GREAT DESIGNS IN STEEL™

GDIS Technical Webinar Series:

Development of C-STAR™ and CCBE, the Cleveland-Cliffs Battery Enclosure

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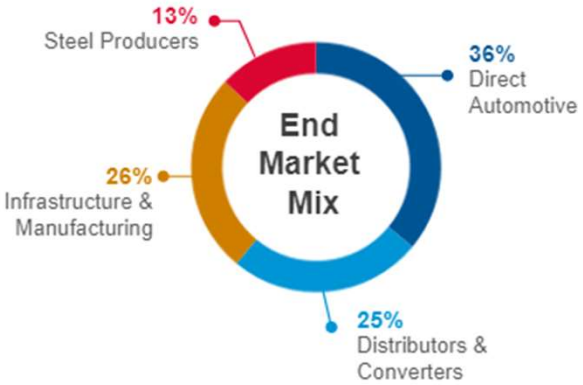
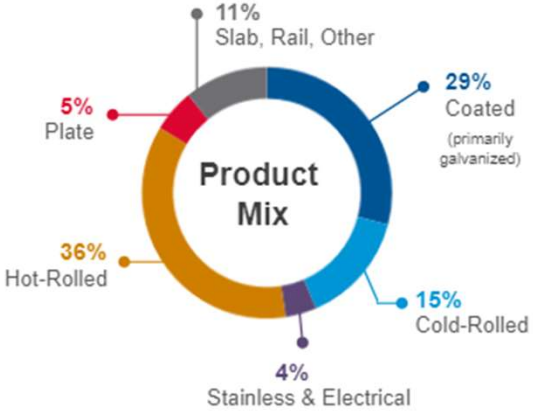
Advanced Engineering Corporate Manager

Cleveland-Cliffs

October 15, 2024

END MARKET AND PRODUCT OVERVIEW





Extensive Product Offering

- Advanced High-strength Steels
- Aluminized
- Cold-rolled Coil
- Electrogalvanized
- Galvalume
- Galvanneal
- Grain Oriented Electrical Steels
- Hot-dipped Galvanized
- Hot-rolled Coil
- Non-oriented Electrical Steels
- Plate
- Rail
- Slabs
- Stainless Exhaust
- Stainless Steel
- Stamped Components
- Tool & Die
- Tubing

Note: Based on Full-Year 2023 – Product Mix includes steel products shipments

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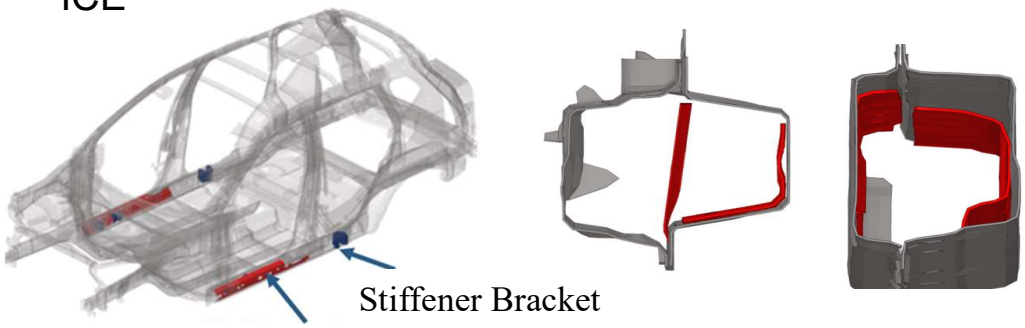
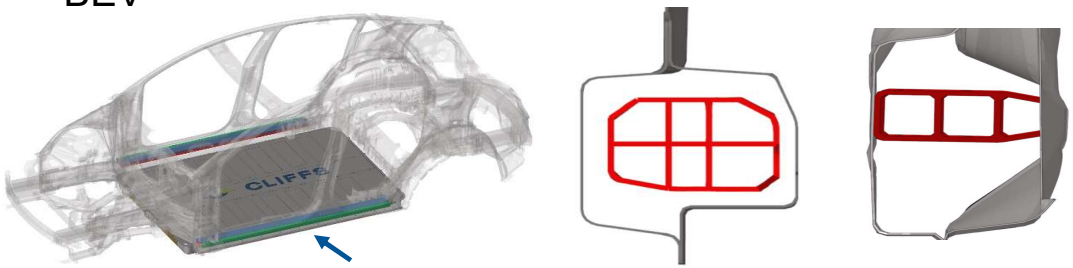
Cleveland-Cliffs Steel Tube As Reinforcement (C-STAR™)

BACKGROUND

ICE



BEV



- Battery electric vehicles (BEVs) are roughly 20% heavier than similar size internal combustion engine (ICE) vehicles.
- One of the major challenges is crash management to protect the battery enclosure under severe side impact load.
- Compared with ICE, more material is distributed at both longitudinal and lateral directions in BEVs' rocker area for energy absorption and intrusion protection.

Side Impact. Source NHTSA

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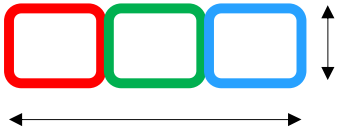
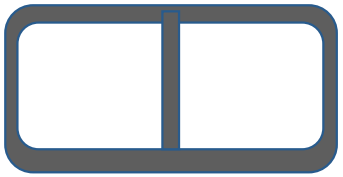
C-STAR™ DETAILS, TUBULAR COMPONENTS

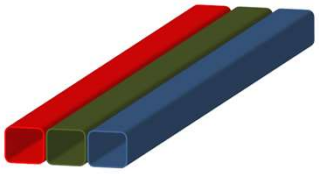
- Long, uniform, hollow design space is ideal for tube design.
- Chamber shapes are effective for energy absorption and light-weighting.
- C-STAR™ is a versatile, scalable solution for structure reinforcement.
- C-STAR™ is developed that matches aluminum baseline design in width: 3 tubes, 1.8mm ULTRALUME® 1500.

