

Air-to-Air Heat Exchanger Validation and Weight Optimization in a Sealed MIL/Aero Chassis

At a Glance

Advanced Thermal Solutions, Inc. (ATS) performed analytical modeling and CFD validation of a custom air-to-air heat exchanger integrated within a sealed 2 ft × 2 ft × 1.5 ft enclosure dissipating 100 W at 43°C ambient. The project validated thermal performance first, then reduced system weight without sacrificing margin.

CUSTOMER OVERVIEW

The customer required a sealed electronics chassis cooled by a custom air-to-air heat exchanger. The enclosure had to reject internal heat while preserving sealed-system integrity and meeting a strict internal temperature target under worst-case ambient conditions.

- Sealed 2 ft × 2 ft × 1.5 ft enclosure
- 100 W internal heat load at 43°C ambient
- Internal chassis temperature required to remain at or below 60°C
- Follow-on need to reduce heat exchanger weight without reducing thermal margin

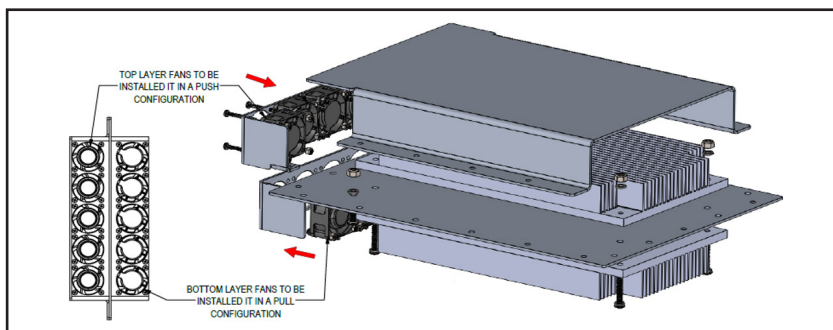


Figure 1.
A Custom-Developed Air-to-Air Heat Exchanger. ATS Evaluated Its Performance and Reduced Overall Weight

CHALLENGE

The system needed to maintain thermal compliance in a sealed enclosure while relying on ducted airflow through a custom air-to-air HEX (Figure 1). After the baseline design was validated, ATS also had to reduce weight and fan count while controlling airflow bypass.

System geometry and constraints:

- Heat sink length: 287 mm
- Heat sink width: 152.4 mm
- Heat sink height: 34.62 mm
- Phase 1 base thickness: 7.6 mm
- Fin thickness: 1.6 mm
- Fin count: 28
- Fan: 40 × 40 × 20 mm axial

Ducting was the critical design variable: it reduced bypass, improved fin utilization, and allowed the sealed chassis to meet its internal temperature target.

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Methodology

ATS used analytical thermal resistance modeling followed by CFD validation. The work was split into two phases: baseline performance validation and weight/airflow optimization.

Analytical performance baseline:

- Ducted configuration: $R\theta \approx 0.10^{\circ}\text{C}/\text{W}$ at 59 CFM
- Unducted configuration: $R\theta \approx 0.18^{\circ}\text{C}/\text{W}$ at 65.5 CFM
- Ducting reduced bypass and improved fin utilization efficiency (Figure 2)

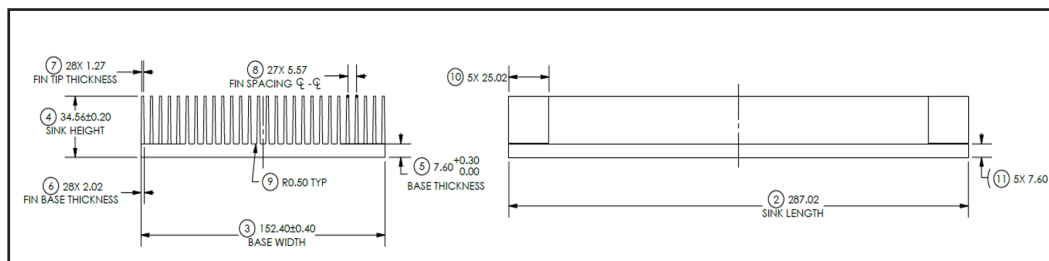


Figure 2.
Profiles of the HEX Heat Sink

Phase 1 - CFD Validation of Baseline HEX Performance

Phase 1 evaluated the original dual-HEX configuration inside the sealed chassis to confirm whether the design met the $\leq 60^{\circ}\text{C}$ internal temperature requirement.

