



GUIDELINES FOR PRE-COMMISSION PREPARATION OF TECHNOLOGY COOLING SYSTEM (TCS) ROW MANIFOLDS IN LIQUID COOLED DATA CENTERS

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Date: January 27, 2025

Version History

1.0 March 17, 2025

Executive Summary

Liquid cooled datacenter deployments require various procedures to ensure clean and correctly functioning secondary cooling loops for coolant to pass through to the racks. Pre-commissioning cleaning of the technology cooling system pipework is to ensure the system is brought to the appropriate level of cleanliness for commissioning, deployment, and ongoing operation of liquid cooled racks. Pre-commissioning steps described herein include: hydrotesting, cleaning, flushing, and preparation for commissioning. Steps and considerations for the development of a comprehensive plan to cover these activities are also provided. The primary audiences for this whitepaper are design and facility engineers and managers who will be responsible for the design, procurement, setup and operation of the TCS loop.

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1. Introduction

The objective of this whitepaper is to propose and promote guidelines for the pre-commissioning cleaning of pipework prior to connections being made to liquid cooled racks and coolant distribution units (CDUs). Pipework cleaning and subsequent flushing is required to ensure that the system is free of corrosion by-products, dirt, and construction debris that could potentially foul the narrow (ca. 100 microns) flow channels typical for current 1-phase liquid cooling cold plate designs. System cleanliness should also extend to fittings and terminal units.

The whitepaper below is one contribution toward a comprehensive specification for the commissioning of a Liquid-Cooled Rack System. Other sections could include Wetted Materials, Quick Disconnects (QDs), In-rack Manifold Design, Tubing (flex hoses), Piping, Instrumentation and Controls, Operating conditions including Temperature, Pressure, Filtration, and Safety.

1.1. Scope

Major components of this whitepaper on pre-commissioning activities for TCS piping include:

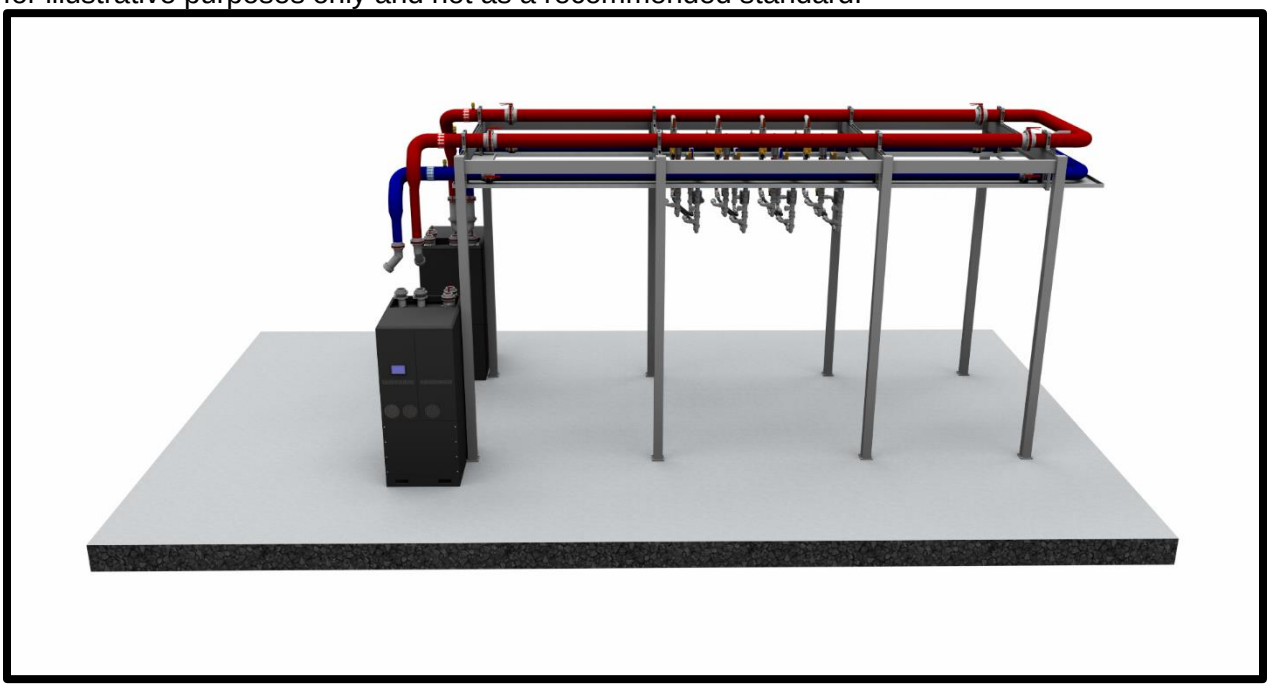
1. Preparation and Planning Considerations
2. Materials and Methods
3. Hydrotesting
4. Cleaning
5. Flushing
6. Preparation for Commissioning

1.2. Detailed Description of Work

Liquid-cooled datacenter deployments require various procedures to ensure clean and correctly functioning secondary cooling loops for coolant to pass through to racks (see Figure 1). Pre-commissioning cleaning of pipework is to ensure optimal heat transfer efficiency during operation of the liquid-cooled racks.

The procedural steps described herein include: hydrotesting, cleaning, flushing, and preparation for commissioning. Preparation for commissioning typically will be filling the system with propylene glycol heat transfer fluid; however, depending on specific conditions different procedures may be recommended.

Figure 1. Overhead Row Piping with CDUs at Pre-Commissioning Stage– Note there are many types of mechanical configurations for this pipework. The design shown below is meant for illustrative purposes only and not as a recommended standard.



Flushing fluid must be passed through the piping to ensure it is free of any cleaning residues. To confirm the quality of the flushing, suspended solids must be monitored over the duration of the procedure. The considerations for water treatment chemicals include the interactions with the materials in the Technology Cooling System (TCS) loop and the appropriate level of operational capacity for the system. The construction contractor, IT system supplier, and heat transfer fluid supplier should agree on the suitability of all wetted materials and procedures. It is important that the procedures, as well as the allowed wetted materials, be thoroughly documented and maintained through refresh cycles and other future changes or additions to the system.

We note here that while for new construction, the dominant design is for overhead piping; there are systems where floor level or sub-floor piping is used in retrofit designs for formerly air-cooled technology loops. Generally, these systems will have similar considerations to those with overhead pipework, but with additional complications for accessing system connections, (i.e., low points in the system which are needed for proper draining).

1.3. Definitions

TCS loop – Technology Cooling System loop consists of the Row Manifold, Rack Manifolds and the secondary side of the CDUs.
CDU – Coolant Distribution Unit
Rack Manifold – Pipework that distributes coolant fluid to the cooling loops of IT equipment.
Row Manifold – Piping (typically overhead) that connects into the secondary side of CDUs and serves as part of the TCS loop. The focus of this whitepaper is on the Row Manifold piping.
Flushing Skid – Collection of skid mounted equipment used to clean and flush Row Manifold piping. Typically contains pump, filter, pressure gauges, flow meter, pot feeder, connections and sample port.

