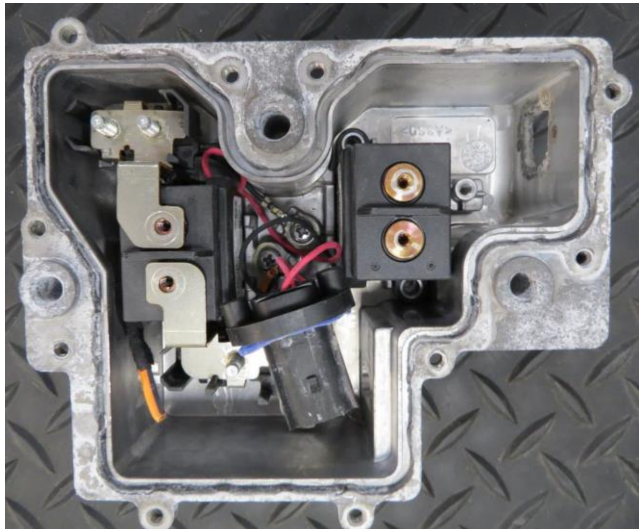
CREVICE CORROSION OF ALUMINUM ENCLOSURES AT SEALING INTERFACES

GENERAL MOTORS



ULLRICH HAUS

MARCH 31, 2022

AGENDA

INTRODUCTION – CREVICE CORROSION ON ALUMINUM HOUSINGS

FACTORS IMPACTING ALUMINUM HOUSING CREVICE CORROSION

IMPROVEMENTS – DESIGN, COATINGS, AND MATERIALS

CONCLUSIONS AND OUTLOOK

INTRODUCTION – CREVICE CORROSION ON ALUMINUM HOUSINGS

THE ISSUE: ELECTRONIC MODULES FAIL IN CORROSION TESTING DUE TO EXCESSIVE CREVICE CORROSION

During corrosion lab and vehicle testing we discovered crevice corrosion issues with corrosion breaching the seal plane at the housing-to-O-ring interfaces and entering the enclosure. In most cases the electronic components inside did not fail on test, meaning no loss of function. But since crevice corrosion is under-accelerated in corrosion testing, any sign of corrosion creeping under the seal can be a potential issue in the field.

Crevice corrosion on Aluminum enclosure sealing interfaces has always been an area of concern, e. g. steering gear, transmission fluid pan, etc. But with electric vehicles many more housings for electronics exist on the vehicle and the problem has become more prominent. Also, in many cases suppliers do not have the experience with automotive applications and long-term durability requirements in corrosive environments.

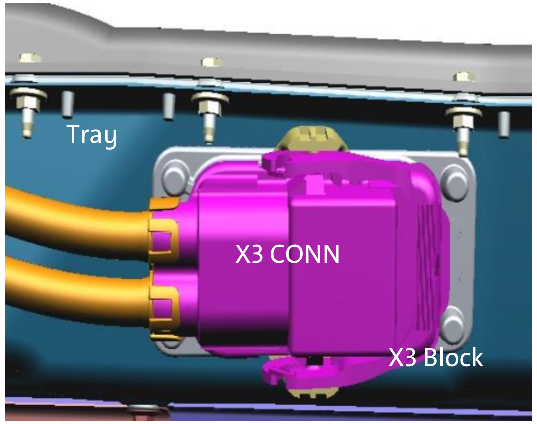
Simple O-Ring or PIP (Press-In–Place) sealing systems that are common for enclosures of electronics are often not robust enough to prevent Aluminum crevice corrosion in locations with severe corrosion exposure like the underbody or lower engine compartment.

