BOYD
TRUSTED INNOVATION

Cooling System Solutions for e-Mobility Powertrain Applications

Focus Areas for eMobility Solutions

Inverter

Liquid Cold Plates
Port Seals
Electrical Isolation
Thermal Interface Materials

Advanced Driving Assistance Systems (ADAS)


Waterproof, Impact absorbing Gaskets
Liquid Cold Plates
Sensor Cooling and LiDAR Solutions
Thermal Interface Materials
Heat Sinks (Cast, Extruded, Advanced)
Heat Pipes
Vapor Chambers
Air Movers

Display and HMI

Display Optical Enhancement
Heat Spreaders
Display Bonding
Ultra-thin Vapor Chambers
Front Panel and Display Integration

EV Battery System

Energy Supply
Collision Protection
Thermal Runaway Prevention
Penthouse Seals
Liquid Cold Plates

Onboard Charger

Liquid Cold Plates
Housing Seals
Heat Sinks (Cast, Extruded, Advanced)
Heat Pipes
Vapor Chambers
Air Movers

AC/DC Converter

Liquid Cold Plates
Enclosure Seals
Speak Voltage Protection
Heat Sinks (Cast, Extruded, Advanced)
Heat Pipes
Vapor Chambers
Air Movers

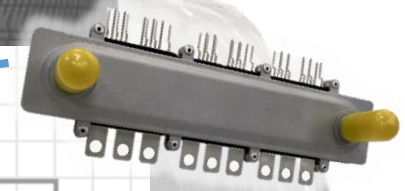
Charging Infrastructure


Liquid Cold Plates
Charge Port Seals
Enclosure Waterproofing
Thermosiphons
Heat Pipes
Vapor Chambers
Air Movers
Heat Sinks (Cast, Extruded, Advanced)