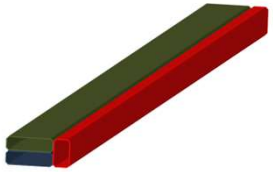


C-STAR™ Design #1



Aluminum Insert



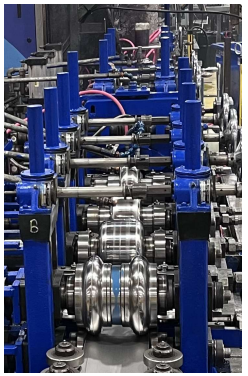


C-STAR™ Design #2

Cleveland-Cliffs Tubular Components

- Leader in AHSS Tubular solutions
- Makers of FORMTUBE®
- Widest product mix in ERW market
  - Carbon and stainless grades
  - Mild Steel through Gen 3 AHSS
  - GI, GA, EG, Aluminized, uncoated

- Un-matched ERW dimensional capability
  - 0.8 mm ~ 3.5 mm thickness
  - 19 mm ~ 168 mm diameter
  - 100:1 D/t capability
  - Twist : 2° tolerance over 2m length
  - Straightness: 2 mm tolerance over 2m



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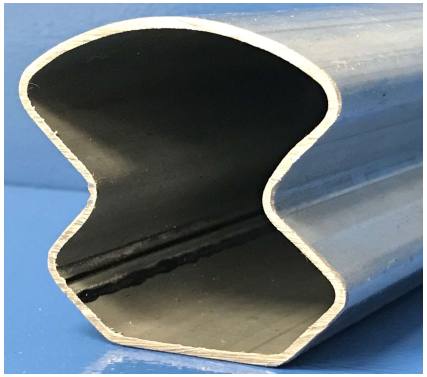
CUSTOMIZED TUBES AND C-STAR™ MANUFACTURING

ULTRALUME® 1500
35:1 D/t ratio, 1.6mm

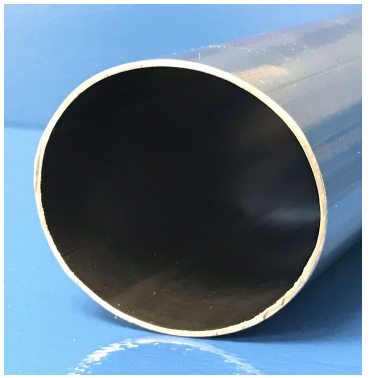
ULTRALUME® 1500
24:1 D/t ratio, 3mm

DP 980
65:1 D/t ratio, 1.0mm



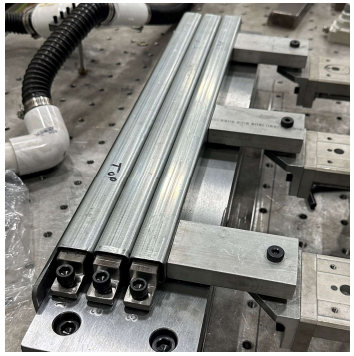
DP 980
100:1 D/t, 1.0mm

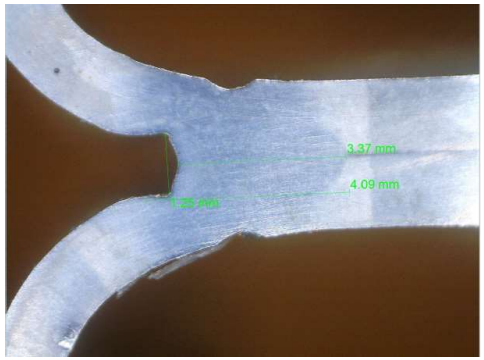
NITRONIC 30 1200
50:1 D/t ratio, 0.8mm



Manufacturing

- Tubes are connected by laser weld by TWB.
- Quality of weld has been checked by Macroetch Test: >3 x thickness penetration.
- Weld strength passes rupture test.





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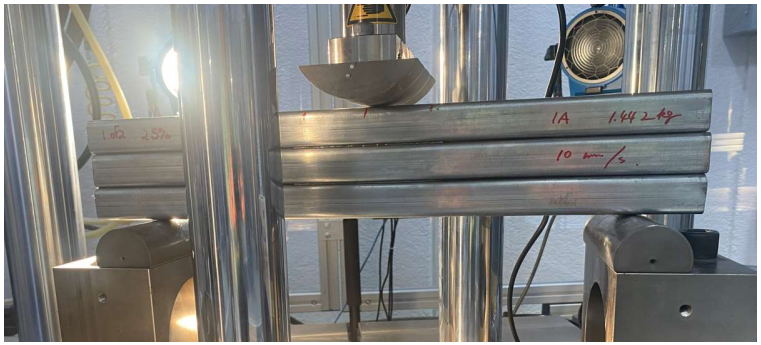
C-STAR™ IMPACT PERFORMANCE

- Three-point bending is conducted to assess the performance.
- The anvil is speed controlled.
- Force-displacement data is collected.
- Both peak force and energy absorption are evaluated.



Zwick Roell HTM 16020

- 0.001~20m/s loading rate
- 160kN nominal force
- Tensile, axial crush, three-point bending capability
- 300mm effective piston stroke

