TECHNICAL CASE STUDY

Thermal Management · CFD Analysis

Dual-Environment Thermal Analysis of a Sealed Offshore Electronics Enclosure

At a Glance

Advanced Thermal Solutions, Inc. (ATS) analyzed a sealed offshore aquaculture electronics enclosure operating in two passive environments: submerged seawater at 30°C and outdoor air at 40°C. The study evaluated whether passive heat rejection alone could keep critical electronics below the 60°C component limit.

CUSTOMER OVERVIEW

The customer was developing a sealed offshore electronics enclosure for aquaculture deployment, housing a Jetson-class module and supporting power electronics in a compact aluminum package intended for both submerged seawater and outdoor air operation.

- Sealed enclosure with no active cooling (Figure 1)
- Dual-environment operation in water and air
- Thermal performance directly tied to electronics reliability and operating margin

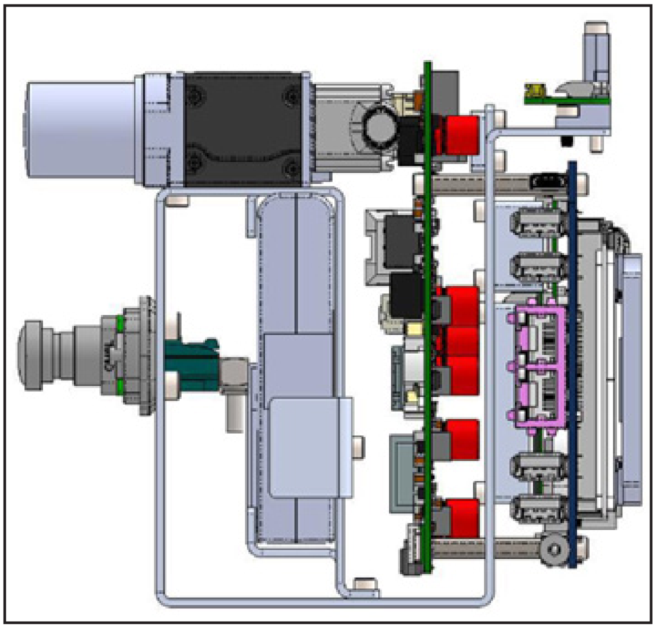

Figure 1. Side View of Exploded Unit Used in Offshore Applications and Exposed to Air and Seawater

CHALLENGE

The enclosure had to maintain component temperatures below 60°C across two passive operating conditions: submerged seawater at 30°C and outdoor air at 40°C. The main question was whether enclosure conduction and natural convection alone could provide enough thermal margin, especially in the more demanding outdoor air case.

Operating load cases:

- **Load Case 1 (Seawater)** (Figure 2):
  30°C ambient, 0 m/s fluid velocity, 49 W heat load
- **Load Case 2 (Air):**
  40°C ambient, 0 m/s fluid velocity, 59 W heat load

With no forced airflow or active liquid cooling, the design had to rely entirely on passive heat spreading and external convection.

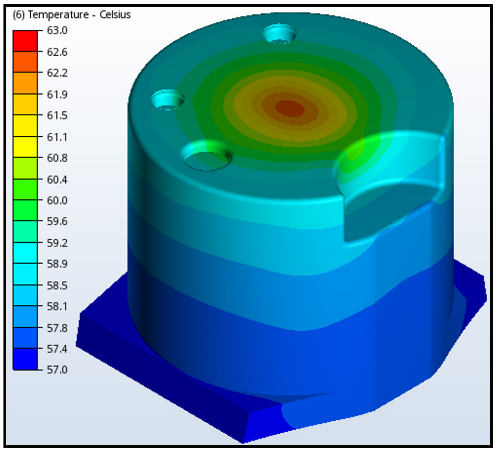

Figure 2. Outer Enclosure Temperature Contours – Seawater Load Case

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METHODOLOGY

ATS performed baseline CFD analysis of the sealed enclosure to evaluate internal heat flow, outer enclosure temperature response, and natural convection effectiveness in seawater and air.