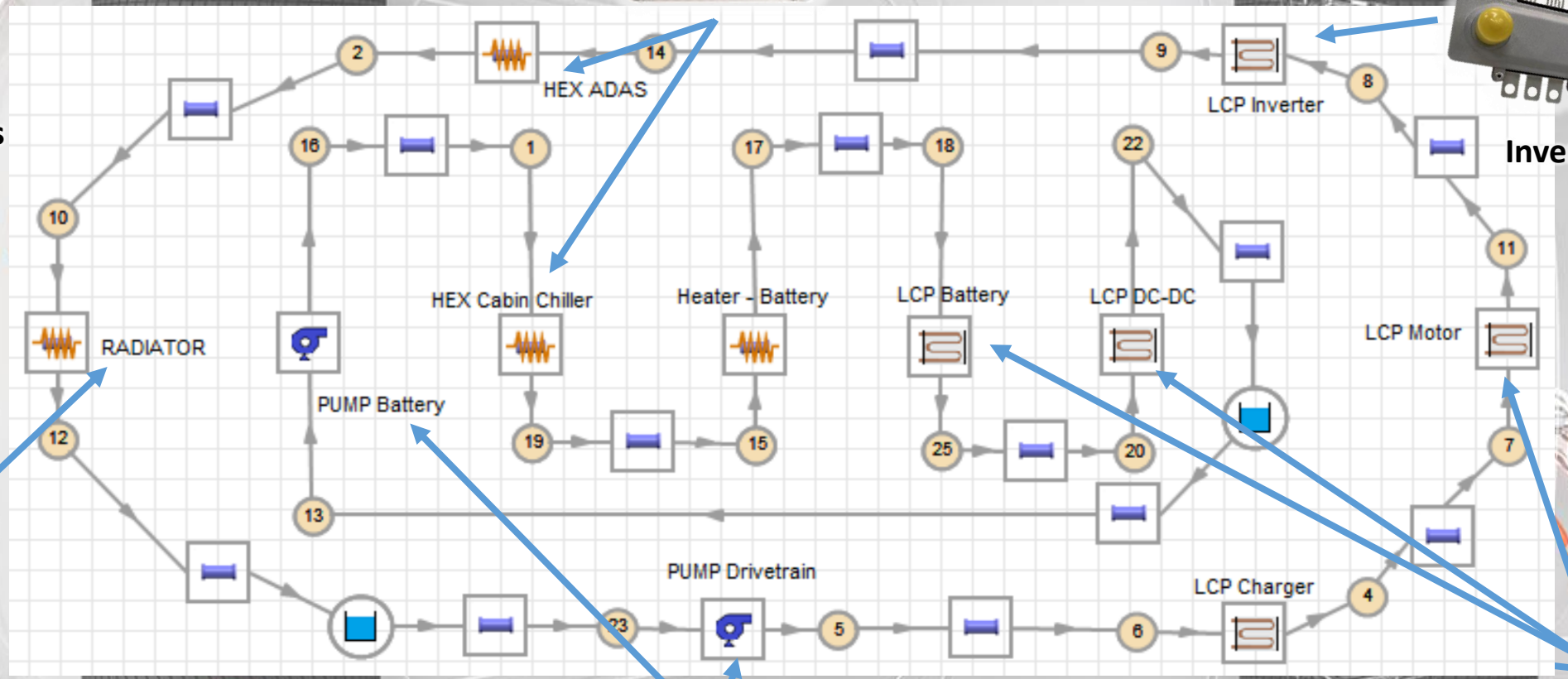
eMobility - Cooling System Flow Network

Heat Exchanger
Liquid to Liquid

Complex Array Of Harnesses Connects All Components



Inverter Cold Plate

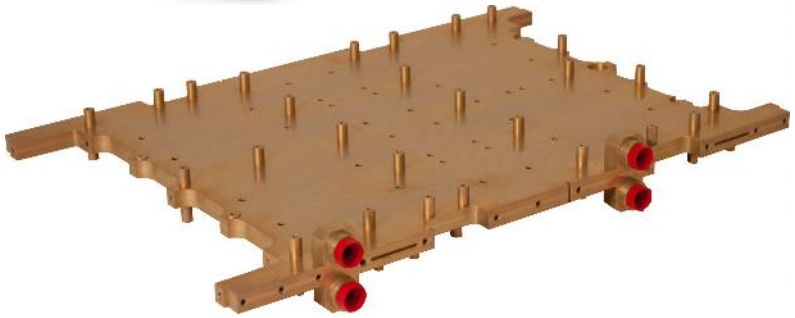


Heat Exchanger Liquid to Air

Pumps

Liquid Cold Plates

Engineering – Design Centre Capabilities & Tools

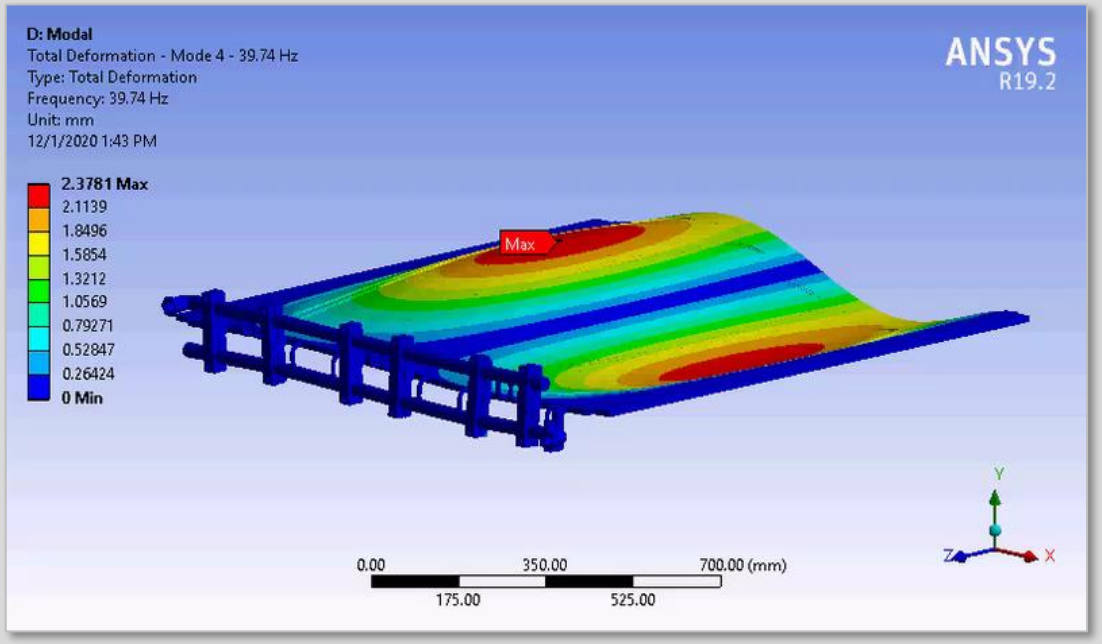


Brazed Cold Plates offer lighter weight and high performance at the best value.

Controlled Atmosphere Brazing (CAB) and Vacuum Brazing are popular processes based on application requirements.

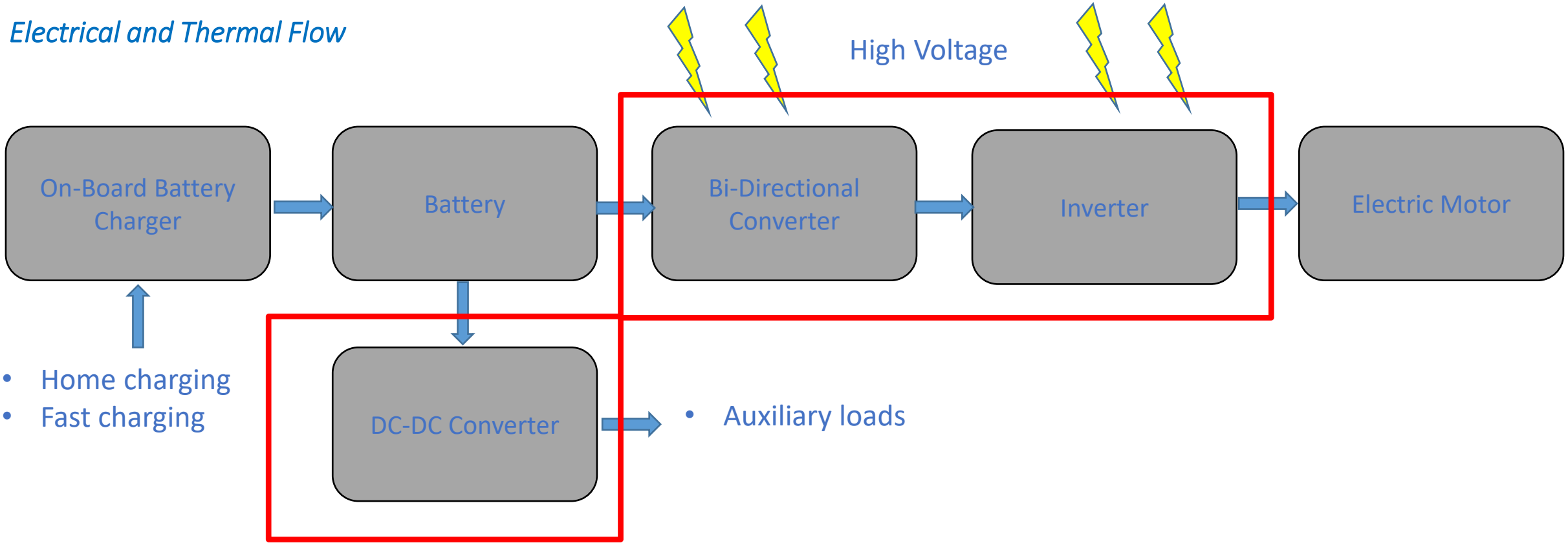
Finite Element Analysis Video

Showing Nodal Stress and Cold Plate Deformation – visible improvement with Boyd adhesive system



