TECHNICAL CASE STUDY

Liquid Cooling · Cold Plate Optimization

4 kW Multi-Cold-Plate Liquid Cooling System Design and Optimization

At a Glance

Advanced Thermal Solutions, Inc. (ATS) designed and validated a 4 kW liquid cooling system using four 1000 W cold plates. Through analytical modeling and CFD validation, ATS optimized cold plate geometry and system flow to maximize thermal performance within manufacturing and hydraulic constraints.

CUSTOMER OVERVIEW

The customer, an EV battery manufacturer, was developing a 4 kW liquid cooling system using four cold plates integrated into a loop with a heat exchanger, DC-DC converter, and onboard charger (Figure 1). The design required a balance between thermal performance, manufacturability, and flow distribution.

- Four cold plates at 1000 W each (4000 W total) (Figure 2)
- Liquid loop with centralized heat exchanger
- Design constrained by geometry, manufacturability, and flow balance

CHALLENGE

The system needed to maximize cold plate performance within geometric and manufacturing limits while operating at 45°C ambient using 50/50 water-glycol as coolant. At the same time, the design had to maintain uniform flow distribution and avoid excessive pressure drop across all four plates.

System requirements:

- 4 cold plates at 1000 W each
- Total heat load: 4000 W
- Ambient: 45°C
- Coolant: 50/50 water-glycol
- Target flow: ~1 GPM per plate

The core challenge was increasing heat transfer area and maintaining temperature uniformity without exceeding tube-bending limits or creating high pressure drop.

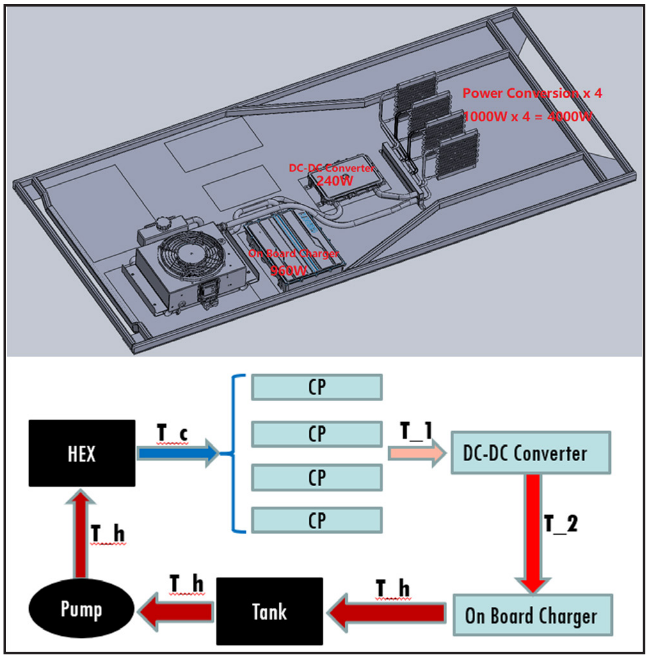

Figure 1. The Four Cold Plates Receive Chilled Coolant from a Heat Exchanger as Part of a Liquid Loop that Includes a DC-DC Converter and On Board Charger

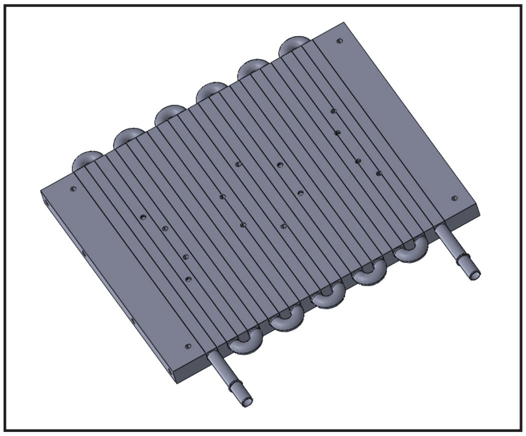

Figure 2. The Original Cold Plate Featured 12 Tube Passes and 11 Tube Bends

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METHODOLOGY

ATS combined analytical modeling with CFD validation to optimize cold plate geometry and evaluate system-level flow behavior (Figure 3). The work focused on tube configuration, manufacturability limits, and balanced coolant distribution across all four plates.

