

The Use of Corrosion and Environmental Sensors in Automotive Test Environments

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Introduction

Laboratory cyclic corrosion testing of specific vehicle parts in corrosion chambers



OR

Close to real driving conditions during proving ground test



In fact, the results of both tests give us information about corrosion performance during and after tests by visual and more in-depth inspection

Lab Cyclic Corrosion Test



View of cyclic corrosion chamber

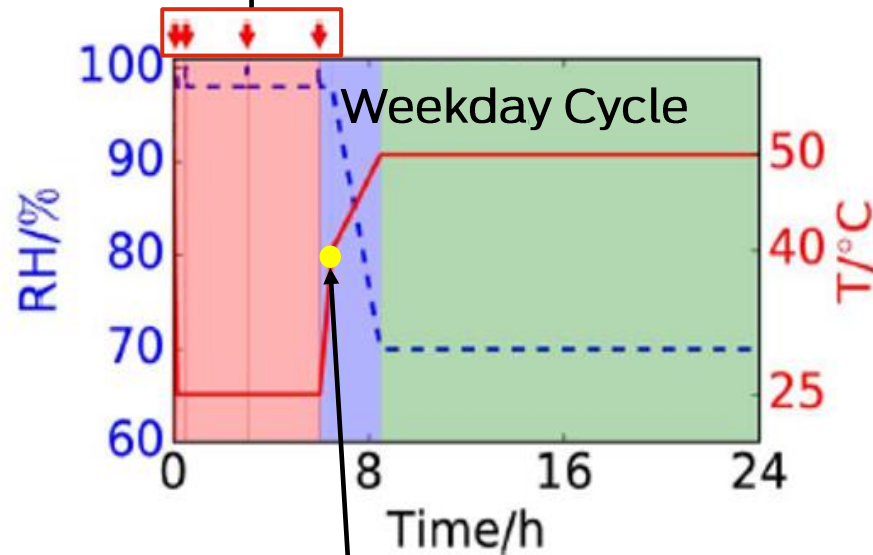


Inside view of cyclic corrosion chamber

L-467 Ford laboratory accelerated cyclic corrosion test

5 continuous days of test cycle

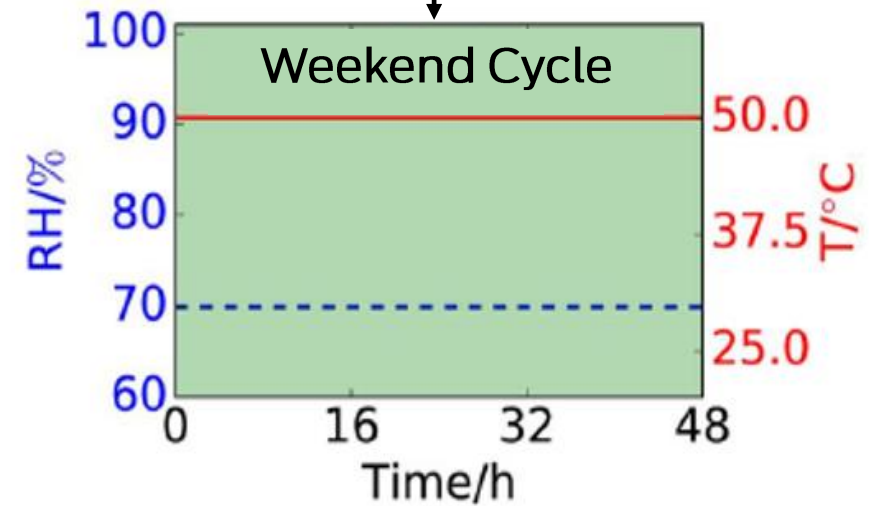
4 salt-solution spray events



Rapid T increase after the last salt spray event increases the salt concentration on the surface

2 continuous days of test cycle

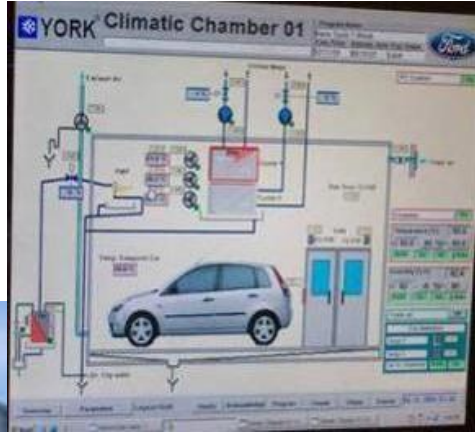
No salt-spray events



- Important - the wet phase consists of controlled high humidity with 4 separate salt solution spray events.

