ASHRAE TC 9.9 TECHNICAL BULLETIN

TCS Coolant Integrity and System Readiness Best Practices

TL; DR

It is too easy to **violate** direct to chip cooling system operational and warranty requirements. This Technical Bulletin flags four areas where deviations from design intent can create problems that aren't immediately obvious but can cause real damage down the line:

Coolant composition: Systems are designed around a specific coolant (e.g., propylene glycol mix). Drifting from that changes corrosion protection, pressure drop, pump behavior, and heat exchanger performance in ways that cascade through the whole system.

Air management: Entrained air reduces cooling effectiveness, causes pump cavitation, accelerates corrosion, and can drag out commissioning. Proper vent placement and purge procedures are critical, especially at startup.

Stainless steel passivation: Welding and fabrication damage the passive corrosion-resistant film on stainless piping. Without proper cleaning, passivation, and flushing afterward, there is risk of metal release into the coolant and fouling of sensitive microchannel surfaces.

System pressure ratings: Designers need to model the full pressure cascade to ensure no component ever sees pressure beyond its rating.

A structured technical review is recommended when coolant composition, air removal, or stainless-steel surface condition is uncertain or deviates from the design basis

Overview

Direct-to-chip liquid cooling is being adopted rapidly to support increasing processor power densities in data centers serving the AI and accelerated computing market. As a result, fluid integrity and system readiness have become critical success factors for technology cooling systems (TCS).

Coolant composition, air management, and material condition are often owned by different stakeholders during construction and turnover, yet these topics are interrelated and collectively influence commissioning outcomes and long-term system reliability.

This Technical Bulletin highlights design and operational-basis assumptions that are commonly embedded in equipment selection, modeling, factory testing, and commissioning. It identifies conditions where additional review may be warranted to maintain alignment with original system intent and to reduce avoidable schedule and reliability risks. A structured technical review is recommended when one or more of the following conditions has occurred:

- Deviation from the design-basis coolant formulation or concentration (e.g., coolant chemistry changed without confirming impacts or coolants mixed).
- Persistent entrained air, recurring air binding, or prolonged difficulty fully venting the system.
- Field welding or fabrication of stainless-steel piping/components after cleaning/passivation.
- Extended construction delays with stagnant or partially filled systems (which increases risk of contamination, oxidation, or inhibitor depletion).
- Change to fill/makeup water source or chemistry management approach.

DESIGN CONSIDERATIONS

Coolant Composition

Coolant composition and quality are typically established during design and used as the basis for sizing and validating cold plates, CDUs, pumps, heat exchangers, and control sequences.

A nominal 25% (by volume) propylene glycol–water mixture (PG25) is commonly used as a single-phase TCS design condition in many deployments.

Why composition matters

- Thermophysical properties change with concentration (viscosity, density, specific heat, thermal conductivity).
- Hydraulic effects include altered pressure drop, flow distribution, and pump operating point (including NPSH margin considerations on the suction side).
- Thermal impacts include changes in heat exchanger effectiveness and approach, and potential impacts to CDU control stability (valve authority, bypass fraction, pump speed control).
- Chemical/biological considerations vary with concentration; glycol–water mixtures can inhibit microbial growth at commonly used concentrations but do not eliminate the need for contamination control and monitoring. Several bacteria-ingress mechanisms are possible during both construction and operation.
- Glycol should meet the minimum recommended quality defined by TC 9.9* or specified by the ITE manufacturer.

Air Management

Air in a liquid cooling loop can reduce heat-transfer effectiveness and disrupt hydraulic performance.

In practice, air management issues can prolong commissioning, contribute to pump noise/cavitation, accelerate corrosion, and create intermittent performance faults (e.g., air binding in high points, reduced flow through heat transfer surfaces).

Air can enter or remain in the system in many ways, including (but not limited to):

- During filling, equipment connection/disconnection, and maintenance activities.
- In-leakage via seals, fittings, vents, and negative-pressure conditions.
- Release of dissolved gases as pressure decreases and/or temperature increases along the circuit.
- High points created by unvented and poorly routed flexible hoses.