Boundary Conditions

- Natural convection only with no forced airflow
- Enclosure material: Aluminum 5052-H32
- Thermal conductivity: approximately 138 W/m·K
- Gravity applied in the –Y direction
- Initial fluid domain set to ambient

Key Investigation Areas

- Outer enclosure temperature in seawater and outdoor air (Figure 3)
- Average internal air temperature within the sealed volume
- Internal heat spreading through the aluminum sled (Figure 4)
- Internal airflow motion (Figure 5)
- Convection-limited heat rejection capacity of the existing design

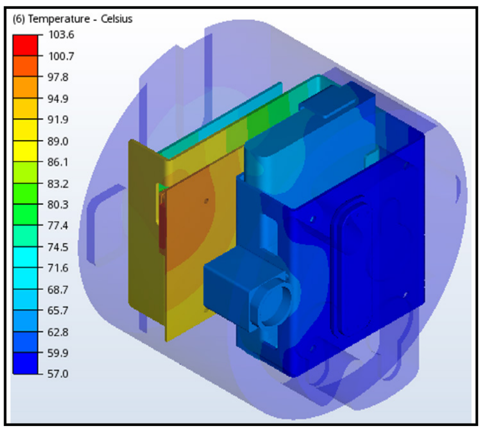

Figure 3. Outer Enclosure Temperature Contours – Air Load Case

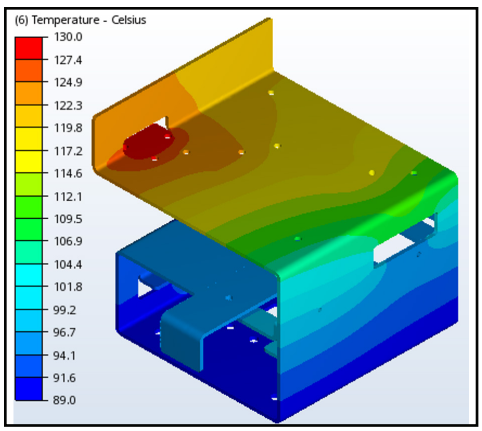

Figure 4. Seawater Load Case. The Internal Aluminum Sled Transfers Component Heat to the Outer Enclosure, But the Heat is Not Spreading Uniformly

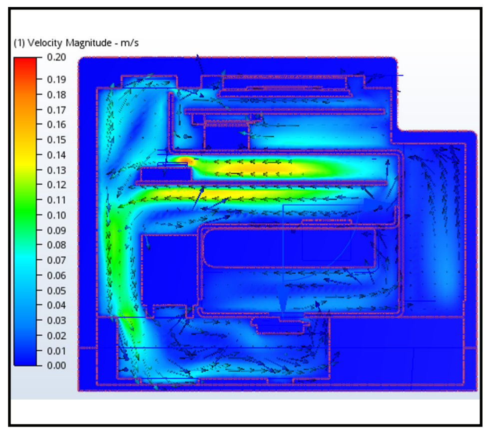

Figure 5. Velocity Vectors Indicate Slow Motion of the Internal Air

SOLUTION

ATS determined that the existing passive enclosure architecture was insufficient for the outdoor air load case and identified the dominant limits as weak external natural convection and inadequate internal conduction from the electronics to the enclosure walls.

- Increase external surface area with external fins or a bonded heat sink
- Improve internal conduction through redesign and lower interface resistance
- Integrate a heat pipe or vapor chamber to reduce spreading resistance
- Use the outdoor air case as the governing condition for redesign decisions

ATS framed the redesign as an enclosure-level thermal architecture change rather than a localized hot spot fix.

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RESULTS & DATA

The CFD study showed that critical temperatures exceeded allowable limits in both load cases, with the outdoor air condition emerging as the dominant constraint.

Key Findings:

- Average outer surface temperature: 58.4°C in seawater and 91°C in air
- Average internal air temperature: 68°C in seawater and 99°C in air
- Both cases exceeded the maximum allowable component temperature of 60°C
- Hot spot-to-enclosure ΔT was approximately 40°C
- Outdoor air operation dictated the required thermal solution

Passive convection assessment in air:

- Estimated natural convection coefficient: approximately 7 $W/m^2 \cdot K$
- Current enclosure area: approximately 0.17 m^2
- Allowable wall-to-ambient ΔT: approximately 15°C
- Maximum passive heat rejection: approximately 18 W
- Required area for 59 W dissipation: approximately 0.56 m^2, or about 3× the current area

These results confirmed that the existing enclosure geometry did not have sufficient passive heat rejection capacity in the air case.

ANALYSIS & CONCLUSION

This study shows that passive cooling performance in sealed electronics enclosures depends on both internal heat spreading and external heat rejection. In this design, the limiting case was outdoor air, where natural convection was too weak to support the required heat load with the available enclosure surface area.

- Passive natural convection was insufficient for 59 W in 40°C outdoor air
- The internal conduction path from the electronics to the enclosure required improvement
- Hot spot spreading resistance contributed significantly to the overall temperature rise
- Solving the air case would effectively address the seawater case as well

ATS provided a clear redesign path showing that achieving the component temperature target would require increased external area and improved internal heat spreading, not minor adjustments to the existing enclosure