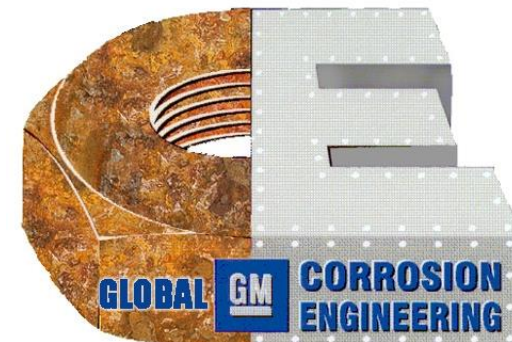


Corrosion Protection of High Voltage Battery Enclosures

SWRI Corrosion Symposium

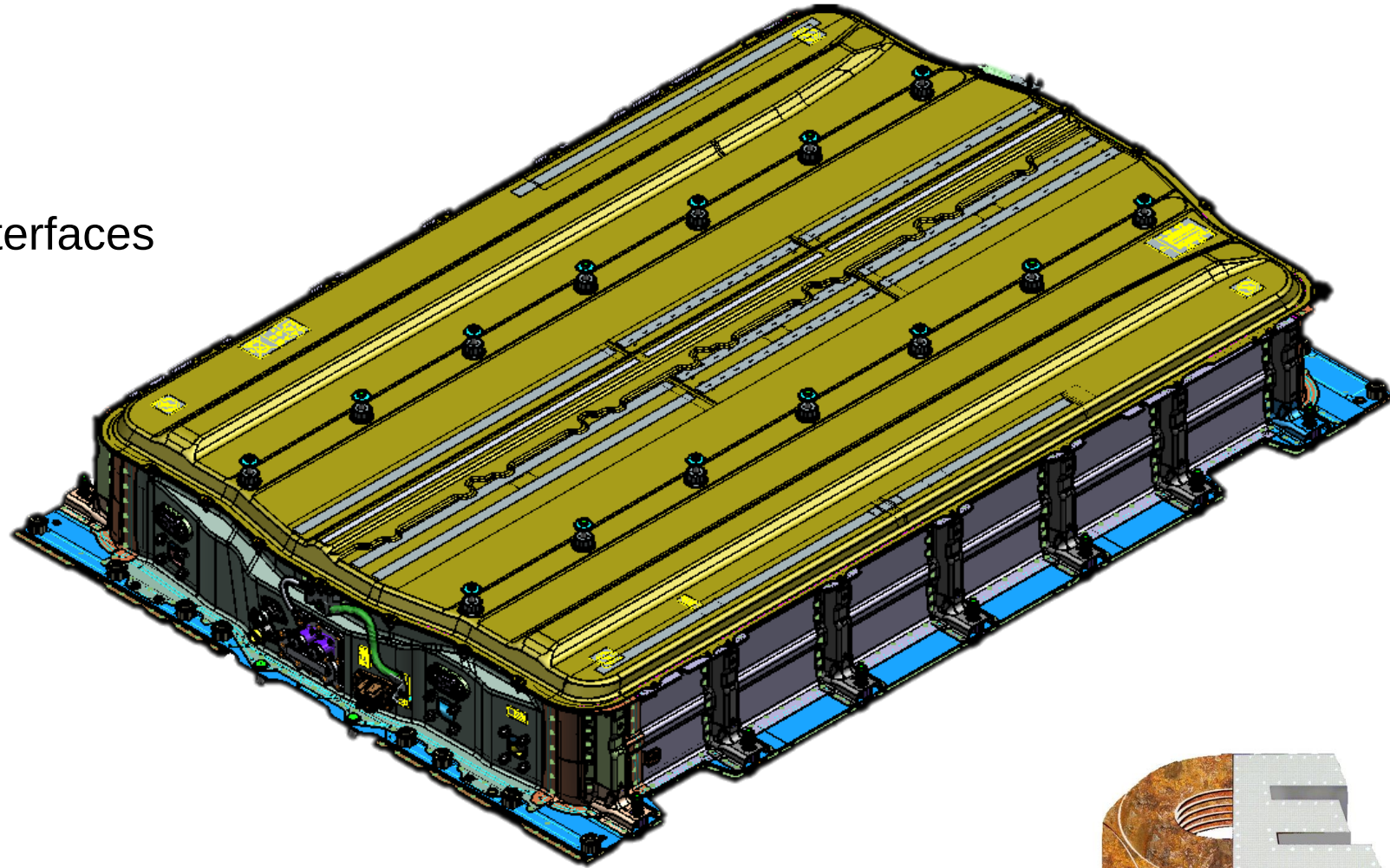


Eric Romanowski



Outline

- Unique Design Considerations
- Material & Coating Strategy
- E-Coat Application
- Joint Design & Enclosure Sealing Interfaces
- Component Sealing Interfaces
- Summary

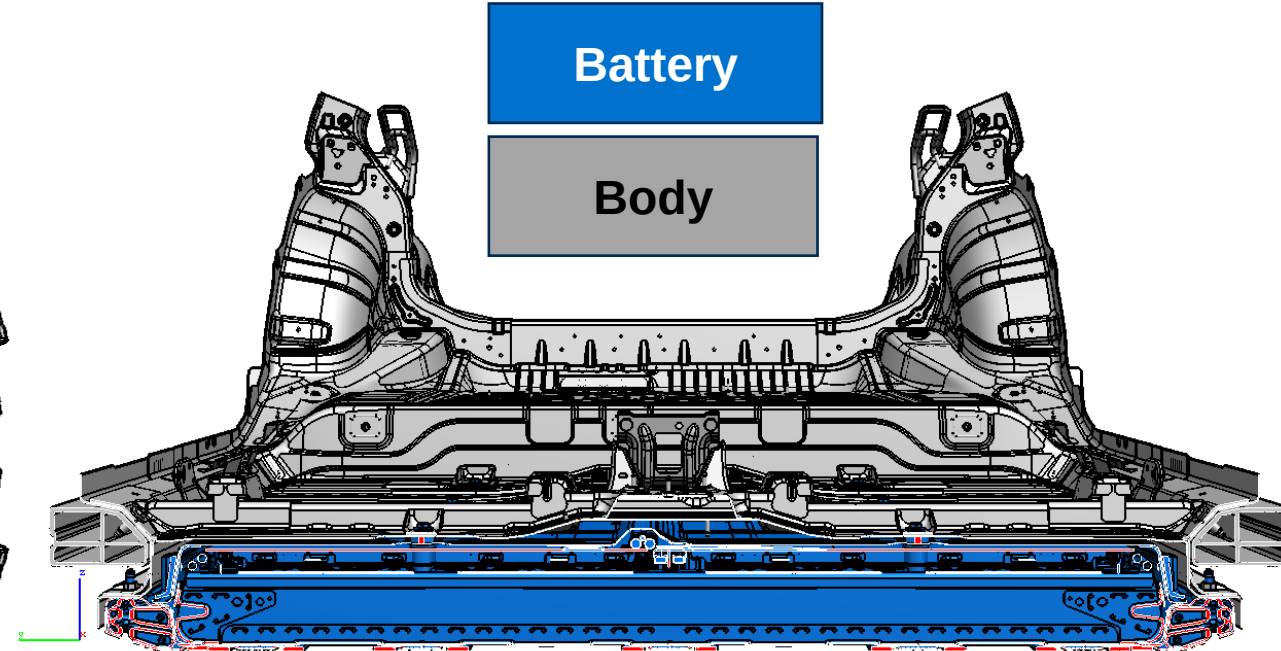
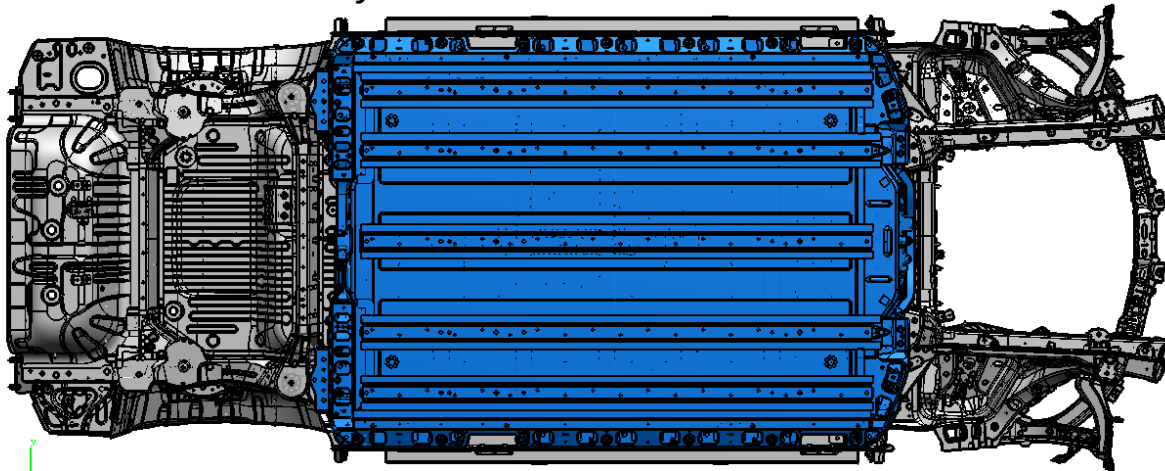