1.4. Assumptions

1) Recommended material of construction: Pipework materials are expected to be stainless steel, minimum grade 304.
2) The piping materials have arrived on site with internal surfaces appropriately treated as per mechanical standards (for example ASTM A380/A380M-25 Standard Practice for Cleaning, Descaling, Pickling, and Passivation of Stainless-Steel Parts, Equipment, and Systems) for removal of any mill scales/oils/greases and surface acidization (pickling).
3) Pipe welding has been properly performed as per mechanical standards (for example American Welding Society “D10.18 Pipe welding (stainless steel)”) under inert atmosphere conditions to minimize heat tint and eliminate the need for onsite pickling.
4) The rack manifolds are not connected to the row manifolds yet.
5) The CDUs are not connected to the row manifolds yet.
6) Expected surface contamination consists primarily of inorganic dust and dirt.
7) Commissioning of the CDUs and Racks is not part of the scope of this document.

2. Compliance with Open Compute Project Tenets

2.1. Openness

This whitepaper is designed to lower the burden of entry into deploying liquid cooled hardware into new and retrofitted datacenters on the secondary cooling loop. It can be used by a wide variety of datacenter operators, MEP (Mechanical, Electrical and Plumbing) consultants, engineering staff and others. The procedures are designed to work for cleaning row manifolds at both small scale and larger scale datacenters

2.2. Efficiency

The guidance in this whitepaper will improve the efficiency of on-site contractors and engineering teams when cleaning the secondary cooling row manifolds during pre-commissioning by providing the teams involved with a common reference document.

2.3. Impact

With the increasing adoption of liquid cooling in datacenters, the pre-commissioning of the new infrastructure projects and the associated best practices are important to address. In this document we directly address an important step of these procedures that many deployment teams are frequently tasked with learning on the job in tight timelines. This document will allow better planning and coordination to take place around the pre-commissioning tasks on the TCS piping and reduce the implementation of various methods ad hoc.

2.4. Scale

Liquid cooled deployments for AI are scalable to clusters of computer hardware in both small (< 100 racks) and large data centers (>100 racks). For both scenarios row manifolds are needed to deliver the secondary coolant to the server racks via the TCS loop.

2.5. Sustainability

With the advances in processor power required for running AI clusters, the heat rejection requirements now typically surpass the capabilities of an air-cooled system design. Using a liquid medium as the heat transfer fluid affords the opportunity to recover the heat generated from AI hardware and to implement heat re-use solutions for a wide range of industry scenarios.

3. Preparation for Cleaning Secondary Piping after Installation

Preparation for the TCS pipework pre-commissioning clean and flush has two aspects: The first is the planning and coordination among the teams involved, and the second is the delivery, setup, and checking physical assets required for the task.

3.1. Planning and Coordination Activities

A comprehensive plan for the cleaning and flushing of the secondary pipework should include the following items:

3.1.1. First and foremost, ensuring that proper risk assessments are performed for specified activities and compliance with all labor and environmental regulations for all planned activities.

3.1.1. a. Verify the availability of appropriate water sources (as specified below) and any required chemistries, as well as provisions for proper spill containment, capture of wastewater, and disposal of wastewater, including sign off by the local environmental team on the anticipated wastewater disposal needs. **It is critical to engage with the local authority having jurisdiction (AHJ) over the water disposal to formalize a wastewater discharge plan**. This step will often be a stumbling block for the procedures contained herein

3.1.2. Due consideration should be given to the timing of the cleaning and flushing activities in the context of the rest of the commissioning schedule, e.g., making the CDU and Rack connections. This is particularly important if there are many rows of liquid cooled racks involved, as period of stagnancy should be avoided.

3.1.2.a. Hydrostatic testing and flushing activities should be coordinated so that flush can be implemented immediately following hydrostatic testing. At a minimum, the plan should seek to minimize time between end of pre-commissioning and actual commissioning and fill of

TCS loop equipment in order to minimize stagnant water issues both in terms of volume and time.

3.1.2.b. Definitive timelines should be provided and coordination maintained with other contractor activities on site.

3.1.2.c. Based on best known processes, the CDU should not be connected during the secondary pipework clean and flush. If any CDUs are connected during the secondary pipework clean and flush (note: they should not be), the CDU manufacturer warrantees should be consulted for potential impacts and additional filtration is likely required.

3.1.3. Supervision and recordkeeping of the activities performed should also be part of the plan. Recordkeeping should extend not only to document pressures, flows, and chemistry as per the plan, but also proof of performance and documentation of desired results. These documents should be provided by the performing contractor to the owner once the job is completed.

3.1.3.a. The plan for measurements on the fluids employed (pre-flush, during, and post-flush) may require a separate sub-contractor to perform the measurements on-site (preferred) or off-site (not preferred) vs. having the mechanical contractor perform such. For analyses suitable for final quality records, the final fluid from each process step can be sent off-site to a certified laboratory.

3.1.3.b. A critical piece of the required documentation is a working piping and instrumentation diagram for the system, as configured for hydrostatic testing and for flushing including temporary equipment and connections.

3.1.4. Specialized equipment considerations such as for flushing skids, temporary connections and drains, and consumables are another key part of the plan, especially for any customer items requiring significant lead times. Other specialized equipment to deal with temperature extremes (hot or cold weather) may be required.

3.1.4.a. The number of flushing skids to be employed is a key consideration based on the overall job timeline and the number of rows of liquid cooled racks involved. Time savings for running skids in parallel (faster) vs. having to wait for serial operation (slower) drives the number of skids which should be balanced against the capital cost of skids and their availability. Rental flushing skids may be used in place of operator owned equipment. One should pay particular

attention to inspecting the skids for cleanliness prior to use. Rental skids are commonly used for most flushing jobs since they are required only during the pre-commissioning stage. However, to ensure their reliability and effectiveness, they must undergo proper maintenance.

It is essential that rental skids are hydrotested and thoroughly cleaned, as visual inspection alone may not be sufficient. To maintain cleanliness and operational efficiency, it is recommended that the internal components of the rental skids be cleaned using flushing fluid on-site before use. Skids should be drained and dried immediately after use.

3.1.4.b. Flushing skid pumps should be properly sized to obtain the minimum acceptable velocities. Ensure that appropriate electrical hookups are available for operating the pumps, especially paying attention to cases where very large pumps may be required for large diameter headers.

