process, passivation chemicals such as citric acid or nitric acid solutions should be used. It is also necessary to have access to high purity water which is used for flushing the passivation chemicals from the system. Additionally, a pH meter is needed for monitoring of the solution.

System Preparation:

If cleaning of the TCS piping has been completed, the system should be clean, free of grease or visible debris and practically dry at the start of passivation.

Passivating Solution Circulation:
To begin the passivation process, mix the passivating chemical per the manufacturer's recommendations and circulate it through the system at a controlled temperature and flow rate for a specific duration. Monitor fluid pH and chemical concentration during circulation. Personal protective equipment (PPE) such as safety goggles, gloves, acid-resistant clothing and a face shield should be worn.

- **Option 1: Nitric Acid Method** - Prepare a 20-50% nitric acid solution (with optional sodium dichromate) and circulate the solution through the piping system for 30-60 minutes at 120–150°F (49–65°C). Ensure the pH level remains between 1.0 and 3.0 during the process.
- **Option 2: Citric Acid Method** - Prepare a 4-10% citric acid solution and circulate the solution through the piping system for 30–60 minutes. If needed, heat the solution up to 120–150°F (49–65°C) for enhanced effectiveness. Ensure the pH level remains between 2.0 and 4.0 during the process. Note: This is the recommended method due to safety.

Neutralization:
Once the solution has circulated for the determined length of time, flush the system thoroughly with high purity water to remove residual the passivating solution. If an acid was used, neutralize the system using an alkaline solution before the final rinse.

Note: Sodium bicarbonate, soda ash, or sodium hydroxide (caustic) could be used for neutralization, if required. This would depend on the local discharge and/or municipal treatment plant guidance here.

Final Rinse:
Once passivation and neutralization (if required) has been completed, perform a final rinse with high purity water and check for pH neutrality (pH 6.5 - 7.5) and conductivity of <50 mmhos. Drain all water out of the piping via valves located in all the low spots. Blow compressed air through the system to help remove any remaining water (ensure contaminants are removed from compressed air). Proceed to System Fill.

Note: Any remaining flush water will inadvertently dilute the PG25 or PG55 heat transfer fluid. It is possible to dilute the glycol concentration below the lower limits set in place by the fluid manufacturer. In this case, it is important to have a way to increase

the glycol concentration to within acceptable limits, such as via addition of PG55 heat transfer fluid or a more concentrated blend from the manufacturer.

Safety Precautions

Always wear appropriate PPE when handling acids and chemicals. Ensure proper ventilation in the work area. Dispose of waste chemicals per environmental and safety regulations.

Documentation and Record Keeping

Record the date, passivation method used, chemical concentrations, exposure time, and test results. Maintain records for quality control and compliance purposes.

System Fill

Once piping has been cleaned, passivated (if necessary) and following removal of all flush water, fill the system with the heat transfer fluid. Usage of pre-mixed fluid (e.g. PG 25) is preferred. If not utilizing a pre-mixed fluid, high purity water must be used for diluting the fluid to the appropriate glycol concentration. Water must meet the following requirements::

Water Requirements:

- Chloride (as Cl) < 25 ppm
- Sulfate (as SO_4) < 25 ppm
- Calcium (as $CaCO_3$) < 25 ppm
- Magnesium (as $CaCO_3$) < 25 ppm
- Total Hardness (as $CaCO_3$) < 50 ppm

Once the heat transfer fluid is installed, verify the propylene glycol concentration of the final blend in the system. This is important as residual water left in the system can lead to inadvertent over-dilution of the heat transfer fluid. For on-site testing, a handheld refractometer can be used to verify concentration. If concentration is low, adjust accordingly following guidance from the heat transfer fluid manufacturer.

Start-up Procedure

During final system start-up, bleed air from the system if necessary and check for any system leaks while circulating fluid for a minimum of 30 minutes. Take a representative sample from each CDU within the first 1-3 days of operation and retain for the life of the fluid. It is also best practice to take a sample of the fresh heat transfer fluid (unexposed to any system components) and keep for the lifetime of the fluid. Be sure to properly label samples with identifying unit, fluid identity and date. See Annual Analytical Analysis, section 7.2, for information on sample analysis. It is advisable to submit this initial sample for analysis to ensure there was no contamination and

provide the time zero values. Monitor the fluid level during the first few hours of operation and add additional heat transfer fluid to achieve the desired fill volume.

