CHARGED
VIRTUAL CONFERENCE
EV ENGINEERING

Innovations in Electric Vehicle Cooling Technology

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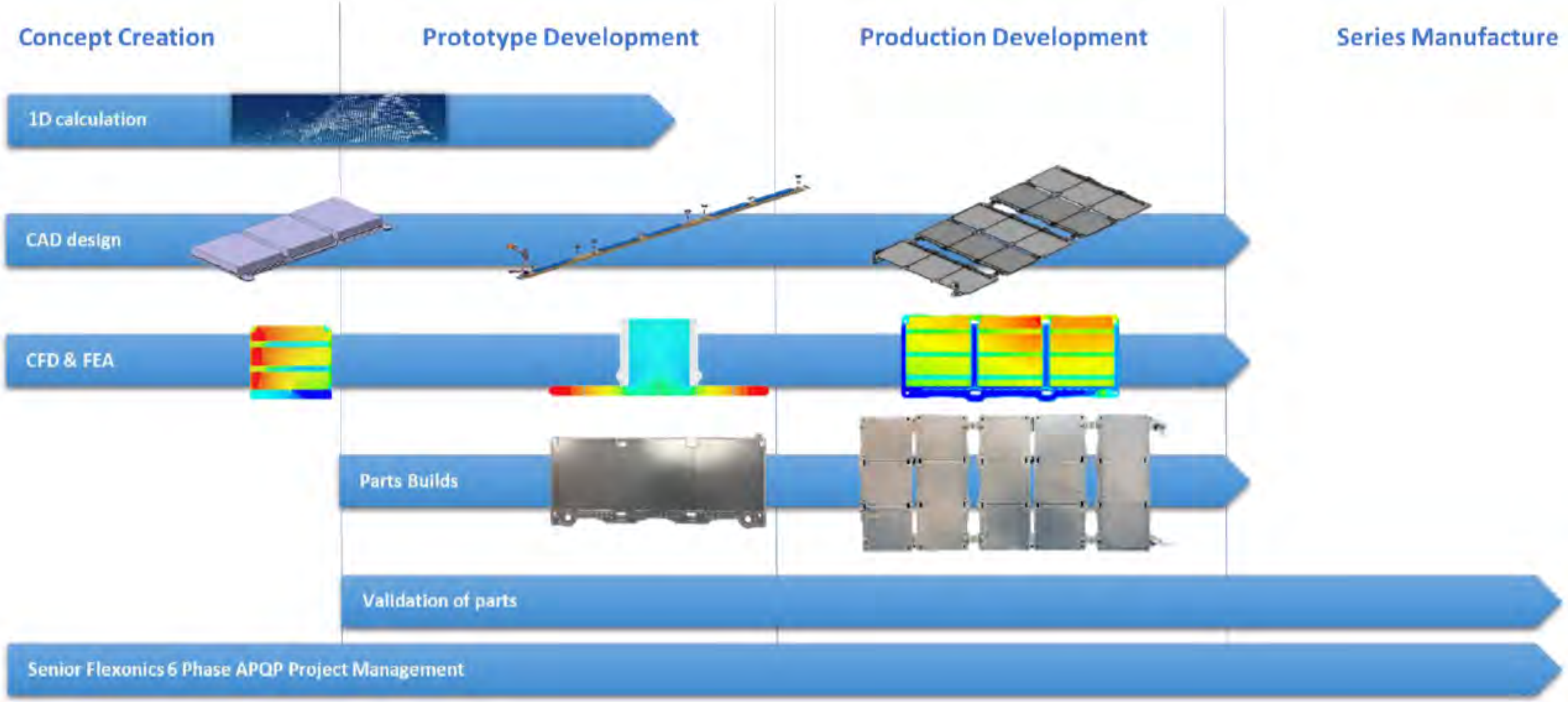
Innovation in Electric Vehicle Cooling Technology

- Development in temperature management is crucial to the success of electric vehicles
- As an OEM supplier we have been working on this challenge with our customers and the results have yielded some promising technology
- Two specific case studies were chosen which showcases the design, analysis, and testing capabilities at Senior
  - Case Study 1 was a collaboration between Senior UK and Senior North America
  - Case Study 2 was primarily developed at Senior North America
  - Senior has applied for patents on both of the technologies that were developed from these two case studies

