

ASHRAE TC 9.9 TECHNICAL BULLETIN

TCS Commissioning: Bringing a New Liquid Cooling System Online

TL; DR

This bulletin provides practical, high-level commissioning guidance for bringing new liquid cooled, direct-to-chip, TCS data center deployments online. The focus is on preventing contamination, verifying installation quality, ensuring fluid integrity, and validating system performance before IT equipment is put at risk.

Each section identifies key considerations to inform operator planning and further research. The guidance incorporates findings from ASHRAE RP-1890 (Minimum Flow Velocities for Purging Air and Debris from Hydronic Piping Systems).

Following these steps enhances system reliability, reducing commissioning issues, and establishing a solid foundation for long-term operational performance.

Notice: This Technical Bulletin is informational guidance developed by ASHRAE TC 9.9 and is not a standard. It does not supersede IT equipment manufacturer requirements, applicable codes, or site-specific operating procedures. Reference to specific products or manufacturers is for context only and does not imply endorsement.

Commissioning Workflow

The proposed ASHRAE Guideline 1.6P builds on the ASHRAE commissioning process and aligns with the data center industry's commonly used Level 0 – 5 commissioning framework. This Technical Bulletin focuses on Levels 2 – 4, with guidance on preventing contamination, verifying installation quality, ensuring fluid integrity, and validating the system performance before IT equipment is put at risk

Level 0: Planning and Design

Level 1: Factory Testing

Level 2: Site Installation and Pre-Start-Up Verification

- 2.1 - Material Receipt & Handling
- 2.2 - Inspection & Installation of System Infrastructure

Level 3: Start-Up and Component Testing

- 3.1 Initial Fill, Flush, and Clean
- 3.2 Fill of Final Working Fluid
- 3.3 Thermal Cycling Before ITE Connection

Level 4: Functional Performance Testing (FPT)

- 4.1 Connection to ITE
- 4.2 Final Commissioning

Level 5: Integrated Systems Testing (IST)

Level 2. Site Installation and Pre-Start-Up Verification

2.1 MATERIAL RECEIPT AND HANDLING

Managing Contamination Risk

Pre-cleaned, bagged, or nitrogen-purged components can be re-contaminated at any transfer point between the factory and the installed location. Handling is as consequential as pre-shipment preparation.

Key considerations

- All components are subject to contamination during transit, staging, crane lifts, and cart transport regardless of prior cleaning.
- End caps and protective bags are routinely damaged in transit; do not assume protection survived delivery.
- No material should be placed into service without post-installation system-level flushing regardless of pre-installation conditions. Pre-installation cleaning efforts should be viewed as a means to reduce duration of system-level flushing, not eliminate it.

Cleanliness of Temporary Components

Bypass hoses, flushing spools, test gauges, and jumper assemblies must meet the same cleanliness standards as permanent components. A contaminated temporary connection can introduce debris that persists through commissioning. Pressure testing verifies leak integrity only. It does not clean internal surfaces or guarantee that joints will hold after the stresses of final installation. Joints confirmed under controlled test conditions may open after lifting, rotating, and bolting into final position.

Key considerations

- Temporary is a scheduling classification, not a cleanliness classification. Pre-clean, label, and store temporary components sealed and covered.
- Test fluids (water, glycol, compressed air) must meet purity requirements otherwise they may leave residue requiring further attention in the system flush.
- Field welds and cut joints introduced after any pre-cleaning invalidate that prior cleaning and any prior passivation.

2.2 INSPECTION AND INSTALLATION OF INFRASTRUCTURE

Material Verification

Before pressure testing, physically verify that installed materials match approved submittals. Last-minute procurement substitutions may introduce material incompatibilities that are not apparent until after filling.

Items to verify against submittals (not comprehensive)

- Pipe material, schedule, and joining method. Verify joint torque meets specifications for the specific type.
- Valve type, pressure and temperature rating, and body/trim material.
- Gaskets, O-rings, and thread sealants compatibility with working fluid.
- Wetted materials for all components including CDU and heat exchanger, instrumentation, flow control valves, etc.

Installation Quality

Before the initial fill, inspect the system to verify the quality of the installation.

Inspect the following before initial fill

- Executed welds: visually inspect for spatter, undercut, and incomplete fusion. Ensure all field welds are identified to ensure they are passivated as part of the flushing process. Weld defects are a primary source of particulate in new loops.
- Mechanical joints: confirm alignment and full engagement. Misaligned couplings raise flushing velocity requirements and trap debris. Excessive thread sealant, tape, and gasket lubricants pose contamination risks and can come loose inside the piping, fouling downstream components
- Thermowells, P/T ports, and flow devices: correct location, orientation, and immersion depth.
- Maintenance access: valve handwheel clearance, strainer blowdown, instrument calibration ports, CDU connections, air vent ports.
- Flexible connectors: piping must be independently supported so flex connectors carry no dead weight or thermal pipe stress

Level 3. Start-up and Component Testing

3.1 INITIAL FILL, FLUSH, AND CLEAN

Minimum Flow Velocity

ASHRAE RP-1890 (Minimum Flow Velocities for Purging Air and Debris from Hydronic Piping Systems) establishes the pre-commissioning flush and purge requirements to ensure system efficiency, reliability, and longevity. Consult RP-1890 for detailed experimental methodology, equations, and test data.