Phase 1 Evaluation

- Modeled two heat exchangers inside the chassis (Figure 3)
- Evaluated bottom-side and top-side heat sink velocity contours (Figures 4 & 5)
- Reviewed internal air temperature and surface temperature contours (Figures 6 & 7)
- Confirmed heat transfer from internal air through the HEX core to ambient

Phase 1 Results:

- Maximum internal chassis temperature remained below 60°C
- Surface contours confirmed effective heat transfer through the HEX core
- Estimated Phase 1 heat exchanger mass: 5508 g

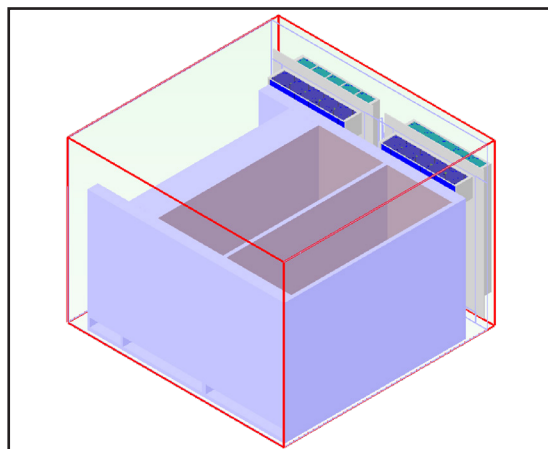


Figure 3.
Baseline CFD Model with
Two Heat Exchangers Inside
the Chassis

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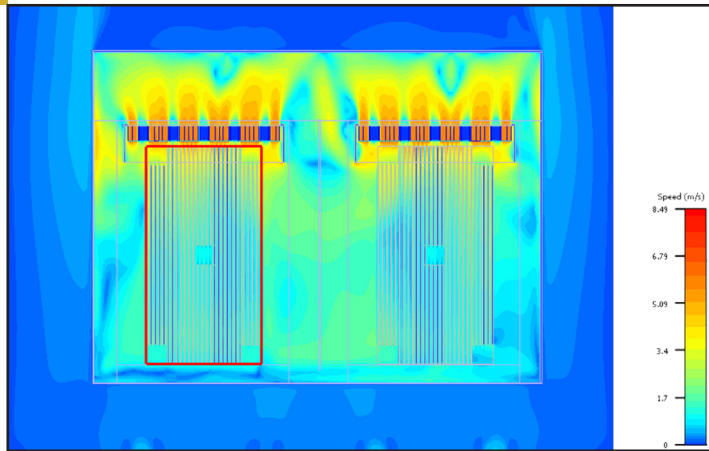


Figure 4. Bottom Side Heat Sink Velocity Contours

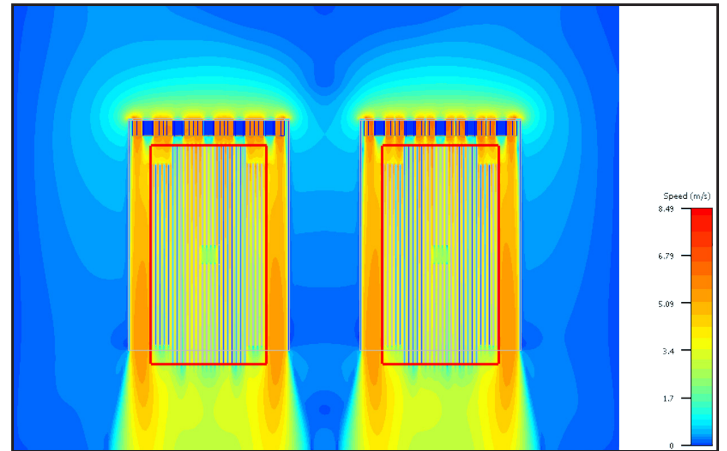


Figure 5. Top Side Heat Sink Velocity Contours

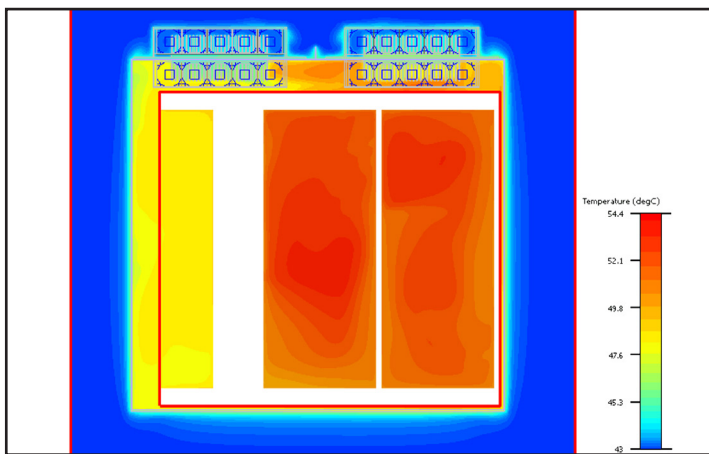


Figure 6. Temperature Contours Inside the Chassis (Front View)