Problem → Design → Analysis → Testing → Solution

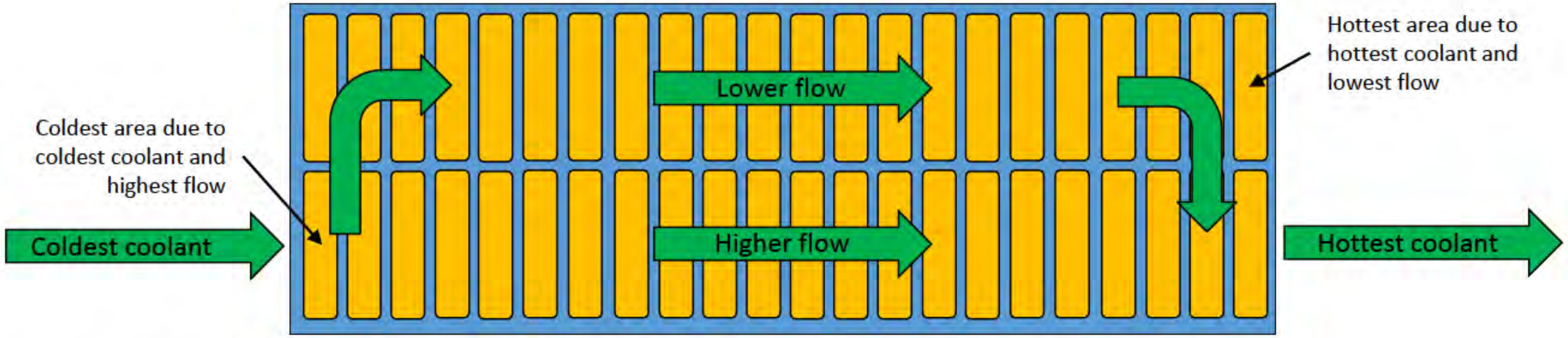
- Case Study 1 (Battery Cooling)
  - Design a battery cooling plate heat exchanger that is 3 mm thick and provides a maximum of 3°C degree delta across the entire contact surface



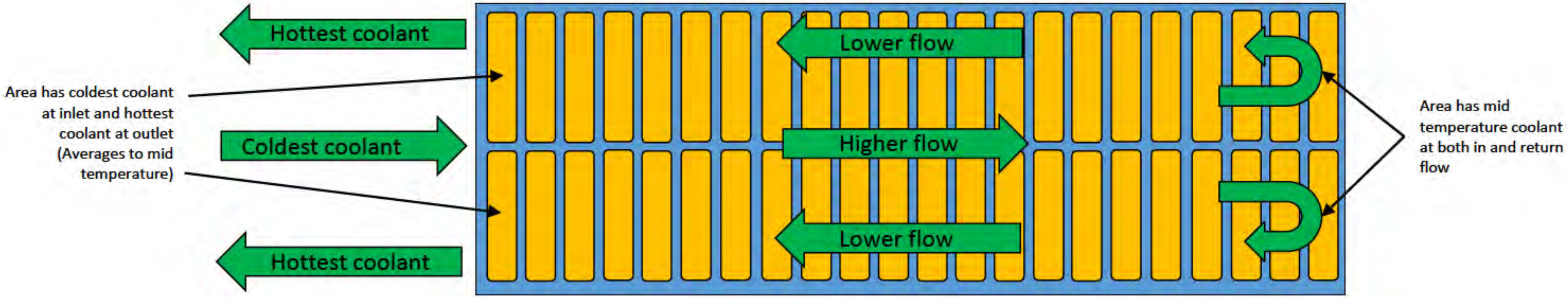
Case Study 1 (Battery Cooling)

- Background on battery cooling system
  - Heat is created when either charging or discharging batteries and this can lead to reduced life or catastrophic failure at high temperatures
  - The heat is generated from the internal resistance of the battery which called Joule or Ohmic heating
  - This fact cannot be avoided with this current generation of EV batteries, so it needs to be managed effectively
    - The current standard is to use liquid cooling
    - Water-glycol coolants can either be passed in between cells, battery packages or even through a cooling plate to manage the heat being generated

- 1D Analysis of Standard Design (Single-pass heat exchanger)
  - Results – Large temperature gradient across surface