3.1.4.c. The flushing skid should be properly instrumented:

- pressure gauges on the filter to monitor filter delta P
- pressure gauges on the pump inlet and outlet
- calibrated flow meter to measure the full skid flow

3.1.4.d. Numerous temporary parts and consumables will be required for these tasks, including spare parts, hoses, flanges and connectors for the flushing skids as well as their consumable items such as filter cartridges or filter bags. The plan should include provisions for stocking all these items as well as all required safety equipment. Materials of compatibility should be verified for all wetted materials that may contact the cleaning chemistry/ final system chemistry.

3.2 Site and System Preparation

3.2.1 Safety Checks

1) Review all Safety Data Sheets (SDS) prior to use and handling.
2) Perform an onsite risk analysis

3.2.2 Safety Equipment

Typical safety equipment needs are shown in Table 1 below. Note that modifications to this list should always be made according to the results of the on-site risk assessment and in conjunction with the safe handling recommendations as listed on the SDS.

Table 1. Safety Equipment Needs

Item	Description
Footwear	In accordance with ASTM F2413 (electrical hazard)
Gloves	Chemical resistant, compatible with all chemistry or fluids being used
Safety glasses or goggles	
Chemical smock/apron	
Eye wash station	Permanent or temporary, nearby
Secondary containment	For any chemical used and spill response/absorbent materials for any chemical spills
Bottles for Water Samples	Water samples will be taken at various points in the process to monitor compliance of specific parameters and to ensure compliance with on-site discharge requirements

3.3 Equipment and Materials

Equipment and Materials are discussed in detail below and summarized in Table 2.

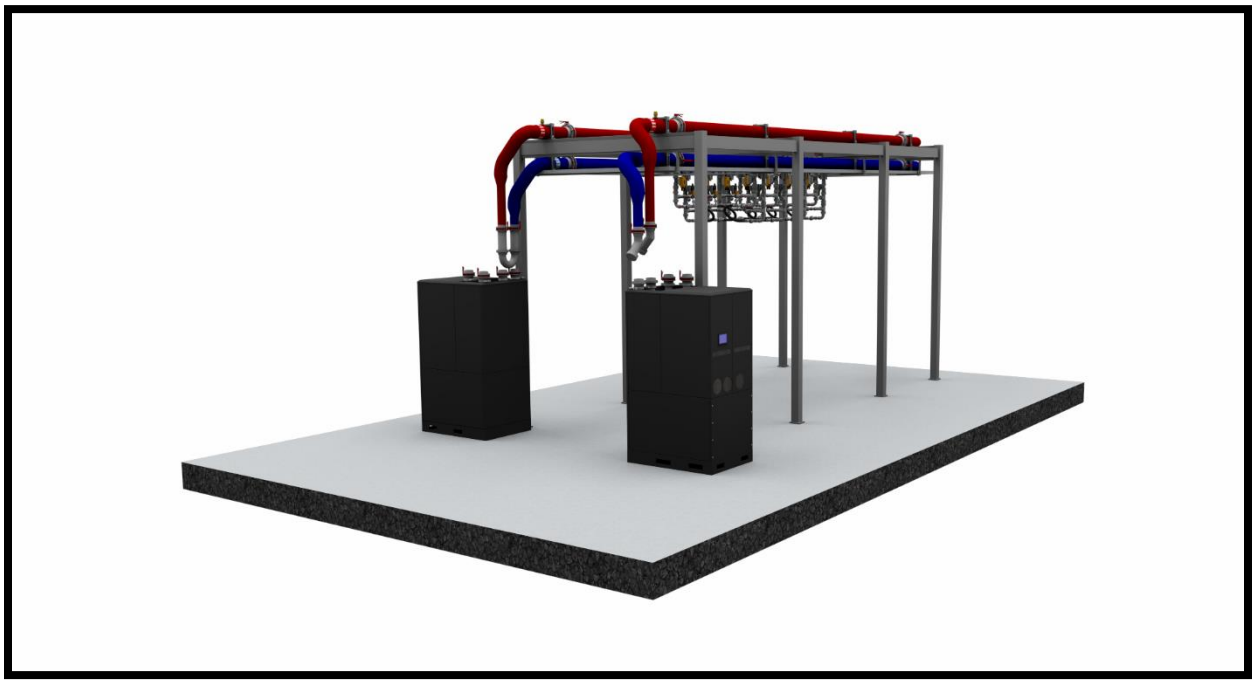
1) Calibrated pH meter: solutions specified in this document typically require a specified pH range which must be checked/monitored.
2) Calibrated Conductivity Meter: High amounts of dissolved solids in the fluids may leave undesirable residue on the piping, hence, conductivity should be low and monitored. Note that conductivity meters can typically read out either in conductivity units such as uS/cm or Mhos or they can use a conversion factor to read out an approximate TDS (Total Dissolved Solids).

3) Digital Refractometer: To produce high quality measurement of glycol concentration/dilution
4) Field Bacteria Test Kit (Total Aerobic Counts): High amounts of bacteria should not be in the water used during pre-commissioning as it may act as a seeding source for biofilm throughout the system, hence it should be measured.
    a. Note: an incubator is required to warm the test slides for 48 hours before reading the results.
5) Temporary flushing skid (pump, full flow filter, pressure gauges, flow meter, pot feeder, connections and sample port), appropriate flanges/connectors, and loop backs.
    a. Note that this includes the U-pipe connector (shown above the CDU in Figure 2) tying the ends of the hot and cold TCS loops together.
    b. The filter should be designed to take filtration media of different micron rating from 100 micron to 1 micron.
    c. Depending on the amount and size distribution of particulates in the system, a staged filtration approach may be required where coarser grades of filtration such as 50 to 100 micron are used at the start of the process, working downward to the final specified filter rating.
    d. The minimum final micron rating recommendation currently in industry has significant variability. Typical final filtration ratings vary 1 micron to 25 micron. For the purposes of this document the final filtration rating of 5-micron level is recommended.
    e. Ideally, the capture efficiency for filter elements employed on the skid should balance pressure drop considerations vs. the time required for the recirculation to clean the water vs. the rapidity of plugging and need for filter changeouts. There is no single “right” answer for this number that fits for all conditions; however, a capture efficiency of roughly 98.7% (Beta = 75) can be a good starting point.
    f. Note that the filter(s) do not necessarily have to be integrated into the flushing skid. A separate pump skid and filter skid may be employed.

Table 2. Basic Equipment and Material Requirements

Equipment	Purpose
Calibrated pH meter	Check/monitor pH range of specified solutions
Calibrated Conductivity Meter	Monitor conductivity to prevent residue from dissolved solids
Field Bacteria Test Kit (Note: Incubator may be required)	Measure bacteria levels to prevent biofilm formation.
Flushing skid	Flushes the piping. Skid typically includes pump, filter, pressure gauges, calibrated flow meter, pot feeder, connections, and sample port.
Colorimeter	Measure turbidity and copper levels
Fluid sampling kit	Ship samples to analytical laboratories
Distilled water	Rinse sample bottles and analytical equipment
Procedure Water	Meet quality specifications for water composition (Table 5).