Electric Traction & Drive System and Battery Assemblies – Inverter/Converter

Electrical and Thermal Flow



- Innovation in **electrical isolation** at high thermal performance is required now, and in the future
- All assemblies utilize a **liquid cold plate** to remove heat generated during operation
- Boyd's suite of engineered materials and liquid cold Plate capability provides trusted solutions quickly

Technology: Multi-Component Cold Plates

Controlled Atmosphere Brazing (CAB) of aluminum cold plate supporting double sided cooling with flexible harness and Quick Disconnect fluid couplings

Aluminum Tube Cold plate supporting double sided cooling

Vacuum Aluminum Brazing (VAB) of machined aluminum cold plate supporting double sided cooling for high reliability

Boyd's Electrical Isolation Capacity

- **Pre-apply any film or tape** to a cold plate or mechanical surface
- Provide cold plates with protective coatings including **epoxy and powder coat**
- In-House **thermal and Hi-Pot testing** capability

Technology: Cold Plate Capability Roadmap

KEY
- Nominal TDP
- TDP Range of Boyd Solution

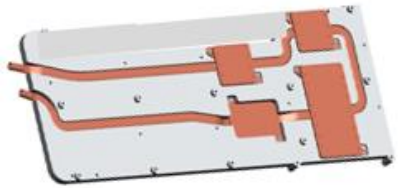
RF AMP - Thermal Design Power

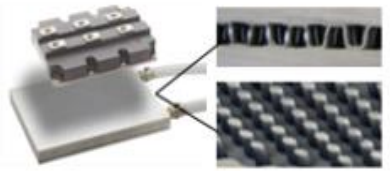
Hi-Contact Tube
Allows device to mounting over the tubes

Flat Tube Manifold
Increase the tube coverage over the mounting area

Meso-Channel Cooling
Adds very high-performance cores to the fluid routing in a flat plate





Wetted Chemistry
Copper / SS

Wetted Chemistry
Aluminum / SS

Tube / O-Ring / Seam Weld
Creates a cooling vessel with moderate cooling

Brazed Cold Plate
Supports increased pressure allowing for more complex flow channels

Meso-Channel Cooling
Adds very high-performance cores to the fluid routing in a flat plate

Technology: Cold Plates – Aluminum Wetted Chemistry

MESO-CHANNEL COLD PLATES

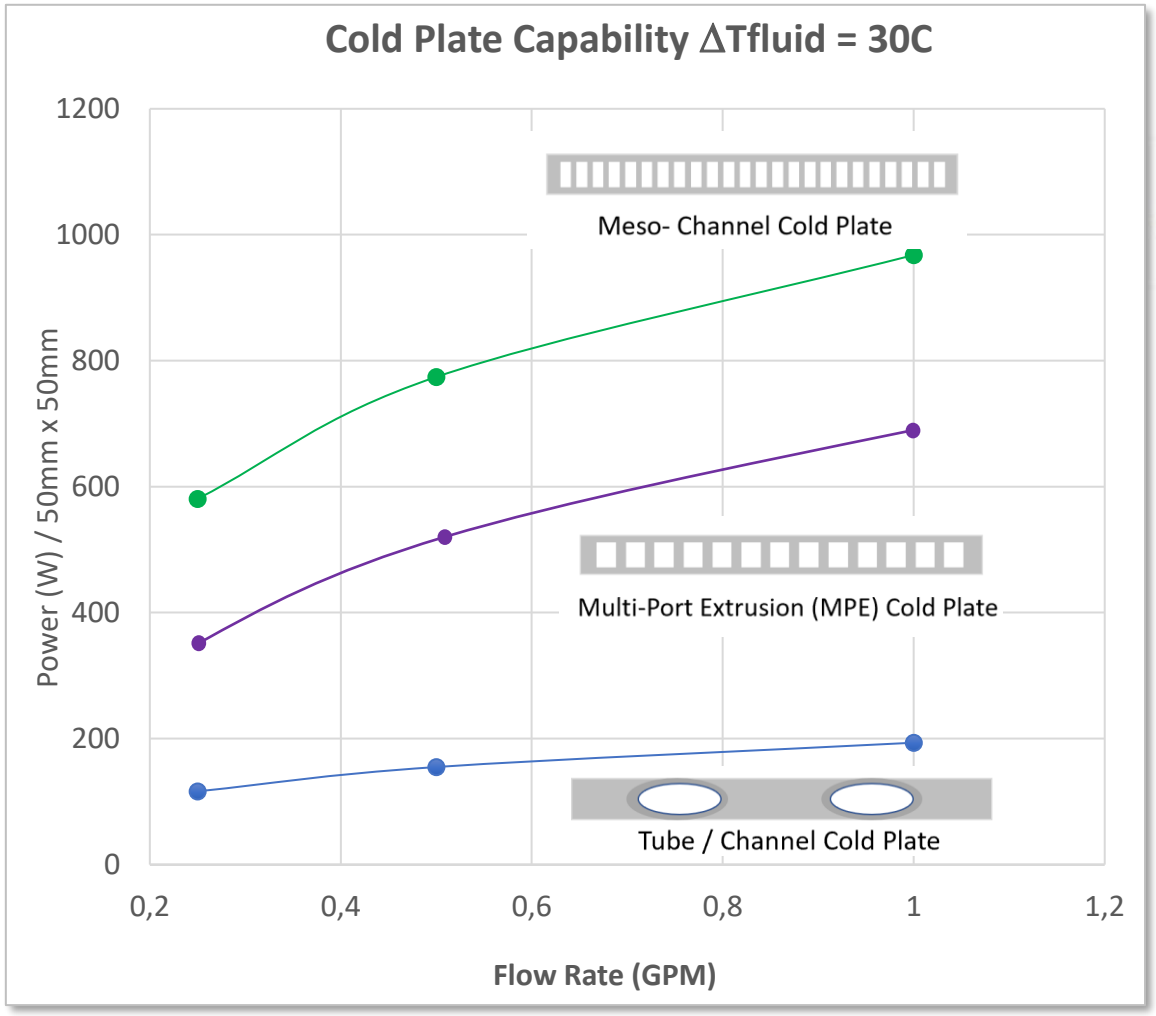
- High-performance direct liquid cooling for > 600W
- Used for Inverter, and AC/DC Conversion