Unique Design Considerations



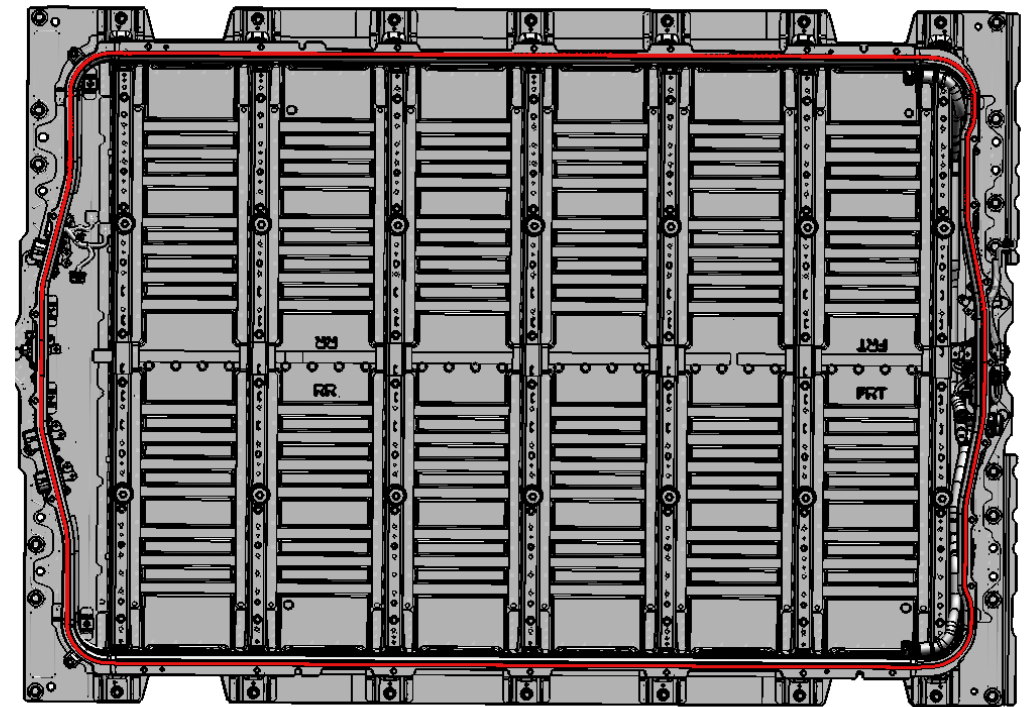
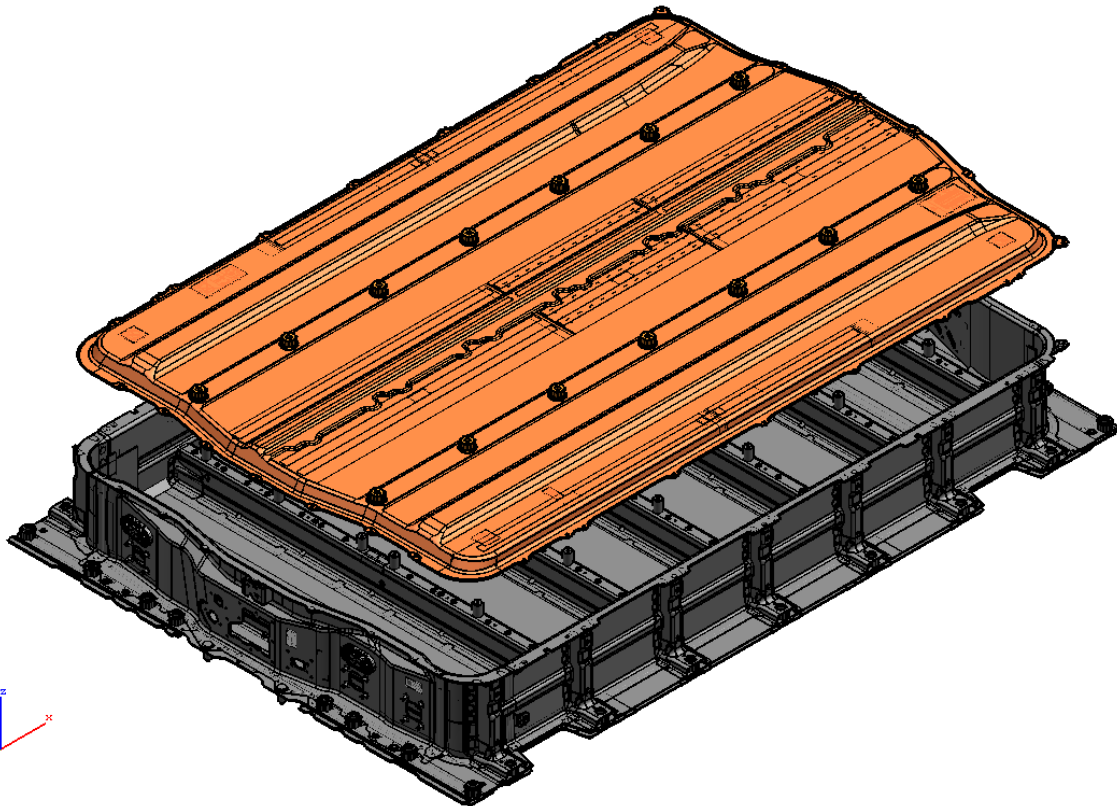
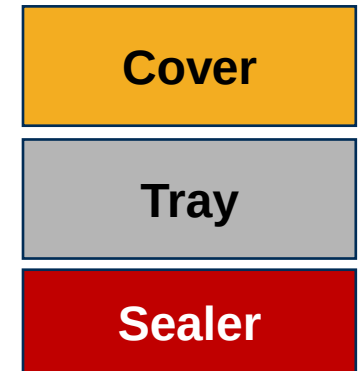
Unique Design Considerations