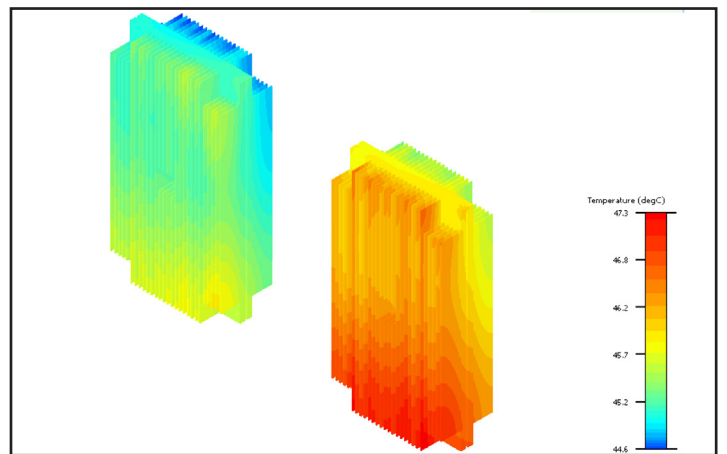


Figure 7. Surface Temperature Contour of HEX Heat Sinks

Phase 2 - Mass Reduction and Airflow Control Optimization

Phase 2 reduced heat exchanger mass and fan count while preserving thermal performance. ATS refined the ducting and top cover to force airflow through the fin field and eliminate bypass over the heat sink.

Phase 2 Modifications

- Reduced heat sink base thickness from 7.6 mm to 3.0 mm
- Reduced fan count from 10 to 8 fans per HEX assembly (Figure 8)
- Redesigned top cover to eliminate airflow bypass
- Refined ducting to force all airflow through the fin field (Figure 9)

Phase 2 Results:

- Maximum internal temperature confirmed at approximately 57°C
- Internal temperature remained below the 60°C requirement (Figure 10)
- Heat exchanger mass reduced from 5508 g to 4550 g
- Total mass reduction: approximately 18%
- Fan reduction lowered power consumption and acoustic output

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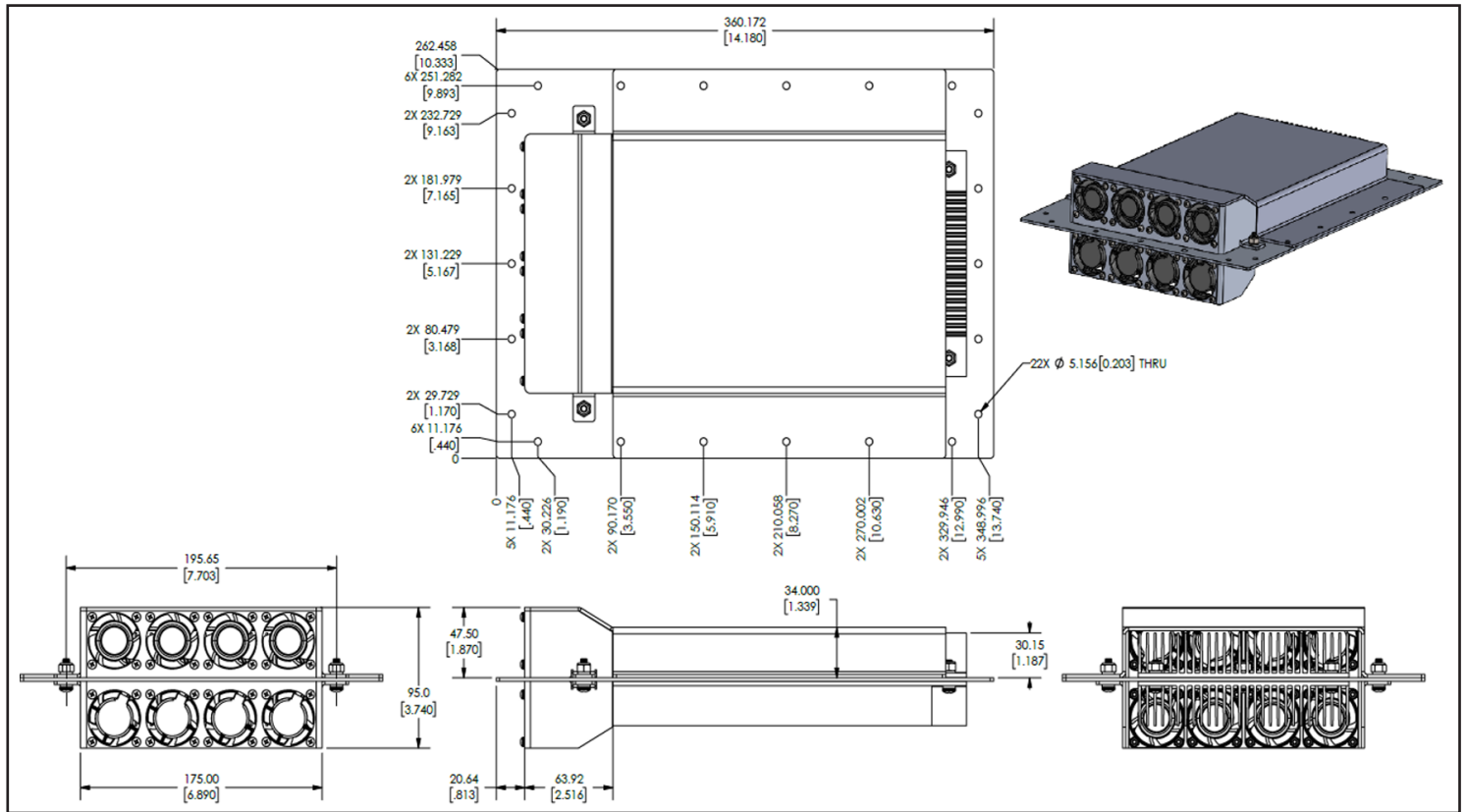


