



Simplifying Data Center Readiness with Liquid-Cooled Load Banks

Commissioning Best Practices for CDU and
Data Center Loop Validation

White Paper

Revision: February 2026

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Simplifying Data Center Readiness with Liquid-Cooled Load Banks

As AI and high-density compute transform data-center design, commissioning teams face the challenge of validating liquid-cooling loops and Coolant Distribution Units (CDUs) under realistic operating conditions — before IT hardware arrives on site.

Liquid-Cooled Load Banks (LCLBs) provide a reliable, controllable, and contamination-free way to simulate IT heat loads, helping operators reduce commissioning time, ensure loop cleanliness, and verify system performance with confidence.

This paper outlines how LCLBs can be integrated into commissioning workflows to simplify validation, improve safety, and ensure readiness for GPU-class rack densities.

The Challenge: Commissioning for AI-Scale Cooling

Traditional commissioning methods using fixed heaters or open loops fail to replicate the dynamic thermal behavior and hydraulic demands of modern CDUs and liquid-cooling systems.

Commissioning teams need a tool that can:

- Accurately emulate GPU heat profiles and ΔT variations.
- Operate safely within closed, contamination-controlled systems.
- Provide measurable, repeatable test data.

Without these capabilities, facilities risk performance drift, uneven flow distribution, or extended startup delays.

The Solution: Liquid-Cooled Load Banks (LCLBs)

LCLBs emulate real server loads within a closed-loop system, allowing commissioning teams to validate CDU and loop performance without live IT equipment.

Key benefits:

- **Realistic thermal emulation** – adjustable load from 10–100% with fine step control.
- **Data-driven validation** – flow, pressure, and temperature data logged in real time.
- **Closed-loop cleanliness** – supports operation aligned with ISO 4406 fluid cleanliness targets by avoiding open heaters and contamination pathways
- **Faster commissioning** – enables early system tuning before IT deployment.

Application of Liquid-Cooled Load Banks (LCLBs)

Liquid-Cooled Load Banks (LCLBs) play a critical role in modern data-center commissioning, enabling teams to validate thermal, hydraulic, and control performance across multiple stages of the liquid-cooling infrastructure. As CDUs, rack manifolds, and liquid-cooled servers become standard in high-density AI and HPC deployments, commissioning agents need a reliable method to introduce controlled heat loads and verify loop behavior before sensitive IT equipment is installed.

LCLBs provide a safe, controllable, and repeatable way to simulate real IT heat output while maintaining strict loop cleanliness requirements. They allow commissioning teams to identify issues early, validate mechanical and control systems under realistic load conditions, and ensure that both facility-side and IT-side infrastructure are performing as designed.

The following subsections outline the primary applications of Liquid-Cooled Load Banks throughout the commissioning lifecycle. These include Factory Acceptance Testing (FAT), CDU secondary-loop validation, rack/manifold loop validation, facility loop validation, and post-maintenance requalification.

Each application serves a distinct purpose—ranging from component-level verification to full facility-level stress testing—and together they provide a comprehensive framework for de-risking the deployment of liquid-cooling systems across hyperscale, colocation, and enterprise data centers.

High-Level Application Summary

Commissioning Stage	Loop Type	Purpose/Objective	Typical Connection Path
Factory Acceptance Testing (FAT)	CDU Secondary Loop	Validate pump capacity, ΔT performance, control logic, and heat exchanger behavior before shipment	CDU → LCLB → CDU
Site Commissioning - IT Loop	CDU Secondary Loop	Verify CDU thermal response, redundancy logic, flow balance, and ΔT stability before installing GPU/CPU racks	Facility Chiller → CDU → LCLB → CDU
Rack / Manifold Validation	Rack or Manifold Loop (CDU Secondary Loop)	Confirm rack distribution, cold-plate loop integrity, valve acutation, and flow uniformity across branches	CDU → Rack Manifold → LCLB → Rack Manifold → CDU
Facility Loop Validation	Facility Chilled Water Loop (Primary Loop)	Validate chiller performance, pump sequencing, ΔT /approach stability, and plant responsiveness, LCLB used in place of CDU	Chiller → LCLB → Chiller
Maintenance / Requalification	Any Loop	Reconfirm system readiness after coolant replacement, upgrade, or maintenance	Varies based on loop type

Factory Acceptance Testing (FAT)

Factory Acceptance Testing is the earliest and most controlled environment where a Liquid-Cooled Load Bank (LCLB) is used to validate the operation of a Coolant Distribution Unit (CDU) before shipment. During FAT, the CDU is operated in a self-contained, vendor-managed test loop, independent of the customer's facility infrastructure. The LCLB provides a precise, adjustable thermal load that enables verification of hydraulic and thermal performance while ensuring the CDU's control logic, pumps, valves, and heat exchanger operate according to specification.