- Important design considerations when designing a High Voltage Battery Enclosure
 - General assembly will install the high voltage battery
 - Must meet modal, noise, and vibration performance requirements
 - Must withstand durability inputs
 - Requires protection and load pathing for crash performance
 - Requires large packaging space to maximize vehicle range
- Corrosion specific design concerns:
 - Battery is placed in aggressive vehicle corrosion environment & stone chipping
 - Enclosure must seal from water intrusion
 - Perforations of the enclosure must be prevented
 - Sealing interfaces must remain intact
 - Thermal Runaway Prevention must be considered



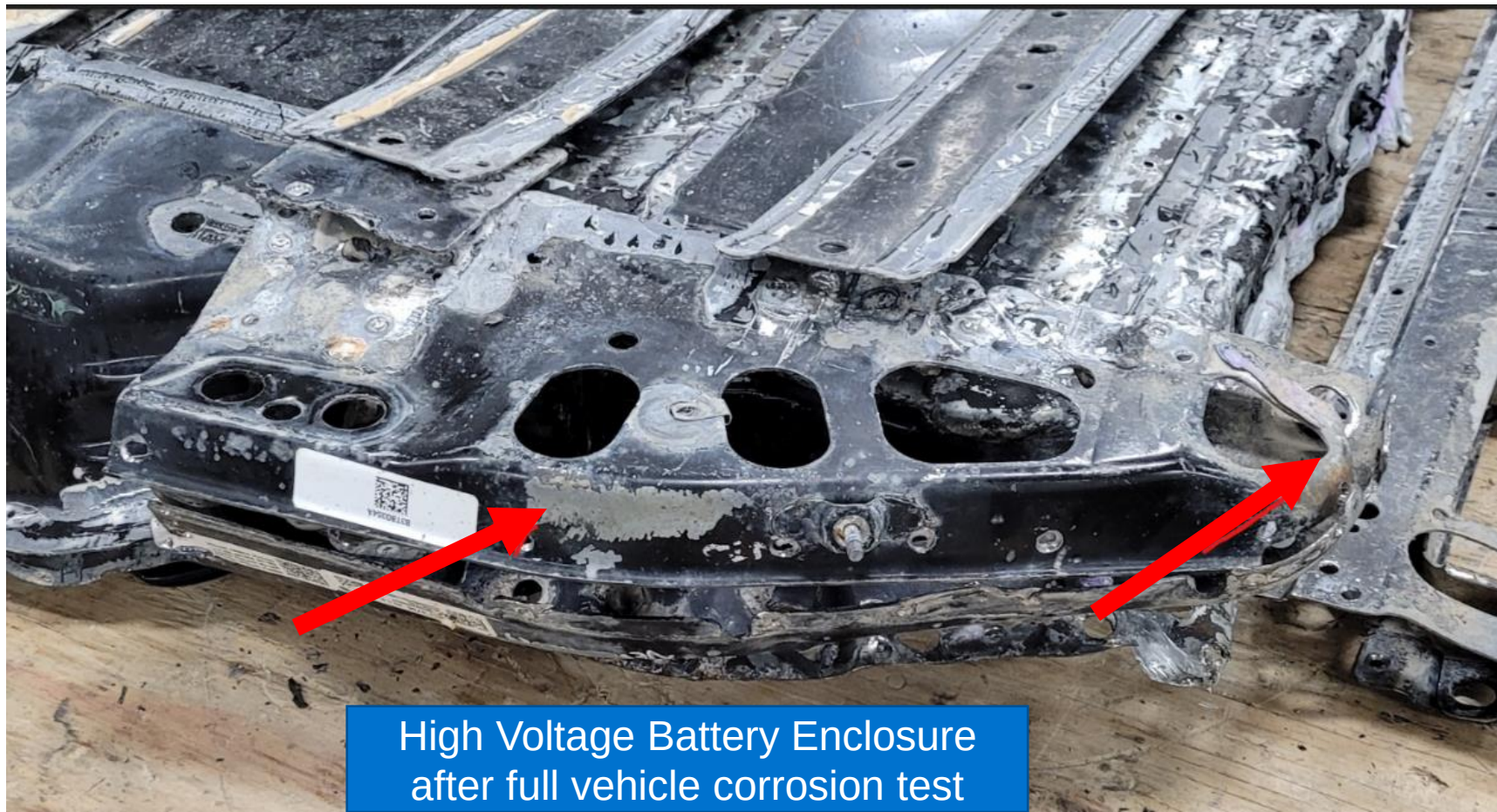
Unique Design Considerations - Wet & Dry Zones

- Two subassemblies are joined together to form the enclosure: the tray and the cover
 - Tray contains most structural elements
 - Cover serves as a closeout piece
 - Sealer bead joins the cover & tray
- Enclosure sealing is similar to body sealing – keep the inside dry



Unique Design Considerations - Stone Chipping

- Stones thrown from the tires can result in cosmetic damage and/or functional damage if this failure mode is not comprehended early.
- The image shows the affect of stone chipping on battery enclosures
 - Issue was identified and analyzed to be a cosmetic issue – Perforation is not anticipated

