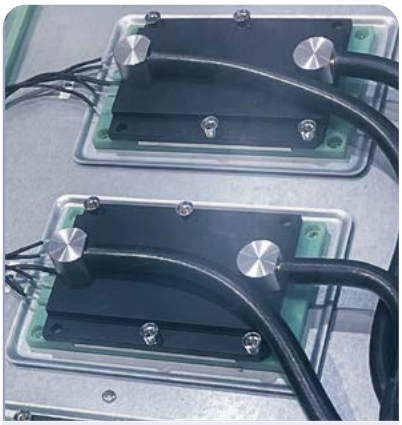
LEAK DETECTION OF DTC COOLING COMPONENTS

How to detect leaks on direct-to-chip (DTC) cooling systems for data centers

As AI workloads drive rack power densities well beyond the limits of traditional air cooling, direct-to-chip (DTC or D2C) cooling has emerged as a critical technology for modern data centers. Since this method introduces liquid or refrigerant circuits inside critical areas such as the rack, any leak can disrupt thermal performance, compromise uptime, and damage high-value hardware.

Application

In DTC cooling, heat is transferred from the chip into a circulating fluid, reducing reliance on air cooling. In these cold-to-chip system designs, coolant is delivered directly to cold plates mounted on high-power components such as CPUs, GPUs, and accelerators, enabling efficient heat removal at the source. A Coolant Distribution Unit (CDU) regulates coolant flow, pressure, and temperature, distributing it through manifolds and hoses to each server rack and ensuring stable operating conditions across the system. Two cold plate technologies are used: single-phase DTC, which circulates liquid coolant in a sealed loop, and more efficient two-phase DTC, which uses a refrigerant that boils inside the processor-mounted cold plate. In single-phase systems, heat is absorbed by the temperature rise of the liquid as it flows across the cold plate surface. In two-phase systems, heat is removed through partial evaporation of the refrigerant within the cold plate, leveraging latent heat for higher thermal efficiency. After absorbing heat, the warmed coolant returns to the CDU, where the heat is transferred out of the IT loop before the coolant is recirculated. This application note describes traditional methods used to detect leaks, and the advantages of INFICON solutions for leak detection.



Prototype of a direct-to-chip cooling design. Components to be tested for leaks include, among others, cold plates, pipes, and quick connectors.

Traditional Methods

Because DTC systems rely on numerous interconnected components, each connection and circuit must remain tightly sealed to prevent coolant loss. Typical leak rate requirements for direct-to-chip liquid cooling components—such as cold plates, manifolds, and quick disconnect couplings (QDCs)—range from 10^{-4} to 10^{-6} mbar l/s.

A common method for detecting leaks on cooling components is **pressure decay**. The component is filled with air, pressurized, and the pressure drop is monitored over time. However, this method is sensitive to temperature fluctuations, which can affect measurement accuracy. While pressure decay indicates overall system tightness, it does not identify the exact leak location. To pinpoint larger leaks, **soapy water** is occasionally applied after testing; yet this approach can be problematic, as the components are intended to remain clean and dry. For data center cooling applications, these methods are frequently insufficiently sensitive. In installed systems, **sensing cables** placed under raised floors, along piping routes, beneath CDUs, and around manifolds can detect leaks of conductive liquids. However, they are prone to false alarms caused by dust, corrosion, or humidity.

Typical components and leak risk

COMPONENT	POTENTIAL LEAK LOCATION	LEAK RISK
Cold plates	Welds, seams, fittings	High risk of electrical shorts, boards damage, overheating, corrosion
Quick disconnect couplings	O-rings, seals	High risk of liquid release inside the rack, potential oxygen displacement, pressure fluctuations
Manifolds / distribution blocks	Seams, seals, ports	High risk of spill potential, overheating, corrosion, unsafe operating conditions

The solution from INFICON

A non-destructive and highly sensitive method is tracer gas leak detection, which allows users to identify even very small leaks without damaging components. Depending on the part, accumulation, vacuum, or sniffing tests can be used.

Typical components leak rates and testing methods

	LEAK RATE REQUIREMENTS	RECOMMENDED LEAK TEST
Cold plates (single-phase liquid) (two-phase with refrigerant)	10^{-4}…10^{-6} mbarl/s ≤10^{-6} mbarl/s	Vacuum test
Heat exchangers	10^{-4}…10^{-5} mbarl/s	Vacuum test Sniffing test
Manifolds / distribution blocks (rack level)	10^{-4}…10^{-5} mbarl/s	Accumulation test Sniffing for rework
Quick disconnect couplings	10^{-4}…10^{-5} mbarl/s	Sniffing test

Vacuum Leak Test

A vacuum test involves placing a component in a vacuum chamber, evacuating it, introducing a tracer gas such as helium, and using an highly sensitive detector, such as the LDS3000 Helium Leak Detector, to identify leaks. If a leak is present, helium escapes from the part into the chamber and is detected by the detector, triggering an alarm signal. The unit has a compact design forensures seamless integration with minimal installation effort and space requirements.

Accumulation Test

For rapid leak tests, when small leaks are expected, the accumulation method with LDS3000 AQ Leak Detector is the preferred testing option. The unit works with both Helium or Hydrogen tracer gas and detects leaks down to the 10^{-5} mbarl/s range. The part to be tested is filled with tracer gas and placed in the accumulation chamber. Any tracer gas escaping from potential leaks accumulates in the chamber and is distributed uniformly by the fans. The leak rate is determined by the quantity of tracer gas accumulated over a time interval.

Sniffing Leak Test

When precise leak localization along joints, seals, and similar areas is needed—during production or rework—a sniffing leak test is preferred. The component is pressurized with a tracer gas (such as helium or forming gas), and a sniffer probe is moved along seams, welds, fittings, and connections, manually or by robot. Escaping tracer gas is detected, allowing accurate identification and quantification of leaks. INFICON's portfolio offers both helium and hydrogen sniffing solutions. The Protec® P3000(XL) Helium Leak Detector and the XL3000flex Helium and Hydrogen Leak Detector are designed for full-time sniffing applications in demanding production environments with the highest througput. The Sentrac® Hydrogen Leak Detector is a compact, cost-effective solution for finding liquid leaks donw to 10^{-5} mbarl/s, suitable for both production and repair lines.

Advantages of leak detection with tracer gas

- Significantly improved sensitivity to detect even the smallest leaks
- Accurate test results with high repeatability
- Exact leak localization
- Clean, non-destructive method
- Fast results and minimal downtime

The **LDS3000 Helium Leak Detector** is the ideal choice for vacuum leak testing systems. This unit is also available as **LDS3000 AQ** for the use in accumulation systems with both helium and hydrogen tracer gas.

LDS3000 AQ Accumulation Leak Detector and accessories

The high-performance industrial **sniffers from INFICON** are designed for highly accurate leak testing and include among others the **XL3000flex** helium and hydrogen leak detector, for full-time sniffing in n demanding production environments, and the **Sentrac** hydrogen leak detector, with its unique ability to handle small and large leaks, both in production and repair lines.

XL3000flex Helium and Hydrogen Leak Detector

Sentrac Hydrogen Leak Detector

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