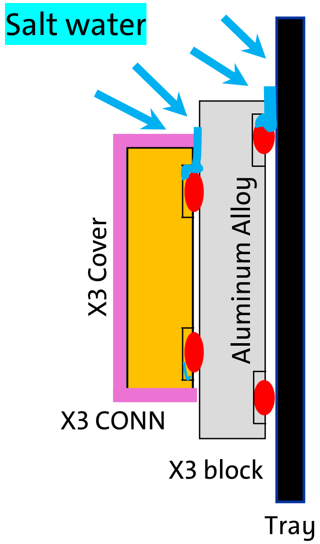
EXAMPLE 1: RESS CONNECTOR BLOCK

Block Material: A380

Connector: Plastic

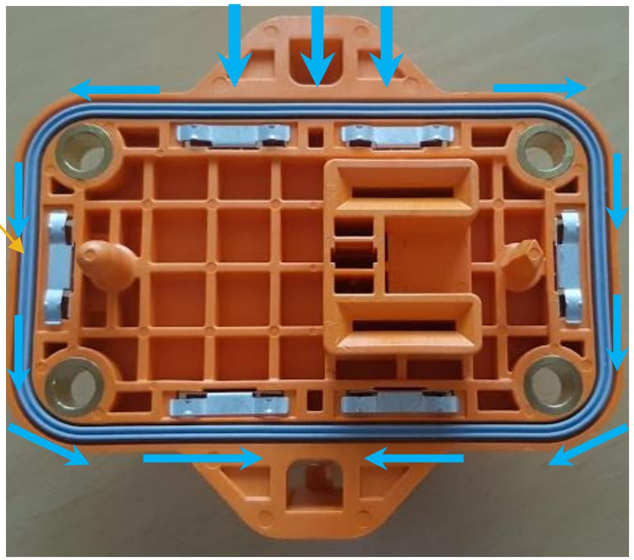
Tray: Elpo Coated Steel

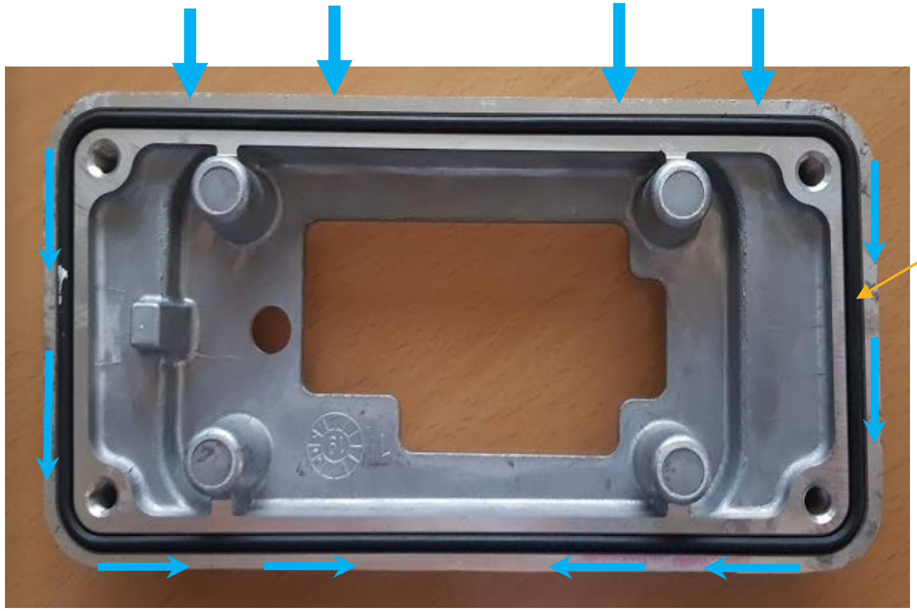




Connector and block are located underbody and exposed to salt water that is wicking into the gaps between the components.

PIP Seal

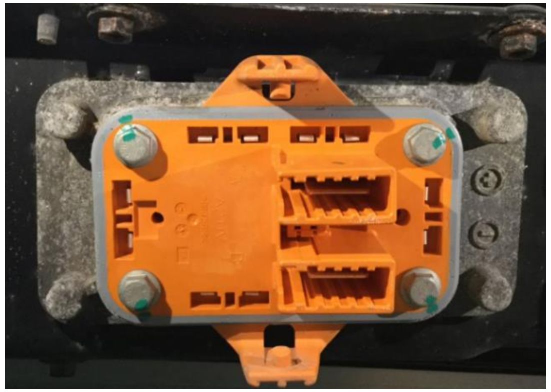


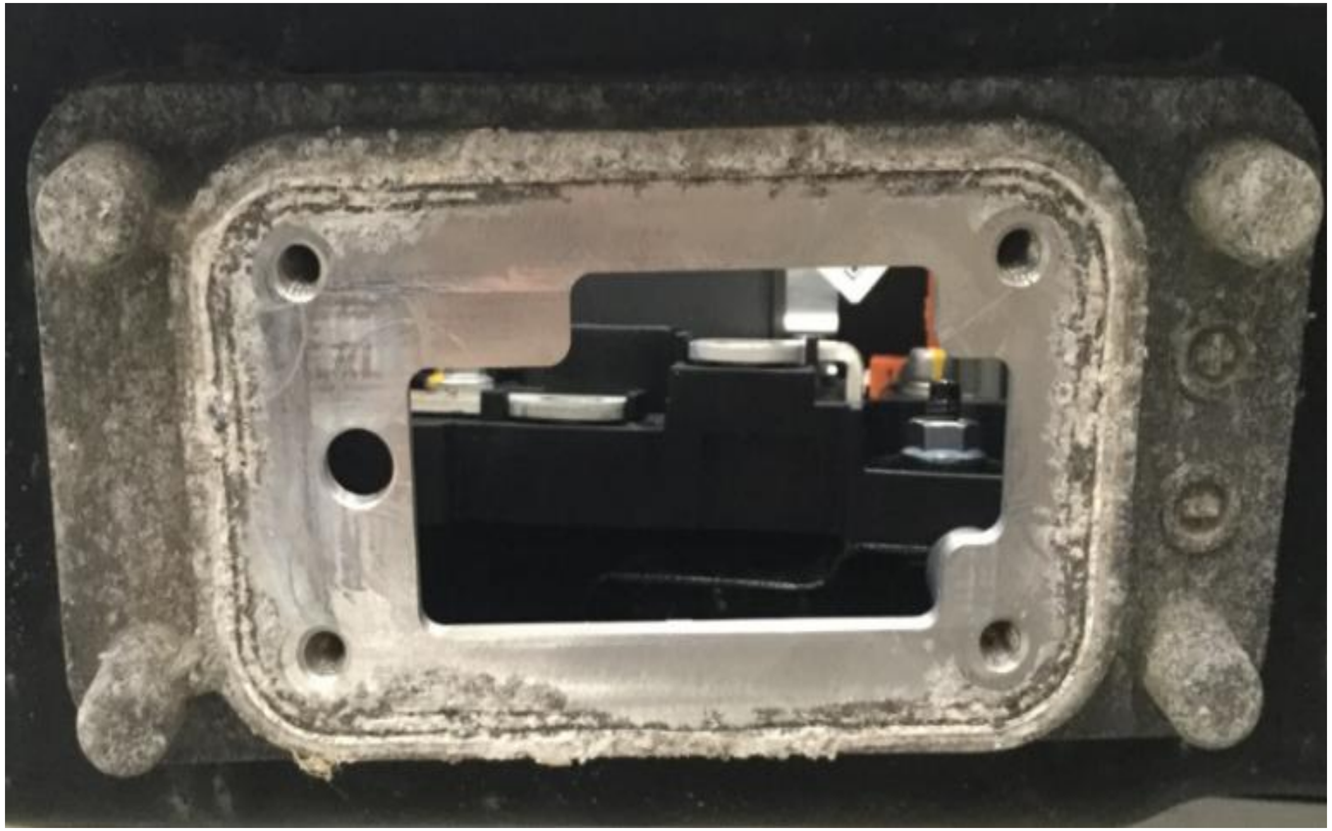


O-Ring

EXAMPLE 1: BATTERY PACK CONNECTOR BLOCK

Issue one: Corrosion has penetrated past the primary seal of the orange connector and entered the inside of the Battery Enclosure.