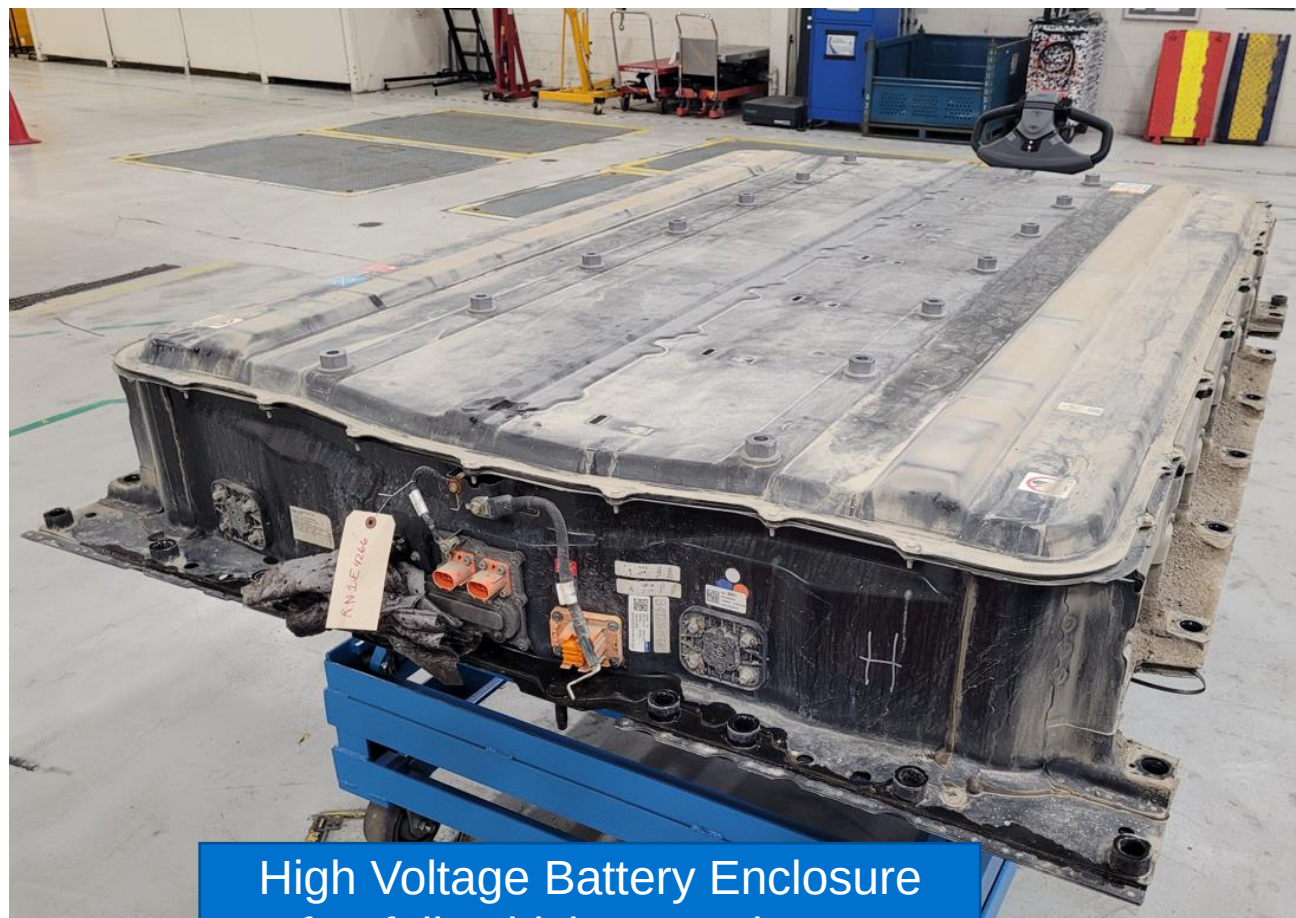


Material & Coating Strategies



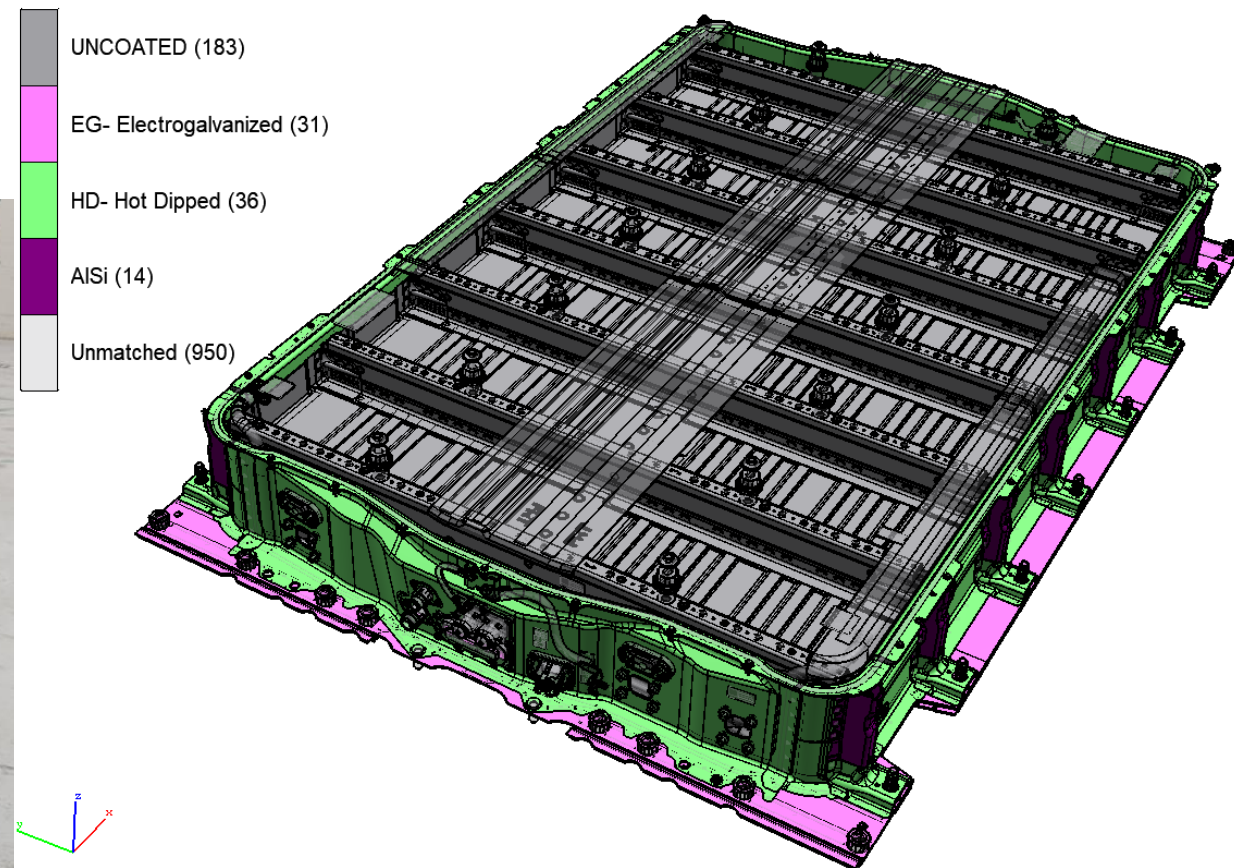
Material & Coating Strategies – Steel Constructions

- The right material in the right place
- Steel structures only require galvanize layer in wet zones
- Steel enclosures are E-Coated to protect from corrosion.



High Voltage Battery Enclosure
after full vehicle corrosion test

Design Check 103 - Coating EG HD AISi UNCOATED v2



Material & Coating Strategies – Material Coating Example

- Thermal Run-Away Prevention (TRP) heat deflector redirects hot gasses during TRP event
 - Organic coatings may not be acceptable due to flammability during TRP event
 - Aluminized steel was chosen as a coating to deflect hot gasses during TRP event.