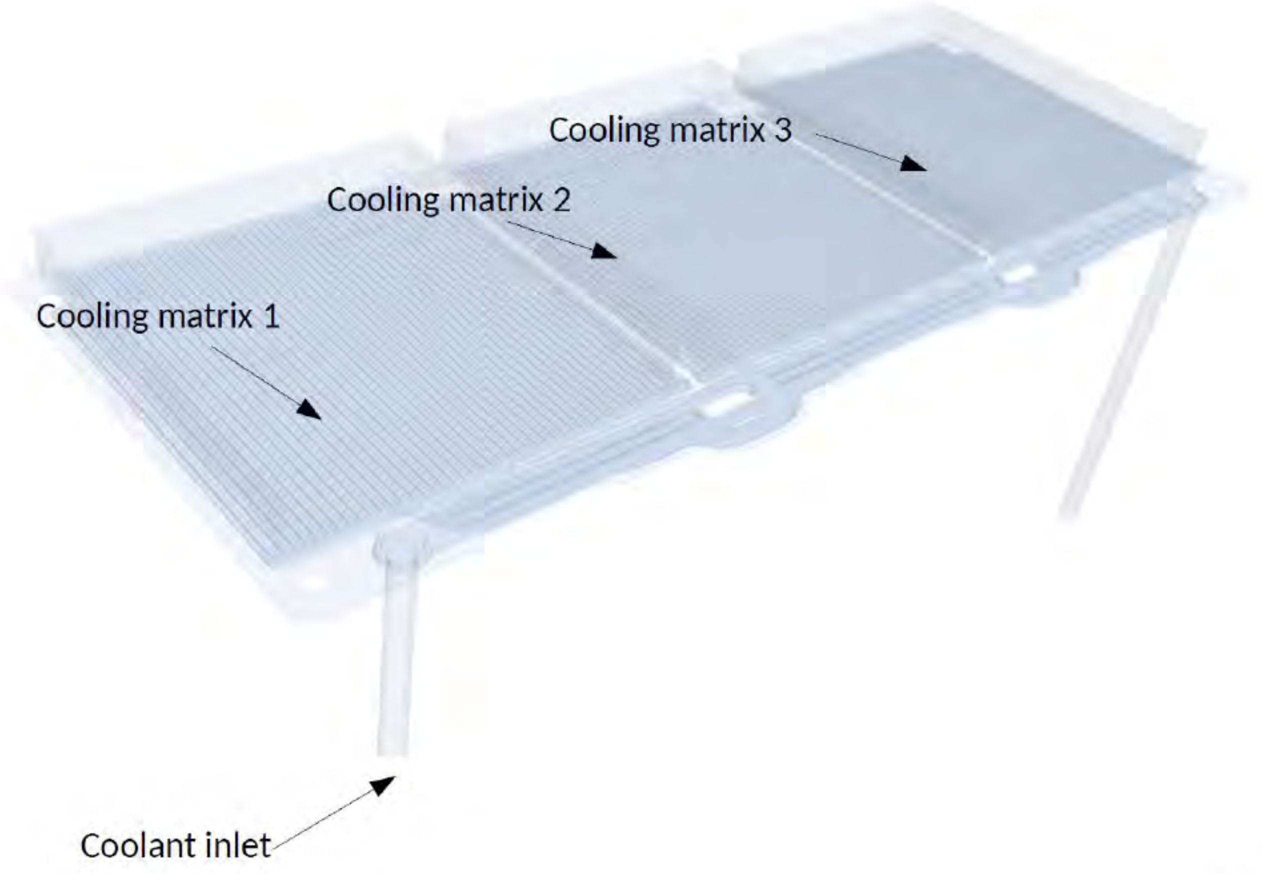


- 1D Analysis of Balanced Design (Two-pass heat exchanger)
  - Results – Small temperature gradient across surface



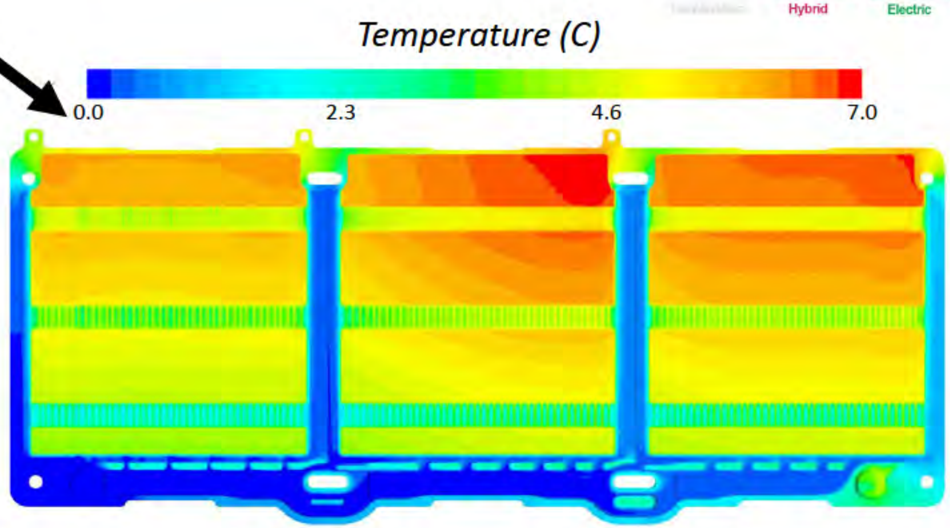
Case Study 1 (Battery Cooling)