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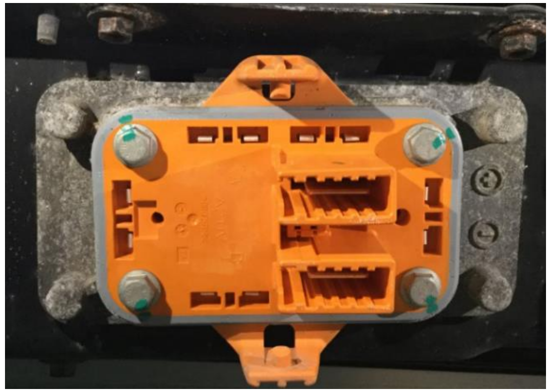
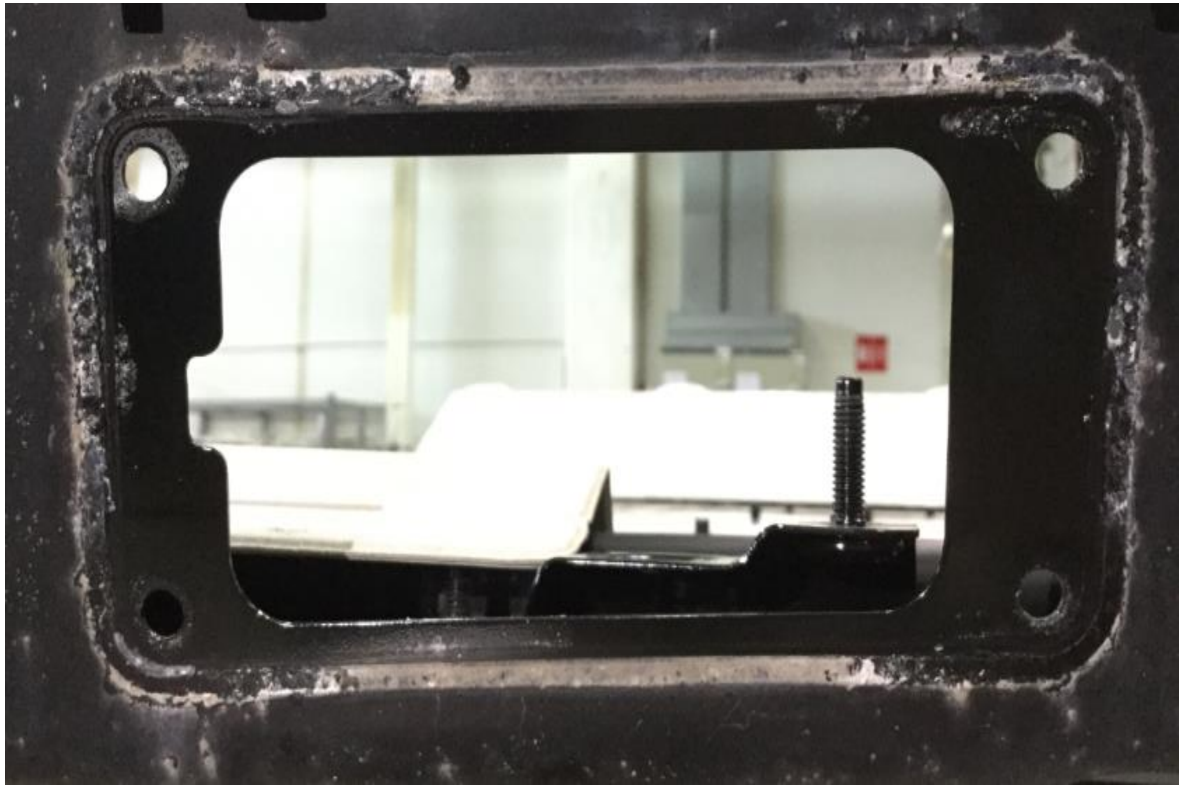


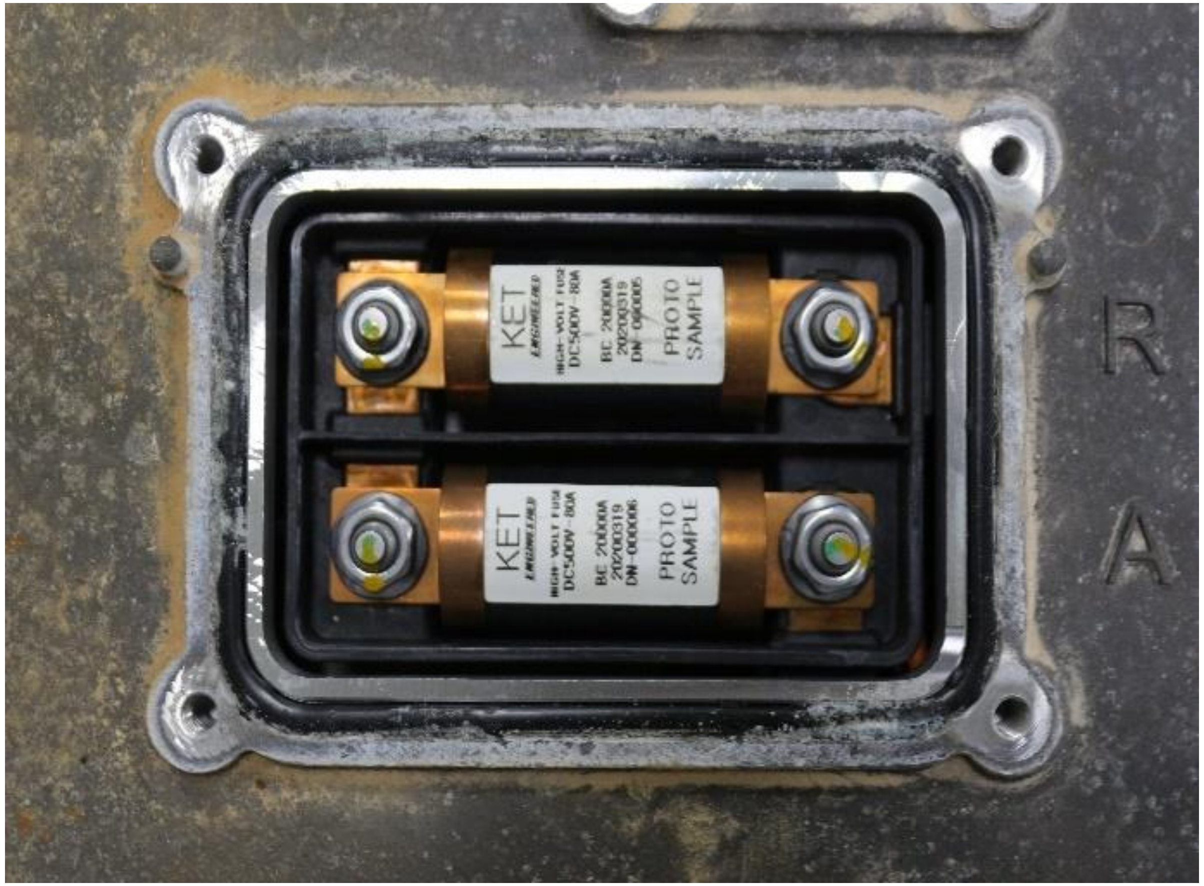
Issue two: Leak through the primary seal of the connector back plate.