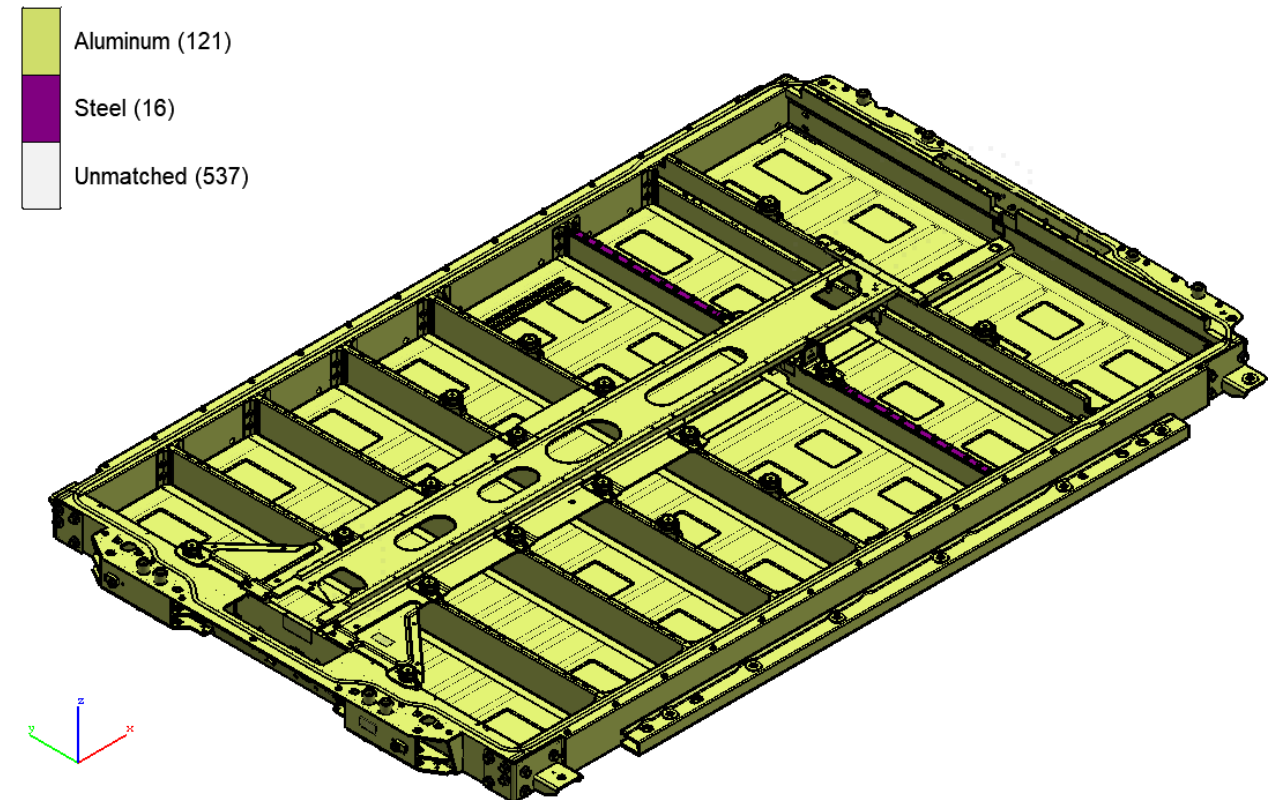
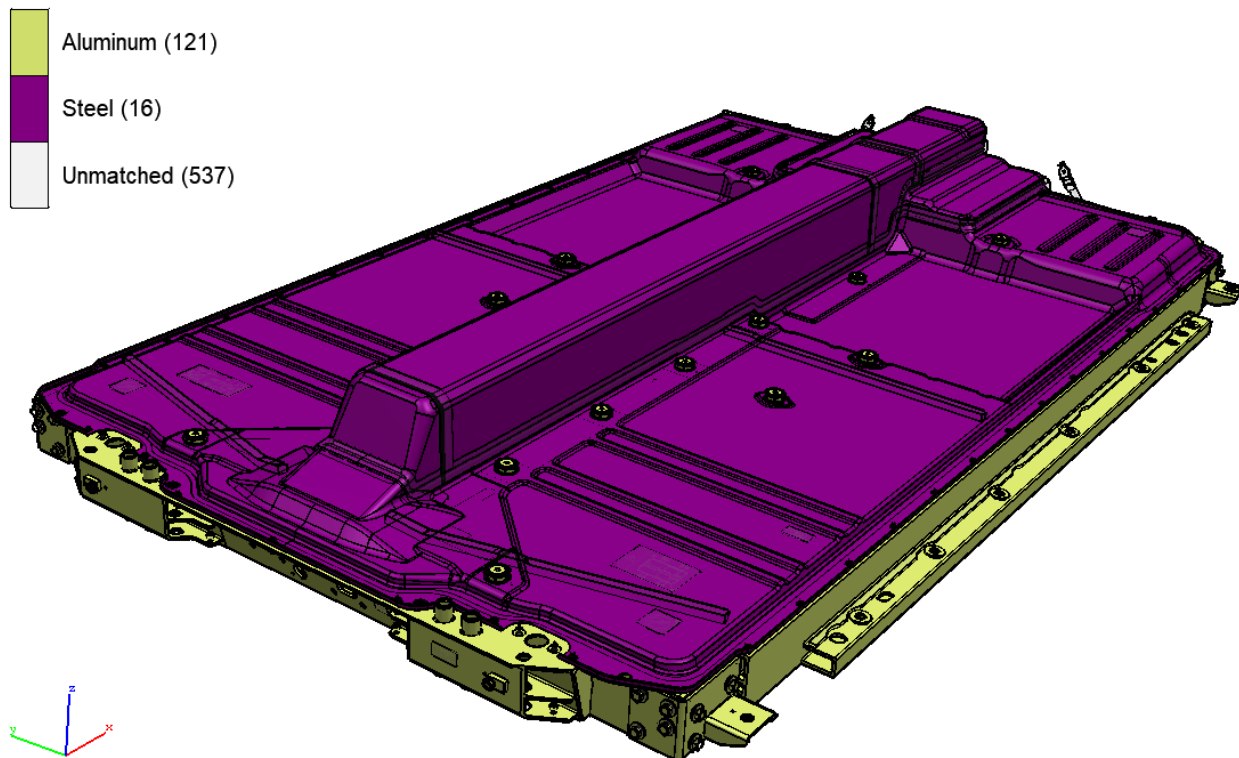


Aluminized steel deflector after vehicle level corrosion testing



Material & Coating Strategies - Aluminum Constructions

- Aluminum enclosure constructions can be used to maximize light weighting while keeping strength
- Aluminum enclosures may not require E-Coat, but other countermeasures may be required based on grade of aluminum
- Extrusions may be employed to support other enclosure requirements
 - Enables good E-Coat & in service drainage
 - Fewer components requiring additional countermeasures (sealing, adhesives, etc.)