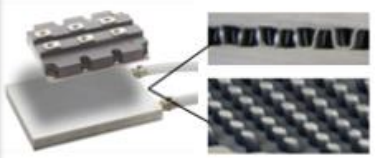
PARALLEL CHANNEL COLD PLATES

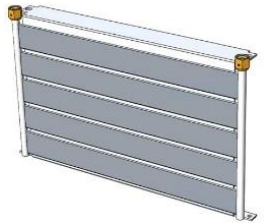
- High-performance direct liquid cooling for > 400W
- Used for Battery and BMS Cooling

TUBE AND CHANNEL COLD PLATES

- Copper, Aluminum, or Stainless-Steel tubes are used with aluminum plates
- Used for Battery Cooling



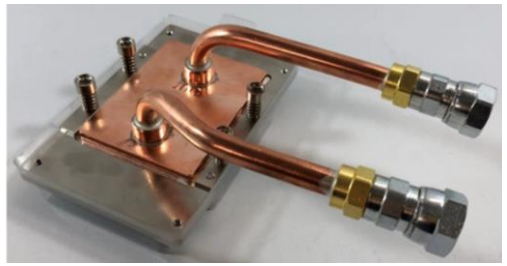




Technology: Cold Plates – Copper Wetted Chemistry

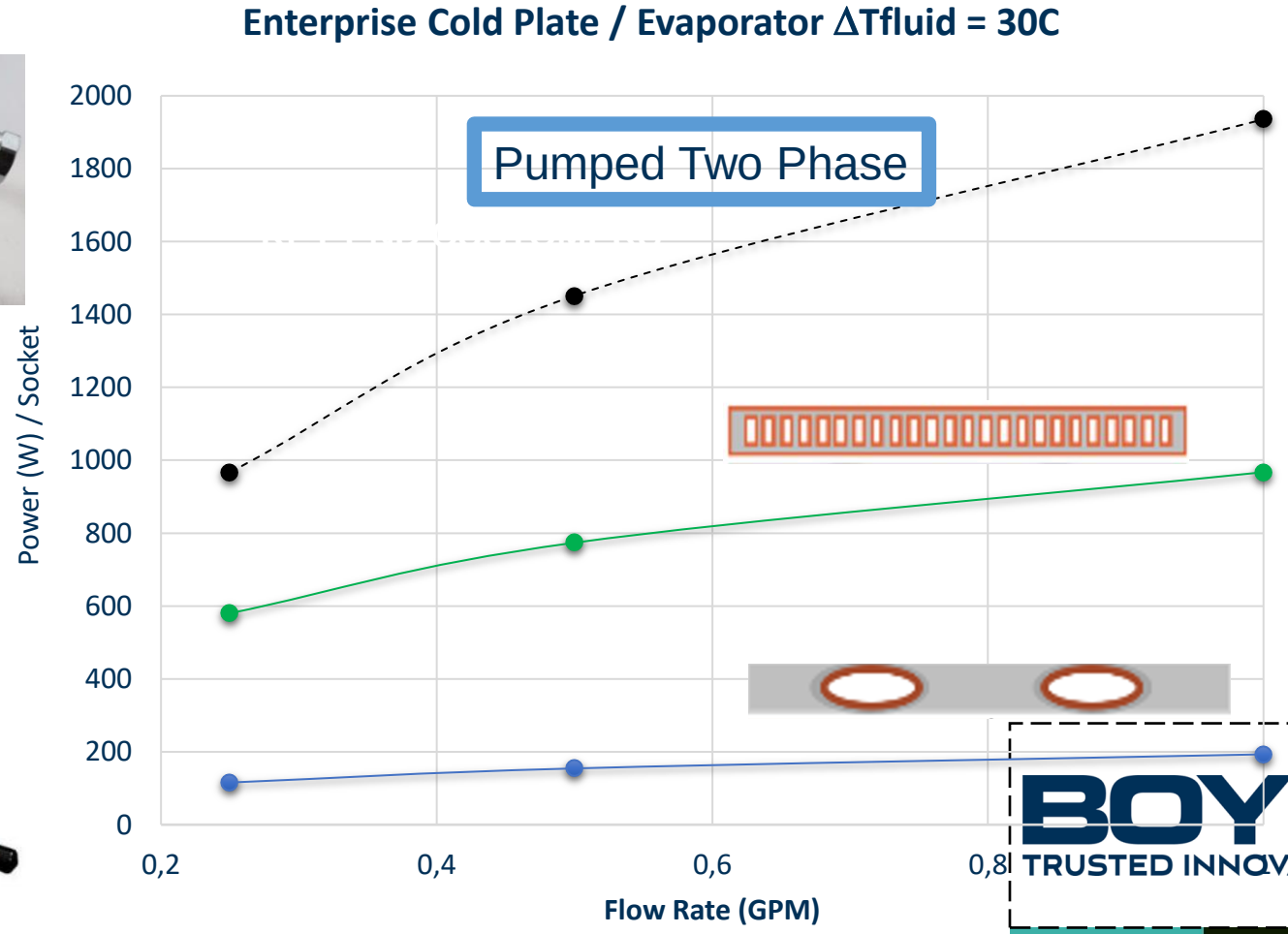
MESO CHANNEL COLD PLATES

- High performance direct liquid cooling for > 400W
- Optimized not just for thermal performance but for maximum liquid flow at design pressure drop