Example 2: IPE (Integrated Power Electronics)- Cast Aluminum Housing (A380) Interfaces to

a) **DC Fuse Cover (Aluminum)**

b) HVAC Connector (Plastic)



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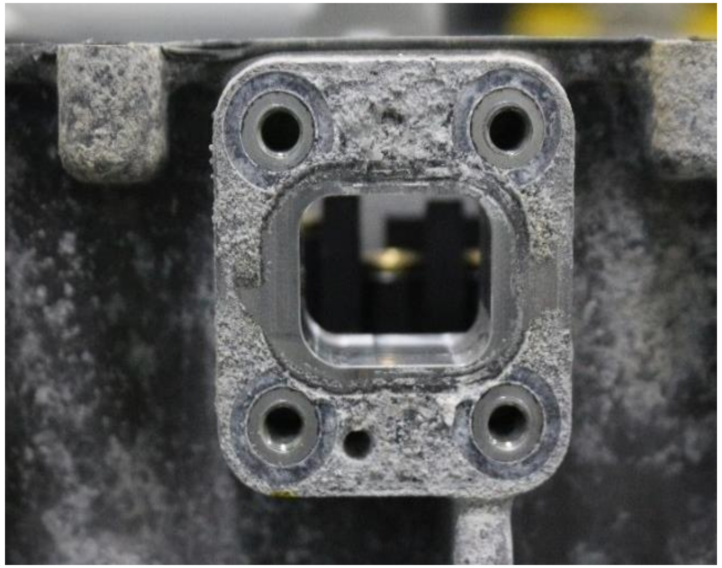
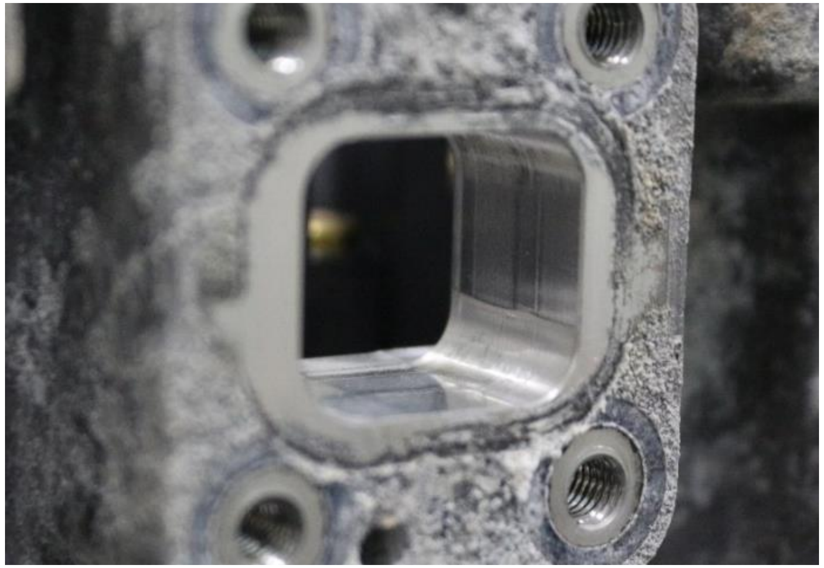
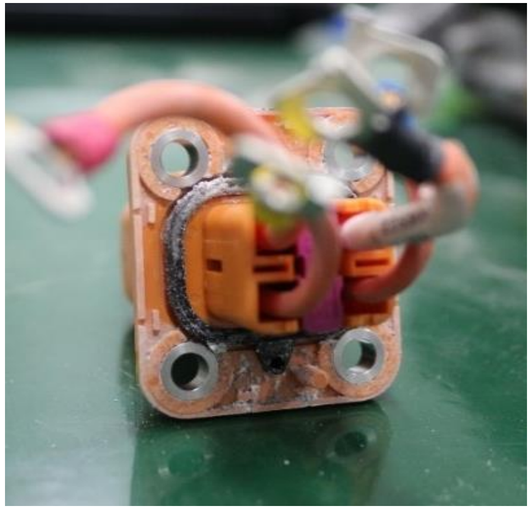
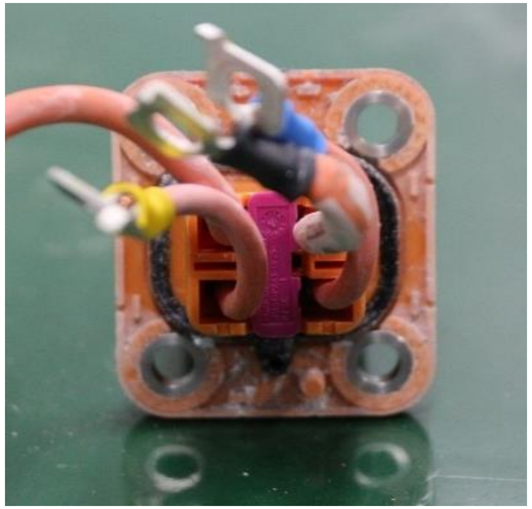
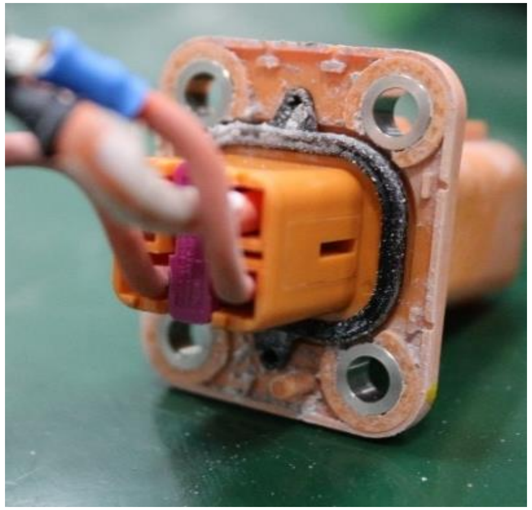