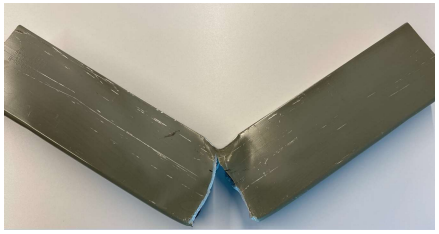
C-STAR™ VS ALUMINUM INSERT TEST

C-STAR™

- 1.8mm, PHS1500, 2.2kg
- Peak force: 143kN

Aluminum insert

- 4.6mm 6000 series, 2.0kg
- Peak force: 107kN



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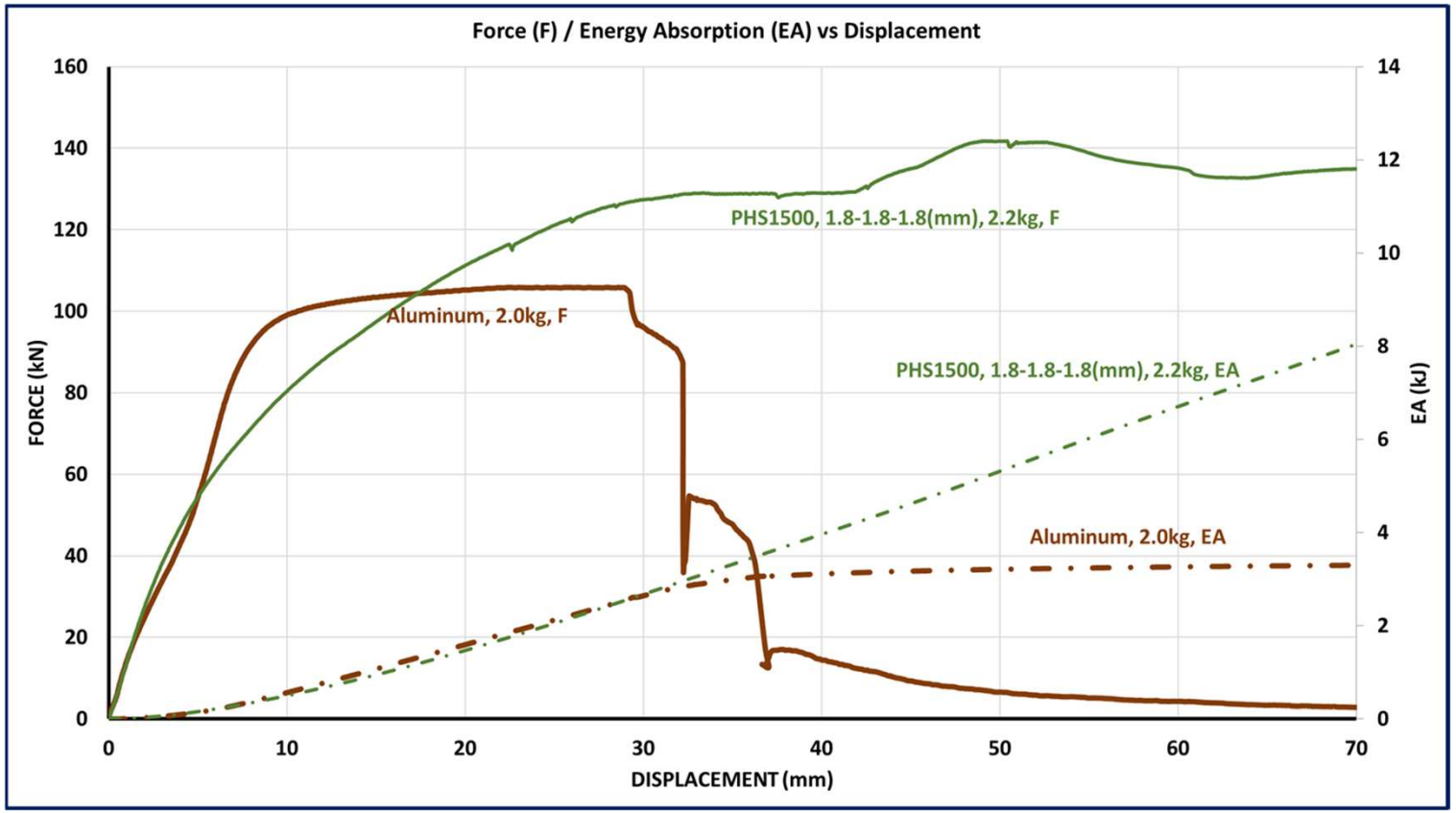
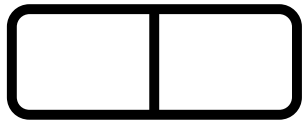
C-STAR™ ADVANTAGES: 3-POINT BENDING TEST RESULTS COMPARISON



Aluminum insert



C-STAR™

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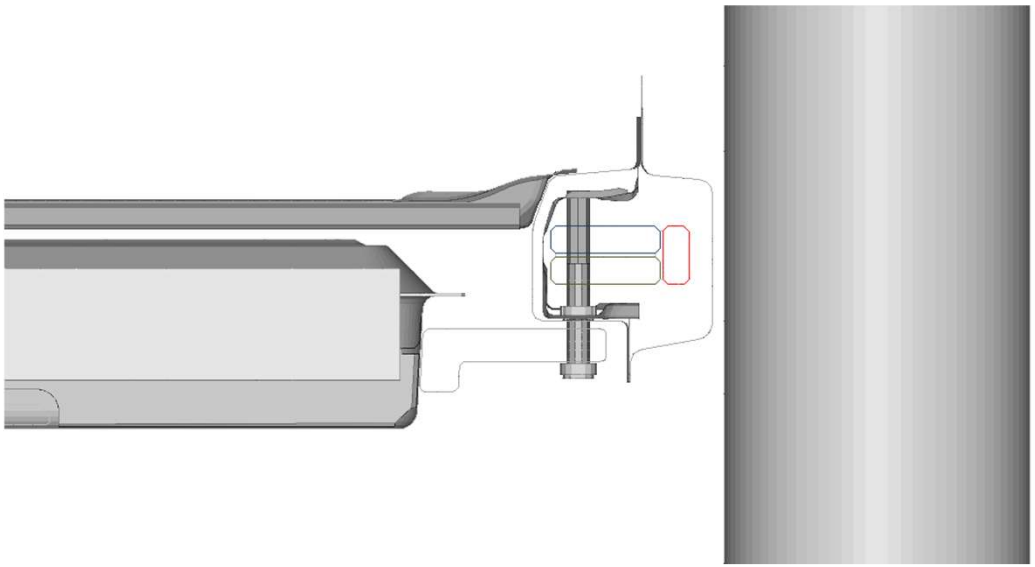
SUB-SYSTEM AND FULL VEHICLE CAE



- Peak force during crash event.
- Energy absorption of the rocker structure.
- Energy of battery structure members.
- Intrusion / deformation of the rocker space.
- Combined with CCBE, C-STAR™ provides superior protection for battery.

Cleveland-Cliffs Battery Enclosure (CCBE)

INTRODUCTION: CCBE

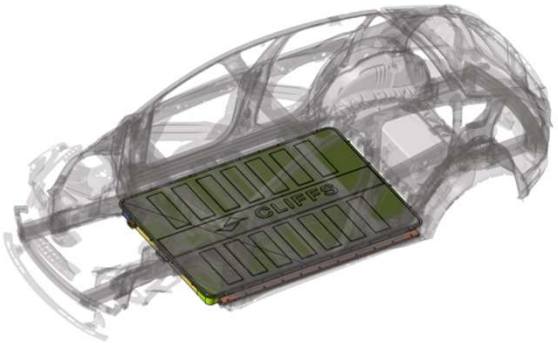
- Electrification is the future of the automotive industry. Battery enclosure, as a power supply unit, is one of the most important components in battery electric vehicles.

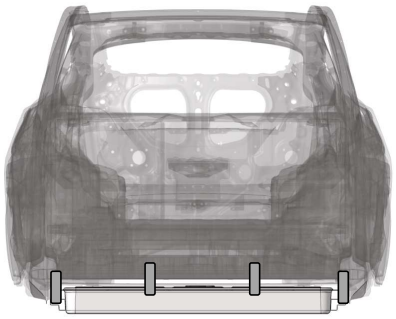
- CCBE is a steel intensive battery enclosure, with an efficient design for minimum cost and weight, while meeting performance targets. It is designed for cross utility vehicle but can be scaled to fit any unibody architecture.