Figure 2. Pipework Setup for Connection to Flushing Skid



g. Pump sizing for the flushing skid should be sufficient to meet the recommended flow guidelines shown in Table 3 (metric units) or Table 4 below (U.S. units). Table 4 also includes information for estimating system volume. Note that the selection of flushing velocity is a balance of many factors. One is the minimum suspension velocity for sand/clay particles, which in the stormwater system design literature tends to be around 0.6 to 0.9 m/s (2 to 3 fps). Another consideration is the water shear stress necessary to provide cleaning action which increases slowly with pipe diameter as per the BSRIA recommendation (see Ref. 1). A third consideration is the chemical mass transfer rate at the wall to provide consistent cleaning chemical effectiveness. Keeping the mass transfer coefficient constant (using standard formulas for the Sherwood, Schmidt, and Reynolds numbers) as a function of pipe size results in a slightly steeper increase in required velocity vs. pipe size. Each of these considerations result in recommended flushing velocities somewhere in the 3 to 5 fps range for the range of pipe sizes considered as shown in Figure 3.

Table 3. Recommend Minimum Flushing Flow Rates (Metric Units)*

Nominal Pipe Size	Minimum Fluid Velocity	Volumetric Flow Rate
mm	m/s	L/s
15	0.96	0.20
20	1.00	0.37
25	1.03	0.60
32	1.06	1.08
40	1.08	1.49
50	1.11	2.47
65	1.15	4.29
80	1.17	6.01
100	1.21	10.50
125	1.24	16.40
150	1.26	23.80

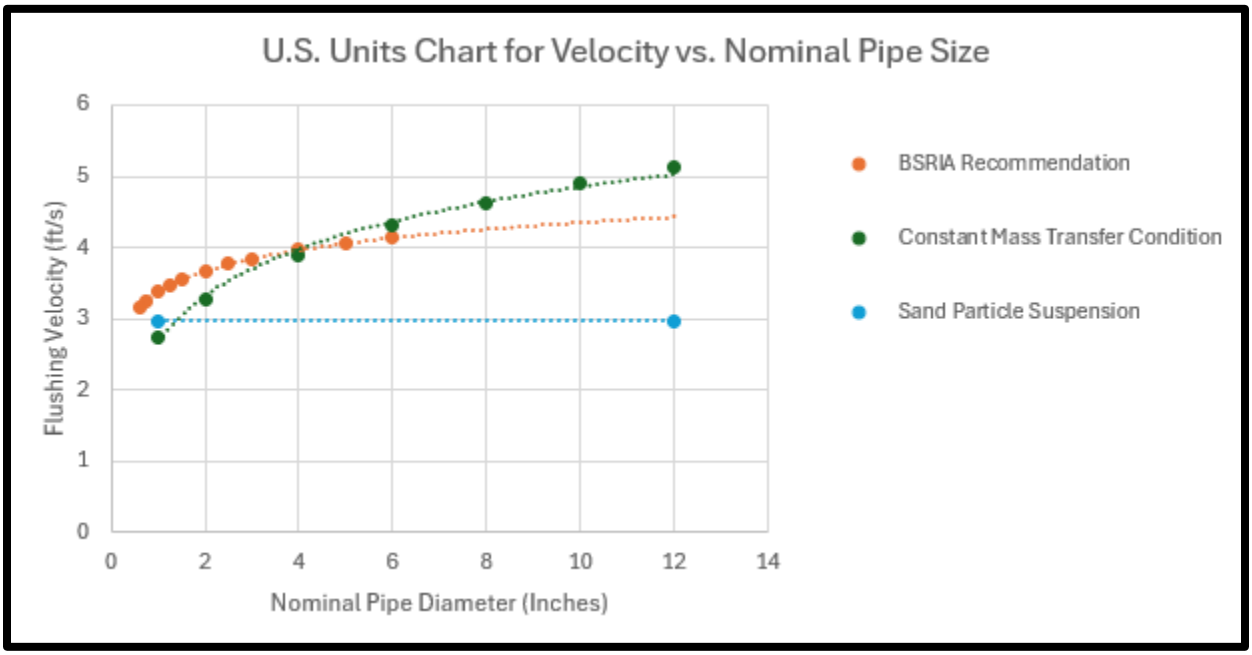
*From: C. Parsloe and M. Ronceray, “BG-29: Pre-Commission Cleaning of Pipework Systems, Amended 6th Edition”, BSRIA, March 2021, p. 50. (Ref. 1)

Table 4. Recommended Minimum Flushing Flow Rates (U.S. Units)

Pipe Size	Velocity	Flow Rate*	Piping Vol.
Inches	ft/s	gpm	gal/(100 ft.)
3	3.84	105	45.4
4	3.96	157	66.1
6	4.13	416	167.5
8	4.26	664	259.9
10	4.35	1069	409.7
12	4.43	1545	581.4

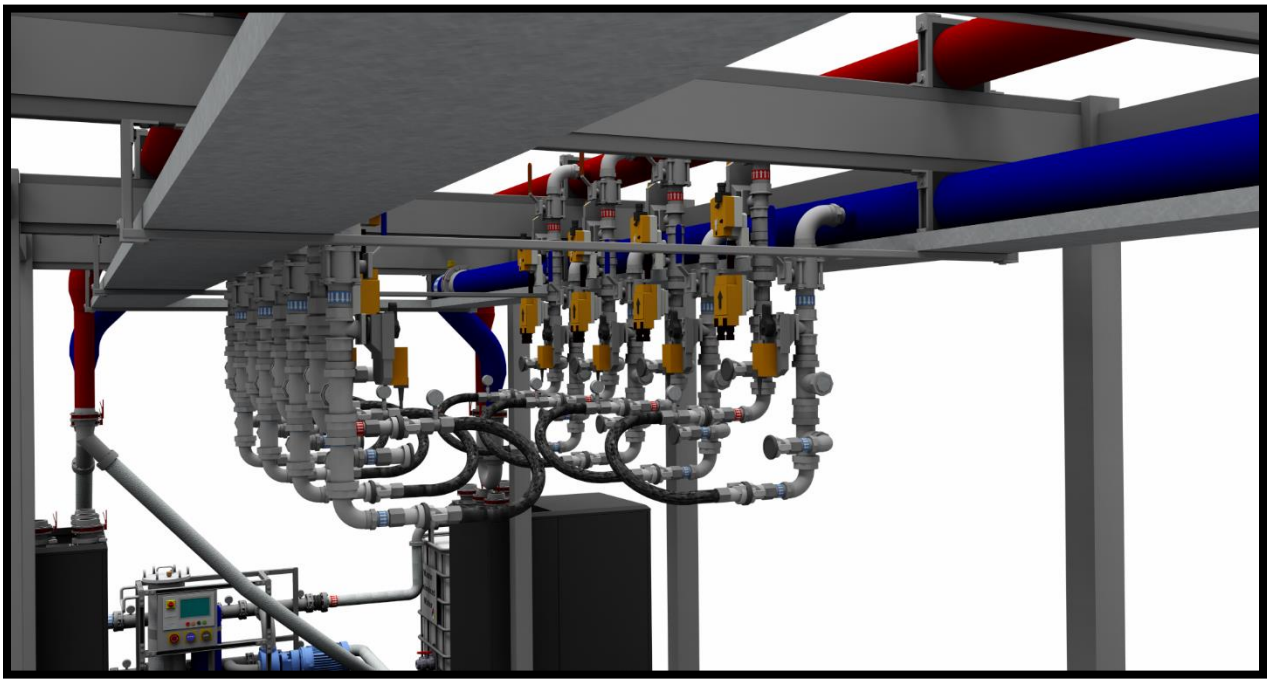
***Depending on equipment availability, it may not be possible to achieve these flow rates; however, they do represent best practice.