Design Practices to Support Effective Removal

- Locate air separation where fluid temperature is relatively high and pressure is relatively low (often on the return line near the CDU inlet and pump suction).
- Provide manual/automatic vents at separators and at known high points; avoid vent locations that can leak or draw in air; capture any vented water/glycol fluid and avoid discharging to sanitary systems.
- Avoid geometries that trap air (vertical dead legs, inverted “U” bends, localized high points without venting).

* Accessed via subscription to the TC 9.9 Datacom Encyclopedia

DESIGN CONSIDERATIONS

Stainless-Steel Passivation

Stainless steel relies on a chromium-oxide passive film for corrosion resistance.

Fabrication, grinding, handling, and welding can introduce free iron and heat tint that compromise this film and can drive localized corrosion or metal release into the coolant. Proper cleaning of weld beads plays an important role in improving surface finish and preventing contamination (e.g., ASME B31.3 and AWS D18.1).

Maintaining surface condition is therefore a key element of TCS cleanliness and chemistry stability. Passivation is the process that is used to:

- Reduce early-life metal release that increases inhibitor demand and complicates initial fluid stabilization.
- Limit particulate formation and downstream fouling risk in strainers, filters, valves, and microchannel heat transfer surfaces.
- Support long-term reliability and repeatable commissioning results across phased expansions.

Typical passivation approaches

- Factory / Shop: controlled cleaning, chemical passivation (e.g., nitric or citric formulations) by submersion, thorough rinsing, drying, and packaging to prevent recontamination.
- Field: Piping system interior is subjected to controlled cleaning, chemical passivation (e.g., nitric or citric formulations), neutralization, thorough rinsing, and control of runoff per site constraints.
- **Note**: It is important to remember that what applies to part of this system MUST apply to all. An individual installed component that is NOT passivated can jeopardize the operation of the system.

System Pressure Rating

Pressure ratings of all components of a TCS system must be understood as part of the design process.

Besides confirming that secondary pumps have sufficient total dynamic head (TDH) to pump through the system, designers must also make certain that possible pump operating conditions will not exceed rated pressure of any component.

If the pressure in any part of the system exceeds the ratings of that component, it may result in a failure condition. This is especially true of IT equipment, where the risk is costly failure.

Pressure analysis

- A hydraulic model is recommended to ensure the pressure cascade is understood at all points in the system.
- Pressure analysis must include conditions outside of normal, steady state operation. Sources include the project specific flush, clean and fill pressures, static height of the system, maximum pressure set by the system pressure relief valve(s), expansion tank pre-charge pressure (both the low- and high-pressure values), and pressure excursions that occur during the connection or disconnection of equipment.
- IEC 62368-1 (4th Edition)* requires a hydrostatic pressure ***safety test*** of 1.5x the *rated maximum working pressure*. The systems pressure relief value must be set to lower than the *rated maximum pressure* – which ITE manufacturers should specify in their product's thermal template*.
- Many CDU manufacturers provide customization for pressure relief valves which must be selected and aligned to the requirements of the system.

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OPERATION CONSIDERATIONS

Coolant Verification

Coolant verification and lifecycle considerations

- Verify using a lab test and document the concentration and fluid quality at initial fill, after any significant addition of makeup fluid, and on a periodic schedule as specified by the manufacturer.
- Control the quality of mix water used for dilution and makeup* to avoid introducing ionic contaminants or particulates.
- Document the design-basis fluid specification (manufacturer, inhibitor package, concentration, target pH, conductivity limits, filtration strategy) and wetted material compatibility* and include it in turnover deliverables. Include guidance indicating ITE manufacturer-approved fluids and limitations of product mixing or replacement
- Recognize that lifecycle changes (adding new racks, activating previously stagnant branches, replacing components) can introduce contaminants or alter fluid conditions; maintain monitoring and corrective-action protocols.

Passivation

Passivation verification and documentation

- Confirm removal of free iron and acceptable surface condition using accepted methods (e.g., ASTM A380/A967 guidance, fluid analysis and associated ferrous contamination tests).
- Retain passivation records and test results as part of turnover documentation; where 100% testing is impractical, apply a documented QA sampling plan.