Because a facility chiller is not available during FAT, the CDU relies on its primary-side built-in heat exchanger, or a vendor-provided closed-loop primary supply, to reject heat generated by the LCLB. This setup (see figure 1) allows the CDU to perform as it would in a real deployment, while remaining fully independent of field conditions.

Use cases include:

- Verifying pump sequencing, speed modulation, and redundancy behavior
- Confirming ΔT performance across the secondary (IT) loop under steady-state and transient loading
- Validating heat exchanger functionality, including approach temperature and heat-transfer efficiency
- Testing valve actuation, sensor accuracy, and control-loop tuning
- Ensuring the CDU meets its nameplate hydraulic and thermal specifications prior to shipment
- Identifying manufacturing or assembly issues before the CDU reaches the customer site

Correct Connection Path:

CDU → LCLB → CDU

(Closed-loop FAT configuration — CDU uses internal or vendor-supplied primary loop for heat rejection)

- The CDU supplies cold coolant to the LCLB through its secondary loop.
- The LCLB applies a controlled electrical load and heats the coolant.
- Warm coolant returns to the CDU, where heat is removed via the internal or auxiliary primary loop.

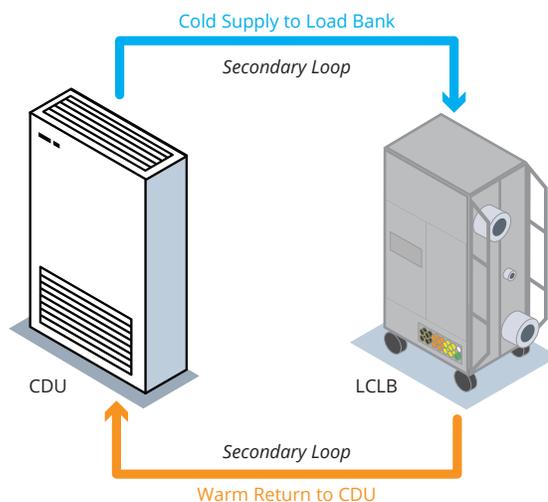


Figure 1. FAT Test Loop Configuration

Why this is important:

Performing FAT ensures the CDU is fully validated before arriving on site, reducing installation risks, shortening commissioning time, and preventing costly delays. By using an LCLB to simulate real IT thermal loads, manufacturers can confirm that the CDU complies with performance requirements and delivers stable, predictable operation even before integration with facility or rack-level cooling infrastructure.

Note: During FAT, CDUs reject heat using their internal or vendor-supplied primary-side loop, as facility infrastructure is not available. This method ensures proper validation of CDU pump, valve, and control performance prior to shipment.

IT Loop / CDU Secondary Loop Validation

IT loop validation is performed on-site after the CDU has been installed and connected to the facility's primary cooling loop (chilled water or equivalent). In this phase, the Liquid-Cooled Load Bank (LCLB) is used to emulate the thermal and hydraulic behavior of a fully populated liquid-cooled IT rack, allowing commissioning teams to validate CDU performance under realistic operating conditions. (See figure 2).

The goal of this testing is to ensure that the CDU can reliably manage heat, maintain the required ΔT , and respond appropriately to dynamic thermal loads before any cold plates, racks, or GPU servers are deployed.

Use cases include:

- Validating CDU pump performance, including speed modulation, sequencing, and redundancy
- Verifying ΔT stability across the secondary (IT) loop at steady-state and transient load points
- Confirming heat exchanger behavior, such as approach temperature and thermal responsiveness
- Testing flow range, flow stability, and valve actuation prior to IT hardware installation
- Exercising CDU control logic, including PID tuning, sensor calibration, and load-following response

Correct Connection Path:

Facility Chiller → CDU → LCLB → CDU → Facility Chiller

- The facility chiller or cooling plant provides cold coolant to the CDU through the primary loop.
- The CDU delivers cold coolant to the LCLB on the secondary loop.
- The LCLB applies a controlled thermal load and returns warm coolant.
- The CDU transfers heat from the secondary loop to the facility primary loop via its internal heat exchanger.