Proving Ground Test

Environmental Chambers
Structural input tracks
High Speed driving
Stone Pecking roads
Environmental input tracks



Climate chamber

Full Vehicle Close to Real Driving
Conditions Test

Driving Inputs

Salt spray passage



High speed track



Dust and abrasion from gravel



Mud trench



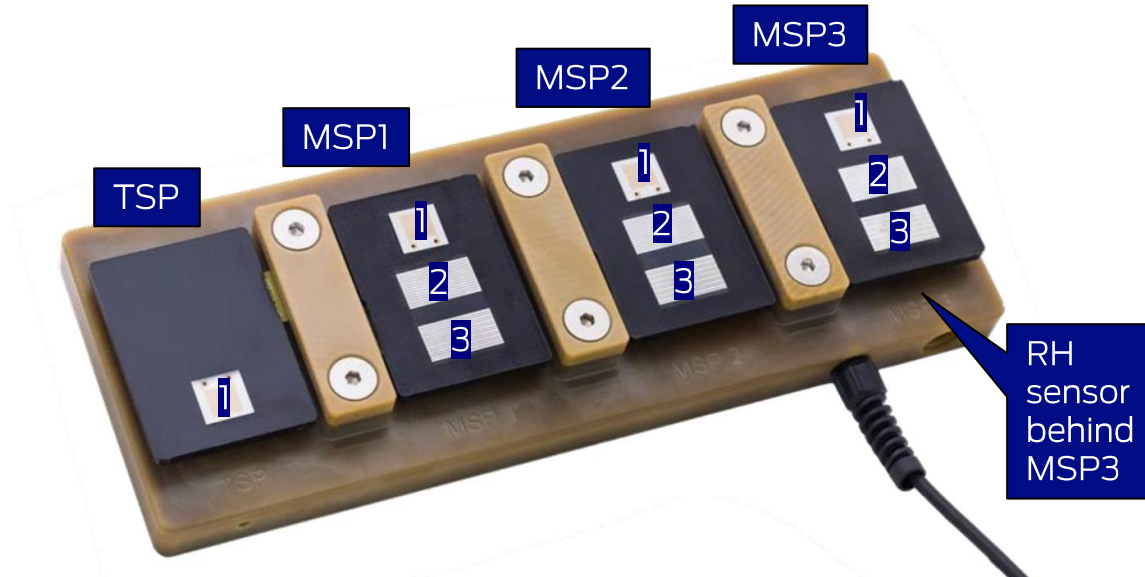
All Environmental Stresses Delivered
By Driving

The overall environmental conditions are prescribed during both the lab and proving ground tests, but corrosion-specific parameters (electrolyte conductance, and corrosion currents) are not controlled or measured.

This gap hinders a complete understanding of corrosion as a phenomenon.

Luna Sensors Technology Overview

Luna CorRES platform used for L467 cyclic corrosion testing in Lab corrosion chamber