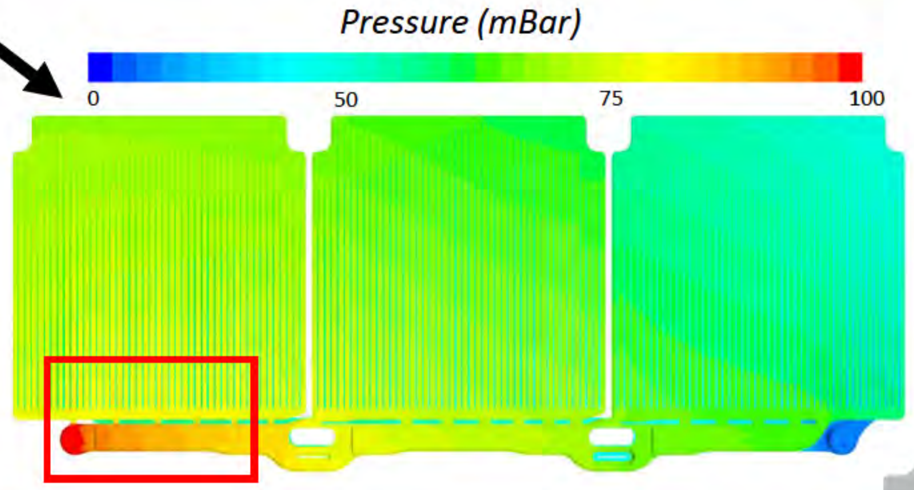
- Analysis Setup
  - CFD analysis of the battery cooler design was used to iterate the design to meet customer requirements
  - Both temperature and pressure drop were key parameters when designing this system

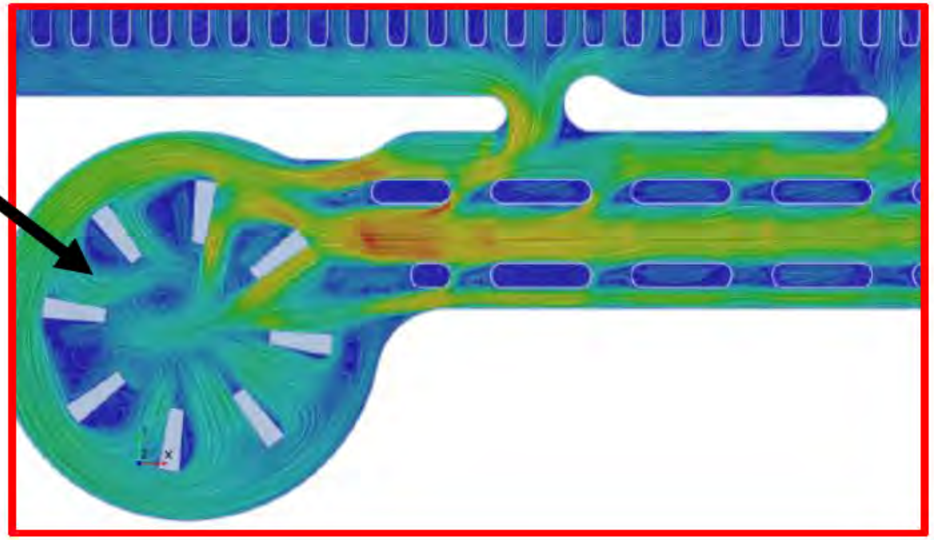


Case Study 1 (Battery Cooling)

- Analysis Results
  - The design of the cooling plates was iterated until the desired temperature and pressure drop profile was reached
  - The temperature plot shows a maximum temperature delta of 3°C and a relatively uniform distribution
  - The pressure plot show a maximum pressure drop of 100 mBar