Figure 8. The Heat Exchanger Fan Count was Reduced to Eight from Ten. This resulted in Lower Power Consumption and Reduced Noise.

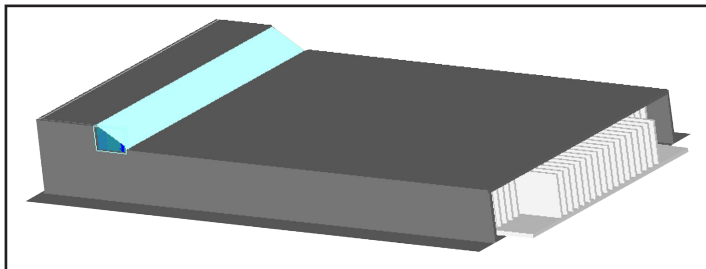


Figure 9. Fan Airflow is Ducted So Flow Does Not Bypass Over the Top of the Heat Sink

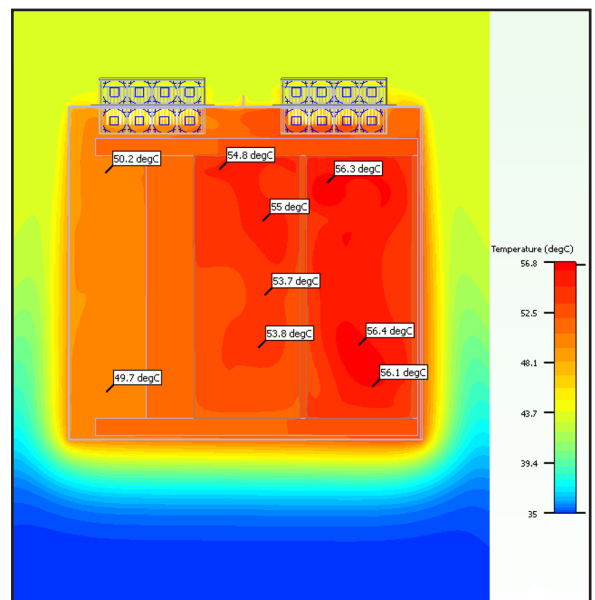


Figure 10. The Air Temperature Inside the Chassis is Below the Target Limit of 60°C

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SOLUTION

ATS validated the baseline air-to-air heat exchanger, then optimized the architecture by reducing conduction mass where it was not needed and improving duct control where airflow discipline mattered most.

- Confirmed thermal compliance through CFD baseline validation
- Reduced base thickness without materially degrading spreading resistance
- Reduced fan count while maintaining thermal performance
- Eliminated bypass using redesigned ducting and top-cover geometry
- Maintained sealed-enclosure thermal margin after weight reduction

RESULTS & DATA

The optimized design preserved thermal compliance while reducing mass, fan count, power consumption, and acoustic output.

Thermal engineering outcomes:

- Ducted airflow was critical for maintaining low thermal resistance in the sealed enclosure
- Reducing base thickness did not materially degrade spreading resistance
- Fan reduction lowered power consumption and acoustic output
- Optimized weight was achieved without sacrificing thermal margin

ANALYSIS & CONCLUSION

This study shows that sealed-enclosure heat exchanger performance depends on both thermal design and airflow discipline. ATS confirmed that the baseline HEX met the requirement, then reduced weight through structural optimization while maintaining ducted flow through the fin field.

- Analytical and CFD methods validated the thermal architecture
- Duct optimization eliminated airflow bypass and preserved fin utilization
- Structural mass was reduced while preserving the conduction path
- Thermal and mechanical objectives were optimized together

ATS delivered a validated, lighter air-to-air HEX architecture for a sealed MIL/Aero chassis while maintaining the internal temperature requirement and improving implementation efficiency.

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.