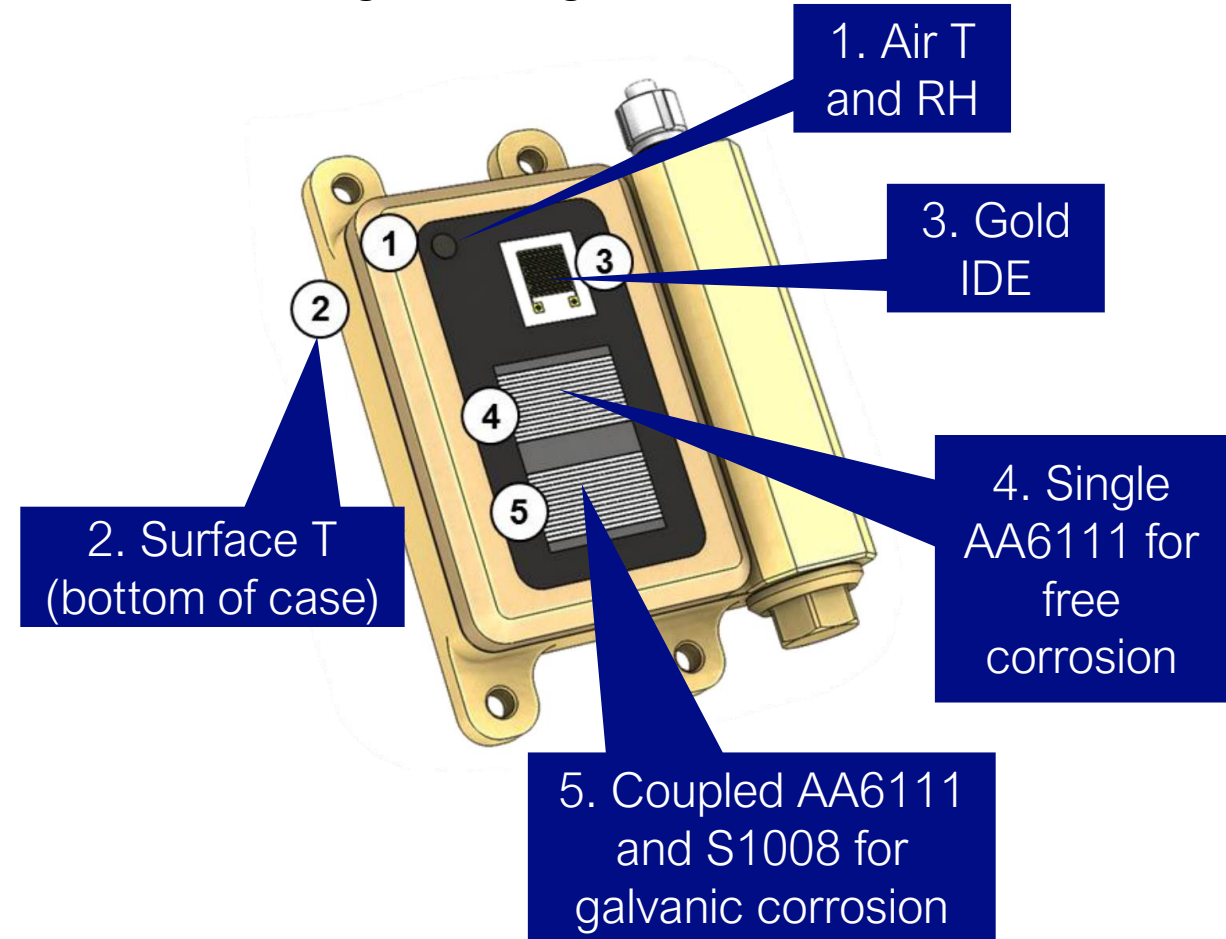


Temperature-sensing panel (TSP) was for T and had a (1) gold interdigitated electrode (IDE) for sensing solution conductance.

Each Multi-Sensing Panel (MSP) had

- (1) Gold IDE for sensing solution conductance
- (2) Single AA6111 for free corrosion
- (3) Coupled A6111 and S1008 for galvanic corrosion

Acuity LS system mounted On-Vehicle corrosion test at Michigan Proving Ground



Objectives

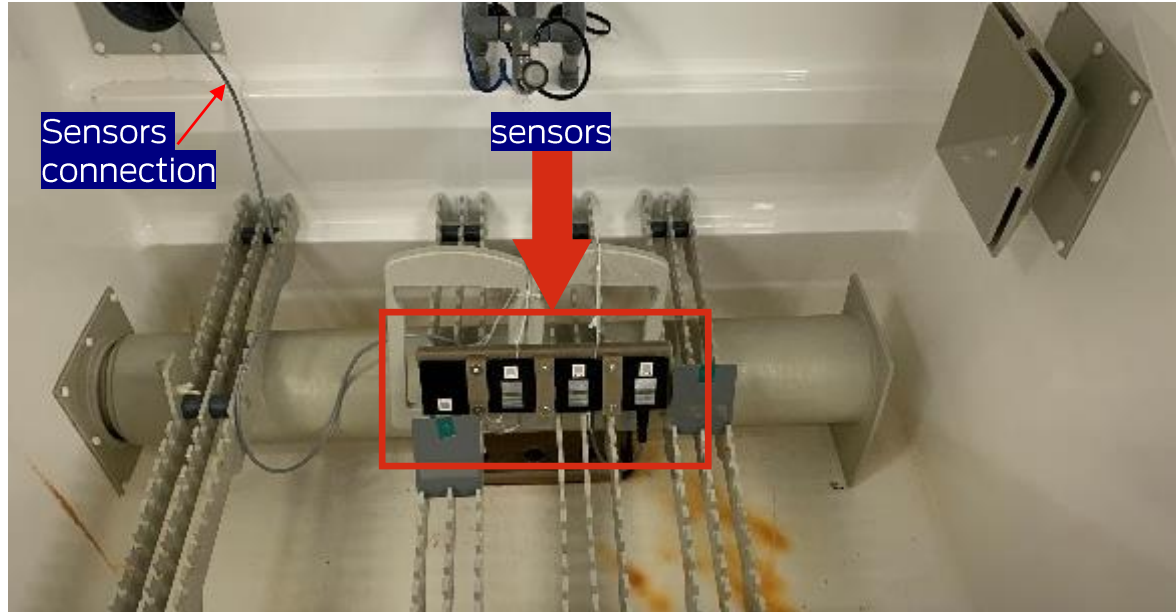
To assess the performance of Luna Labs' corrosion and environmental sensors for real-time measurement of:

- free corrosion rates in AA6111,
- galvanic corrosion rates between AA6111 and S1008, and

To quantify and compare the corrosion rates of similar sensors exposed in the laboratory chamber test and exposed on-vehicle at the proving ground.

Luna Sensors and Experimental

Inside view of laboratory chamber with Luna CorRES platform used in L-467 cyclic corrosion test



Testing protocol:

1. Method: L-467 test
2. Duration of data recording: 2 weeks
3. Solution: 0.5wt% NaCl

Externally mounted an Acuity LS sensor on a F-150 truck used for on-vehicle at proving ground corrosion test