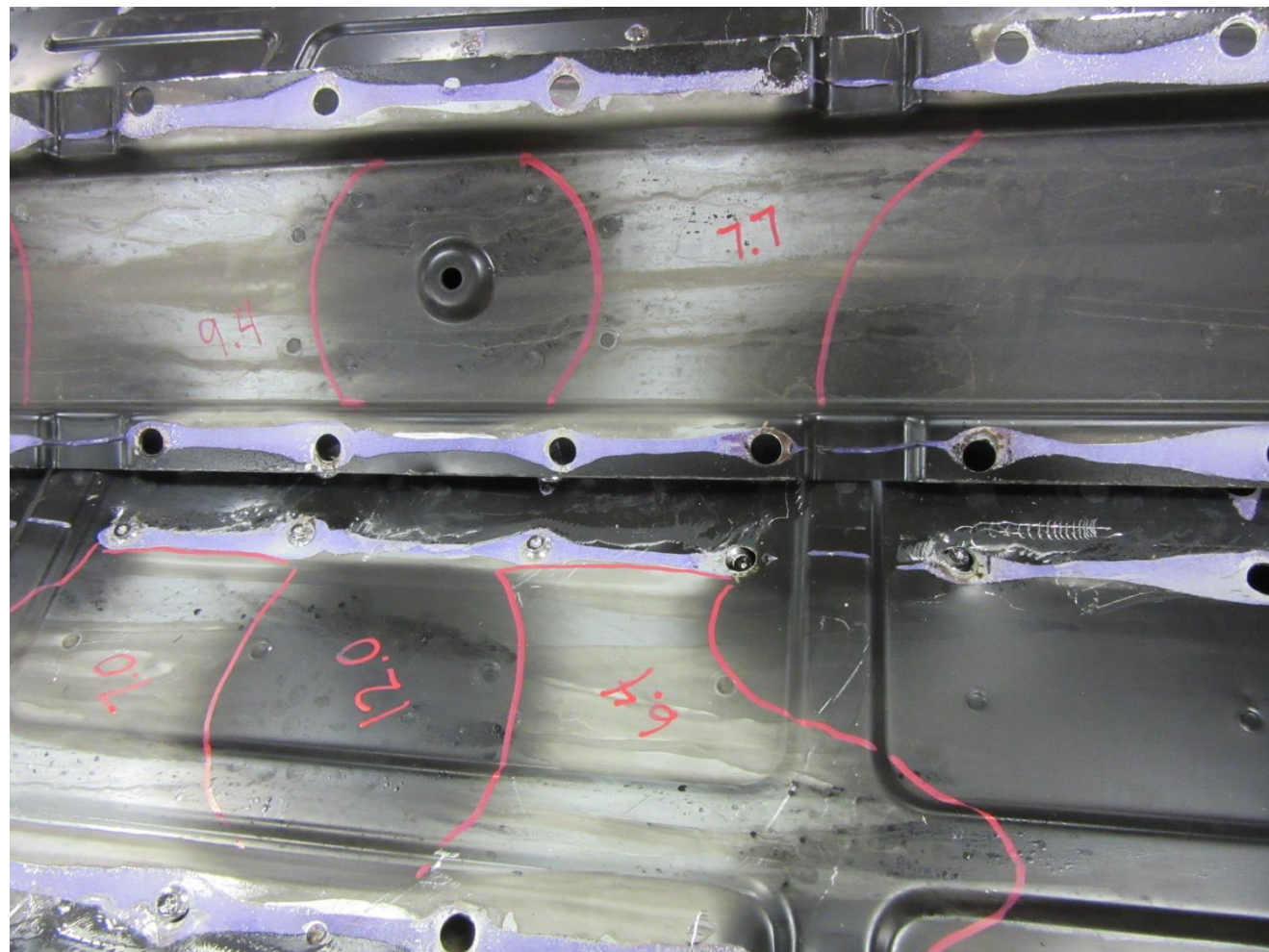


E-Coat Coverage for High Voltage Battery Enclosures



E-Coat Coverage for High Voltage Battery Enclosures

- E-Coat operations for enclosures follow the same fundamentals as vehicle bodies.
 - Deposition
 - Venting
 - Throw
 - Drainage
- The tray (lower portion) and the cover (top portion) get processed through E-Coat separately
- The image shows poor E-Coat throw performance
 - Additional holes were added to the panel to allow E-Coat throw

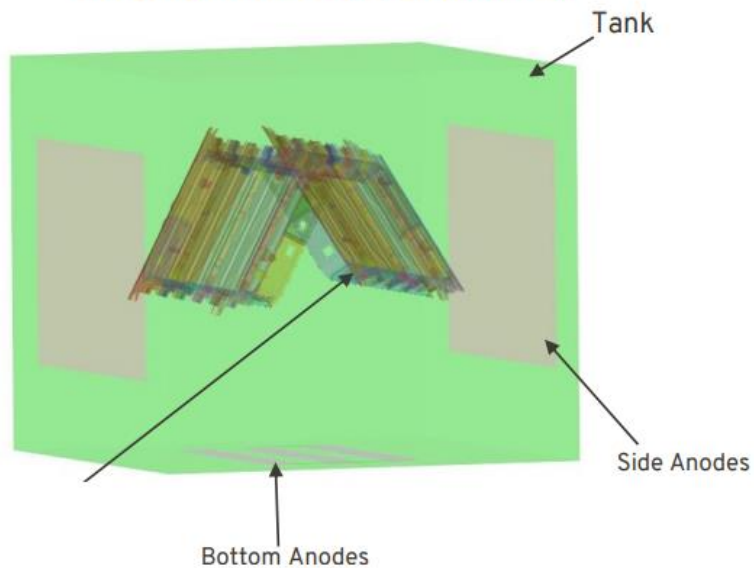


Part of an enclosure after an
E-Coat Teardown
(no corrosion testing performed)

E-Coat Coverage for High Voltage Battery Enclosures

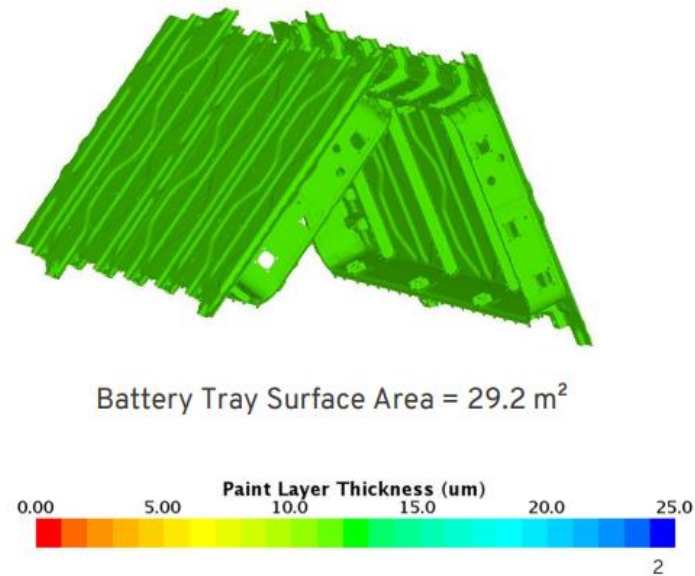
- ELPO processing of enclosures may differ from the body in orientation and travel
 - Enclosure design must consider ELPO process details
 - Rotation and travel allow movement of air bubbles around/out of the enclosure during E-Coat

Simulation Setup (Snapshot)



GM Confidential

Simulation Result (Snapshot)

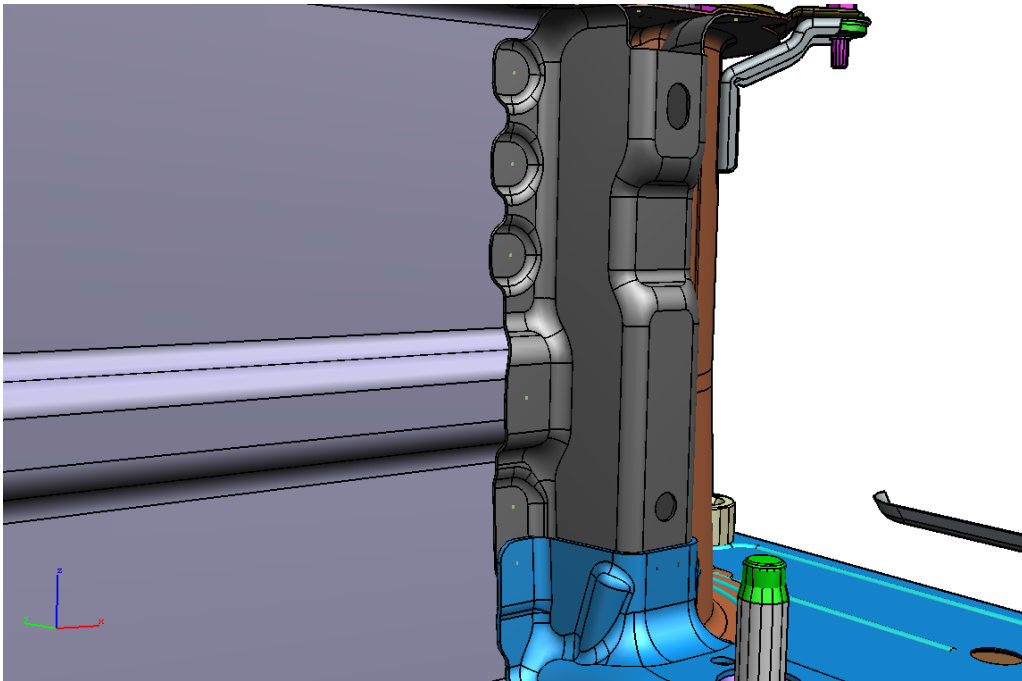


Joint Design & Enclosure Sealing for High Voltage Battery Enclosures



Joint Design for High Voltage Battery Enclosures

- Joint design for battery enclosures must follow similar practices to body joint design
- Single spot weld castellations will enable drainage & prevent crevice corrosion
- If castellations cannot be employed:
 - Double sealing crevices is required for the exposed underside enclosure structure
 - Cover to tray sealer must have excellent adhesion to paint or base material