- 8 battery modules are bolted to the cross members, with 104 4680-type batteries in each.

- CCBE is connected to BIW through two side rails as well as bolt connections in the middle of battery pack.

L*W*H: 2132mm*1497mm*157mm
80 kWh





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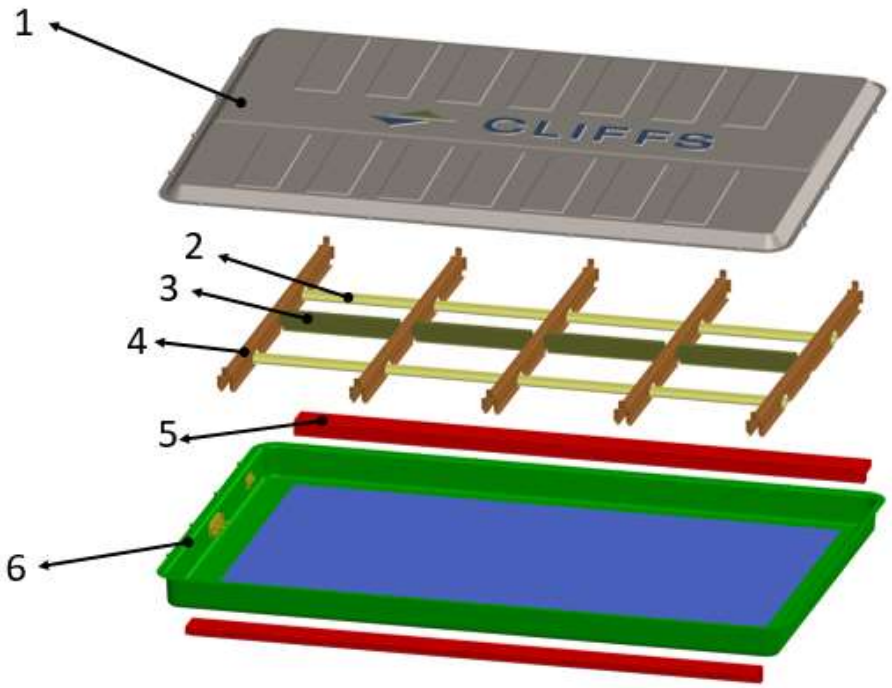
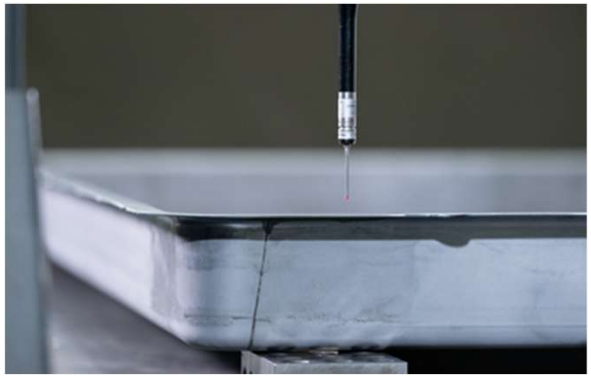
DESIGN DETAILS



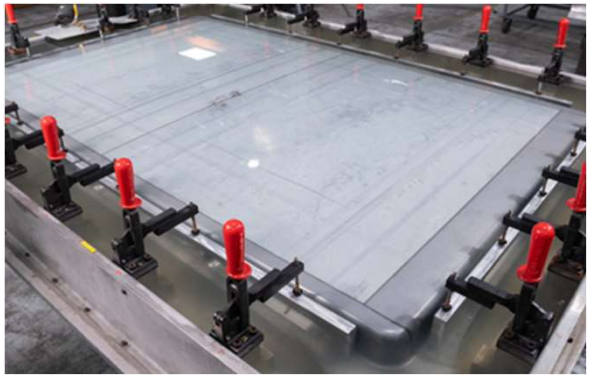
	Component	Grade	Gauge (mm)
1	Top cover	Mild Steel	0.8
2	Longitudinal stiffeners	ULTRALUME® 1500	1.2
3	Longitudinal members	MP980	1.0
4	Cross members	M1500	1.2
5	External side crash protection / attachment rails	ULTRALUME® 1500	2.0
6	LWB battery tray	M1500 / Mild Steel	2.0 / 2.0