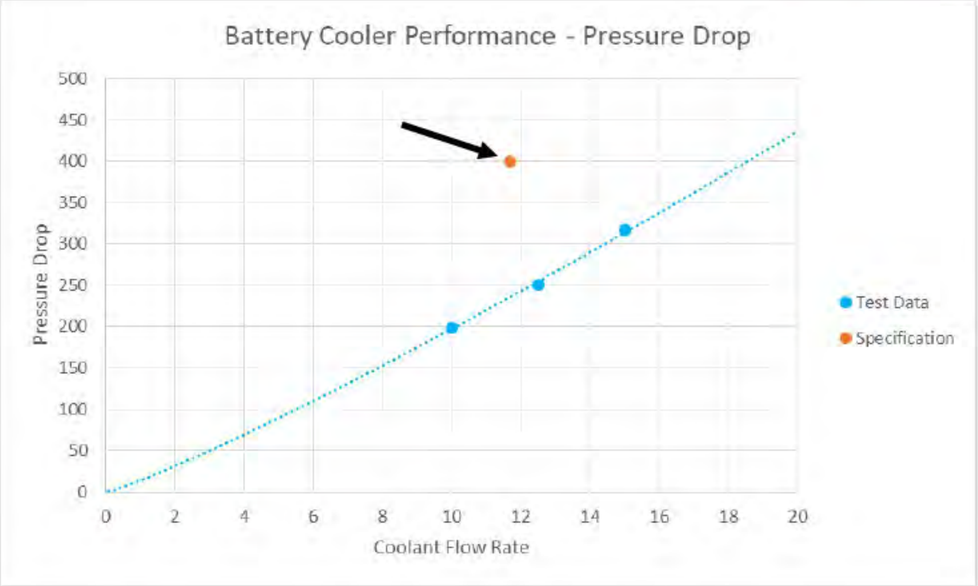
- Test Setup
  - Custom test bench at Senior was used to measure pressure drop at various flow rates and temperatures

Test Bench

Battery Cooler

Case Study 1 (Battery Cooling)

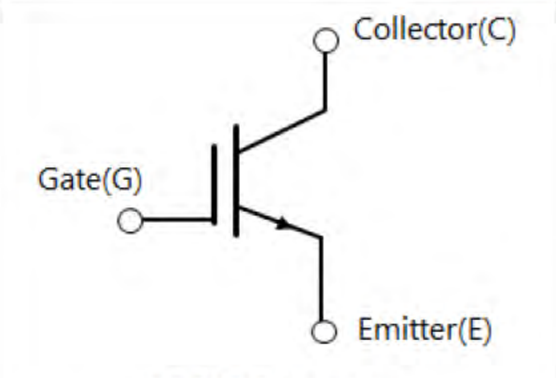
- Test Results
  - Pressure drop test results show that the battery cooler design is 50% lower than customer specifications
  - Temperature performance on application was verified by our customer to meet expectations



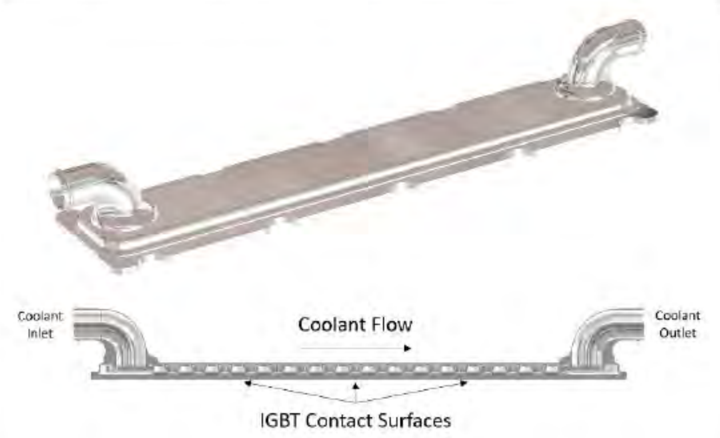
- Final Thoughts
  - Through the use of CFD analysis and design iteration we were able to create a unique solution that met our customers expectation
  - The final design not only met our customers requirements but also our own internal requirements for manufacturability

- Case Study 2 (IGBT Cooling)
  - Design a fin that fits within a given heatsink that lowers IGBT surface temperature while maintaining a 1mm gap for particle flow to avoid clogging

- Background on IGBTs ([redacted] *Bipolar Transistor)*
  - Uses
    - Transfer power between the motors and batteries
  - Development
    - Cooling of IGBT's has become critical in reliability and efficiency
- Background water cooled IGBT heatsinks
  - Used to cool IGBT chips
  - Needs some way of transferring heat from IGBT to water
    - Pin Fins
    - Wavy Fin
    - Etc.
  - Contain a inlet and outlet water connection