HI-CONTACT COLD PLATES

- Copper tubes are used with aluminum plates and gap filling TIM to remove heat from Memory, Chipsets, VRMs, and SSD Drives

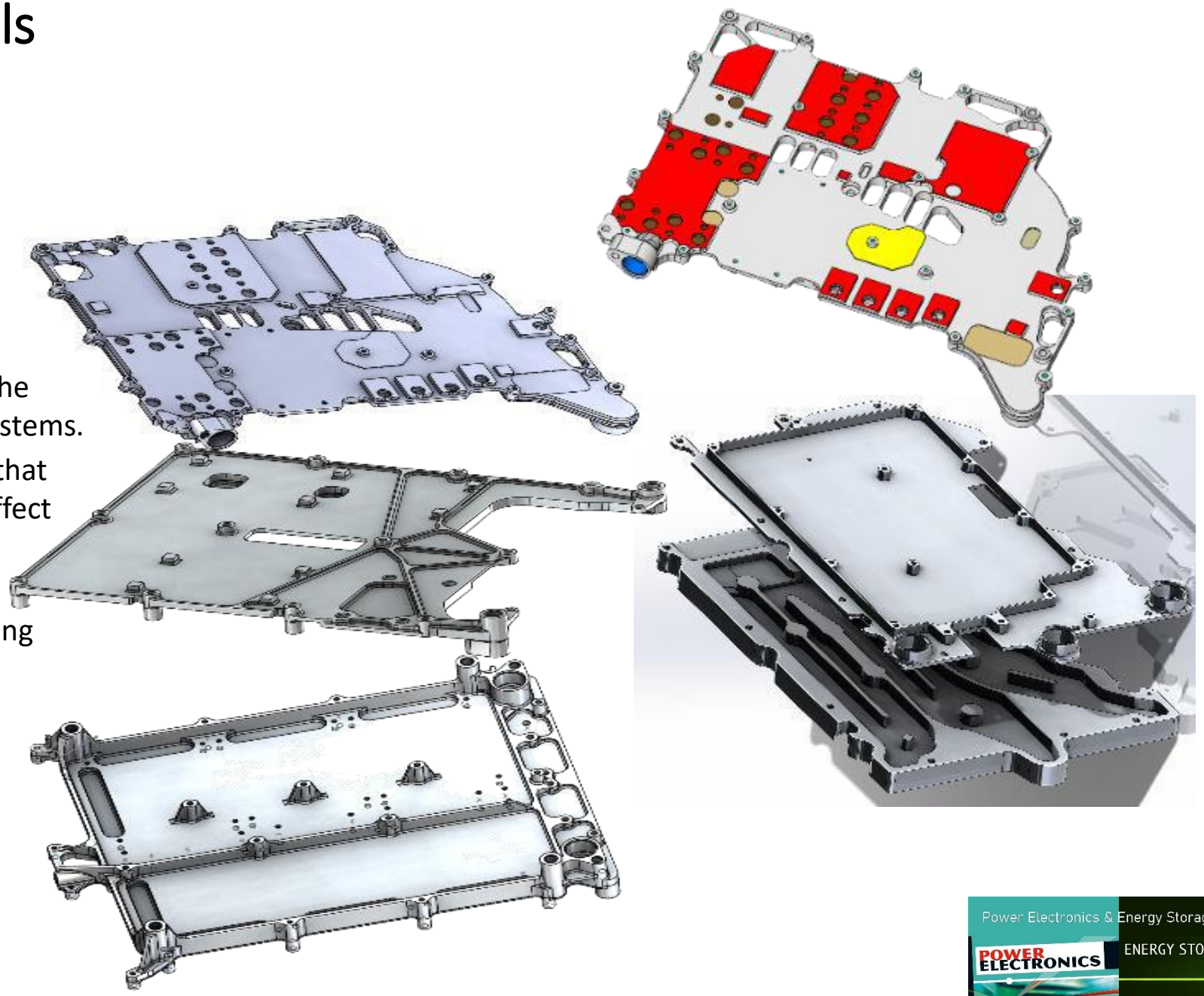


BOYD TRUSTED INNOVATION

Precisely Managing Thermals

High Performance Automotive

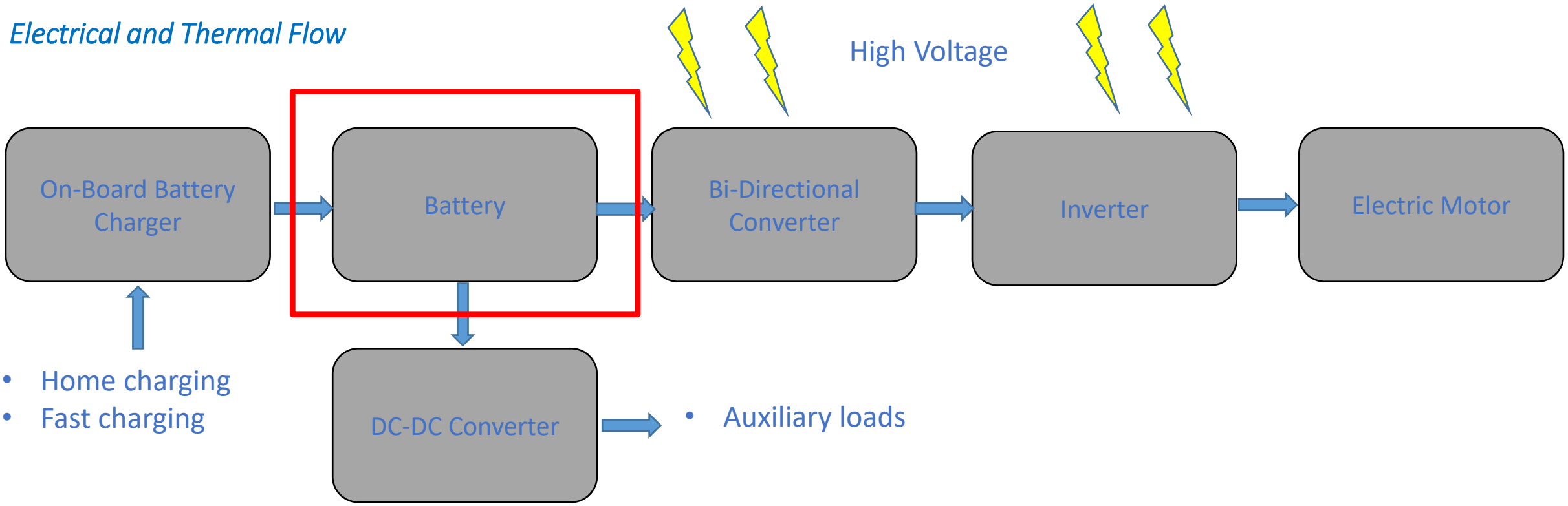
- High Performance Power Trains
- Battery Cooling
- Power Electronics/Inverter Cooling
- MPU/PSU Cooling
- Vacuum brazed liquid cold plates used in the cooling of energy recovery and storage systems.
- Designs may comprise several cold plates that are linked in series or parallel. This may affect testing/thermal analysis.
- Improvements and design modifications expected each year to improve for following season.



Technology

- Vacuum Brazed - Ultra Thin Cold Plates
- Weight, Reliability, Joint Integrity, Quality, Cleanliness & Aesthetics are Key Characteristics

Electric Traction & Drive System and Battery Assemblies - Battery