DESIGN VALIDATIONS

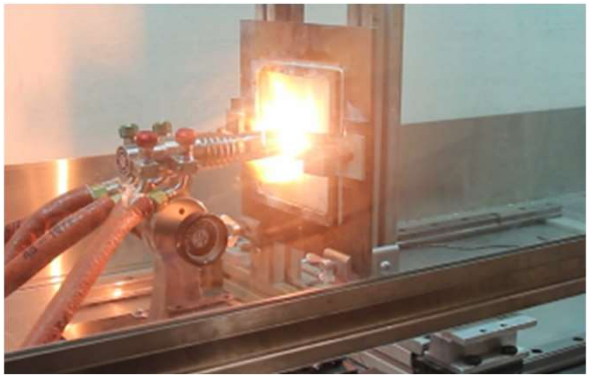
Stamping and CMM



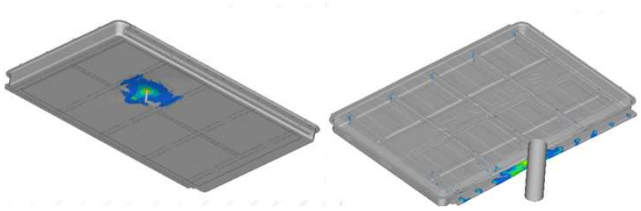
Leak Test



Thermal Runaway

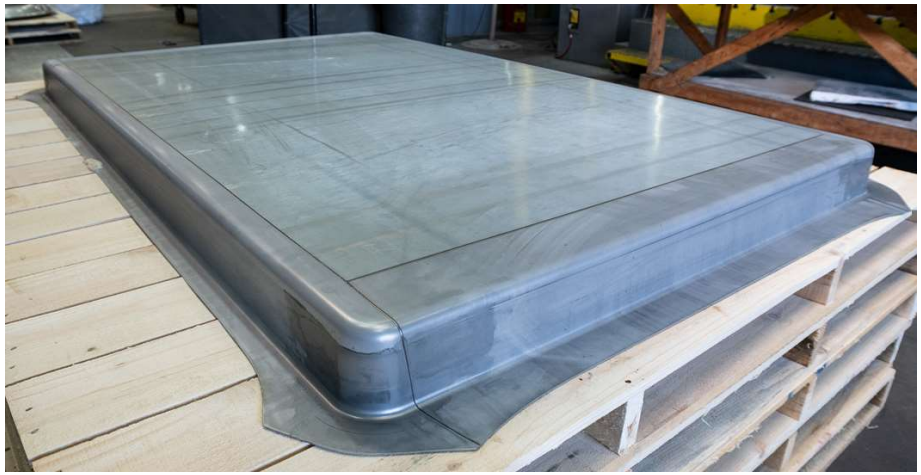


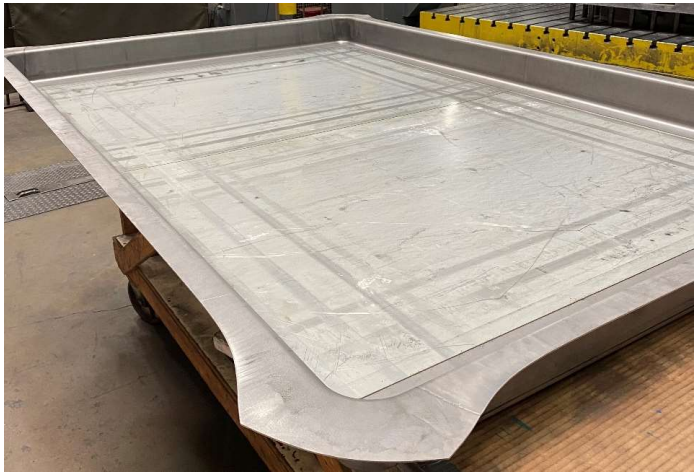
Underfloor and Side Pole Impact Simulations



	Judgment
Side Pole	✓
Underfloor Intrusion	✓
Stamping	✓
Flange Flatness	✓
Leak Test	✓
Thermal Runaway	✓

TRAY STAMPING



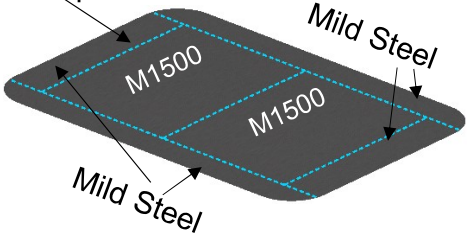


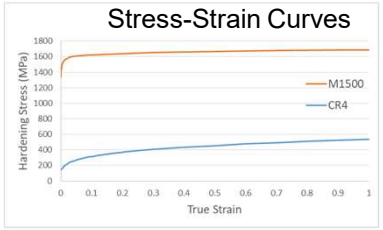
- The laser welded tray is successfully stamped
- Judgment: OK ✓