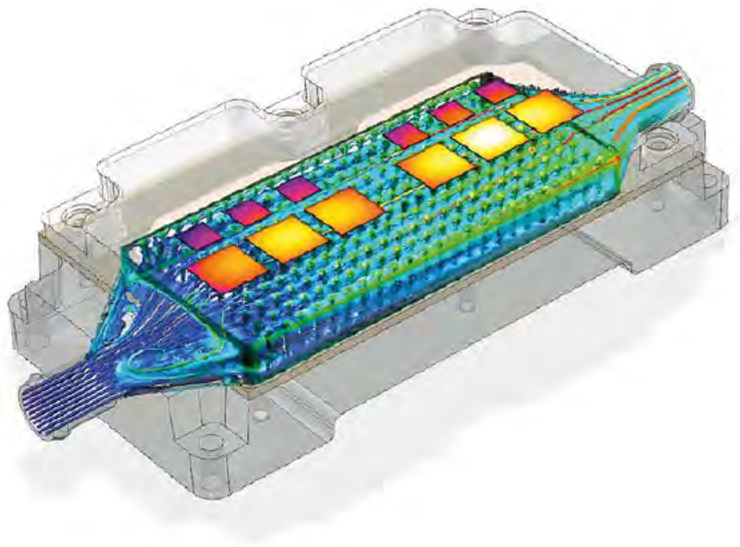


IGBT Diagram

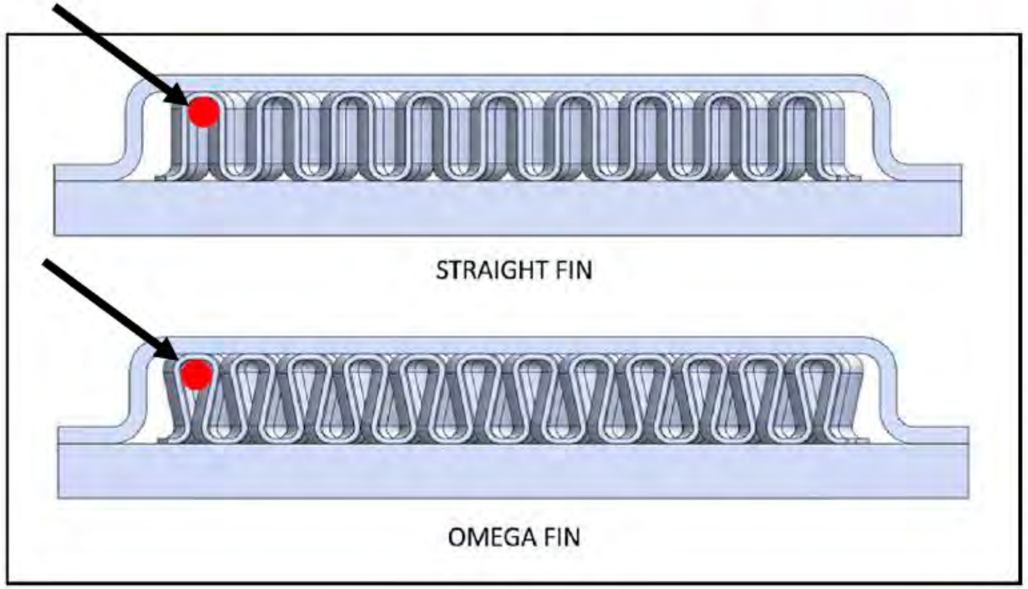


Case Study 2 (IGBT Cooling)

- Reason for having increased performance
  - High efficiency results in smaller IGBT chip or higher current carrying capacity
  - Reducing surface temperature improves thermal cycling