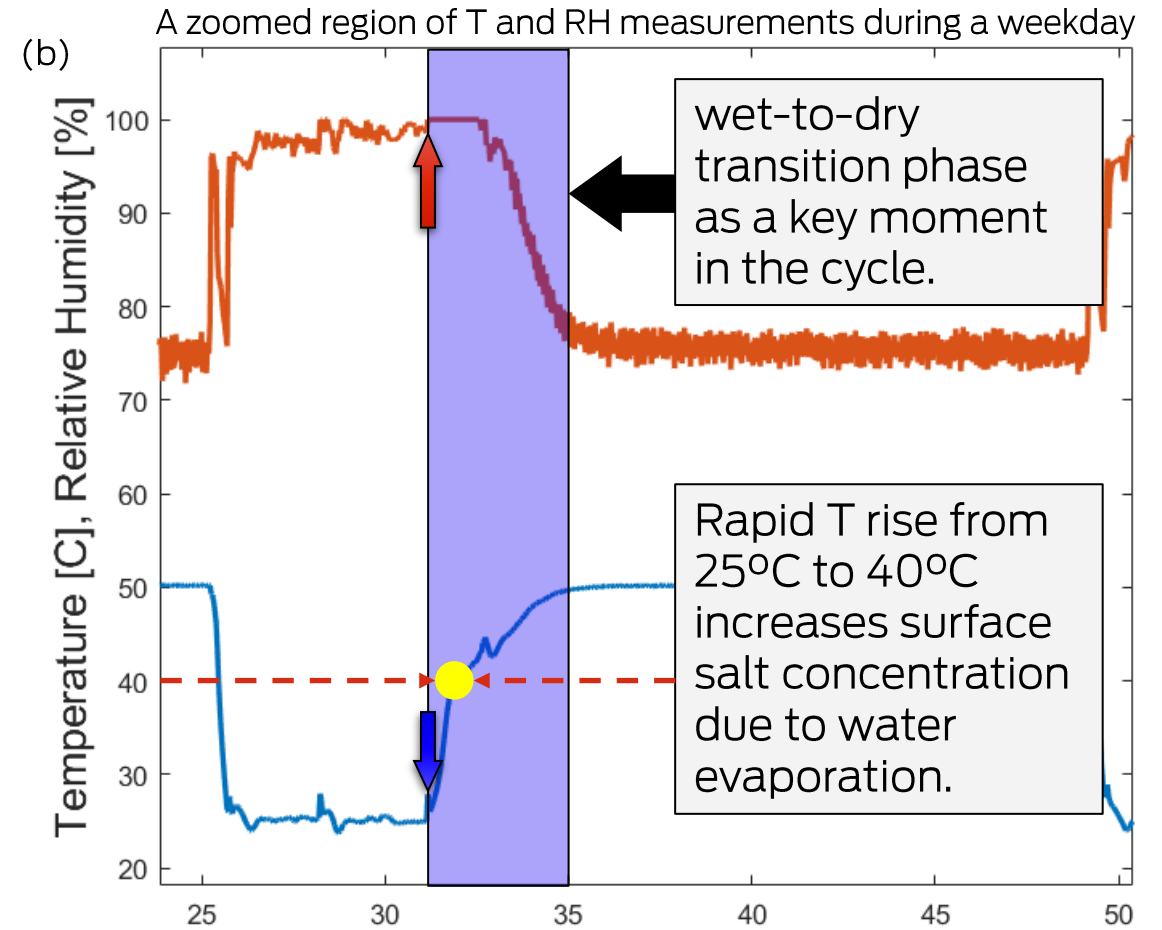
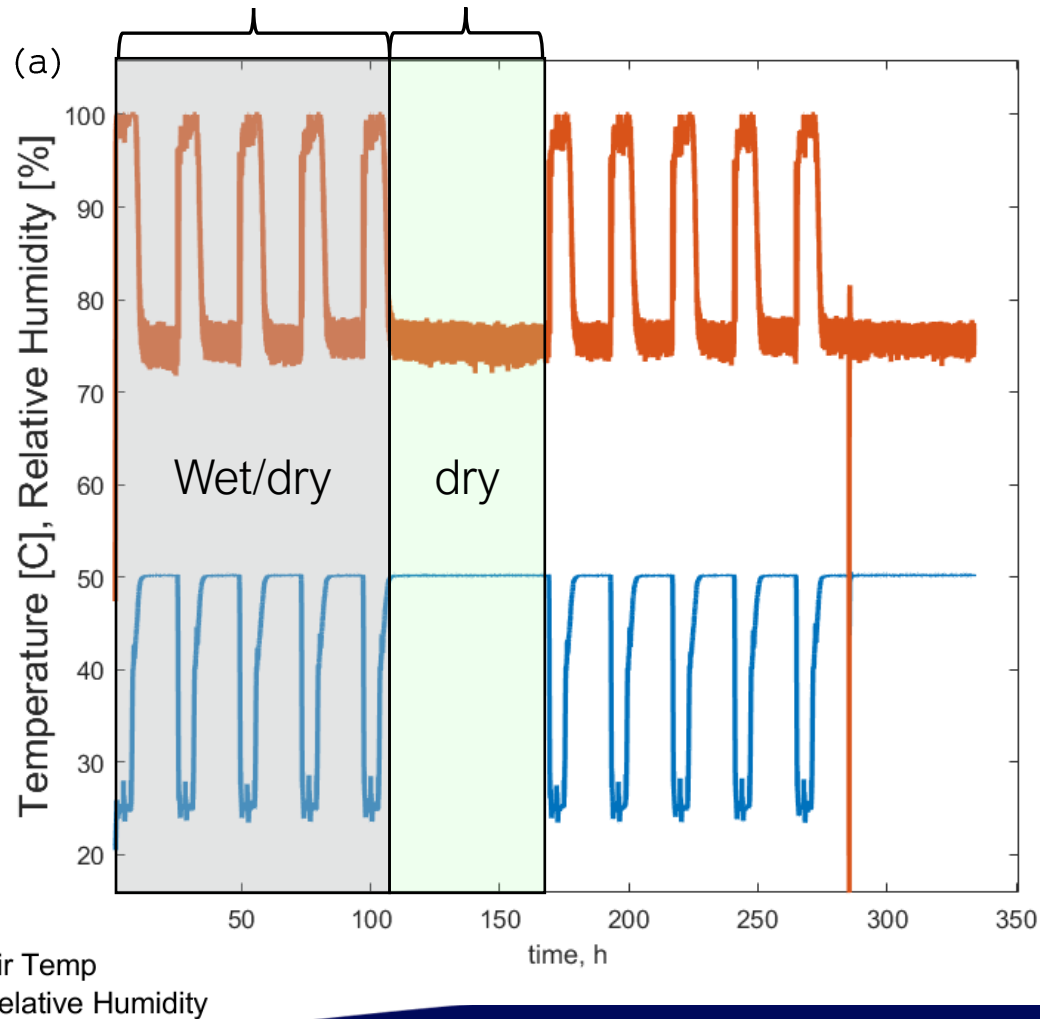
Testing protocol:

1. Method: R-343 test
2. Duration of data recording: 6 weeks
3. Solution: 0.5wt% NaCl for passage and 1.0%NaCl for wading bath

Results for Lab vs On-vehicle corrosion test conditions

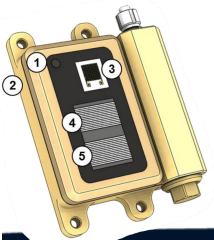
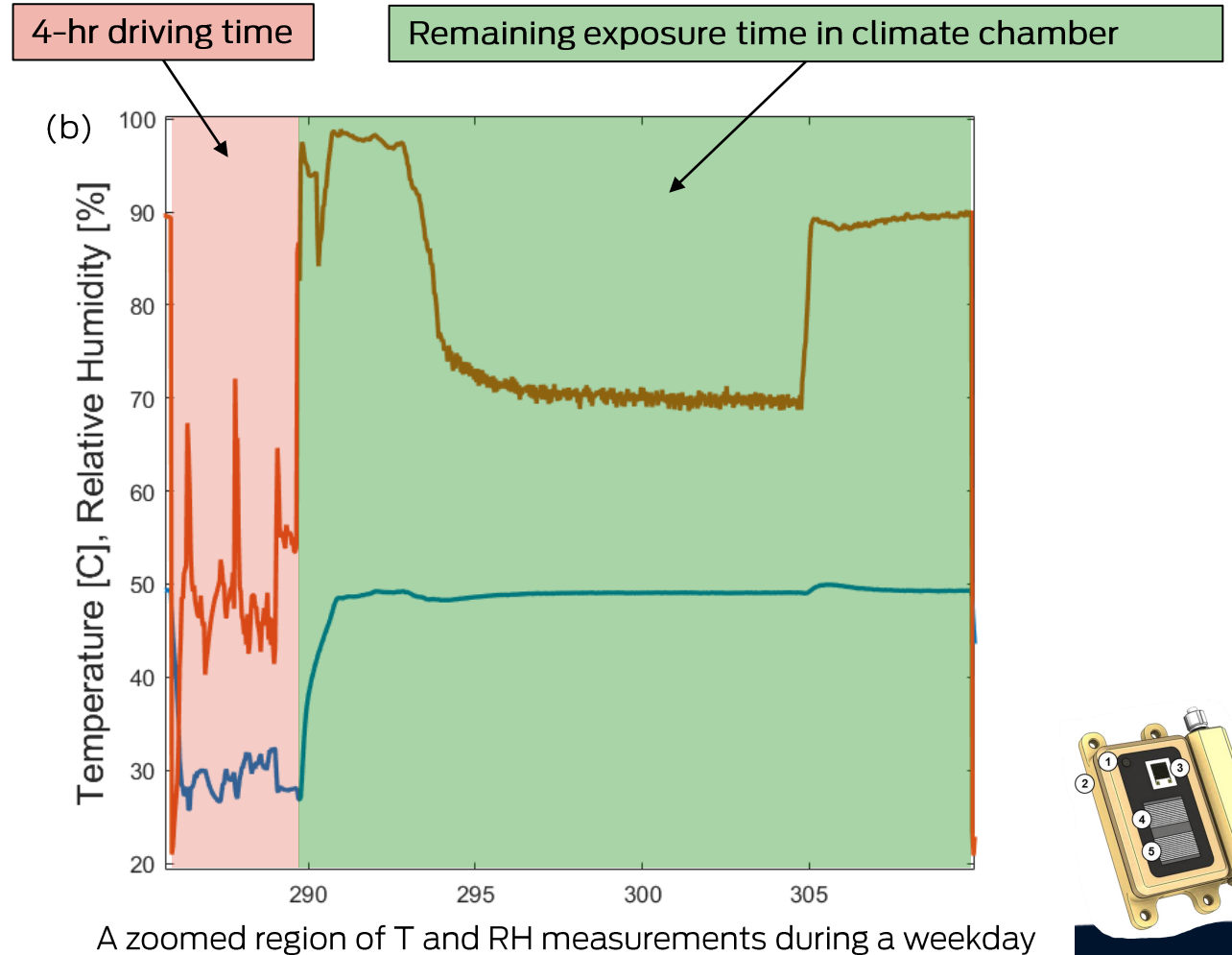
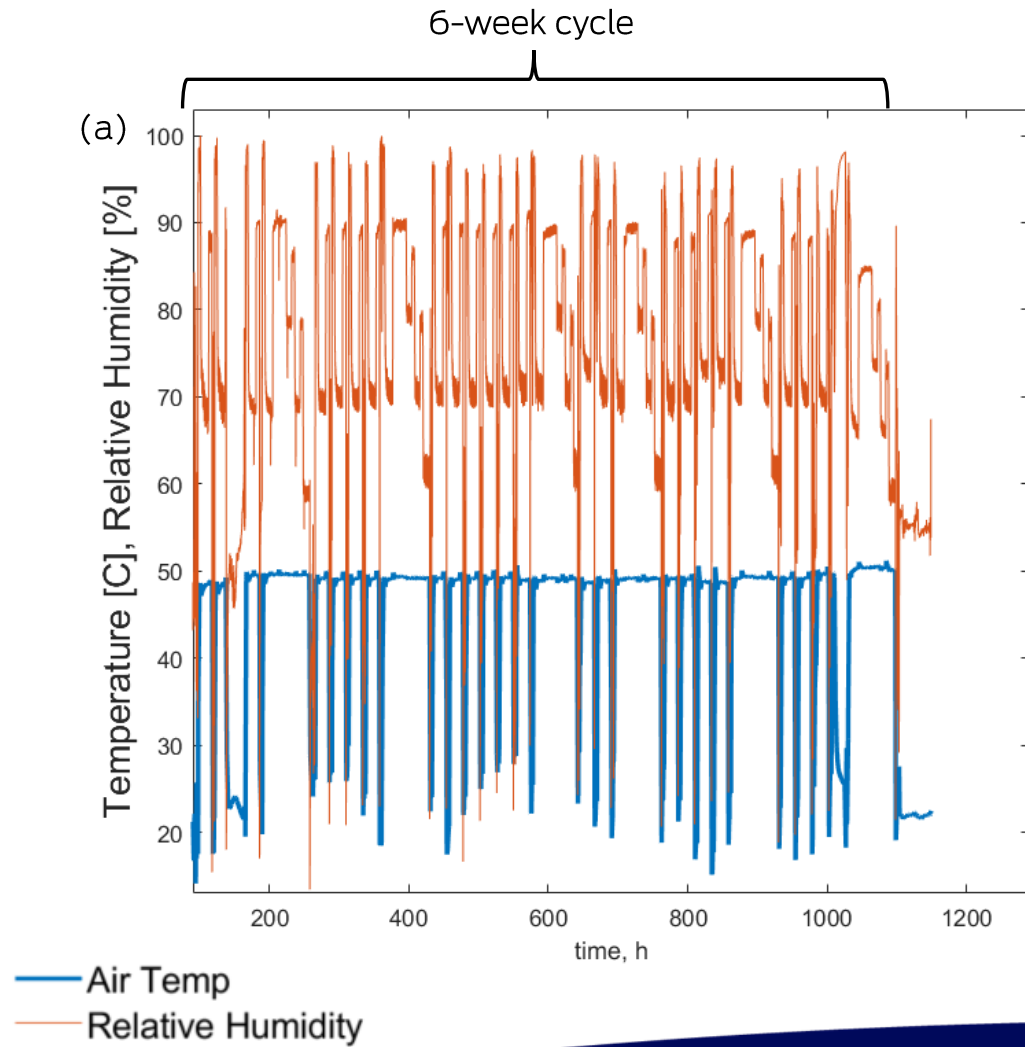
Results: 2-week Lab cyclic corrosion test