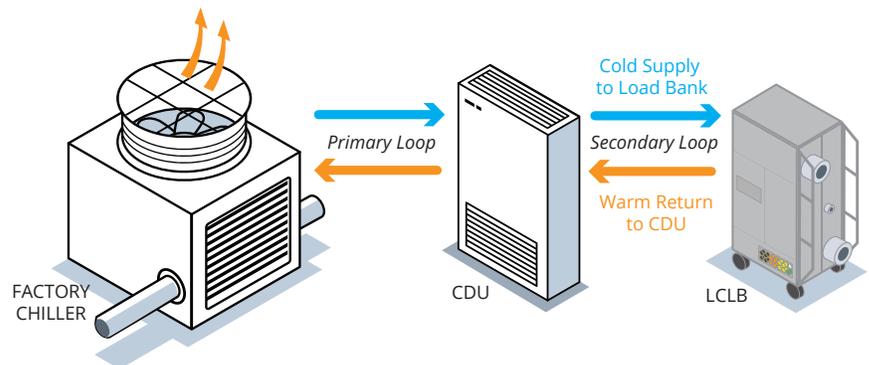


Figure 2. CDU Secondary Loop / IT Loop Validation

Why this is important:

This on-site test ensures that the CDU operates within design parameters once integrated with the facility cooling plant. By simulating real IT heat loads, commissioning teams can validate CDU control performance, avoid thermal instability issues, and de-risk the transition to production hardware. It confirms that the CDU—and the primary cooling system supporting it—are fully ready for GPU and cold-plate deployment.

Rack / Manifold Loop Validation

Rack and manifold validation focuses on verifying the IT-side hydraulic network that delivers coolant to cold plates, modular manifolds, and direct-to-chip loops. In this commissioning phase, the Liquid-Cooled Load Bank (LCLB) emulates the thermal and hydraulic behavior of a fully populated server rack. (See figure 3).

Because rack manifolds are always supplied by a CDU's secondary (IT) loop, validation must include the CDU to ensure realistic flow, ΔT , and control behavior.



Use cases include:

- Verifying branch-level flow distribution across the manifold
- Confirming cold-plate loop integrity before IT hardware arrives
- Testing valve actuation, bypass logic, and balancing mechanisms
- Measuring ΔT and ΔP across the rack loop under controlled load conditions
- Ensuring that manifold and rack plumbing were installed correctly and are leak-free

Correct Connection Path:

CDU → Rack Manifold → LCLB → Rack Manifold → CDU

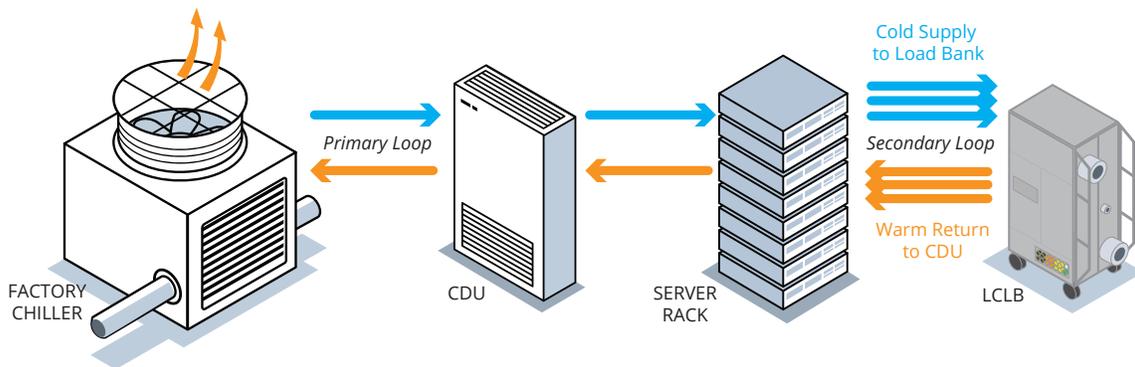


Figure 3. Rack/Manifold Validation

- The CDU sends cold coolant to the rack manifold, as it would for CPUs/GPUs.
- The manifold distributes coolant to what would normally be cold plates — in this test, the LCLB serves as the heat-generating load.
- The LCLB heats the coolant, simulating IT load.
- The warm coolant returns through the manifold and back to the CDU, completing the loop.

Why this is important:

Using an LCLB at the rack/manifold level allows commissioning teams to verify hydraulic balance, flow stability, and branch operation without risking sensitive IT equipment. It ensures the entire IT cooling loop functions correctly before servers are installed.

Facility Loop Validation — LCLB Used in Place of a CDU

Facility loop validation is performed early in the construction and commissioning cycle, often before CDUs or racks are installed. In this scenario, the Liquid-Cooled Load Bank (LCLB) is used in place of a CDU to generate a representative thermal load directly on the primary (facility) chilled-water loop. (See figure 4).

This approach enables commissioning teams to validate the performance of the central cooling plant under realistic heat-rejection conditions, ensuring the mechanical system is stable and fully capable of supporting downstream CDUs and IT equipment.