DESIGN MANUFACTURABILITY OF CCBE TRAY USING FEA SIMULATION AND PROTOTYPE BUILD

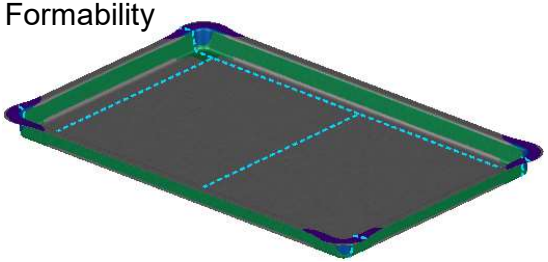
Stamping FEA Simulation

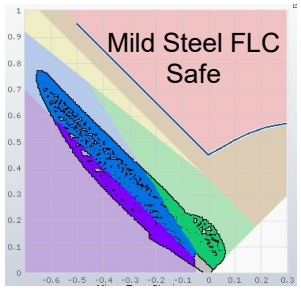
#-Shaped 2.0mm LWB



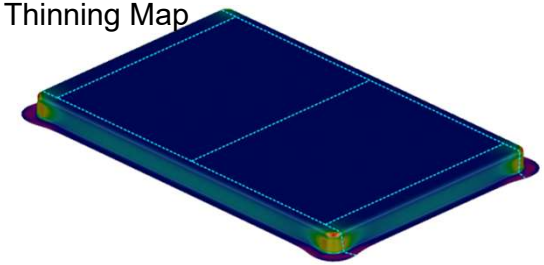


Formability



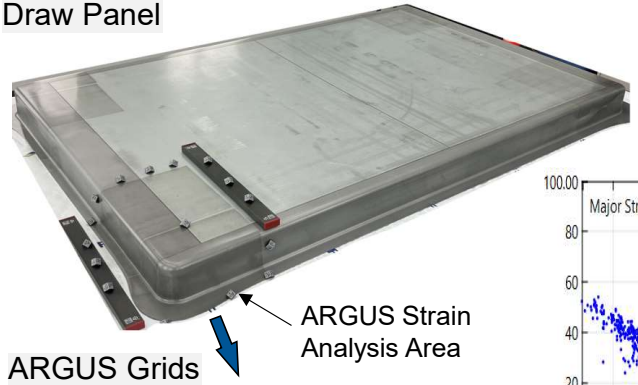


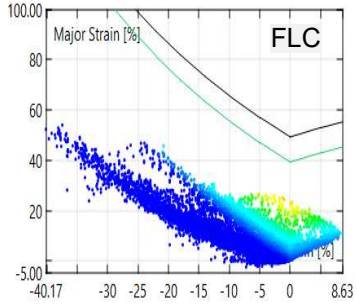
Thinning Map



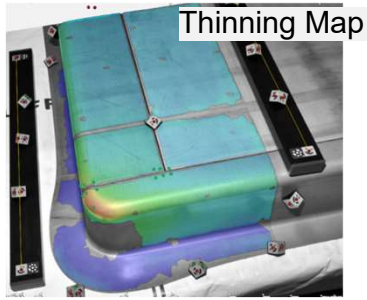
Prototype Panel

Draw Panel





ARGUS Grids



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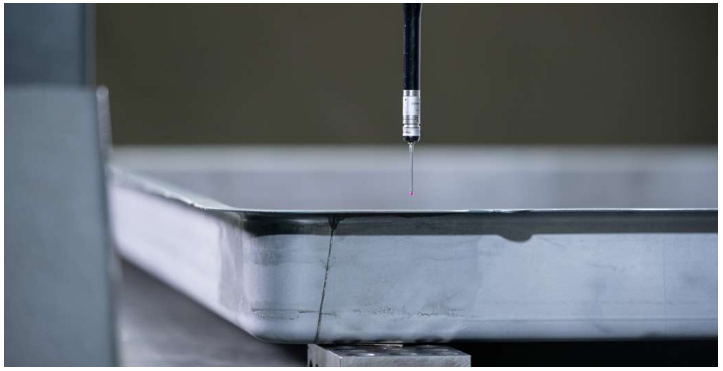
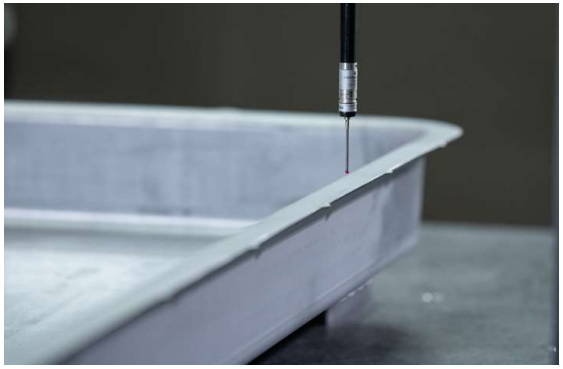
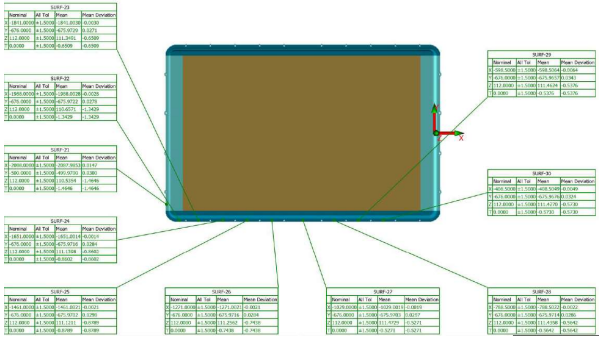
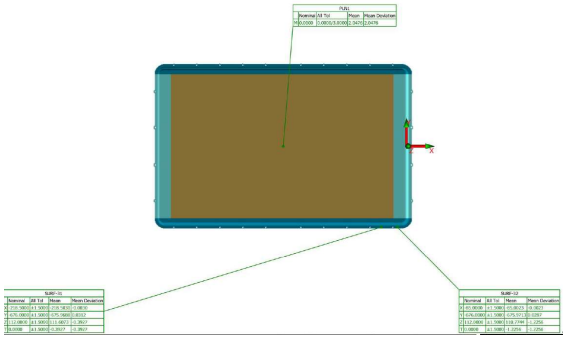
CMM FOR PROTOTYPE TRAY









- The flange achieves +/- 1.5mm flatness tolerance
- Judgment: OK

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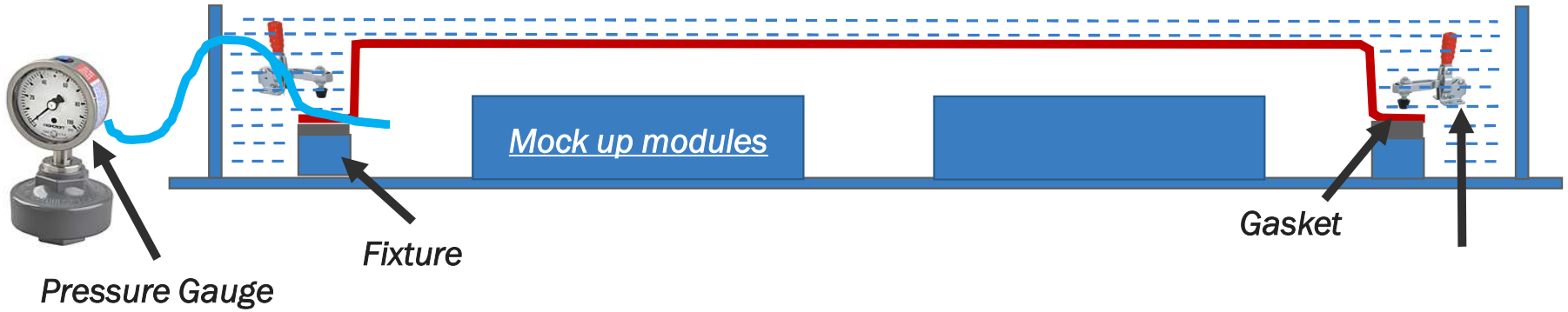
LEAK TEST SETUP



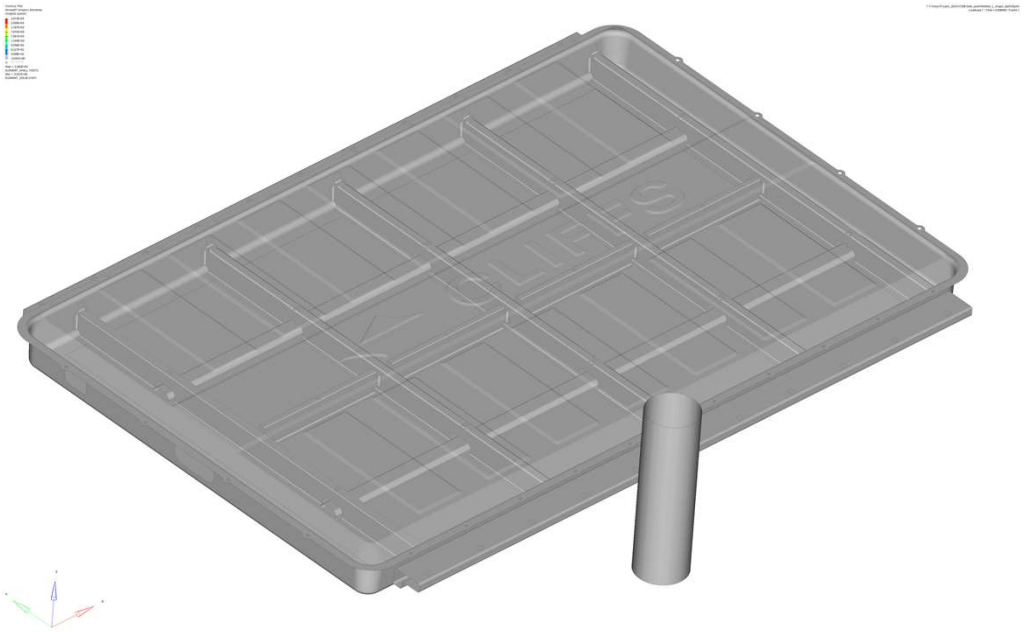
- The tray is placed in test tank upside down and clamped on the fixture.
- Tank is filled with water to submerge the tray.
- Tray is pressurized internally to 0.5 psi.