Figure 3. Comparison of Different Minimum Flushing Velocity Criteria



h. Loop backs connect the hot and cold drops of the rack manifold for pre-commissioning operations shown in detail in Figure 4. Loop backs will be peroxide cured EPDM material or flexible Stainless Steel consistent with what will be used to provide the connection between the rack manifold and the technology.

Figure 4. Loop Back Configuration in Rack Manifold



6) Colorimeter for measurement of turbidity and copper. During the piping flush there should be no copper componentry hooked up to the secondary piping system. However, for copper piped systems, it is advisable to perform a low-level colorimetric soluble copper analysis on the flush water prior to and after flushing is one way to check that the piping was adequately protected during hydrotesting, cleaning and flushing.
    a. The colorimeter can also be used for measuring active biocide residual (such as free chlorine or peroxide) in the Procedure Water (see point 9 below) tank to ensure consistent microbial control in the Procedure Water. Test strips for low level free residual chlorine (0 to <10 ppm as Cl_2) or low level peroxide (0 to 100 ppm as H_2O_2) may also be used depending on the biocide being applied.
7) Fluid sampling kit for shipping samples to analytical laboratories for water composition verification.
8) Distilled water to rinse analytical equipment
9) “Procedure Water” is the base water for all the work described herein, prior to adding any chemicals to it. It should meet the quality specifications in Table 5 below. Reverse

osmosis permeate or deionized water that has been previously disinfected will typically meet these criteria. If site water is being used in lieu of meeting the specifications in Table 5, the water quality should be documented in terms of the parameters shown in Table 5. Using water that does not meet the conductivity criteria may increase the risk of later deposit formation. Any of the ASTM standard reagent waters (I, II, III, or IV) described in ASTM Standard D1193-99e1 will meet the conductivity requirement in Table 5.

a. Note that using water that does not meet the microbial contamination criteria increases the risk of subsequent biofilm problems in the system. Field testing for bacteria based on dip slides take 48 hours to return results, therefore, to minimize the risk of out of compliance Procedure Water, it is recommended to maintain a small residual of oxidizing biocide in the Procedure Water storage tank. Typically, this would be accomplished using simple oxidants such as bleach or peroxide as directed by the water treatment provider involved in the operation.

Table 5. Procedure Water Quality

Parameter	Units	Max/Min
Conductivity	µS/cm	50 Max
pH	Std. Units	6 Min
Total Aerobic Bacteria	CFU/ml	1000 Max

4. Operating Procedures

Prior to completing any cleaning steps for the secondary piping, it is important to ensure the installed pipes are not susceptible to leaks. This section contains procedures for the hydrostatic system test, cleaning, flushing and preparation for commissioning that should be used prior to filling with heat transfer fluid. These procedures assume that a compressed air or other gas pressure test has already been performed on the TCS row manifold.

4.1. Pre-Hydrostatic Test System Check

There may be undesirable contamination in any or all pieces of the temporary flushing equipment including filter housings, pumps, piping, temporary hoses, etc. It is worthwhile to put a loop back on the end of the flushing equipment (entire assembly of pumps, pipes, hoses, and filters) and operate the system with Procedure Water in it for a short period of time both to check the system hydraulics, operation and to be able to examine the resulting water to assess the level of cleanliness of the equipment. Further cleaning or filtration may be required to get the equipment itself to an appropriate state for use on the TCS system.

4.2. Hydrostatic Test

The rack piping hydrostatic test will be a “proof pressure” test in the range of 1.3 to 1.5x the anticipated working pressure in the system. Specific test pressure should be defined in the system design documentation. Mechanical contractors should supply the equipment (pressurization pump, pressure gauges, connective piping, etc.) for the hydrostatic pressure test. The equipment needs to be cleaned ahead of time to ensure there is no contamination of the secondary piping. The ASME provides an excellent reference for hydrotesting in their ASME B31.3 “Process Piping” document (Ref. 2). As such, we will not cover it here in detail.

4.2.1. Important Notes on the Hydrostatic Test Procedure

1) All potentially hazardous equipment on the system should be locked out as per the Safety Plan for the job. This includes electrical and hydraulic energies.
2) Add future connection to the distribution piping to the supply and return loop to allow for pumping skid connection, at the high point in supply near where the CDU will be positioned.
3) Fill and vent system loop with Procedure Water for hydrostatic test—note fill should be conducted gradually at a low point of the system with the system vented at its high point to ensure air removal.
4) Complete hydrostatic pressure test of system loop to specified pressure with pressure relief valve should be appropriately set.

5) Loop backs can be in place or removed but the valves on the drop downs should be closed.
6) After completion of the hydrostatic pressure test, the piping connections that have been tested and approved should not be taken apart. If row manifold piping connections must be disassembled, then the hydrostatic pressure test should be repeated. For example, to remove residual water in low points post cleaning, then an additional hydrostatic test should be performed prior to final fill.