Use cases include:

- Validating chiller capacity, approach temperature, and ΔT response under controlled load
- Stress-testing primary loop pumps, including lead/lag sequencing and redundancy
- Confirming hydraulic balance and eliminating installation issues before CDUs arrive
- Verifying facility control logic (BMS integration, sensor mapping, stability under transient conditions)
- Exercising heat-rejection systems (cooling towers, dry coolers, heat exchangers)

Correct Connection Path:

Chiller → LCLB → Chiller

- The facility chiller supplies cold coolant directly to the LCLB.
- The LCLB applies a defined thermal load and warms the coolant.
- Warm return coolant flows back to the chiller, allowing the plant to stabilize and reject heat.

Why this is important:

Using an LCLB at the facility loop level allows mechanical and commissioning teams to validate the cooling plant well before CDUs, manifolds, or IT hardware are installed. This reduces project delays, confirms system readiness early, and prevents costly rework during later commissioning stages when schedules are tighter and risks are higher.

Summary of Applications

Liquid-Cooled Load Banks offer commissioning teams a versatile and highly effective tool for validating liquid-cooling systems at every stage of deployment — from facility infrastructure to CDU performance to final rack-level balancing. By providing controlled, adjustable thermal loads and precise hydraulic behavior, LCLBs help ensure that each subsystem operates within design parameters before introducing production hardware.

Using an LCLB across multiple commissioning stages reduces project risk, accelerates readiness, and improves confidence in liquid-cooled architectures. Whether validating chiller plant behavior, confirming CDU stability, or verifying manifold distribution, LCLBs create a consistent, repeatable testing framework aligned with emerging best practices from OCP, ASHRAE TC9.9, and hyperscaler commissioning teams.

As liquid cooling becomes foundational to AI-class compute, the systematic application of LCLBs during commissioning will be essential to ensuring reliability, safety, and long-term performance of next-generation data-center systems.

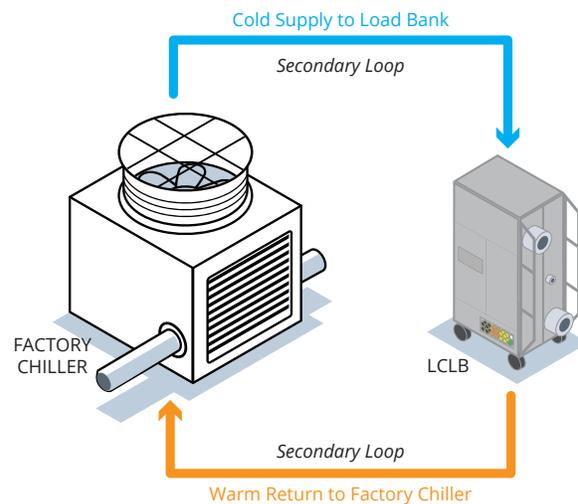


Figure 4. Facility Loop Validation



How It Works

Once connected to the liquid-cooling system, the Liquid-Cooled Load Bank (LCLB) emulates realistic server heat loads within a closed-loop environment. This allows commissioning teams to test CDUs, manifolds, and facility loops under controlled and repeatable conditions — without the risk of using live IT hardware.

Typical Commissioning Workflow:

1. **Connect:** The LCLB is connected to the CDU or test loop via standard flanged or Victaulic fittings.
2. **Configure:** Load parameters, target ΔT , and flow rates are configured through Avtron's RX Control platform, enabling precise control of load steps and thermal response.
3. **Validate:** The system is run through programmable load profiles (step, ramp, or transient). The CDU response, control logic, and pump redundancy are verified in real time.
4. **Monitor & Record:** Using LB View software, telemetry data such as inlet/outlet temperatures, ΔT , flow rate, and kW load are continuously monitored and logged for commissioning validation.
5. **Report:** Test data and validation results are exported in CSV format for documentation, compliance, or further analysis.

This integrated hardware–software approach gives commissioning teams a safe, repeatable, and data-rich method to confirm CDU and loop readiness long before GPUs or servers are installed.

Advantages of Using Avtron Liquid-Cooled Load Banks

While LCLBs in general bring precision and safety to CDU and loop validation, Avtron's integrated control and software ecosystem delivers measurable commissioning advantages that set it apart.