5-day cycle weekend cycle



T and RH measured by Luna sensor in corrosion chamber

Results: 6-week On-vehicle corrosion test

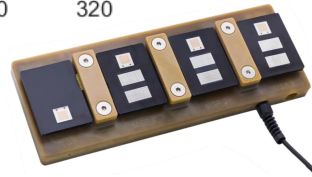
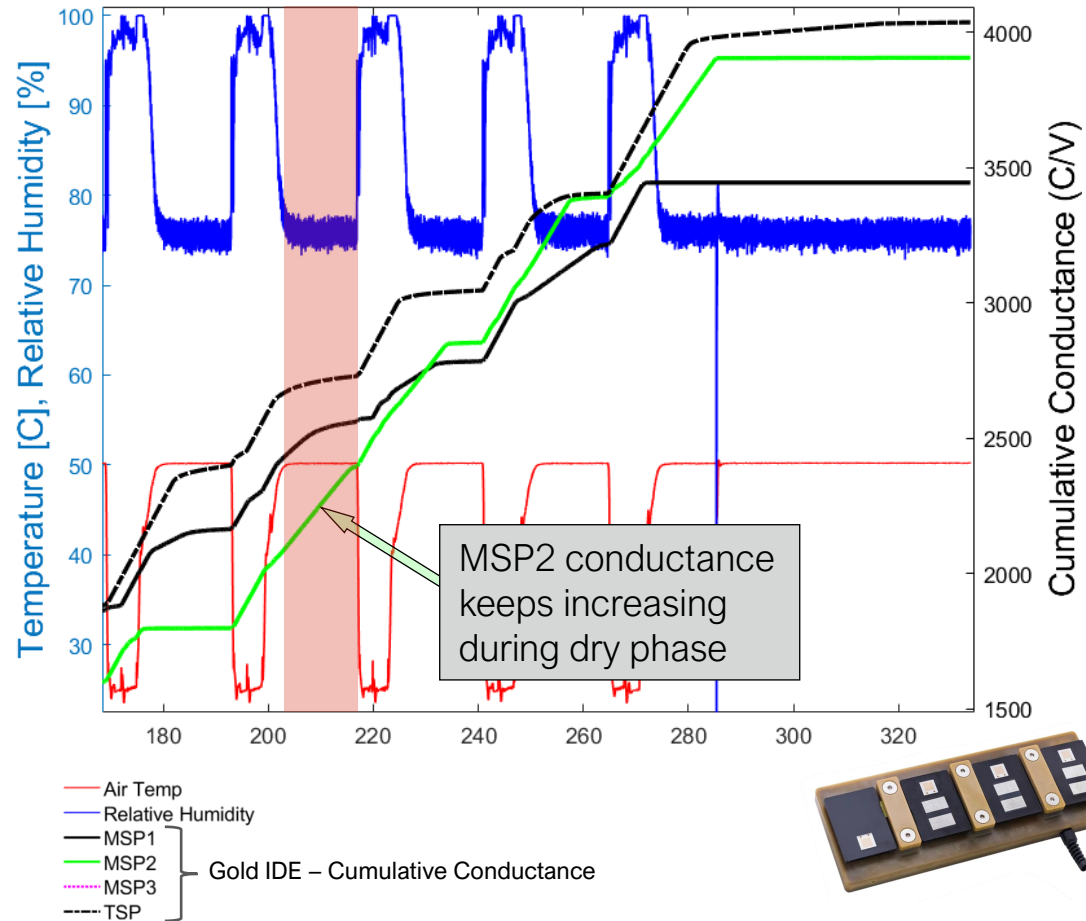


T and RH measured by Luna sensor
during driving and climate chamber conditions

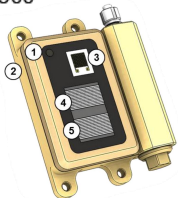
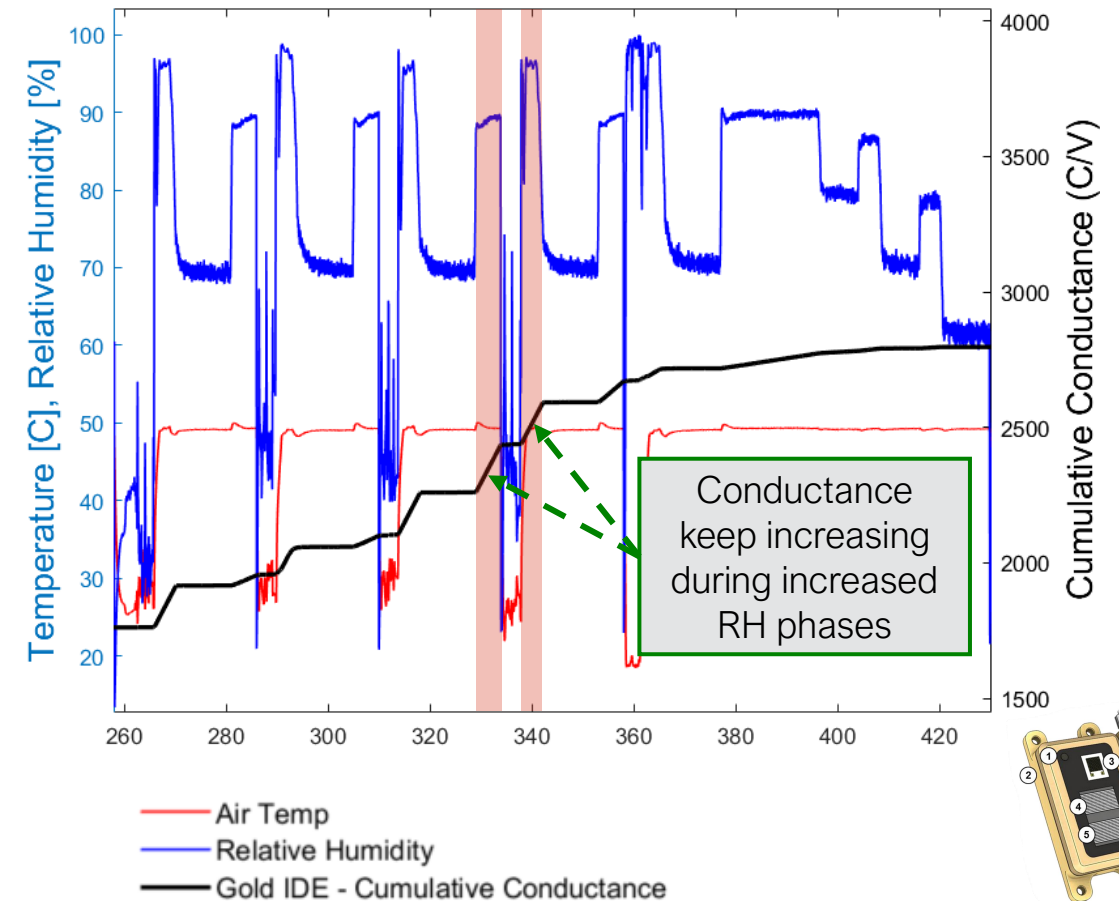
Results: Comparison of Cumulative Conductance for Lab vs On-vehicle conditions on week two