Replacing Equipment in an Existing System

(provide guidance on cleaning protocol for new equipment)

Replacing Fluid in an Existing System

(provide guidance on cleaning protocol)

Check side-stream and in-line filters, if applicable, and replace as needed. Fill the system with new heat transfer fluid. Refer System Cleaning and Filling, section 5.3, for guidance on system fill.

7 Monitoring & Maintenance

7.1 OVERVIEW

Maintaining optimal thermal performance and system reliability is crucial in a liquid cooled data center environment. An essential aspect of this is the regular testing of heat transfer fluids—whether through a qualified laboratory or on-site diagnostics. Over time, fluids can degrade or become contaminated, leading to corrosive conditions that damage piping, heat exchangers, and other critical components. Bio-growth may also occur if the propylene glycol concentration is not maintained at ~25% or above. Testing can help detect early signs of potential corrosion or chemical imbalance, allowing for corrective action before irreversible damage occurs. Additionally, some equipment manufacturers may require routine fluid analysis as part of warranty conditions or compliance protocols. Adhering to these requirements helps protect investments and ensure accountability.

Routine analysis provides insight into fluid properties such as pH, propylene glycol concentration, inhibitor levels, corrosion, and contaminants. These indicators are essential for assessing the overall health of the cooling system and ensuring it operates within manufacturer-recommended limits. Whether conducted on-site or through a qualified lab, it provides critical data that supports informed decision-making and long-term operational success.

7.2 SAMPLING FREQUENCY

Section is currently under development – content to be added once reviews have been completed by sub-team

7.3 ON=SITE TESTING -

Section is currently under development – additional content to be added once reviews have been completed by sub-team

It is recommended that on-site testing be performed on a quarterly basis with results documented (refer to Section 8). Testing can be performed to confirm the heat transfer fluid remains within the supplier's recommended guidelines.

On-Site Testing

1. **Fluid pH** - Handheld pH meters, or pH paper calibrated to 0.5 units within a pH range of 7 to 11, can be used to verify whether the heat transfer fluid has an acceptable pH (refer to Table 4).
2. **Glycol Concentration -** A handheld refractometer can be used to monitor propylene glycol concentration to ensure fluid is not over or under-diluted (refer to Table 4).
3. **Fluid Appearance** - A visual check of the fluid should show as the color specified by the fluid supplier and free of contaminants or cloudiness.
4. Copper (optional) - Add guidance on testing for copper in solution with DR900 - turbidity can also be tested on DR900 (blank is DI water, no reagents needed)

Deviations from Acceptable Ranges

1. **Fluid pH** - If fluid pH falls outside of the fluid supplier's recommended range, fluid should be replaced, unless further adjustments have been recommended by the fluid supplier.
2. **Glycol Concentration -** Glycol concentration should meet specifications in Table 4. If glycol concentration falls outside of this range, fluid should be replaced. For larger systems, contact the fluid supplier for guidance on adjusting glycol concentration.
3. **Fluid Appearance** - If evidence of sediment, debris or particulates are noted, this may indicate material incompatibility, corrosion or equipment issues which should be investigated before filtering or filling the system with new fluid.

7.4 INLINE MONITORING

Section is currently under development – content to be added once reviews have been completed by sub-team

Automated Monitoring: For larger systems (e.g. >250 gallons in a single TCS loop) or critical systems, consider continuous monitoring of heat transfer fluid chemistry including: fluid pH, glycol concentration (refractive index), corrosion rate (corrosion coupon racks) and turbidity.

If inline monitoring indicates changes outside of the manufacturer's recommended ranges, a comprehensive fluid analysis should be completed. Equipment changeouts may necessitate the need for more frequent monitoring.