FACTORS IMPACTING ALUMINUM HOUSING CREVICE CORROSION

Seal

- Compression. The O-Ring is compressed in the radial direction when seated in the groove. For static seals, O-ring and grove are usually designed to achieve a compression of about 40%. Low seal compression can increase crevice corrosion.

- Conductive elastomers (carbon black filler) can cause galvanic corrosion.

- O-Ring Geometry and features. The wider the seal, the more time needed for crevice corrosion to pass the seal. Gasket retention beads can cause inconsistent compression rate and gaps between O-Ring and groove.

Aluminum Housing/Cover

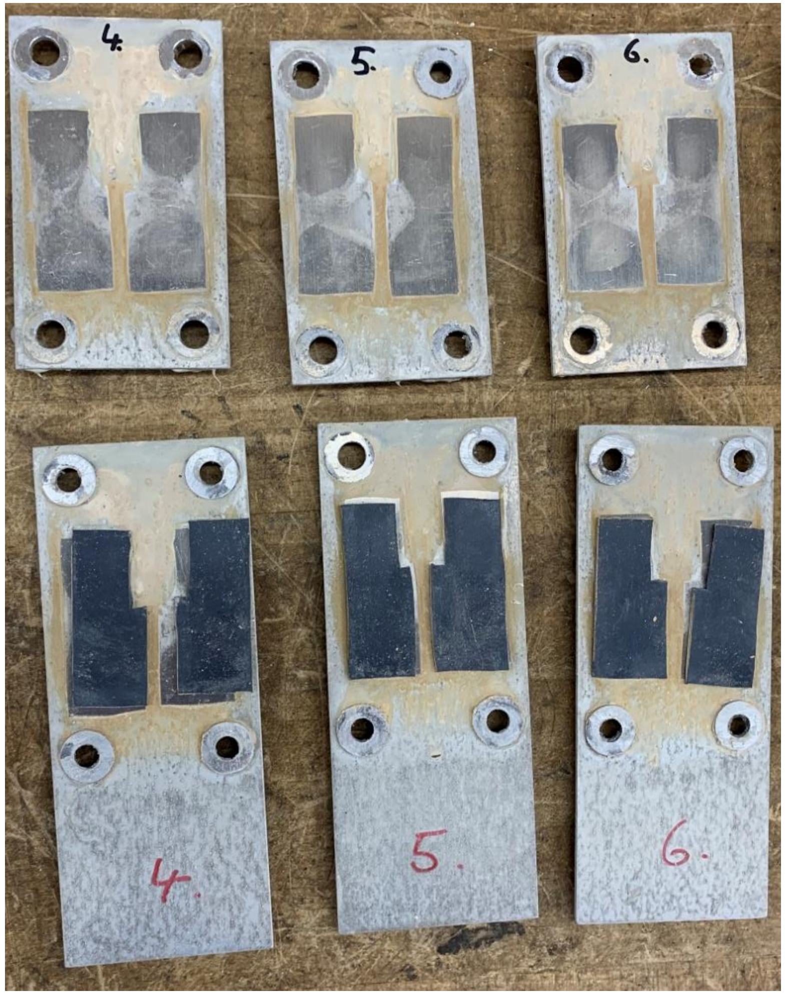
- Chemical Composition. E. g. A360 (Cu<0.6 wt%) has better corrosion resistance than A380, (Cu<1.5-3.5 wt%).

- Bushing materials like brass or stainless steel can cause galvanic corrosion

GALVANIC CORROSION CAUSED BY CONDUCTIVE ELASTOMERS

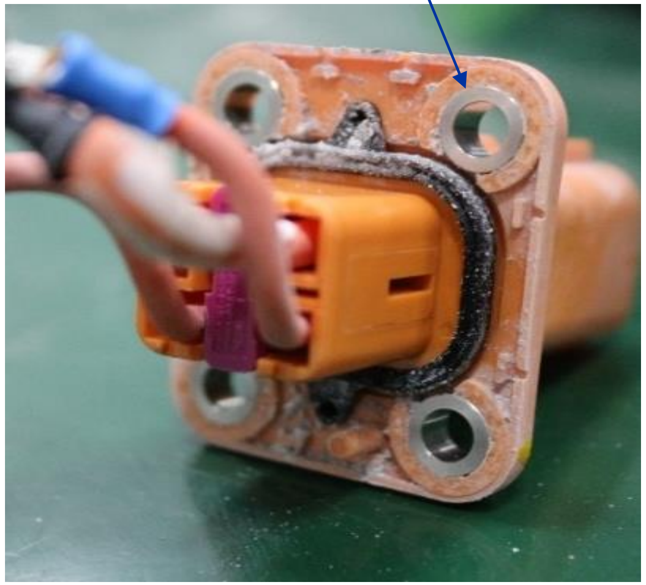
CONDUCTIVE (< 10E4 ΩCM)