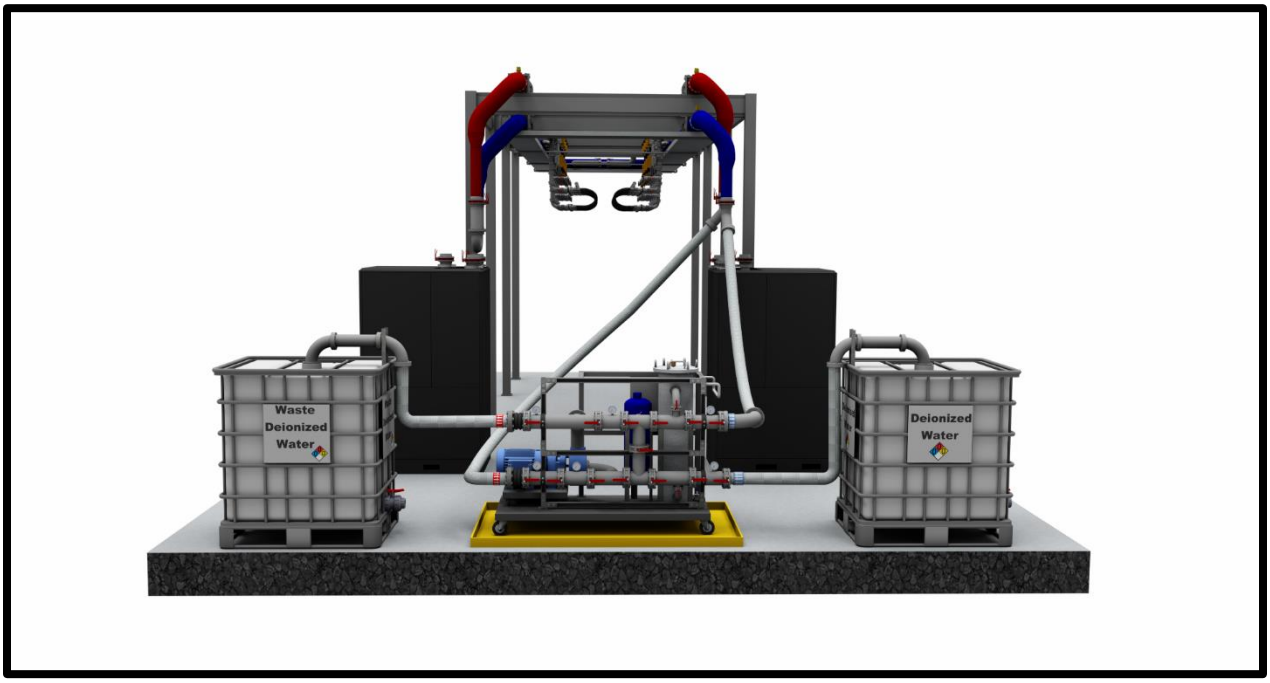
4.3. Cleaning of Rack Piping Loop

Once the hydrostatic test has been completed, if any leaks are found they should be remediated and the hydrostatic test repeated. Water should not be left in a system with no circulation for more than 24 hours due to microbial growth risk without proper chemical treatment. The flushing skid can be connected to the system as shown in Figure 5 below with both the supply water and wastewater tanks in place. The Cleaning procedure has 3 steps: recirculate, clean, and drain. Note that if the hydrostatic test revealed leaks requiring repair, the system will typically have to be drained for this work, necessitating a refill of the system prior to purging. If the hydrostatic test is passed, work should proceed directly into the recirculate of the Cleaning phase with no drain and refill required.

The initial recirculation is to filter large particles and debris from the system using coarser filtration than what will be employed later. A filter in the range of a nominal 50 to 100 microns at should suffice for this initial step. Particulate matter removal throughout the process is paramount due to the exceedingly small tolerances in the cold plates that the system will ultimately operate.

During the initial recirculation, the valves to the rack manifold piping should be closed to prevent flow of large debris into the smaller diameter piping. After the initial recirculation, prior to the cleaning step, these valves can be opened to allow flow through the loop backs. If after the initial recirculation, the water cleanliness criteria cannot be met, the system should be drained and this part of the procedure repeated before proceeding on to the cleaning step.

Figure 5. Connection of Flushing Skid to Row Manifold Piping with Loop Backs Installed on Rack Manifold and Supply Water Tank and Wastewater Tank in Place



Ideally, the piping materials in the system has been properly pretreated to remove nearly all oils, greases, and other organic matter; however, a chemical cleaning is still typically combined with the recirculate step that is used for particle removal from the surfaces. The chemical cleaning additive typically consists of caustic inorganic cleaner (examples include: borates, phosphates, carbonates, and polyphosphates) and a surfactant. If there is copper metallurgy in the system, the cleaner should also contain a copper corrosion inhibitor (azoles, typically). The site water treatment vendor should be consulted for precise cleaning product and inhibitor recommendations. Typical caustic cleaner formulations provided by water treatment vendors will provide a few hundred to a few thousand ppm of actives once diluted down to use concentration. These solutions are preferred to hardware store formulations which tend to be much more concentrated and will result in extended rinse down times after their use. For any cleaning products in use, the environmental restrictions on their discharge as well as the safety precautions must be carefully considered.

The additive can be added via the pot feeder on the flushing skid once the purge is complete. The amount of additive required is based on the flushing system volume or as determined by you water treatment specialist. This value can be validated by noting the amount of water required to initially fill the system from the Procedure Water tote. The Procedure Water with the diluted cleaning additive is then recirculated for a specified period of time, while the water is simultaneously filtered. A typical Cleaning procedure overview is shown in Table 6. Cleaning preparation steps are shown in Table 7.

Table 6. Cleaning Procedure Overview

Step	Water Source	Time	Success Criteria
Fill (only if needed)	Procedure Water	As needed	Air bleed is complete
Recirculate	Procedure Water	Filter system volume minimum 3 times	No visible particles, Turbidity < 20 NTU (or AFU depending on instrument--water should be clear), conductivity < 60 µS/cm
Clean	Water contained in loop with chemical Cleaner added	Minimum 4 hours	No increase observed in filter differential pressure for 1 hour
Drain	No source needed	As needed	System completely drained through lowest point(s)*

*Nitrogen at less than 5 psig may be used to help drain the system as needed. Compressed air is only acceptable if it meets ISO Standard 8573.1 Class 2 properties.

Table 7. Cleaning Procedure Preparation

Activity	Description
Safety Check	Ensure adherence to pre-job safety plan including personal protective equipment and all required lock-out/tag-out procedures are followed.
Drain Validation	Validate that sufficient drain capacity or wastewater totes are available to handle the wastewater generated and that it can be safely disposed of.
Pump Inspection	Confirm there is no visible damage to the pump, it is installed correctly, and operable.
Install Flushing Skid	Connect skid to system as specified in the PID for pre-commissioning work. See for example Figure 4.
Piping Inspection	Inspect temporary and permanent piping to ensure conformance to PID developed for pre-commissioning work, e.g., no racks connected, no CDUs connected, loop backs in place, proper flow direction, etc.
Piping Conformance	Eliminate any deadlegs found during piping inspection or piping non-conformances.
Procedure Water Inspection	Measure conductivity, pH, and Total Aerobic Bacteria in Procedure Water supply to validate conformance with specification. Record results. Dose with biocide as per Site Water Treatment Vendor recommendation if bacterial counts are above specification.
Fill System	Fill the system with Procedure Water ensuring air is bled from the system using air bleed valves where appropriate.