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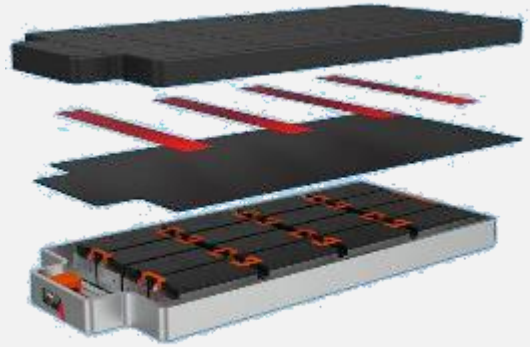
Battery Thermal Management

VEHICLE LEVEL

Thermal and Seal Cushioning barrier for battery pack

PACK LEVEL

Electrical insulation of battery pack

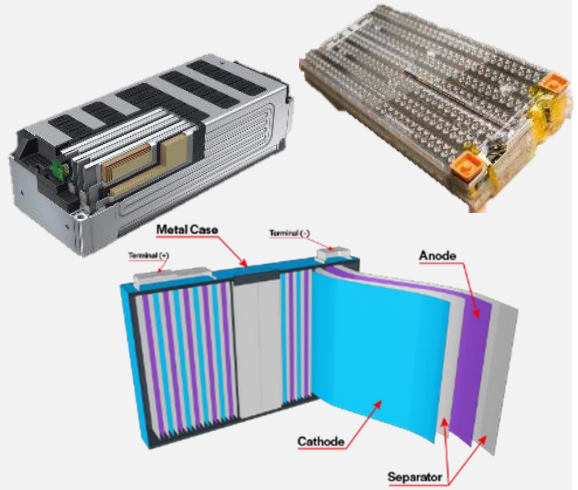


MODULE LEVEL

Thermal Runaway Barriers, Electrical Insulation of module

CELL LEVEL

Cell to cell insulation



Solutions

APPLICATIONS:

- Seals and Gaskets
- Electrical Insulation
- EMI Shielding
- Thermal Interface Materials

APPLICATIONS:

- Electrical Insulators
- Compression Pads
- Thermal Interface Materials
- Seals and Gaskets
- Liquid Cold Plates

APPLICATIONS:

- Thermal Runaway Materials
- Compression Pads
- Flexible Bushbar
- Seals and Gaskets
- Liquid Cold Plates

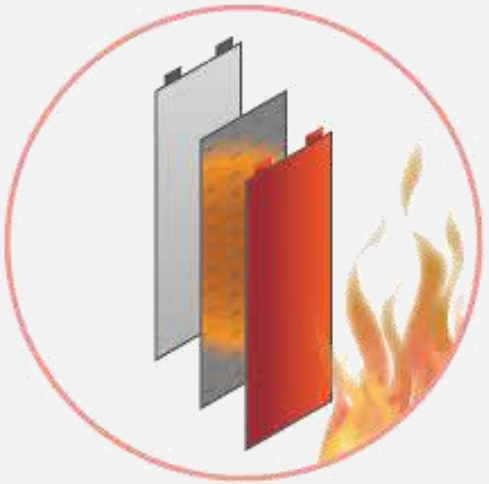
APPLICATIONS:

- Thermal Runaway Materials
- Cell to Cell Bonding
- Compression Pads
- Energy Absorbers