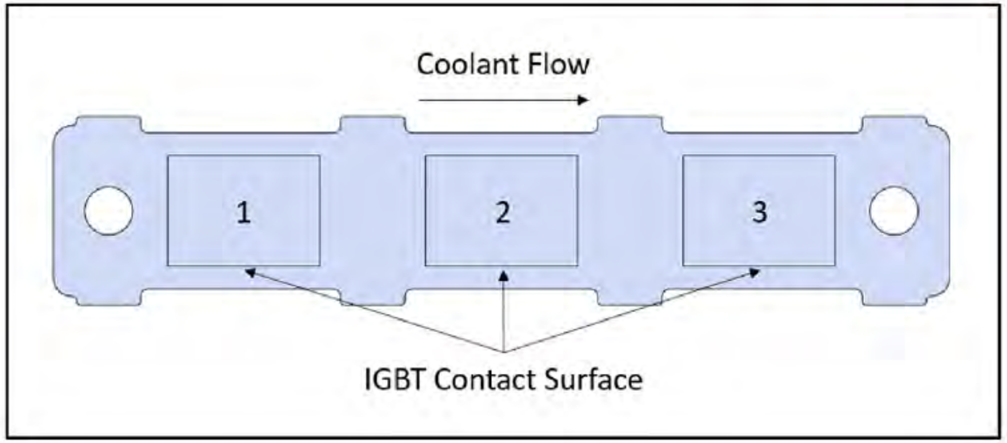


- Omega fin design benefits
  - Developed to increase performance while maintaining a minimum gap for particle size
  - More surface area can be utilized with the Omega fin
    - Straight fin design has 9 fins while the Omega fin design has 12 fins a 33% increase



Case Study 2 (IGBT Cooling)

- Analysis Setup
  - CFD analysis setup for both standard and Omega fin
  - 133W was applied to each contact surface for a total of 400W
  - Coolant flow rate was varied to observe changes in surface temperature and pressure drop
  - Heatsink assemblies made out of copper



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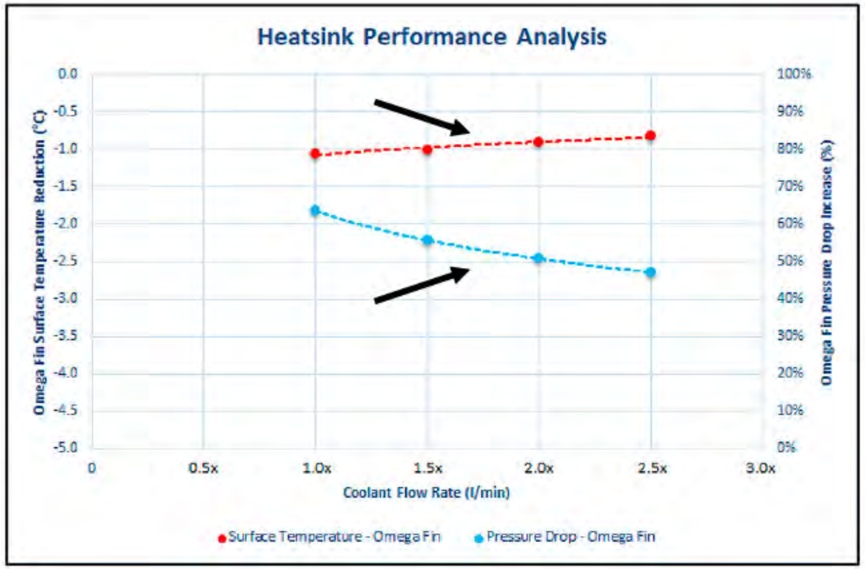
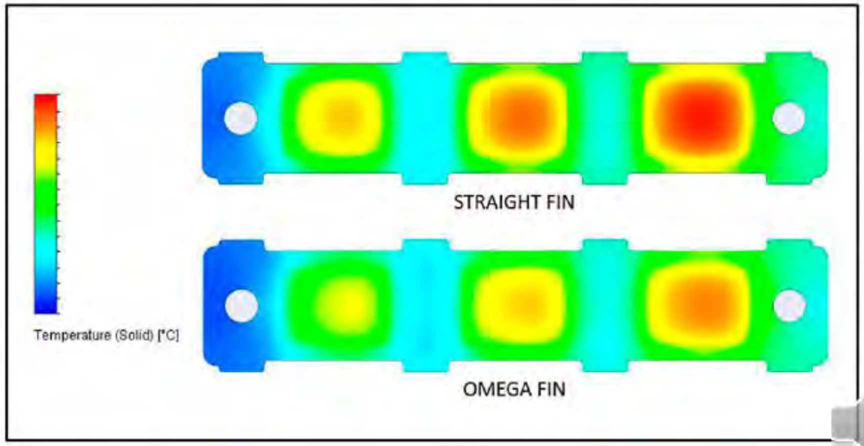
Hybrid Electric Energy

- Analysis Results
  - Omega fin shows a 1.0°C reduction in surface temperature compared to the straight fin
  - Omega fin shows a ~58% average increase in pressure drop compared to the straight fin
- The increase in heat transfer of the Omega fin allows 600W, *50% more,* to be applied to the Omega fin design to reach the same temperature as the Straight fin