4.3.1. Important Notes on the Cleaning Phase

1) The initial Recirculation with Procedure Water should be conducted until water is free of debris and looks clear. Typically, clear water will have a turbidity <20 NTU. While large debris is being removed from the row piping, the valves to the rack piping should be closed.

2) During Cleaning, water should be circulated for a minimum of 4 hours through all legs of the system, isolating required valves to ensure velocity flush through each leg of the system as shown in the flushing schematics.
3) Verify operation and ensure minimum flow rates are achieved. Record flow rates, pump speed, and differential pressure (ΔP) across filter(s). Should the differential pressure across a filter exceed the specified limit for filter element changeout (typically around 10psi), isolate the filter vessel and remove the filter element for replacement.
4) During recirculation, the flushing skid filter is engaged to gradually bring down the amount of particulate matter in the system. Several bag or filter element changes may be required based on pressure differential across the filter during this stage. Once the specified cleaning time is met **and** the pressure differential no longer rises on the filter, the particulate removal stage is complete. The manifold can then be drained for the next stage. Please note that all filtration should have a minimum pressure differential. A pressure differential of 0 psi could be representative of a breached filter.

4.4. Flushing

The purpose of the Flush step is to remove the cleaning chemistry from the system, so that an acceptable water chemistry is present in the system prior to Preparation for Commissioning. After the Drain step of Cleaning, Flushing involves Filling the system with Procedure Water, Recirculating the water in the system, and then Draining—repeating this procedure as many times as needed until the conductivity at the outlet is within conductivity specification for this step. These steps are shown in Table 8 below. **Flushing should be completed immediately following the cleaning step to minimize the potential for contaminants in the water to settle out and foul the system surfaces.**

The conductivity specification can be when the outlet water is within 10 to 20 µS/cm of the original Procedure Water conductivity or simply a maximum conductivity of 60 µS/cm. Piping connections are the same as in the Cleaning step.

Table 8. Flushing Procedure Overview

Step	Water Source	Time	Success Criteria
Fill	Procedure Water	As needed	Air bleed is complete
Recirculate	Water in loop	Recirculate the system volume minimum 8 times	Water homogenized within loop
Drain	Water in Loop	As needed	System completely drained through lowest point(s)*
Repeat as Needed	Procedure Water	As needed	Until conductivity specification is met at loop outlet

*Nitrogen at less than 5 psig may be used to help drain the system as needed. Compressed air is only acceptable if it meets ISO Standard 8573.1 Class 2 properties.

4.4.1. Important Notes on the Flushing Phase

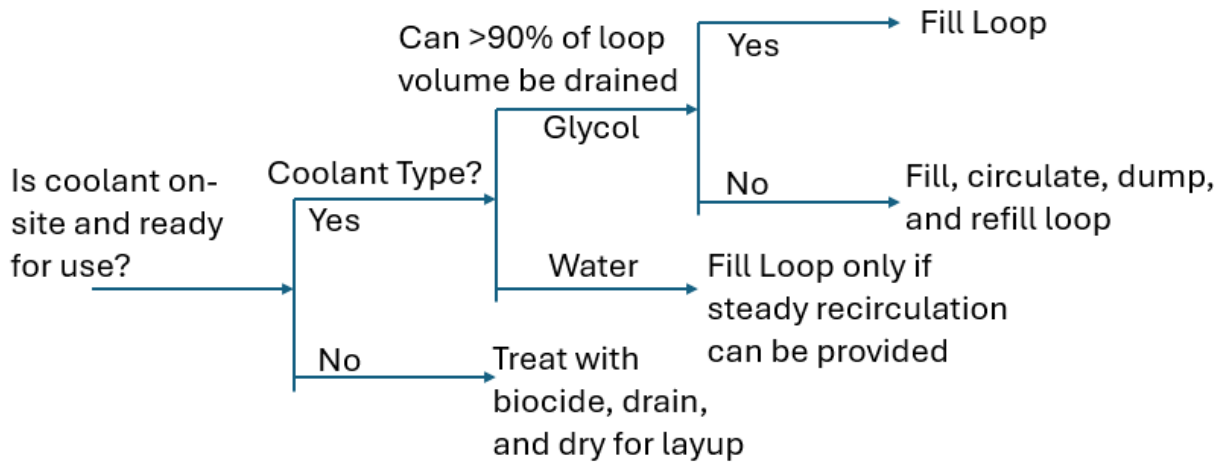
1) Isolate valves as required to ensure velocity flush through each leg of the system as shown in the flushing schematics. Verify operation and ensure minimum flow rates are achieved. Record flow rates, pump speed, and differential pressure across filters. Should the differential pressure across filters exceed 10 psi, isolate filter vessel and remove filter for either cleaning and reinsertion or replacement.
2) Take water samples periodically during the Recirculation to document the water quality, conductivity and turbidity.
3) Repeat the procedure as needed until the conductivity specification is reached. The final turbidity should be reliably less than 5 NTU or approximately equal to that of the Procedure Water.
4) Gentle closing and opening of each valve are recommended during flushing to knock loose any entrapped materials.
5) If flushing to drain is not possible given the deployment, flush the loop contents to an empty tote for later discharge.
6) After the main flushing is complete, perform a terminal flush at all future connection outlets that might have deadlegs. Simply open the valves and flush into a bucket or similar but ensure continuous pressure and flow to the drain valve.

7) Take a final water sample to send off-site to measure conductivity, turbidity, pH, and total aerobic bacteria to provide documentation of the final loop water quality before executing the last Drain phase.

4.5. Preparation for Commissioning

This phase of the pre-commissioning **must follow immediately after the Flushing phase** to avoid the possibility of additional contamination events after the Flushing has been completed. There are four potential paths for preparation for commissioning as shown below in Figure 5. The first and most preferred path is to immediately fill the system with glycol-based coolant, assuming that such is on-site and ready to use. If a water-based coolant is to be used, it should only be added to the loop if the loop has been prepared to provide on-going recirculation either through an external pump or the CDU pumps if the CDUs are verified clean and ready for commissioning.

Figure 5. Decision Tree for Preparation for Commissioning



On-going recirculation is not critical for a glycol-based fluid because it will be biostatic, assuming the proper minimum glycol concentration is maintained. The criticality of glycol concentration to maintaining a biostatic system is why it is recommended to do a fill and dump with the glycol if the system is not able to be sufficiently drained before the glycol addition. Due to the risk of

microbiological growth in a water-based coolant, recirculation is required to distribute any biocidal treatments to all parts of the system. If the coolant is not available and ready to use, or if on-going recirculation cannot be provided for a water-based coolant, then at this point the system should be purged as dry as is practicable and sealed with a nitrogen blanket to prevent contamination until the site is ready for the next commissioning phase.