Battery Thermal Management

THERMAL INSULATION

Cell to cell thermal insulation

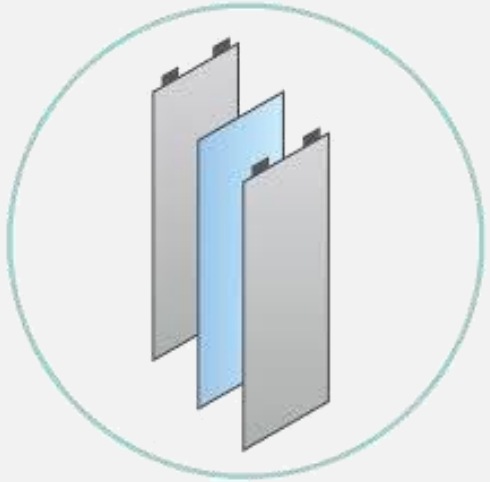


Requirement profile cell insulator

- T_{max}: 700 – 1200 °C
- Break through voltage resistance: ~2.4 kV

CUSHIONING

Cell to cell swelling force compensation

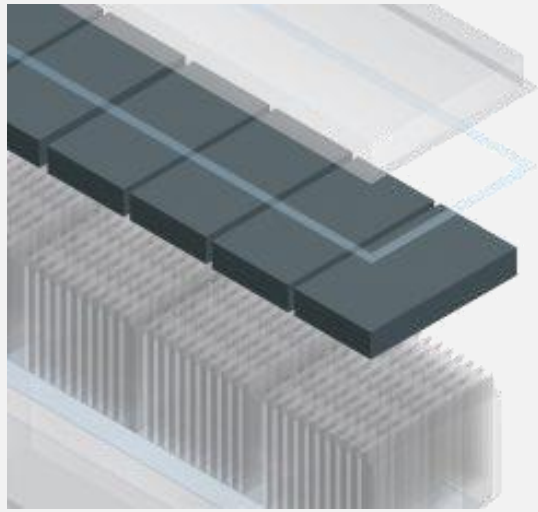


Requirement profile compressible insulator

- Compensation of specific swelling forces of up to 20 kN
- Flame retardancy: UL 94 V-0

HEAT SHIELD

Heat shield for battery module

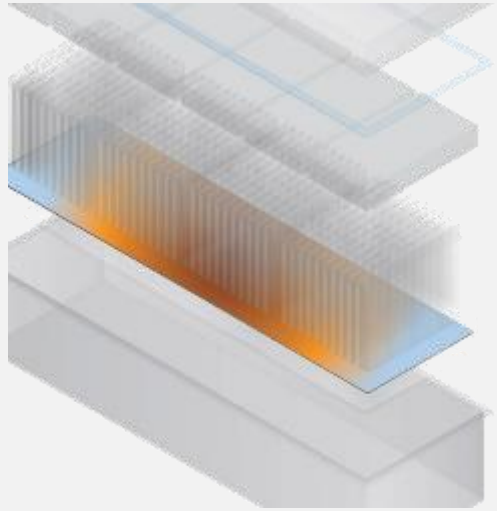


Requirement profile heat shield

- T_{max} : 900 – 1200 °C for 60 s
- Resistance against Hot gas particle loaded gas stream

HEAT TRANSFER

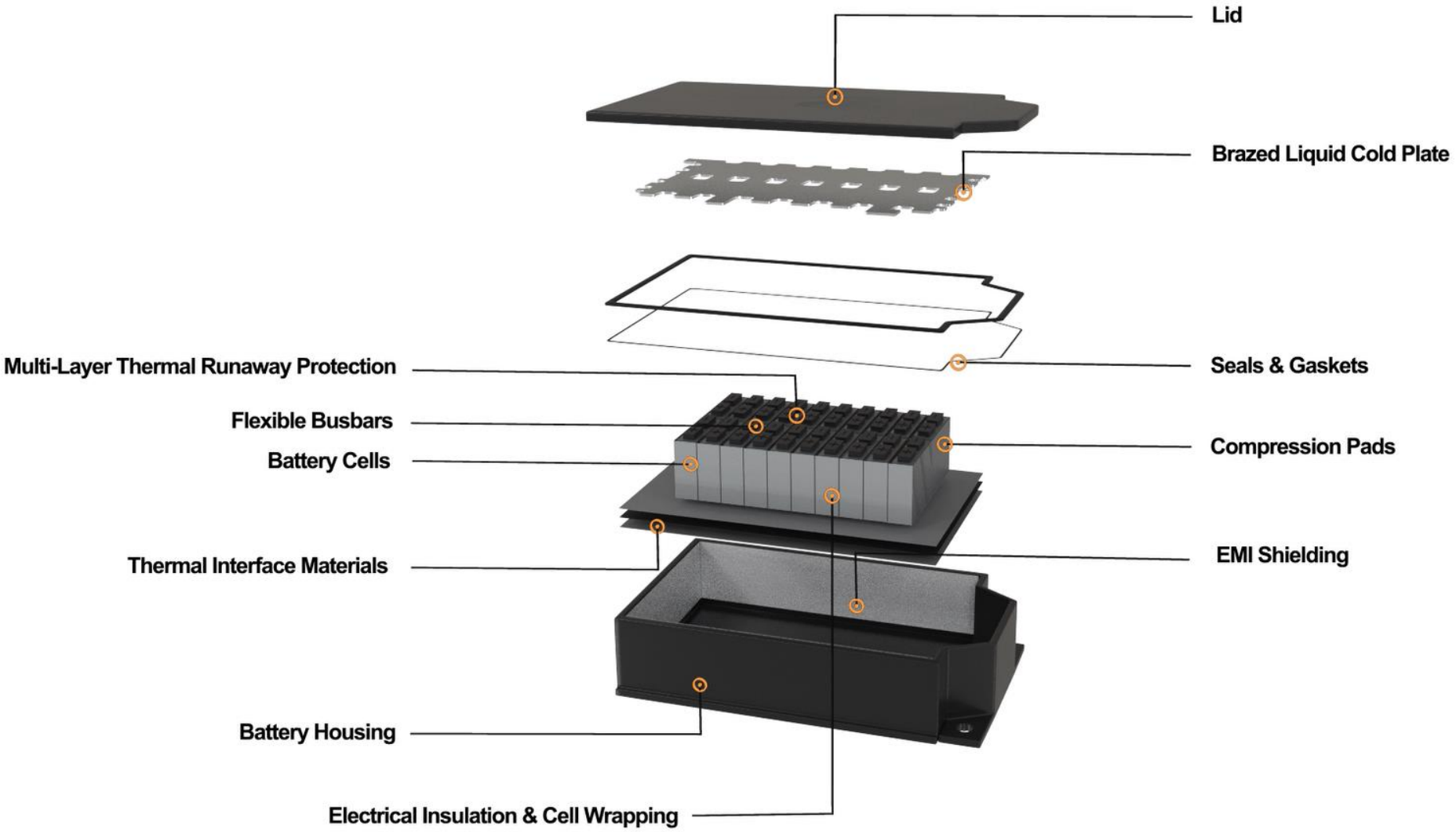
Cell to module thermal interface material