LEAK TEST FOR PROTOTYPE TRAY

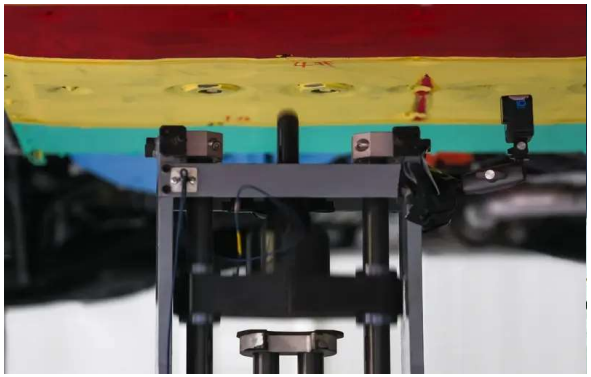
- Requirement: Leaking rate less than 15 Standard Cubic Centimeters per Minute (SCCM) in 15 minutes.
- The tray passes the test.
- Judgment: OK

SIDE POLE IMPACT CAE

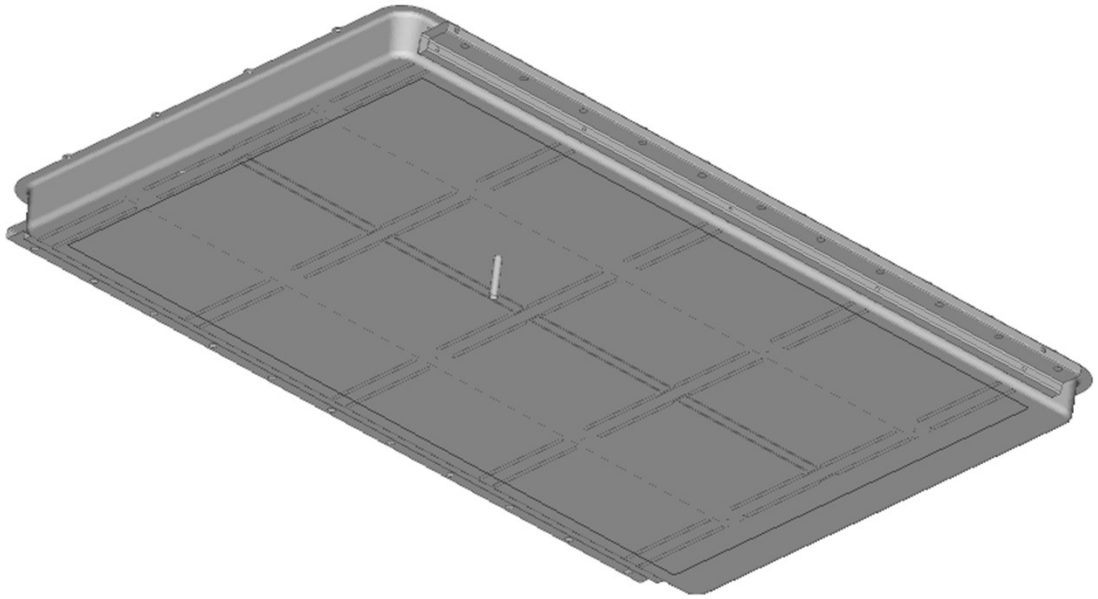
- Analysis object: Battery enclosure component
- Method: Enclosure is impacted by a 150mm pole from side, no contact with battery module before 100kN
- Judgment: OK



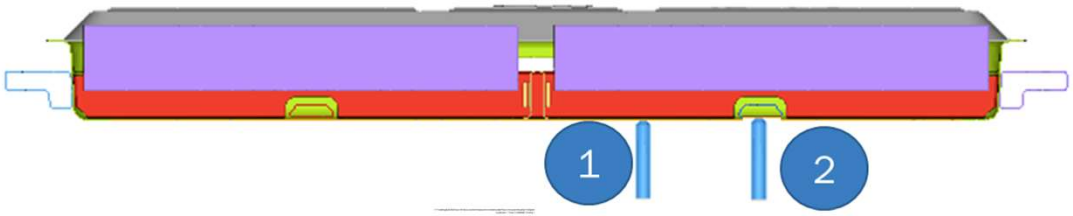
UNDERFLOOR IMPACT CAE

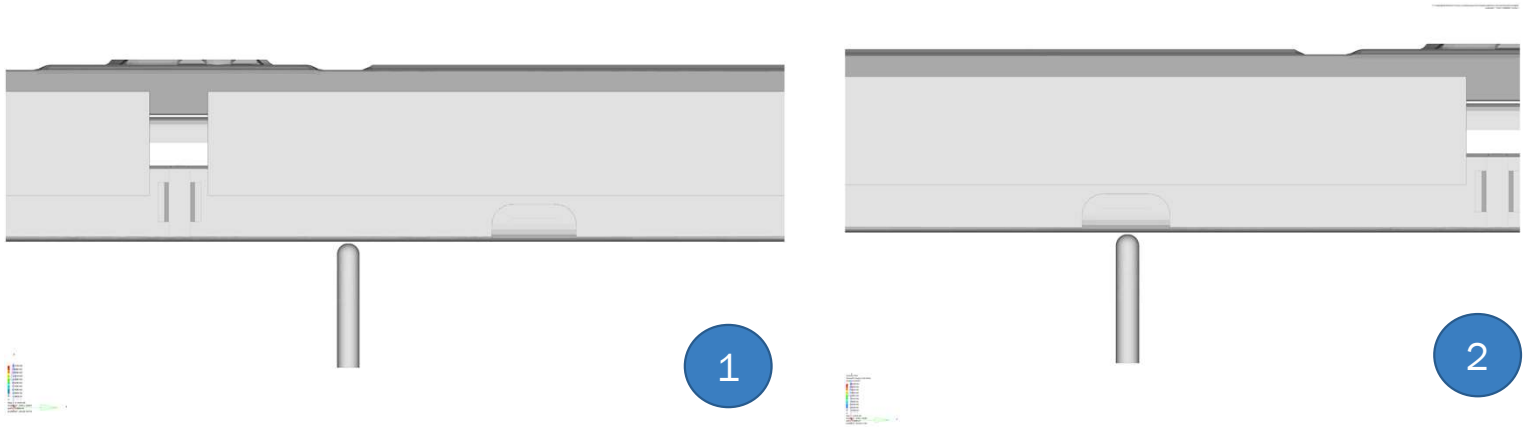


- Analysis object: Battery enclosure component
- Method: Enclosure is impacted by a 20mm diameter pole from bottom, no contact with battery module before 35kN