Cold Plate Design Basis

- Envelope: 214.8 × 264.3 × 15.2 mm
- Original: 3/8" OD, 12-pass design
- ATS standard: 3/8" OD, optimized wall/ID
- Manufacturing limit: 10 passes max

Key Investigation Areas

- Tube pass count and routing optimization
- Thermal resistance and pressure drop tradeoffs
- CFD validation of temperature performance
- Manifold design for balanced flow

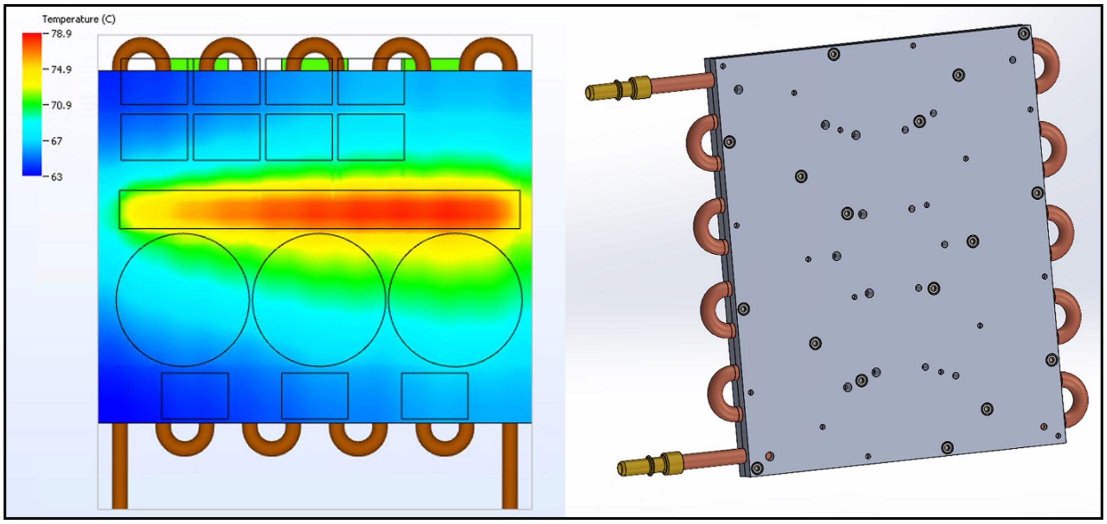

Figure 3. CFD Simulation of Revised Cold Plate with 10 Tube Passes and 9 Tube Bends

SOLUTION

ATS selected a 10-pass serpentine tube design that maximized heat transfer while maintaining acceptable pressure drop and manufacturability. The system was further optimized with improved tube inner diameter and balanced manifold routing.

- 10-pass 3/8" serpentine geometry
- Improved internal diameter via optimized tube wall
- CFD validation aligned with analytical predictions
- Manifold design for ~1 GPM per plate balance
- Material options for glycol compatibility

Together, these changes improved thermal distribution while maintaining the fully passive enclosure concept.

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RESULTS & DATA

The optimized design delivered strong thermal performance with close agreement between analytical and CFD results, confirming the selected geometry.

Key Findings:

- Optimized configuration: 10-pass 3/8” serpentine cold plate
- Analytical and CFD agreement validated the design
- Cold plate thermal resistance: approximately 0.0081 °C/W at 1 GPM
- Cold plate surface temperature: 69°C at 1000 W
- Temperature uniformity across the cold plate footprint was confirmed

The analysis also showed that while the cold plate design was successfully optimized, the system heat exchanger remained the dominant constraint for rejecting the full 4 kW system load.

Qualitative Wins

- Validated manufacturable tube-bend-constrained cold plate optimization
- Confirmed hydraulic and thermal coupling at the system level
- Supported balanced manifold flow design across four cold plates
- Identified the heat exchanger as the dominant overall system limitation

ANALYSIS & CONCLUSION

This study shows that effective liquid cooling at the kilowatt level requires coordinated optimization of cold plate geometry, pressure drop, and system flow distribution.

- Balanced conduction and convection is critical
- Targeted passive changes can deliver meaningful gains
- System-level optimization is more effective than a single isolated fix

ATS delivered a validated, manufacturable cooling solution that improved cold plate performance while supporting full system integration.

Take control of your thermal performance with expert analysis and design services, contact ATS to speak with our engineers and start optimizing your system today.