

Ruggedized Telecom Infrastructure Application Note: Hybrid Heat Pipe and Liquid Cooling Module Thermal Conduction Guide

RUGGEDIZED DESIGN PHILOSOPHY

The Hybrid Heat Pipe and Liquid Cooling Module Thermal Conduction Guide represents a paradigm shift in thermal management for high-density telecom infrastructure. As edge computing and 5G radio access networks push power densities beyond 400W per rack unit, traditional air-cooling architectures have reached their physical limits. This application note details a dual-phase thermal conduction solution engineered for carrier-grade environments where reliability, acoustic performance, and thermal headroom are non-negotiable.

The guide integrates sintered copper heat pipes with a closed-loop liquid cooling plate, creating a hybrid conduction path that dynamically switches between passive and active cooling based on workload. This ensures optimal thermal performance across the full operational envelope, from -40°C to +65°C ambient, without compromising mean time between failures (MTBF).



THERMAL & ELECTRICAL TOLERANCE

The module is designed for extreme environmental tolerance, meeting Telcordia GR-63-CORE and GR-487-CORE standards for outdoor and uncontrolled environments. The hybrid architecture employs a hermetically sealed liquid loop with dielectric coolant, eliminating leakage risks and enabling maintenance-free operation for over 10 years.

Electrical tolerance is equally robust. The integrated pump and control electronics operate from a wide -48V DC input with reverse polarity protection, surge immunity per EN 61000-4-5, and EMI filtering to EN 55032 Class A. The thermal control unit features a fail-safe passive mode: if pump power is lost, the heat pipe array alone can dissipate up to 250W, ensuring continued operation of critical line cards.

Key thermal performance metrics include:

- Thermal resistance (heat pipe only): 0.08 °C/W
- Thermal resistance (hybrid mode): 0.035 °C/W
- Maximum heat dissipation: 600W continuous
- Coolant flow rate: 1.2 L/min nominal
- Pump MTBF: > 100,000 hours

OPERATIONAL ADVANTAGES

The hybrid design delivers tangible operational benefits for network operators:

1. Acoustic Noise Reduction: Eliminates high-RPM fans, reducing acoustic noise from 75 dBA to below 45 dBA, enabling deployment in space-constrained urban cabinets and indoor edge sites.
2. Extended Component Life: Lower junction temperatures (typically 15-20°C reduction) extend semiconductor lifespan and reduce thermal cycling fatigue.
3. Energy Efficiency: Pump power consumption is under 15W, compared to 120W for equivalent fan arrays, yielding a PUE improvement of up to 0.08.
4. Compact Form Factor: Enables 2RU chassis designs that previously required 4RU with air cooling, doubling port density per rack unit.

5. Maintenance-Free Operation: Sealed liquid loop requires no coolant top-off or filter replacement over the product lifecycle.

CERTIFICATIONS MATRIX

The module has been validated against the following industry standards:

- Telcordia GR-63-CORE (Network Equipment Building System)
- Telcordia GR-487-CORE (Outside Plant Equipment)
- IEC 60950-1 / IEC 62368-1 (Safety)
- EN 300 019 (Environmental Conditions)
- RoHS 2011/65/EU and REACH compliant
- IP55 rated enclosure for dust and water ingress

EXACT SPECS

The following table summarizes the precise technical parameters of the Hybrid Heat Pipe and Liquid Cooling Module Thermal Conduction Guide.

Parameter	Specification
Form Factor	2RU chassis-compatible module
Cooling Technology	Hybrid sintered copper heat pipe +

	closed-loop liquid plate
Maximum Heat Dissipation	600W continuous (hybrid mode); 250W passive fail-safe
Thermal Resistance	0.035 °C/W (hybrid); 0.08 °C/W (heat pipe only)
Coolant Type	Propylene glycol-based dielectric fluid
Coolant Flow Rate	1.2 L/min nominal
Pump Power Consumption	< 15W
Pump MTBF	> 100,000 hours
Operating Temperature	-40°C to +65°C ambient
Input Voltage	-48V DC nominal (wide input range)
Protection	Reverse polarity, surge immunity (EN 61000-4-5), EMI Class A
Acoustic Noise	< 45 dBA
Ingress Protection	IP55
Monitoring Interface	I2C to shelf controller; SNMP telemetry
Compliance	Telcordia GR-63-CORE, GR-487-CORE, IEC 62368-1, RoHS, REACH

FIELD DEPLOYMENT SCHEMATIC

The deployment schematic illustrates a typical installation in a ruggedized outdoor cabinet. The thermal conduction guide mounts directly to the chassis midplane, with flexible heat pipe assemblies routing to the liquid cooling plate. The pump and reservoir are housed in a serviceable tray, while the control electronics integrate with the shelf management controller via I2C.

Field deployment considerations include:

- Mounting orientation: horizontal or vertical, with no performance degradation
- Coolant: pre-filled, factory-sealed, propylene glycol-based dielectric fluid
- Service access: pump module is hot-swappable in under 5 minutes
- Monitoring: real-time telemetry for coolant temperature, flow rate, and pump status via SNMP