NON-CONDUCTIVE> 10E11 ΩCM

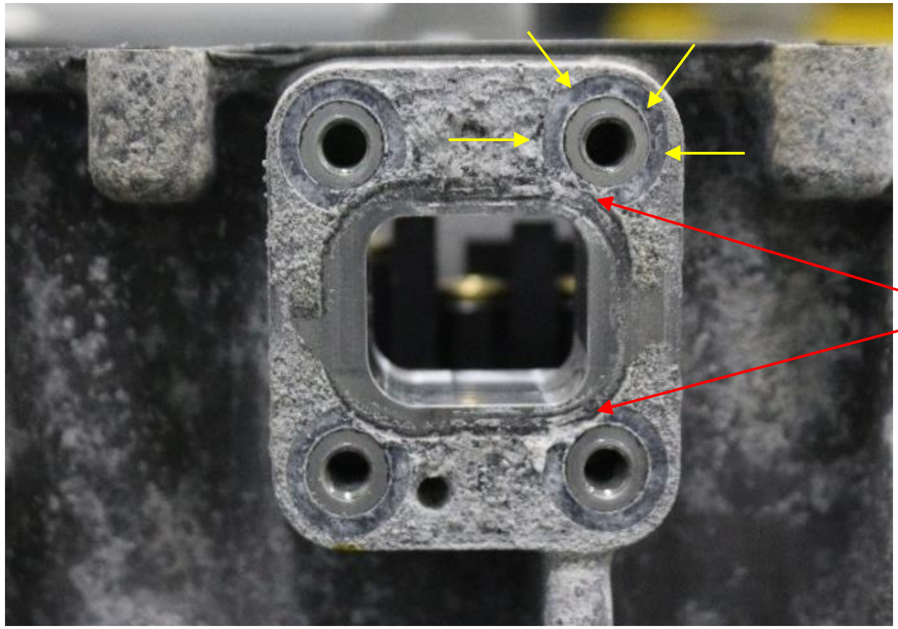


GALVANIC CORROSION CAUSED BY STAINLESS STEEL BUSHING

Stainless Steel Bushings



Galvanic corrosion appears around edge of bushing (causes “raised surface” which reduces seal compression)



Highest corrosion observed at corners near bushing locations.

FACTORS IMPACTING ALUMINUM HOUSING CREVICE CORROSION

Other “Noise” Factors

- Surface roughness of housing and cover in seal interface.
- Porosity of Aluminum casting
- Seal material (EPDM, Silicone, PTFE, Nitrile…)
- Spacing of Fasteners (Distance between Bolts)
- Fastener Torque

Those factors all potentially affect crevice corrosion, but impact cannot always be quantified.

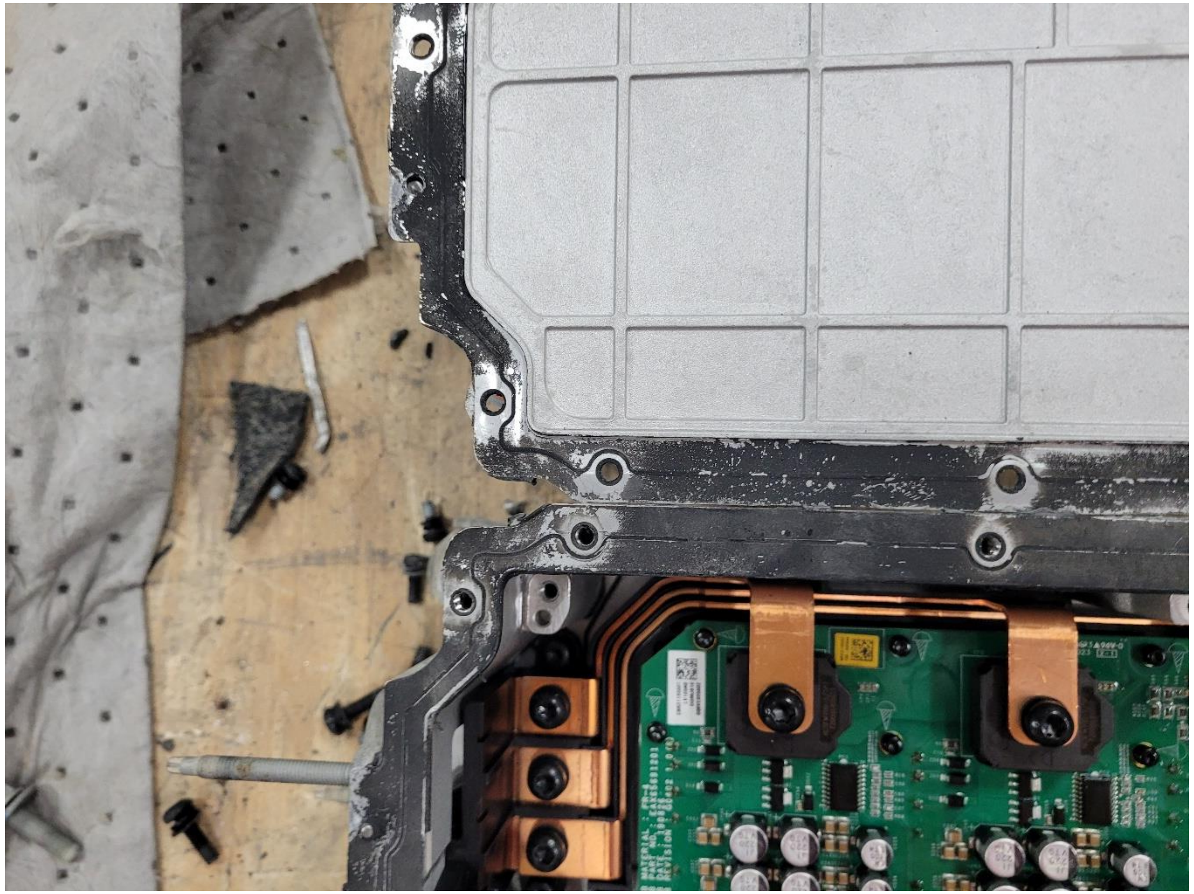
IMPROVEMENTS – DESIGN, COATING AND MATERIALS