Joint Design for High Voltage Battery Enclosures - Example

- The image shows a pre-production trial of a single seal interface where double sealing is required and is now implemented.
- **POOR EXECUTION**



- The image shows good performance of double sealing.
- **GOOD EXECUTION**



High Voltage Battery Enclosure
after full vehicle corrosion test

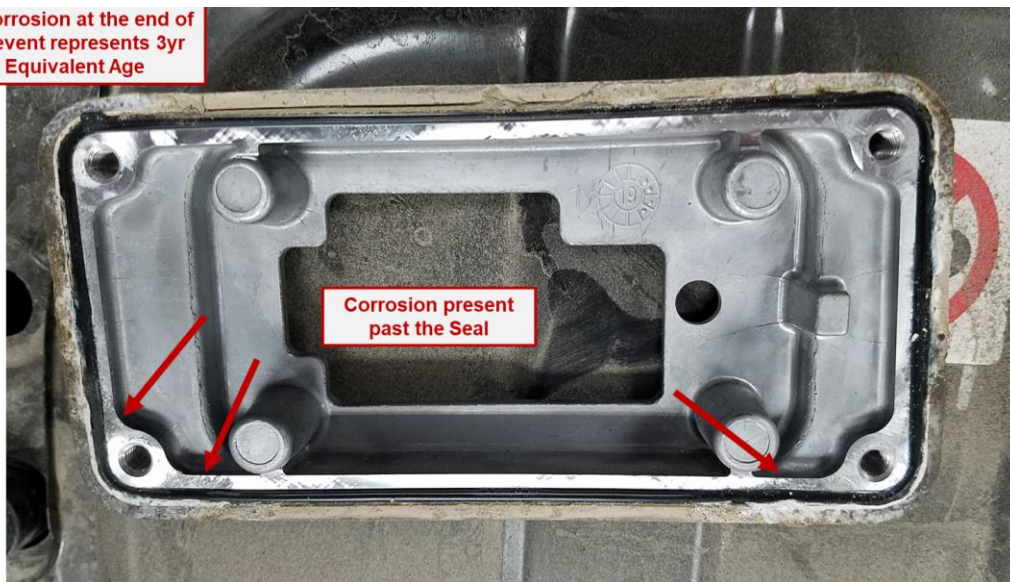
Component Sealing



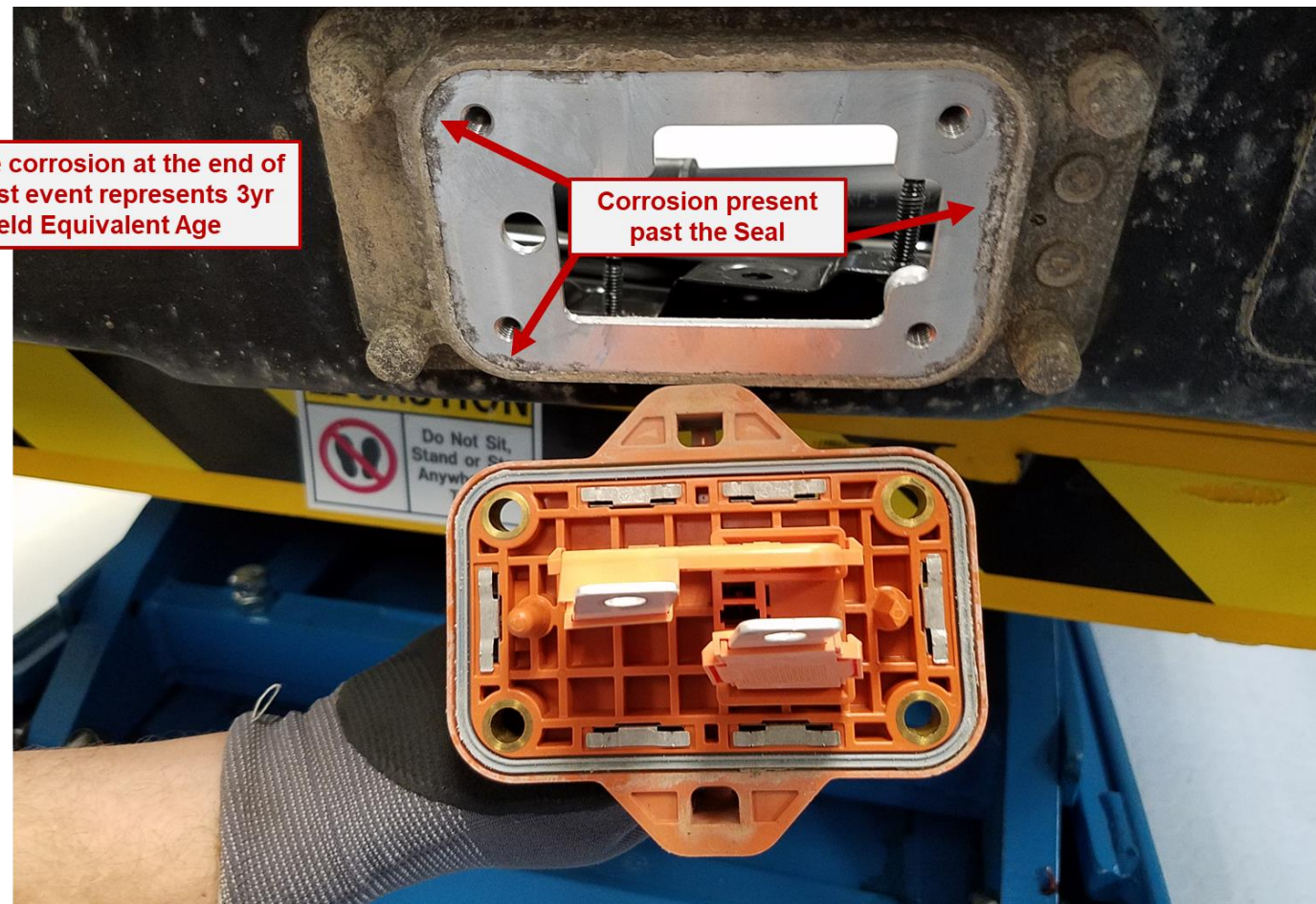
Component Sealing – PIP / O-Ring Sealing

- Electrical connectors with PIP (Push in Place) O-Rings may pose a crevice corrosion risk
- Corrosion creep under seal may compromise the sealing interface
 - Anodization or E-Coat may be required on aluminum enclosures
 - Other solutions are currently under investigation