Commissioning

Commissioning practices that support air removal

- Automatic air vents are an important part of system startup, ensuring air is effectively removed during the initial filling and commissioning process. Everyday service activities (e.g., filter maintenance or IT equipment additions) can introduce air into the system that needs to be removed. Automatic air vents provide ongoing protection against this. While some end users may desire to replace these with manual air vents once the system has been confirmed air-free via real time monitoring of performance, this decision deserves careful consideration. Many automatic vents contain a cap that can be closed; effectively making them manual vents, or if allowed by local code, a more practical approach is to install a manual isolation valve at the vent that can be closed when the system is confirmed air-free.
- Degassing is most effective at elevated temperatures, which are often only reached during normal operating conditions or commissioning with load banks. Issues can appear weeks after start-up once the system is at steady state temperatures.
- Provide purge connections and commissioning procedures that enable high-velocity flushing of branches to mobilize trapped air (do not exceed equipment manufacturer limits).
- Confirm operation of vents and separators during functional testing and after thermal transients (startup, step-load changes).
- Vacuum or semi-vacuum filling is a technique that some in the industry have found effective for reducing trapped air in the TCS. Because a mixture like TCS coolant may undergo a separation of components when exposed to a vacuum, it is recommended that coolant sampling and laboratory testing be performed after the filling process to ensure that acceptable concentrations of all coolant components are present throughout the TCS.

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OPERATION CONSIDERATIONS

Foreign Material Exclusion

Foreign material exclusion (FME) and post-treatment practices

- Protect cleaned/passivated surfaces during transport and installation using clean, non-contaminating materials.
- Perform controlled flushing and filtration prior to final fill; flush water should meet or exceed Water Quality Guidelines for TCS loops* or ASTM D1193 Type II (C).
- Verify cleanliness (via fluid testing and analysis) before connecting sensitive equipment.
- Reassess surface condition and fluid quality after late work or extended stagnation periods via fluid testing and analysis.

Pressure Management

System pressure safeties

- A combination of controls-based pressure management and mechanical pressure management should be considered, as required by local code and/or authority having jurisdiction (AHJ).
- Controls-based alarms and bypass valves can be included to ensure pressure remains within expected ranges during normal operation.
- Mechanical safeties, such as pressure reducing valves and/or pressure relief valves, should be considered as ultimate safeties, since fill pressure settings and controls sequences could be subject to operator overrides. These should be visually verified to be operable and not left in an override position after commissioning.

Field Verification Checklist

Topic	What to verify	Examples of methods / evidence	Why it matters
Coolant formulation	Manufacturer, concentration, quality and inhibitor package match design basis	Refractometer/density check; chemical vendor documentation; mixing procedure	Hydraulic/thermal performance and chemistry stability are concentration-dependent
Particulate / cleanliness	Filtration strategy implemented and effective	Filter ratings; differential pressure trends; flushing records; cleanliness sampling plan	Protects sensitive heat transfer surfaces and valves; reduces commissioning churn
Air management	Air separators, vents, and purge points function; high points are able to be vented	Functional test results; vent locations; purge procedure; observed stable DP/flow after transients	Avoids air binding, cavitation, corrosion, and performance instability
Stainless surface condition	Post-fabrication cleaning/passivation completed and documented	ASTM A380/A967-based procedure; ferrous contamination tests; records	Reduces localized corrosion and metal release into coolant
Lifecycle changes	Expansion/maintenance plan includes fluid QA before reconnecting	MOP/SOP; sampling schedule; acceptance criteria; corrective actions	Phased deployments can re-introduce contamination or alter chemistry

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Summary

TCS performance and reliability depend on maintaining alignment with design-basis assumptions for coolant composition, air management, and material condition.

Although these factors may be managed by different stakeholders, they are interdependent and can collectively influence commissioning outcomes and long-term operation.

When deviations are contemplated or discovered, a structured review can help confirm continued alignment with system objectives and reduce the risk of latent operational issues.

This Technical Bulletin accompanies the previously issued [Liquid Cooling: Resiliency Guidance for Cold Plate Deployments], which covers critical design and operation recommendations for ensuring resiliency.

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