The following measures have been shown to successfully prevent crevice corrosion

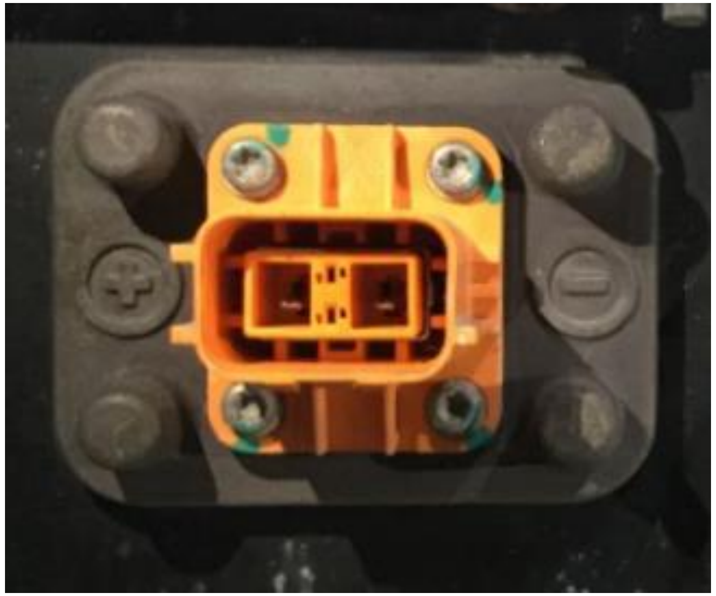
- Liquid Applied Sealer (RTV). Although RTVs, continuous welds, and other methods for continuously sealing a crevice might be effective, not all components can realistically have these kinds of sealing methods (e.g. serviceable covers or connectors).
- Bushings: Stainless steel and brass can cause galvanic corrosion. Use coated steel or Aluminum.
- Add protective coating to housing and cover. Coatings like anodization bring significant improvements. Might have to add laser etching process after anodizing for electrical grounding.
- Isolation Film (Polyurethane).

RTV SEAL - EXAMPLE

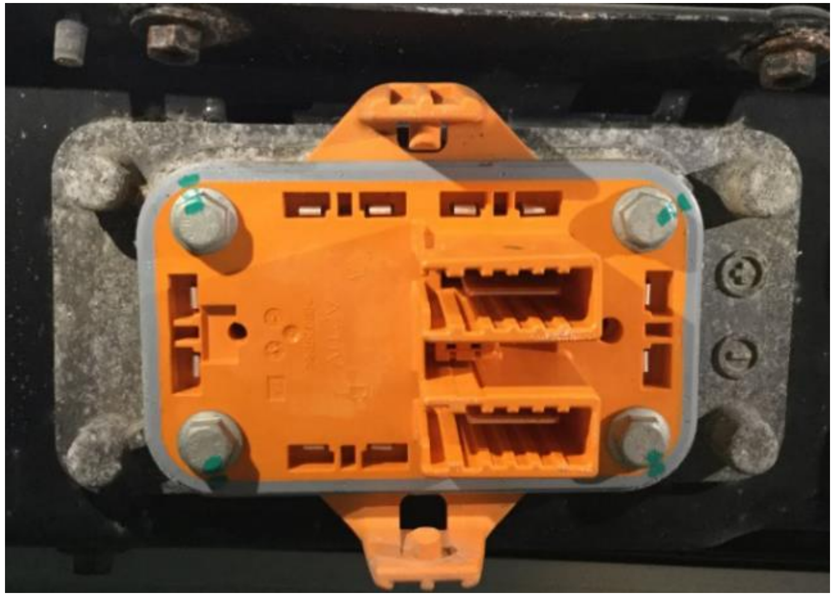
This sealing concept utilizes RTV liquid applied sealer on cover plates vs metal/rubber gasket.