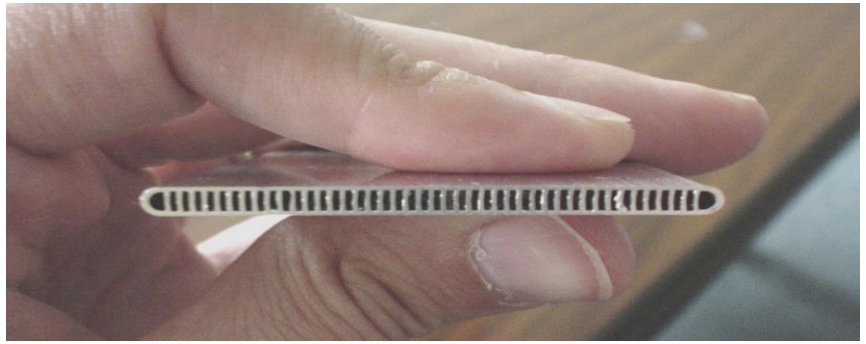
Requirement profile thermal interface material

- Thermal conductivity: >2 W/mK
- Flame retardancy: UL 94 V-0
- Compressibility

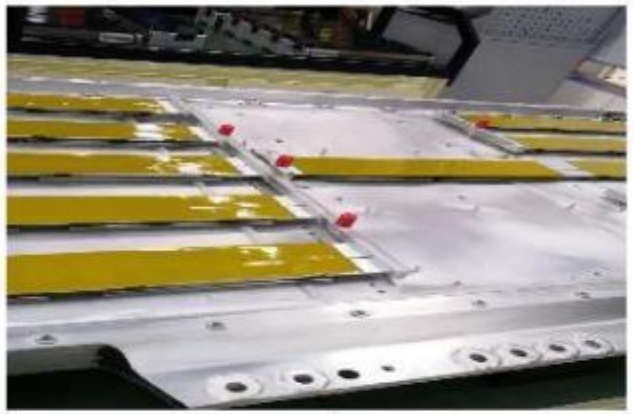
Battery Thermal Management

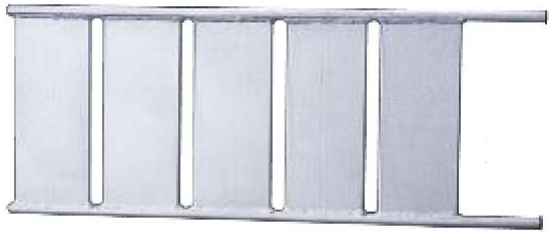


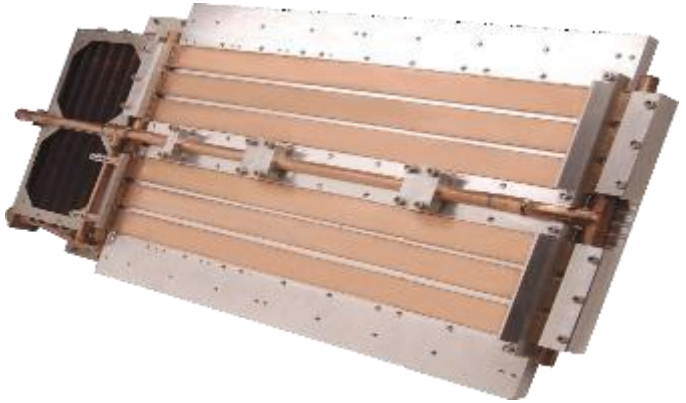
Flat Tube, Multi-Port Extrusion Cold Plates

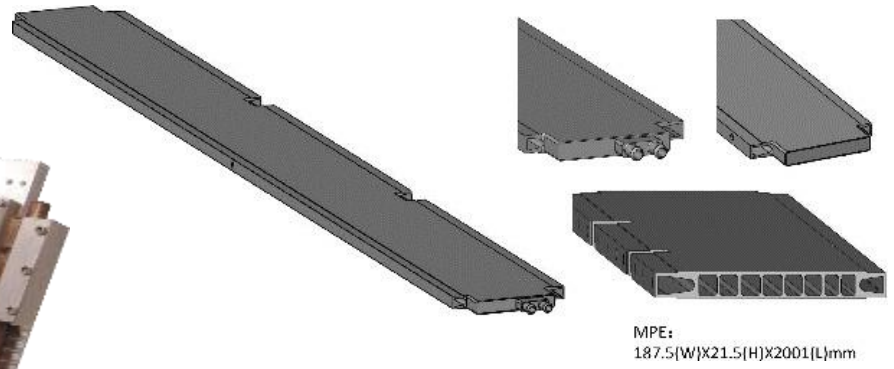


- Flat Tube MPE Cold Plates are a popular method for EV Battery Cooling globally with high volume production
- Very efficient & lightweight cold plate design with extremely low thermal resistance that allow large area cooling
- Multi-port extrusions can be joined using friction stir welding, flame brazing or furnace brazing
- Straight fin (Al) or rifled fin (Cu), Ladder Constructions & Curved Design
- Mounted on surface or brazed inside the middle
- Reference designs: Flat Tube Liquid Cold Plate









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