Key Takeaways from RP-1890

- The piping configuration governs the required flush velocity. Vertical elbows set the baseline; blind tees require approximately 30% higher velocity than vertical elbows. Evaluate against the most demanding fitting, not average conditions.
- Air purging and particulate removal require different velocities. Plan and execute each phase accordingly.
- Pipe joining method matters. Weld beads, misaligned couplings, and internal discontinuities all raise the velocity needed to clear debris.
- Flush duration scales with system length. Minimum flush time is set by round trips along the longest flow path.

Minimum flushing velocity for clearing debris ^[a]

Nominal Pipe Size inch (mm)	Velocity
< 2" (50)	4 ft/s (1.2 m/s)
2" to 10" (50 to 250)	7 ft/s (2.1 m/s)
> 10" (250)	10 ft/s (3.0 m/s)

Flushing Procedure

After filling, bulk air removal, and hydro testing, isolate sections of the system as needed to flush each segment at the recommended minimum velocity.

Key Considerations

- Critical equipment must be bypassed ^[a, b]. Use temporary bypasses to achieve specified velocities in dead legs. Segmentation must also consider sequencing of flushes to eliminate redeposition of contaminants.
- Debris should be cleared with a high velocity in the first stage of flushing; any subsequent stages of chemical cleaning or passivation are typically at lower velocities.
- Hydronically balance the system to achieve appropriate flow rates and fluid velocities in all branches. If additional chemical flushing or passivation is required, verify that minimum chemical treatment velocities recommended by the chemical provider are respected.
- If required, circulate cleaning or passivation chemistry per chemical provider procedures.
- Drain and rinse the system ensuring final water quality meets the TCS fluid compatibility specification.

Notes:

- a. If a CDU is under consideration as a means of flushing, the following conditions must be met:
- The CDU manufacturer must approve use for flushing.
 - High-capacity full flow filtration must be installed upstream of the CDU inlet.
 - The CDU must be powered and commissioned for use prior to flushing.
 - Sufficient flow and head pressure must be available to meet the velocity minimums, including the upstream filtration.
- b. Racks are critical equipment. They are commonly not yet installed. If racks are installed, they are bypassed.

Level 3. Start-up and Component Testing

3.2 FILL OF FINAL WORKING FLUID

Fill Procedure

When using propylene glycol (PG) as the working fluid, it is important to note it is susceptible to foaming when introduced rapidly. Fill slowly through filtration and from the lowest point in the system, allowing fluid to rise and push air upward. The [filtration used during the fill](#) process should be more stringent than the system's operating filtration requirement.

Key considerations

- Fully open all air vents before starting fill; direct each to a catchment vessel.
- Close any manual vents sequentially low-to-high only after sustained fluid flow (not air or foam) is confirmed at each vent. Reduce fill rate immediately if foaming is observed at any vent point. Some settling time, often 2-3 hours, can be required before resuming.
- Bottom-up fill eliminates the air-versus-falling-fluid conflict that traps pockets in descending pipe.
- Deaeration is critical and may require temporary air-separators. Alternating between higher (3 fps to entrain trapped air pockets) and lower velocity (<0.5 fps to allow bubbles to coalesce and rise to vent locations) may also be required. A sight glass can be used to visually confirm adequate deaeration in glycol systems.
- Confirm expansion tank pressure and suction pressures are within range to ensure system is full and properly charged.

Chain of Custody and Transfer Equipment

The working fluid must be a high-purity process fluid from the supplier's tote to the system connection. Every step is a contamination opportunity.

Key considerations

- Obtain and review a certificate of analysis for each tote lot before transfer. Do not introduce off-spec fluid.
- Transfer pumps, hoses, intermediate vessels, and fittings must meet the same material compatibilities and cleanliness as permanent components.

- Dedicate transfer hoses to working fluid service; label and store them sealed and covered.
- Do not hold fluid in open vessels for extended periods.
- Use of inline filtration between the totes and the system is required.

3.3 THERMAL CYCLING

Prior to ITE Connection

Before connecting IT racks, thermally cycle the liquid cooling loop to expose joints that may hold at ambient temperature but leak under differential thermal expansion loads. Leaks identified at this stage must be remediated.

Procedure

- Bring the system to full operating temperature (with a temporary load source or with pump power), hold to thermal equilibrium and return to ambient. Repeat for a minimum of two full cycles.
- Visually inspect all joints, fittings, instrument connections, and flex connector end fittings during each heating and cooling phase. Use of a UV flashlight can help identify slow leaks in a propylene glycol-filled system.
- Infrared thermography can supplement visual inspection in restricted-access areas.

Threaded Joints

Threaded joints are susceptible to thermal cycling leaks. Incompatible or over-applied thread sealants can degrade or lose effectiveness over the first several cycles when exposed to glycol-based fluids.