The quality documentation supplied with the coolant should be reviewed for all coolant totes received on-site before injecting any of the coolant into the loop. Likewise, the key monitoring parameters that will be used to assess proper distribution of coolant within the row piping loop should be measured on a representative sample of coolant totes using the on-site instrumentation that will be used for assessing the state of coolant within the loop. The coolant supplier should also be consulted for what to do if the loop is slightly below specified concentration after filling. There may be concentrates available to much more efficiently make up the difference as opposed to just purging with virgin coolant.

4.5.1. Important Notes on System Filling with Coolant

1) The flushing skid can be used to provide recirculation on the piping loop as the coolant fill nears completion to ensure good mixing throughout the row piping. Once fill is achieved, it can be valved off and disconnected from the loop. Alternatively, if the CDU's are certified as clean and ready to commission, they can be connected to the piping loop and their pumps used to provide the recirculation flow.

2) The coolant should be injected through the normal fill points built into the loop for maintenance. These will typically be 1" sanitary fittings. The pump used for chemical injection should be stainless steel construction with variable speed capability to be able to adjust the flow as the loop approaches a full state.

3) Air bleed from the high points in the system should be carefully monitored during filling.

4) Once the loop is approximately 90% full, recirculation can be started to ensure good coolant distribution within the loop and to help with air removal.

5) Once fill has been achieved, a minimum of 3 system volumes should be passed through the recirculation pump(s) before taking coolant samples from 3 locations in the system to analyze

for key characteristics such as pH, turbidity, inhibitor level, and glycol % (if a glycol coolant is used) as specified by the coolant manufacturer.

6) If the analyses reveal differences >5% between samples from different locations, the system should be further recirculated until homogeneity is achieved.

7) As noted above, the coolant supplier's recommendations should be followed to achieve the final concentration specification if the coolant proves to be significantly diluted once homogeneity is achieved.

4.5.2 Dry Layup Procedure

Ideally, commissioning will quickly follow on the heels of the completion of pre-commissioning work; however, this is not always feasible. Longer wait times (>1 week) will increase the chances of undesirable contamination events. While the primary risk factor is always for microbial growth and establishment of biofilms, in rare circumstances there may be opportunity for ingress construction debris, particulate matter, or undesirable vapor (e.g. diesel exhaust) if the system seal is not maintained. Table 9 contains an overview of the steps of the Dry Layup Procedure.

Table 9. Dry Layup Procedure

Step	Water Source	Time	Success Criteria
Fill	Procedure Water	As needed	Air bleed is complete
Recirculate	Water in loop with chemical Biocide added	6 to 12 hours	Loop bacteria levels in conformance with plan (<1000 cfu/ml)
Drain	No source needed	As needed	System completely drained through lowest point*
Remove Flushing Equipment	No source needed	As needed	
Dry	Compressed air*	As needed	Internal piping surfaces visibly dry
Seal	Nitrogen**	As needed	All piping entrances closed

* Compressed air is only acceptable if it meets ISO Standard 8573.1 Class 2 properties.
**The final gas blanket applied should be nitrogen.

The biocide to be used should be selected working with the site water treatment provider. Typically, the recommendation would be for a slower acting, non-oxidizing biocide that can maintain its residual while the system awaits commissioning. The biocide will be dosed based on system volume to achieve the desired use concentration. Note that the biocide will have an application label as specified by federal law, and the label directions for its use and maximum concentration must be followed scrupulously. The safety protocols should also be carefully followed as per the Safety Plan as these chemicals can have several human exposure hazards. The site water treatment provider may also suggest alterations to the procedures discussed herein that would be within their purview. Their input is vital during the planning phase for all the work described in this document to ensure that the proper chemistries and safety procedures are in place to achieve the desired results from this pre-commissioning work.

4.5.2.a. Important Notes on Dry Layup

1) The Fill and Recirculate steps can be performed with the same equipment setup as used for Clean and Flush. The difference is that for the Recirculate step here, the biocide will be added using the pot feeder on the flushing skid.
2) As above, during this Recirculate step, ensure that the water/biocide mixture touches all wetted surfaces at recommended flow rates. Verify by recording flow rates, pump speed, and differential pressures where applicable. Valves can be isolated to increase flow, but all surfaces must see their minimum flow rates for at least the minimum specified amount of time.
3) Upon completion of the Recirculation, the system should be drained as per above, including any and all accessible dead legs. The Flushing Equipment can then be removed, drained and rinsed prior to moving to the next job.

4) All the easily removable moisture should be purged from the system to prevent condensation in low spots that may create a breeding ground for bacteria. Filtered and dried compressed air meeting ISO Standard 8573.1 Class 2 properties can be used to accelerate the drying until there is no visible moisture on the inside of the row piping. Once the row piping is confirmed dry, the loop backs can be removed from the rack manifold and the state of the rack manifold piping can be assessed. Drying of the rack manifold piping may be speeded up by limiting the number of open valves at one time to increase air purge through specific sections.
5) Once the moisture has been removed and dead legs drained, all the piping entrances on the rack manifold and row manifold should be closed off by the appropriate valving or installation of caps or blinds so that the system may be blanketed with an inert gas such as dry nitrogen.
6) The TCS piping loop now awaits its glycol fill and commissioning.

5. Conclusion

There are four key pre-commissioning phases for the row piping manifold of the TCS loop that should be applied in a new construction setting. These phases are hydrotesting, cleaning, flushing, and preparation for commissioning. This document has contributed explanations and procedures for each of these phases. If the guidelines presented herein are followed, the row piping manifold should be ready for the commissioning phase to commence without any missteps or surprises that might compromise the final operation or the integrity of the TCS loop. It is anticipated that this document will be one in a series of documents to help guide new or even retrofit data centers through the steps required for a robust TCS loop setup and final performance.

6. Glossary

TCS loop – Technology Cooling System loop consisting of the CDU(s), the Row Manifold, the Racks.

CDU – Coolant Distribution Unit

Rack Manifold – pipework that distributes coolant fluid to the cooling loops of IT equipment

Row Manifold – Piping (typically overhead) that connects into the CDU(s).

7. References

7.1. Literature

(1) C. Parsloe and M. Ronceray, “BG-29: Pre-Commission Cleaning of Pipework Systems, Amended 6th Edition”, BSRIA, March 2021.

(2) American Society of Mechanical Engineers, Codes and Standards, “B31.3 Process Piping - 2024,” (2024).

(3) American Society for Testing of Materials (ASTM), “Standard D1193-99e1 Standard Specification for Reagent Water,” August 2017 (D1193 Standard Specification for Reagent Water)

7.2. Additional Resources

FLUSHING & CLEANING | Pipework Systems Overview - Constructandcommission.com

8. License

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