1. **Simplified Setup and Control**
 - Avtron's RX Control platform provides intuitive test orchestration through a modern HMI, allowing users to apply programmable load profiles (step, ramp, or custom scripts) without manual intervention.
 - Can significantly reduce commissioning setup time, often by up to ~50% based on project experience.
2. **Real-Time Monitoring and Telemetry**
 - Integrated LB View software offers live dashboards for temperature, flow, ΔP , and load visualization.
 - Telemetry is time-stamped and logged at a configurable rate, supporting traceable commissioning validation and data export (e.g., CSV) aligned with OCP-style reporting practices.
 - Event logging and alarm capture provide transparency for every commissioning phase.
3. **Enhanced Safety and Reliability**
 - Intelligent interlock logic automatically unloads the system on over-temperature or loss-of-flow conditions.
 - Configurable fault thresholds and user-defined safety margins support facility safety protocols and reduce human error.

4. Comprehensive Reporting and Data Export

- Built-in reporting modules generate commissioning summaries with key parameters (ΔT stability, pressure margins, and flow rate).
- Reports can be exported directly for inclusion in Cx documentation or shared with CDU / facility partners.

5. Integration and Flexibility

- Supports TCP IP interfaces for integration with BMS and customer data systems.
- Network scalability supports multiple synchronized LCLBs, making it ideal for high-capacity AI or hyperscale deployments.

Networked Architecture for Scalable and Hybrid Commissioning

Commissioning modern AI infrastructure is no longer about validating a single device. It requires orchestrating systems, collecting defensible data, and repeating results consistently at scale.

As data centers evolve toward higher densities and phased liquid-cooling deployments, commissioning teams are often required to validate environments where air-cooled and liquid-cooled infrastructure coexist—either permanently or during transition periods.

Avtron's network-capable load bank architecture enables mixed fleets of Avtron air-cooled and liquid-cooled load banks to be connected, coordinated, and managed within a unified commissioning workflow. Rather than operating isolated test devices, commissioning teams can synchronize load application and monitoring across cooling technologies using a common control and data framework.

This capability allows teams to:

- Coordinate commissioning activities across air-cooled rooms and liquid-cooled AI zones
- Validate shared upstream infrastructure such as power distribution, controls, and facility cooling systems
- Execute repeatable commissioning sequences during phased or hybrid deployments
- Maintain a consistent commissioning methodology and data set as facilities transition from air cooling to liquid cooling

By enabling coordinated testing across mixed cooling architectures, Avtron's networked load bank platform supports system-level commissioning, reduces risk during phased deployments, and improves confidence in data center readiness as facilities scale toward AI-class densities.

Case Example: Accelerated Commissioning for AI-Ready Infrastructure

[Reference Commissioning Scenario (Illustrative): The following scenario is illustrative and based on typical commissioning workflows observed in high-density, liquid-cooled data center deployments. It does not represent a specific customer installation]

Example: AI-Ready CDU Commissioning Using Liquid-Cooled Load Banks

In a high-density AI data center deployment, a 1 MW-class Coolant Distribution Unit (CDU) is installed to support liquid-cooled GPU racks. Prior to IT hardware delivery, commissioning teams use Liquid-Cooled Load Banks to validate CDU secondary-loop performance under controlled load conditions.

The LCLB is connected to the CDU secondary loop and operated through a series of step and ramp load profiles designed to emulate expected GPU heat output. During testing, commissioning agents verify pump sequencing, flow stability, ΔT behavior, and control response while operating in a closed-loop environment using water as the working fluid.

Using the LCLB, the commissioning team is able to:

- Confirm CDU capacity and redundancy behavior before GPU installation



- Validate flow balance and pressure margins across the secondary loop
- Identify and resolve control tuning issues early in the commissioning process
- Document measurable performance data to support owner acceptance

This approach allows the facility and IT teams to complete CDU validation in advance of server delivery, reducing schedule risk and improving confidence during transition to production hardware.

Key Outcomes

- **Up to 50% faster commissioning** through pre-GPU validation.
- **Reduced field rework** by verifying control logic and redundancy before IT deployment.
- **Improved safety and cleanliness** through closed-loop operation.
- **Data transparency** supporting continuous improvement and ASHRAE/OCP alignment.

Best Practices for Commissioning Teams

- Integrate LCLB testing during FAT and site commissioning phases.
- Maintain consistent coolant chemistry with the facility system.
- Calibrate sensors and flow meters before each test sequence.
- Document all $\Delta T/\Delta P$ data to support performance validation reports.
- Collaborate with CDU and facility teams to align test envelopes.

Summary

As AI infrastructure drives unprecedented rack densities, commissioning tools must evolve. Liquid-Cooled Load Banks provide commissioning agents and data center operators with a safe, precise, and repeatable method to validate thermal and hydraulic performance before go-live. By integrating LCLBs into CDU and loop validation workflows, operators can achieve faster deployment, higher reliability, and measurable performance assurance — key outcomes for next-generation data centers.



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