Crevice corrosion at the end of this test event represents 3yr Field Equivalent Age

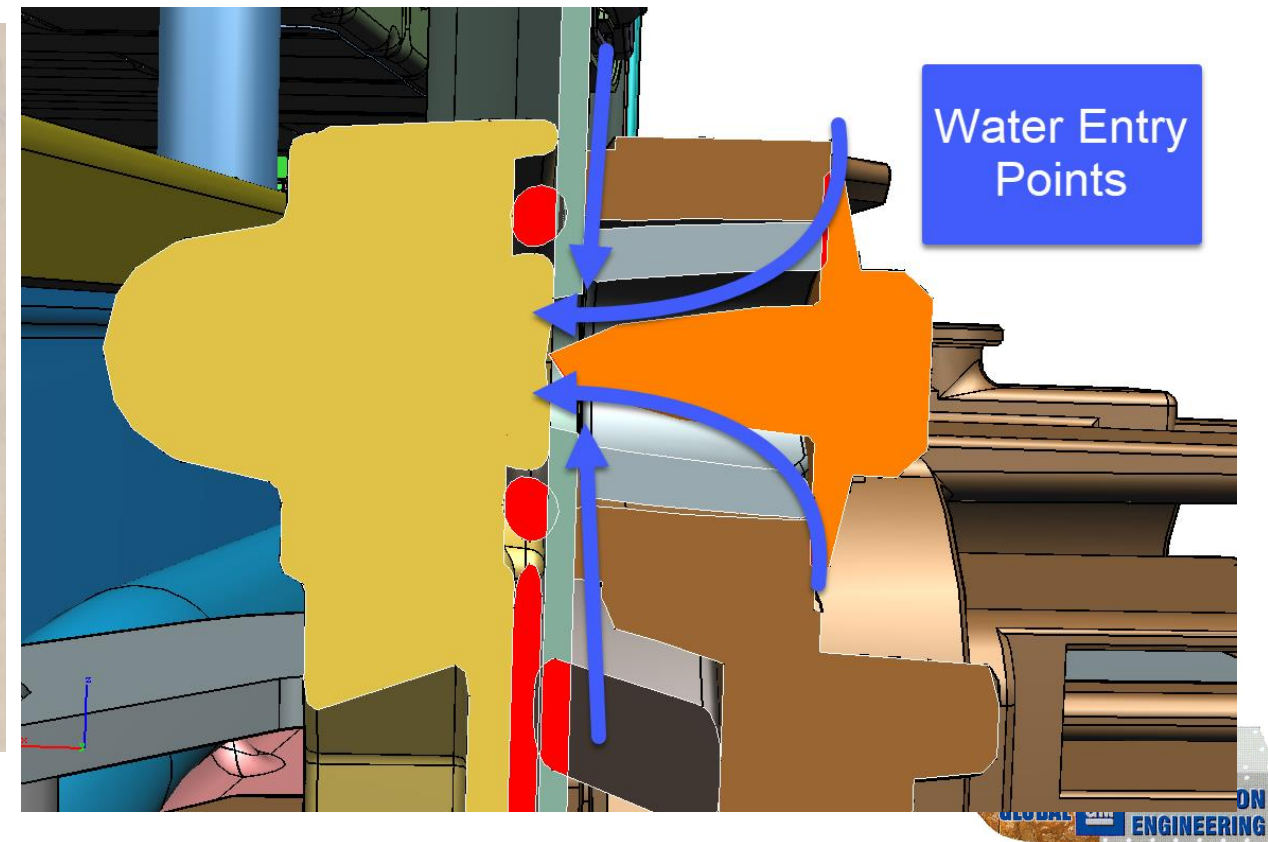
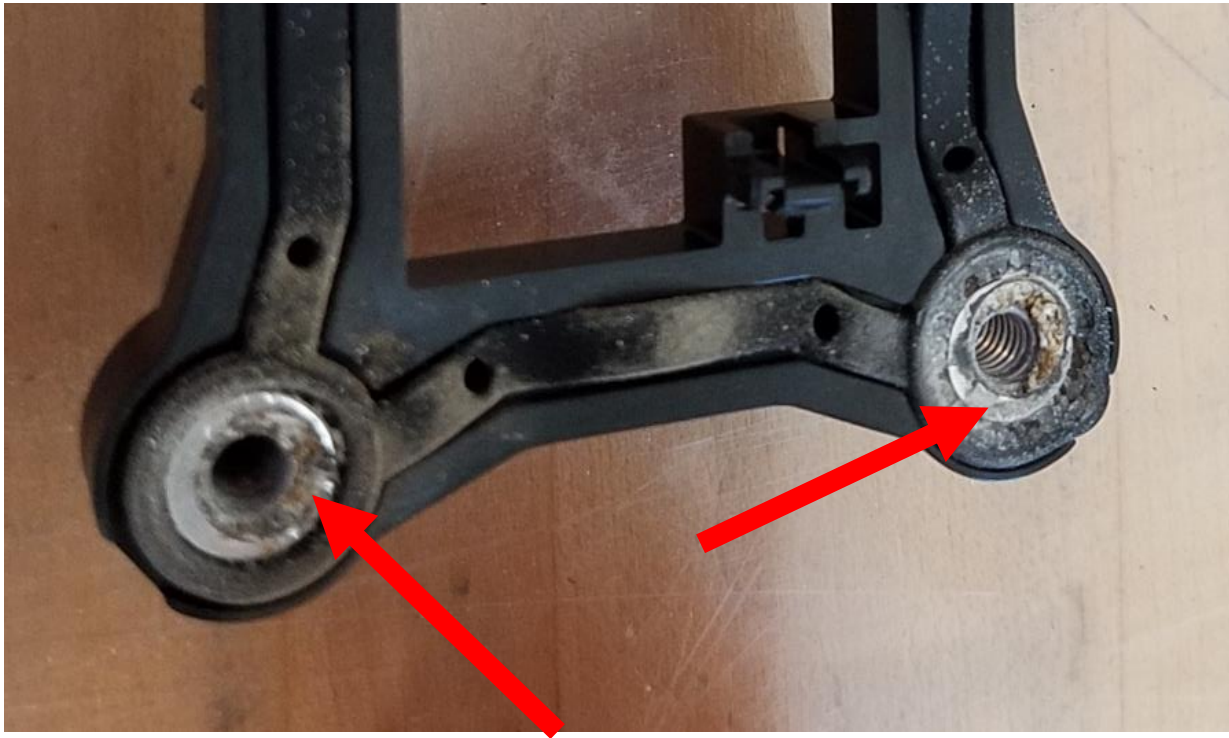


Crevice corrosion at the end of this test event represents 3yr Field Equivalent Age



Component Sealing - Fastener Sealing

- Fastener sealing must be evaluated at a component level
 - Water entry points may allow for unintended crevice or galvanic corrosion
- The images below show where the sealing interface had observable crevice corrosion due to an overlooked water entry point



Summary



Summary

- The High Voltage Battery Enclosures have unique design criteria that must be addressed
- Material selection of steel, aluminum, and mixed metal must be analyzed on a case-by-case basis
- E-Coat application may be appropriate for steel and aluminum constructions
- Each joint must be investigated for proper application of castellations and sealers
- Components must prevent crevice corrosion and water leak paths into the enclosure
- Future design considerations
 - Address coatings that are TRP friendly
 - Further investigation of aluminum PIP sealed interfaces



Questions?



Eric Romanowski