Key considerations

- Confirm thread sealant compatibility with the working fluid before fill.
- If a threaded joint weeps, drain, disassemble, clean, and remake with a confirmed compatible sealant. Do not overtighten as a remedy.
- Document any joints remediated and retest before advancing to ITE connection.

Level 4. Functional Performance Testing (FPT)

4.1 CONNECTION OF ITE

Fluid Compatibility

ITE may contain residual factory fluid that could mix with the TCS working fluid upon connection. This can be an issue if the factory fluid formulation differs from the production fluid. Supply/Supply and Return/Return connections should be verified before energizing.

Key considerations

- Consult the ITE manufacturer for the factory fluid specification early in the planning phase and confirm again before connection.
- Consult the TCS fluid supplier as the mixing of incompatible fluid formulations can cause inhibitor precipitation, corrosion, or fouling. Where compatibility is uncertain, flush and drain ITE before connection.
- Sample and verify both TCS fluid and ITE fluid meet quality specifications before connecting any rack.

Instrumentation and Air Management

Validate the measurement methods and acceptance threshold with the fluid supplier.

Key considerations

- At a minimum, measure and monitor the pH, conductivity, glycol concentration, inhibitor reserve, and turbidity for the specific fluid with appropriate instruments and tests.
- Turbidity instrumentation used in traditional HVAC systems are often calibrated for clear water. Measurements obtained using visible-light attenuation methods are biased by fluid color. Near-infrared nephelometric instruments minimize color interference.
- Each rack connection introduces air. Active vent bleeding is required after each rack or bank of racks, not only at the end of all connections. Venting changes system pressure and should be accompanied with fluid makeup to the system as part of the process.
- The system is air-free only after all manual vents show fluid-only flow following final rack connection and full circulation. At automatic vents, no venting indicates the area is air-free.

4.2 FINAL COMMISSIONING

Air Elimination and Thermal Cycling

Air introduced during rack connection must be driven out through sustained circulation and active venting before the system is considered air-free.

Key considerations

- Circulate at or above design flow rate with all high-point vents actively monitored and bled. Alternate flow direction to reach air in branches.
- Perform at least one thermal cycle under load (ambient to design temperature and back) to release dissolved gas and verify leak integrity. Vent actively during all phases of the thermal cycle. Note the system will likely experience on-going venting during early operations. Fluid levels in reservoirs should be closely monitored.
- Pre-charge systems to avoid air entrainment after connecting.

Fluid Quality and Performance Testing

Assess fluid quality only after the system has reached thermal and hydraulic steady state. Samples during transient conditions are not representative. Establish ongoing [fluid quality](#) monitoring per TC 9.9 guidance as part of operational handover.

Key considerations

- Verify pH, conductivity, glycol concentration, inhibitor reserve, turbidity, particulate, dissolved oxygen (if specified), and microbiological activity against [TC 9.9 guidance](#) and fluid supplier limits.
- Confirm system meets design basis: supply temperature at design flow, pressure drop across TCS and rack circuits, CDU heat rejection, control response to load transients, and alarm setpoint function. Adjust system pressure as necessary to ensure acceptable minimum suction pressure at the pumps to avoid cavitation or foaming.
- Document all results against commissioning plan acceptance criteria before transferring to operations.

ASHRAE TC 9.9 TECHNICAL BULLETIN

TCS Commissioning: Bringing a New Liquid Cooling System Online

Summary

Successful TCS commissioning depends on treating contamination control, material verification, and fluid quality as first-class concerns from material receipt through final handover.

Each step in the workflow gates the next — do not advance until acceptance criteria for the current phase are met.

ASHRAE Guideline 1.6P establishes a commissioning framework specifically for data centers. This Technical Bulletin leverages that framework in combination with the recently established guidance from ASHRAE RP-1890 to highlight critical considerations for the system flush and purge to ensure system efficiency, reliability, and longevity.

Acknowledgements

Section 3 summarized ASHRAE RP-1890, conducted by PurgeRite (PI: Russell Buras; Co-PI: George Land), monitored by TC 6.8, co-sponsored by TC 6.1 and TC 6.2.

TC 9.9 would like to thank the following contributors for their time and expertise in getting this necessary industry guidance published.

- Chris Campbell (Vertiv), Dave McGlocklin (Schneider Electric), George Land (PurgeRite), Greg Alexander (Motivair), Jason Matteson (nVent), John Gross (IREN), Sara Hitt (Vertiv)

References

1. ASHRAE RP-1890, [Minimum Flow Velocities for Purging Air and Debris from Hydronic Piping Systems](#).
2. ASHRAE TC 9.9, [TCS Coolant Integrity and System Readiness Best Practices](#)
3. ASHRAE TC 9.9 Datacom Encyclopedia ([Liquid cooling](#), [Fluid quality considerations](#), [Wetted materials](#), [commissioning](#))
4. ASHRAE Handbook—Fundamentals
5. ASHRAE Handbook—HVAC Systems and Equipment
6. BSRIA BG 29, Pre-Commission Cleaning of Pipework Systems.
7. ASHRAE Guideline 1.6P Data Center Commissioning Process