7.5 ANNUAL ANALYTICAL ANALYSIS

Section is currently under development – additional content to be added once reviews have been completed by sub-team

Overview

Testing shall be performed by a qualified analytical laboratory on an annual basis. Please contact your supplier to discuss available testing options. Some suppliers may provide a free annual analysis for larger volume systems. Analytical reports should indicate the following, at a minimum: propylene glycol concentration, fluid pH, reserve alkalinity, visual appearance (e.g. sediment, cloudiness, etc.), inhibitor concentration(s), chloride, total hardness, sulfate, degradation acids, dissolved metals. Dissolved metals tested should be consistent with the wetted materials in the TCS loop. Specifications are listed in Table 4.

External Laboratory Requirements

Laboratory should be managed or recommended by the heat transfer fluid supplier and be capable of performing a comprehensive heat transfer fluid analysis. The laboratory should have a service department and qualified technical service representatives on staff that is capable of analyzing results and making appropriate fluid recommendations. Alternatively, the supplier may provide the interpretations of the results and make the fluid recommendations when a third-party laboratory is used.

Acquiring Fluid Sample

Appropriate PPE should be worn when collecting a representative fluid sample, such as safety glasses, impermeable gloves (e.g., nitrile) and long sleeves. Fluid should be collected in a clean, dry, unused sample bottle (e.g. HDPE) with 4-6 oz. of sample being necessary for analysis. Label sample bottle with all identifying information such as company name and system name/number. Keep sample labeling consistent each time samples are sent for analysis. Ship the samples to the identified testing lab via the

preferred carrier, submitting all necessary paperwork. Retain a copy of the analytical report for quality assurance purposes.

Fluid Specific Parameters

Heat transfer fluid quality shall be maintained as specified in Table 4, below:

Table 5: Heat Transfer Fluid Quality Characteristics

Characteristic	Performance	Test Method
Appearance	**Clear and particulate free**	**Visual**
Propylene Glycol, vol %	**PG25:** 24 - 29% **inhibitors + water should make-up ~75% of formulation* **PG55:** 53 - 58% **inhibitors + water should make-up ~45% of formulation* **Biocides are not necessary when glycol concentration remains above 25% by volume, as the fluid is considered bio-static* **Weight % propylene glycol will be ~0.5-1.0% greater than volume % propylene glycol*	**ASTM D3321**
Freeze Point	**PG25:** 9 to 15°F (-13 to -9 °C) **PG55:** -37 to -51 °F (-38 to -46°C) **Increasing glycol concentration will result in a lower freeze point*	
pH	**8.0 - 10.5**	**ASTM D1287**
Reserve Alkalinity	> 4 mL, for conventional technologies For OAT-based technologies, reserve alkalinity is 'to report' *Reserve alkalinity is dependent on corrosion inhibitor formulation*	**ASTM D1121** *Based on a 10 mL sample of ready-to-use fluid*
Copper	**<2 ppm**	**ASTM D6130**
Iron	**<2 ppm**	**ASTM D6130**
Total Hardness (as $CaCO_3$)	**<50 ppm** **High hardness values indicate the use of poor-quality water*	**ASTM D6130**
Chloride	**<25 ppm** **High chloride values indicate the use of poor-quality water*	**ASTM D5827**

Sulfate	**<25 ppm** **High sulfate values indicate the use of poor-quality water*	**ASTM D5827**

7.4 SYSTEM ADJUSTMENTS (FLUID REMEDIATION)

Section is currently under development – additional content to be added once reviews have been completed by sub-team

Overview
Adjustments should only be made under guidance from the heat transfer fluid supplier, based on results of analytical testing. Assure effectiveness and compatibility of additives with wetted materials and subsequent chemical treatment. Chemicals shall meet required governmental and local environmental regulations for the treatment of hydronic systems.

Guidelines
If additives or inhibitors have been recommended by the fluid supplier, the system volume must be known before any dosing can occur. Document any changes that are made to each system.

Making System Adjustments
Add the predetermined amount of inhibitor or additives to the system reservoir, pot feeder or chemical addition point while the heat transfer fluid is circulating, making sure the additive is fully introduced into the loop. The technical support team at the fluid supplier should be able to calculate exactly how much inhibitor should be added based on the exact system volume. Circulate for a sufficient length of time (2-3x total system volume turnover or up to 24 hours) to ensure thorough mixing and collect a representative sample to submit for follow-up testing at an analytical lab. If results don't align with the specifications in Table 4 or the fluid suppliers recommended limits, consult with technical support at the fluid supplier. Keep a record of the date adjustments were made, the system which was adjusted and the amount and type of inhibitor added. Also keep a record of the analytical report from before and/or after fluid addition is complete.