X3 Connector with Anodization



X4 Connector without Anodization



Block Material: A380

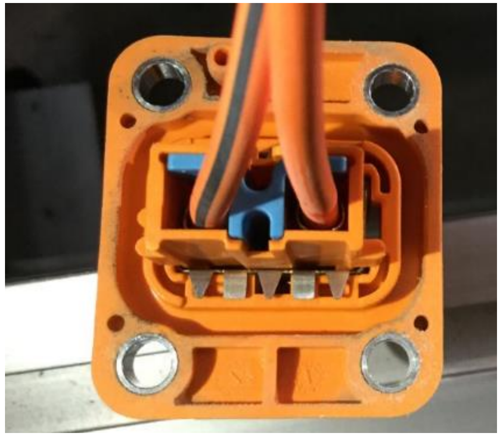
Connector: Plastic

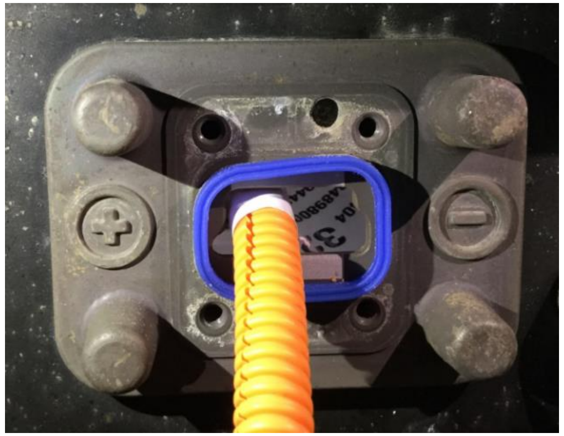
Tray: Elpo Coated Steel

ANODIZED CONNECTOR BLOCK

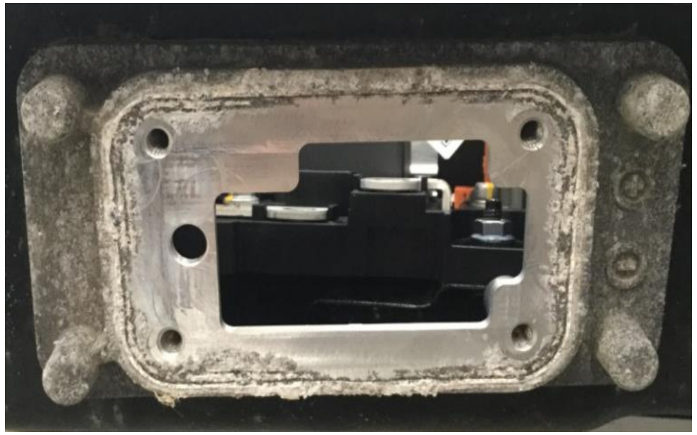
X3 Connector with Anodization

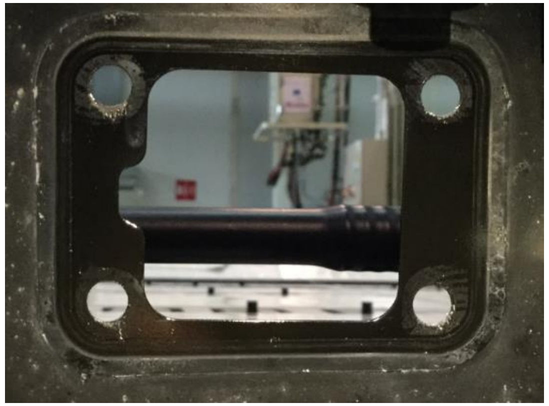
X4 Connector without Anodization



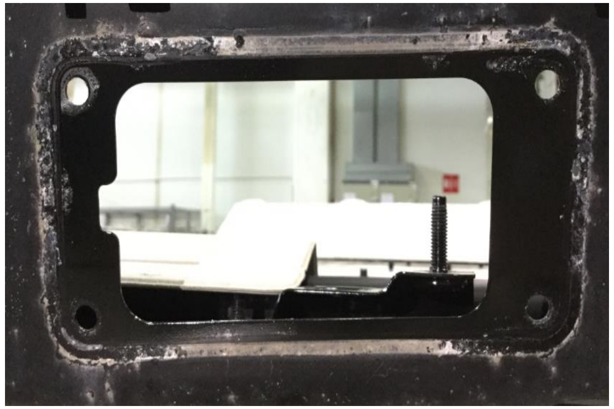


Front





Back



No significant corrosion on anodized block

ANODIZED FUSE COVER AND TOP COVER ON IPE MODULE

With Anodization		Without Anodization
	Fuse Service Cover	
	Top Cover	

No significant corrosion on anodized parts

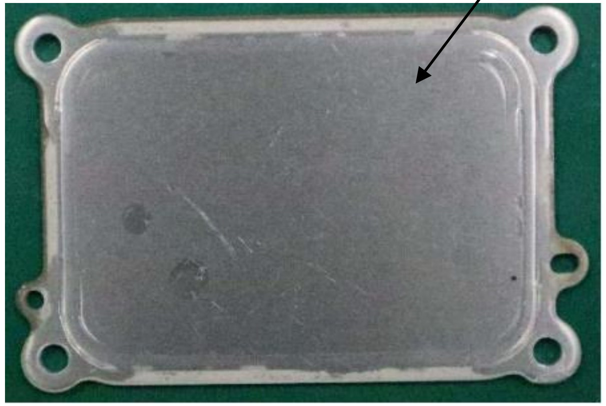
ISOLATION FILM – IPE FUSE COVER AND CONNECTOR INTERFACE

DC Fuse Cover

Without Film

With Film

Clear film present



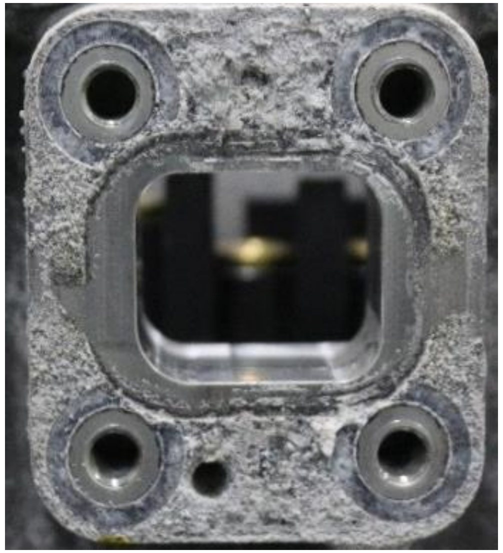
No significant corrosion

Connector Interface

Without Film

With Film

Clear film present



No significant corrosion

CONCLUSIONS AND OUTLOOK

- Simple O-Ring/PIP sealing concepts are not robust enough for uncoated Aluminum enclosures in severe corrosion locations.
- Surface treatments like anodizing, isolation films and RTV type sealer can be used to eliminate crevice corrosion to prevent corrosion creeping passed the seal.
- Limited correlation between lab and vehicle test / field performance. Need to get parts from vehicles in the field to collect test-to-field correlation data.
- Kicked of project to evaluate alternative Aluminum casting alloys that can meet corrosion targets without additional surface treatment.
- Need to further investigate the role of conductive seals in crevice corrosion


THANK YOU