

Single-Phase Immersion Liquid Cooling Compute Module Standards - Official Technical Overview & Hardware Datasheet

EXECUTIVE SUMMARY

The Single-Phase Immersion Liquid Cooling Compute Module Standards define a carrier-grade, high-density compute architecture engineered for direct single-phase immersion cooling environments. This standard establishes mechanical, thermal, electrical, and management interfaces for compute modules deployed in next-generation edge and core data centers. By replacing air-based thermal management with dielectric liquid immersion, the standard enables a 4x increase in rack power density, a 40% reduction in cooling energy overhead, and a 99.999% availability target for telecom and enterprise workloads.

The standard is vendor-agnostic in its interface definitions while remaining fully compliant with NEBS Level 3, ETSI, and IEC 60950-1 safety frameworks. It supports both 48V DC and 400V HVDC power distribution, making it suitable for telco central offices, edge micro-data centers, and hyperscale immersion-ready facilities.



ARCHITECTURE & CHASSIS DESIGN

The immersion compute module standard specifies a sealed, liquid-compatible chassis with a standardized 1RU/2RU horizontal form factor and a blind-mate fluid manifold interface. The chassis is constructed from nickel-plated copper and stainless steel 316L to resist long-term dielectric fluid exposure. Internal components are coated with a parylene-C conformal layer to prevent electrochemical migration and tin whisker formation.

Key mechanical features include:

- Standardized immersion-safe connectors with IP68 sealing
- Integrated drip trays and fluid containment channels
- Tool-less module extraction with self-sealing quick-disconnects
- Front-to-back fluid flow path with $<0.5^{\circ}\text{C}$ temperature delta across the

module

The architecture supports up to 48 compute modules per 42RU immersion tank, with each module independently serviceable while the tank remains filled.

HARDWARE FEATURES

Each compute module integrates a dual-socket x86 or ARM SoC complex, up to 16 DDR5 RDIMM slots, and dual 100GbE KR4 backplane links. The module includes an onboard Baseboard Management Controller (BMC) with dedicated 1GbE management port and support for Redfish and IPMI 2.0. Thermal sensors are distributed across the PCB to provide per-component fluid temperature monitoring.

Additional hardware capabilities:

- Support for PCIe 5.0 x16 mezzanine cards
- Optional integrated TPM 2.0 and secure boot
- 12V and 48V auxiliary power rails for line cards
- Hot-swappable boot drives (M.2 NVMe)
- Immersion-compatible polymer capacitors and inductors

COMPLIANCE & STANDARDS

The standard aligns with the following normative references:

- NEBS GR-1089-CORE and GR-63-CORE Level 3
- ETSI EN 300 019-2-3 (climatic and mechanical)
- IEC 62368-1 (safety)
- OCP Immersion Requirements Rev 2.0
- IEC 61000-4-2/4/5 (EMC)
- RoHS 2011/65/EU and REACH

All modules are qualified for continuous operation in single-phase dielectric fluids with flash points above 160°C and dielectric constants below 2.5.

TECHNICAL SPECIFICATIONS

The following parameters define the baseline performance and physical limits of compliant immersion compute modules.

Parameter	Specification
Form Factor	1RU / 2RU immersion-safe chassis
Compute Architecture	Dual-socket x86 or ARM SoC
Memory	Up to 16x DDR5 RDIMM, 4800 MT/s
Network Interfaces	2x 100GbE KR4, 4x 25GbE SFP28, 2x

	400GbE QSFP-DD
Management	1GbE BMC, Redfish 1.8, IPMI 2.0
Power Input	48V DC nominal, 400V HVDC optional
Power Consumption	800W to 2400W per module
Cooling Fluid	Single-phase dielectric, flash point >160°C
Operating Temperature	15°C to 45°C fluid inlet
Dimensions (HxWxD)	44mm x 430mm x 800mm (1RU)
Weight	12 kg to 22 kg depending on configuration
MTBF	>500,000 hours at 40°C fluid inlet
Compliance	NEBS Level 3, ETSI, IEC 62368-1, RoHS
Serviceability	Hot-swap module, blind-mate fluid manifold
Security	TPM 2.0, Secure Boot, optional line-rate encryption

ORDERING OPTIONS

The standard supports multiple SKU tiers to address varied compute and network requirements:

- ICM-1000 Series: 2RU, dual-socket, 32 DIMM, 2x100GbE
- ICM-2000 Series: 1RU, single-socket, 16 DIMM, 4x25GbE
- ICM-3000 Series: 2RU, dual-socket, 16 DIMM, 2x400GbE
- ICM-4000 Series: 1RU, single-socket, 8 DIMM, 2x100GbE, NEBS Level 3

Each series includes immersion-compatible power cables, fluid-compatible gaskets, and a factory-applied conformal coating certificate.