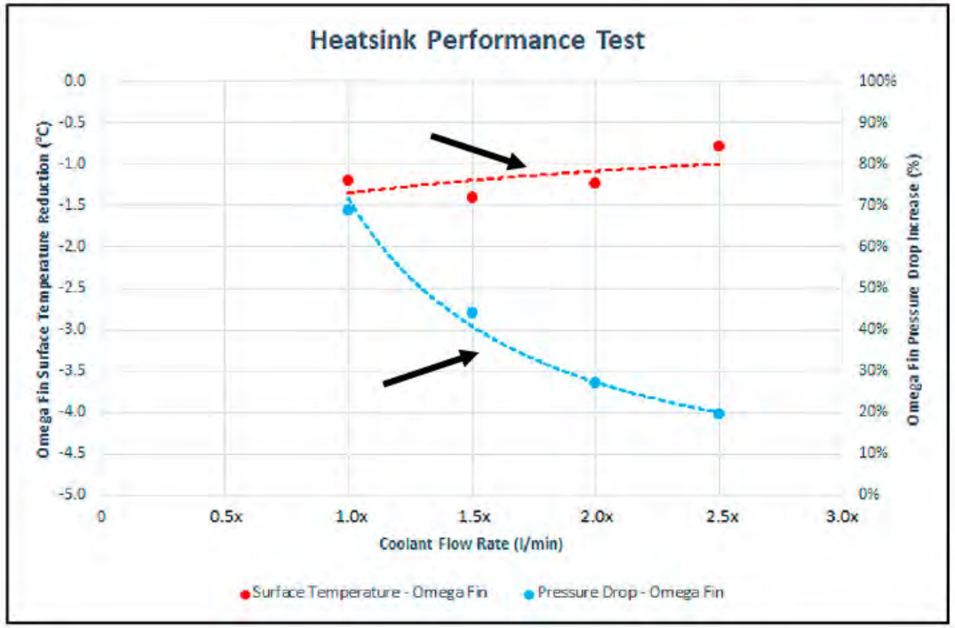


Case Study 2 (IGBT Cooling)

- Test Setup
  - Parts were built to match analytical models
  - Custom test bench built to simulate IGBT heat input
  - Thermocouples measure surface temperature of heatsink and fluid temperature
  - Pressure transducer measures system pressure drop

Case Study 2 (IGBT Cooling)

- Test Results
  - Omega fin shows a 1.1 C reduction in surface temperature compared to the straight fin
  - Omega fin shows a ~40% average increase in pressure drop compared to the straight fin



- Final Thoughts
  - Both analysis and test results show a decrease in surface temperature when using the Omega fin
  - Any existing heatsink design, using an internal fin, could be switched to an Omega style fin in order to increase heat transfer and improve efficiency

Senior Summary

- Senior is an international, market-leading, engineering solutions provider with 30 operations in 13 countries
- We design, manufacture and market high-technology components and systems for the principal original equipment producers in the worldwide aerospace, defense, land vehicle and energy markets
- In 2019 Senior generated £1.1B in sales revenue

Flexonics Division

WHAT WE DO

Serving markets with products for land vehicle emission control and process control industrial applications

2,766 Employees Worldwide

Aerospace Division

WHAT WE DO

Serving both commercial aerospace and defence markets with a range of products and systems for structures, fluid conveyance and gas turbine engines

4,893 Employees Worldwide

Hybrid Electric Energy

- All our products are developed by a dedicated and customer focused team, manufactured in world class facilities, and proven through an exceptional warranty record

EGR & ICE Thermal Management

Gasoline & Diesel Common Rails

Flexible Connectors & Turbo Dampeners

Waste Heat Recovery

Fluid Transfer & EGR Tubes

Electronics Thermal Management

Battery Thermal Management

Fuel Cell Heat Exchangers

Recuperators & Cathode Air Pre-Heaters

Hybrid: Our expertise in a vast array of applications gives our customers the flexibility to develop efficient, market leading propulsion technologies to meet this growing demand.

Energy: The need for clean and efficient sources is greater than ever before. We are working with some of the world's leading companies to develop clean sources of energy generation, whilst dramatically improving efficiency and energy security.

Combustion: Our key focus for combustion engines is to improve fuel efficiency and reduce harmful emissions. We combine decades of manufacturing expertise with the latest technologies to ensure our customers are always one step ahead.

Electric: We are using our wealth of knowledge to implement creative solutions, enabling our customers to maximise battery life and performance. We also develop highly efficient range extender technologies.

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