UNDERFLOOR CAE





- No contact to battery module while reaching 35kN for both locations
- Judgment: OK

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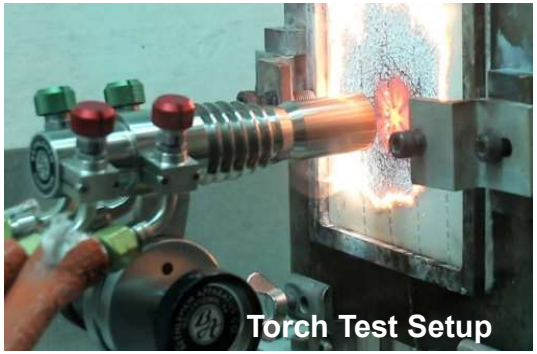
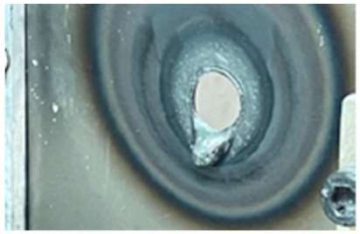
THERMAL RUNAWAY - TORCH TEST BENCHMARK STUDY AT 1500 °C



- Current solutions
  - Steel (0.8mm) with Mica (1.5mm)
    - Burn through less than 70 seconds.
  - Aluminum
    - 2.5mm, burn through less than 1.0 min.
    - 6.0mm, burn through less than 5.0 min.



- Our solution
  - Steel with Protexx-Shield 7040
    - No burn through for 15 min.
    - Backplate temperature is 295 °C at 15 min test.

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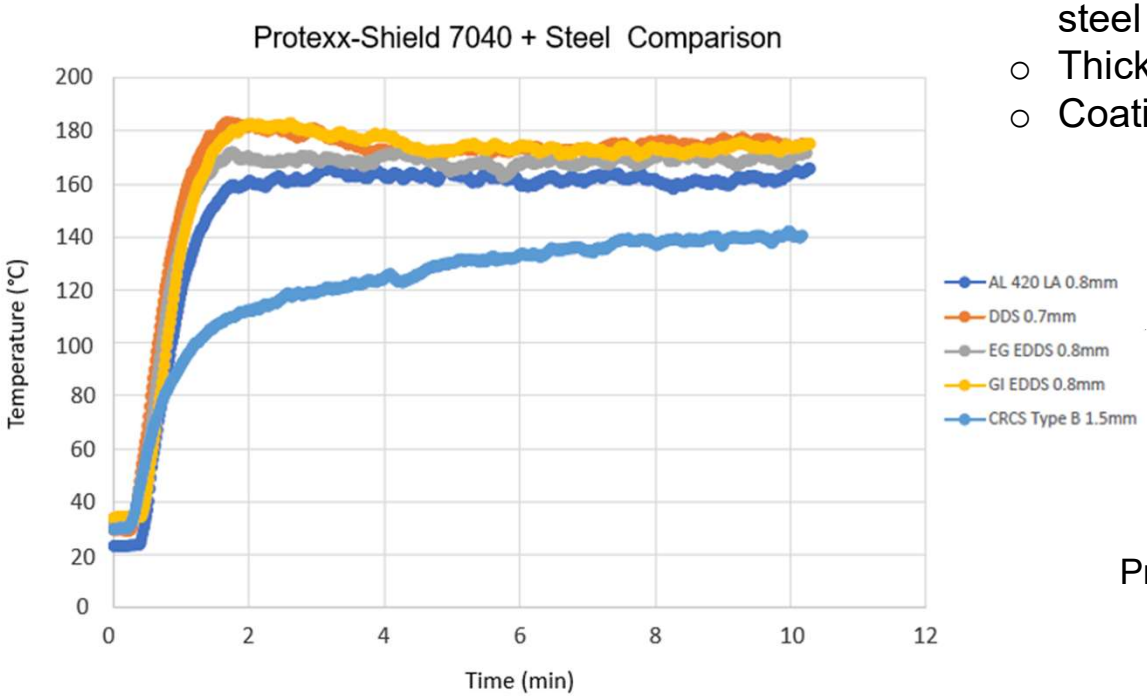
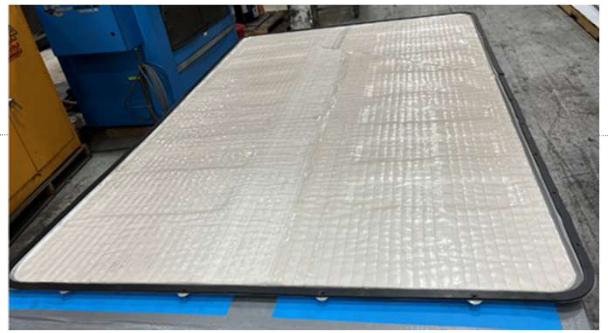
THERMAL RUNAWAY - TORCH TEST USING CLIFFS STEEL + TENNECO PROTEXX-SHIELD 7040 AT 1000 °C



- Torch test results at 1000 °C for 10 minutes
  - Backplate temperature under 185°C for all steel sheet.
  - Thicker gauge performs better.
  - Coating effect is not significant.



Protexx-Shield 7040 Applied to CCBE top cover

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SUMMARY

- Summary
  - C-STAR™ is a highly configurable and scalable product that provides superior protection for battery and occupants with advantages of cost efficiency and ease of manufacturing.
  - CCBE is a sustainable and robust steel solution that utilizes an innovative one-piece bottom tray stamped with laser-welded blank that passes flange flatness dimensional requirements and leakage test.

- Current joint developments
  - Working with multiple OEMs and Tier 1 customers to develop C-STAR™ and CCBE designs that fit their design space and meet their performance, mass and cost targets.
  - These projects are at various stages of prototype build, full-vehicle validation, and ready for commercialization.

Q & A:
Please use the Q & A feature to ask your questions

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