8. Fluid Lifetime and Disposal

8.1 FLUID LIFE EXPECTANCY AND REPLACEMENT

Overview
The service life of the heat transfer fluid can vary significantly depending on the specific application. Key factors influencing fluid longevity include operating

temperature, system materials and the type of fluid used. To maximize fluid lifespan, it is essential to operate the system within the parameters outlined in this document and to avoid using materials that are incompatible with the fluid. The fluid manufacturer can provide specific recommendations regarding replacement intervals and any necessary system modifications.

Replacement Guidelines

The heat transfer fluid should be replaced with fresh fluid either at the end of its useful life—as determined by the supplier's recommendations—or when it no longer meets the performance specifications outlined in Table 4. It is important to note that fluid suppliers typically do not guarantee the performance or lifespan of the fluid.

8.2 REGULATORY CONSIDERATIONS

Refer to supplier's SDS to review regulatory information and ensure safety and compliance guidance is followed.

8.3 Storage

Unopened containers (5-gallon pails, 55-gallon drums or totes) stored out of direct sunlight and high humidity (dry) have a shelf life which is determined by the heat transfer fluid supplier. Do not store in galvanized steel containers.

8.4 FLUID DISPOSAL

DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. All disposal practices must be in compliance with all Federal, State/Provincial and local laws and regulations. Regulations may vary in different locations. Waste characterizations and compliance with applicable laws are the responsibility solely of the waste generator. Contact fluid recycler if recycling is preferred over disposal. Most used propylene glycol-based heat transfer fluids can be supplied as feedstock to commercial glycol recycling companies.

9 Conclusion

In this whitepaper, the contributors have developed a series of guidelines on how to deploy propylene glycol-based heat transfer fluids for single-phase cold plate-based liquid cooled racks. Some key areas included wetted materials to be used with the

fluids, as well as properties and maintenance. The authors have also worked alongside industry experts from other industry forums such as ASHRAE completing similar types of documents to deliver a consistent message across the ecosystem.

10 Glossary

OAT - Organic Acid Technology
IAT - Inorganic Acid Technology

11 References

The publications listed below form a part of this whitepaper, to the extent referenced.

1. **Open Compute Project (OCP)**
   A. Liquid Cooling Integration and Logistics White Paper
      - https://www.opencompute.org/documents/ocp-liquid-cooling-integration-and-logistics-white-paper-revision-1-0-1-pdf
   B. Cooling Environments Advanced Cooling Solutions
      - https://www.opencompute.org/wiki/Rack_%26_Power/Advanced_Cooling_Solutions
2. **American Society for Testing and Materials (ASTM)**
   A. "Standard Test Method for Corrosion Test for Heat Transfer Fluids in Glassware," ASTM D8040-17 (West Conshohocken, PA, ASTM).
   B. "Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens," ASTM G1-90 (West Conshohocken, PA, ASTM).
   C. "Standard Test Method for Analysis of Engine Coolant for Chloride and Other Anions by Ion Chromatography," ASTM D5827-22 (West Conshohocken, PA, ASTM).
   D. "Standard Test Method for Use of the Refractometer for Field Test Determination of the Freezing Point of Aqueous Engine Coolants," ASTM D3321-19 (West Conshohocken, PA, ASTM).
   E. "Standard Test Method for pH of Engine Coolants and Antirusts," ASTM D1287-11(2020) (West Conshohocken, PA, ASTM).
   F. "Standard Test Method for Reserve Alkalinity of Engine Coolants and Antirusts," ASTM D1121-11(2020) (West Conshohocken, PA, ASTM).
   G. "Standard Test Method for Determination of Silicon and Other Elements in Engine Coolant by Inductively Coupled Plasma-Atomic Emission Spectroscopy," ASTM D6130-11(2018) (West Conshohocken, PA, ASTM).

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