Lab corrosion conditions

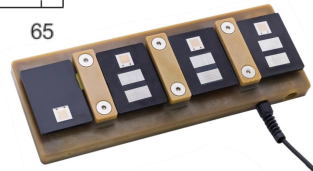
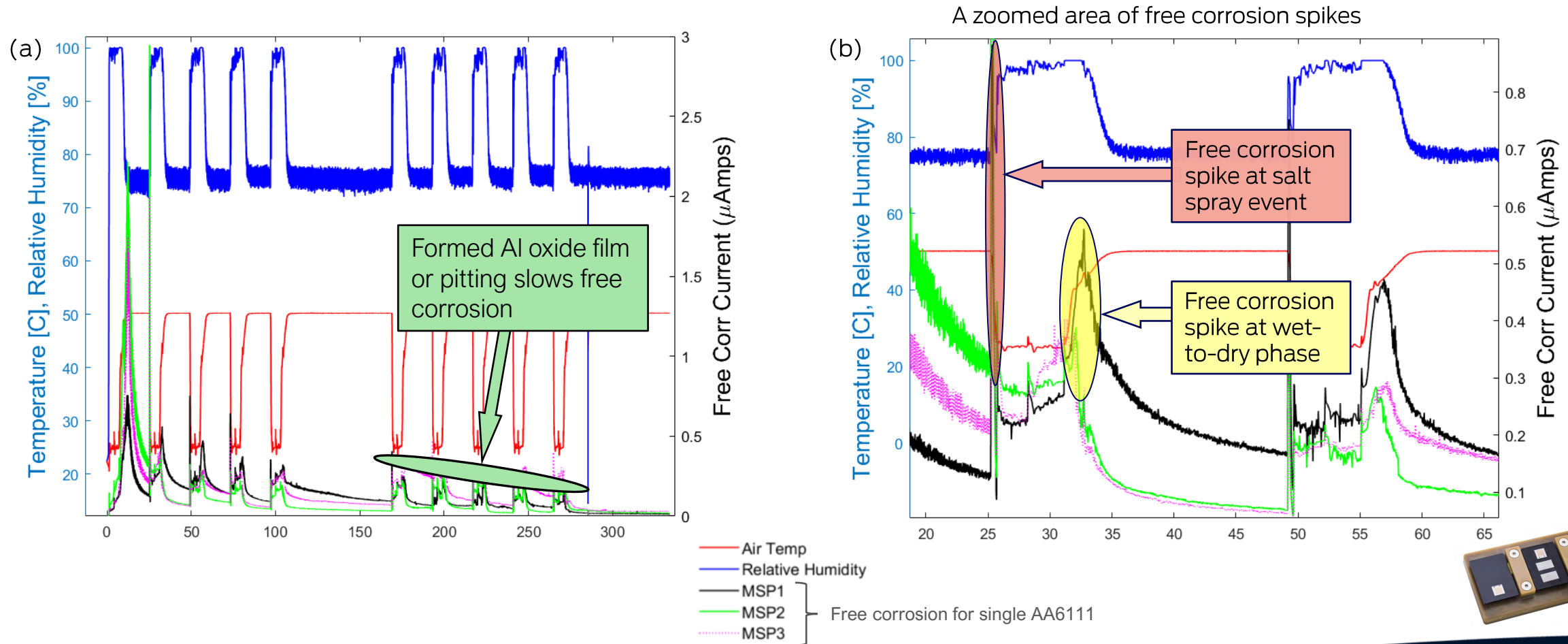


On-vehicle corrosion conditions



- Conductance for the selected sensor location in On-vehicle test is ~1.5 times lower than conductance in Lab test over 2 weeks

Interesting observation: Lab test - Free corrosion for single alloy AA6111



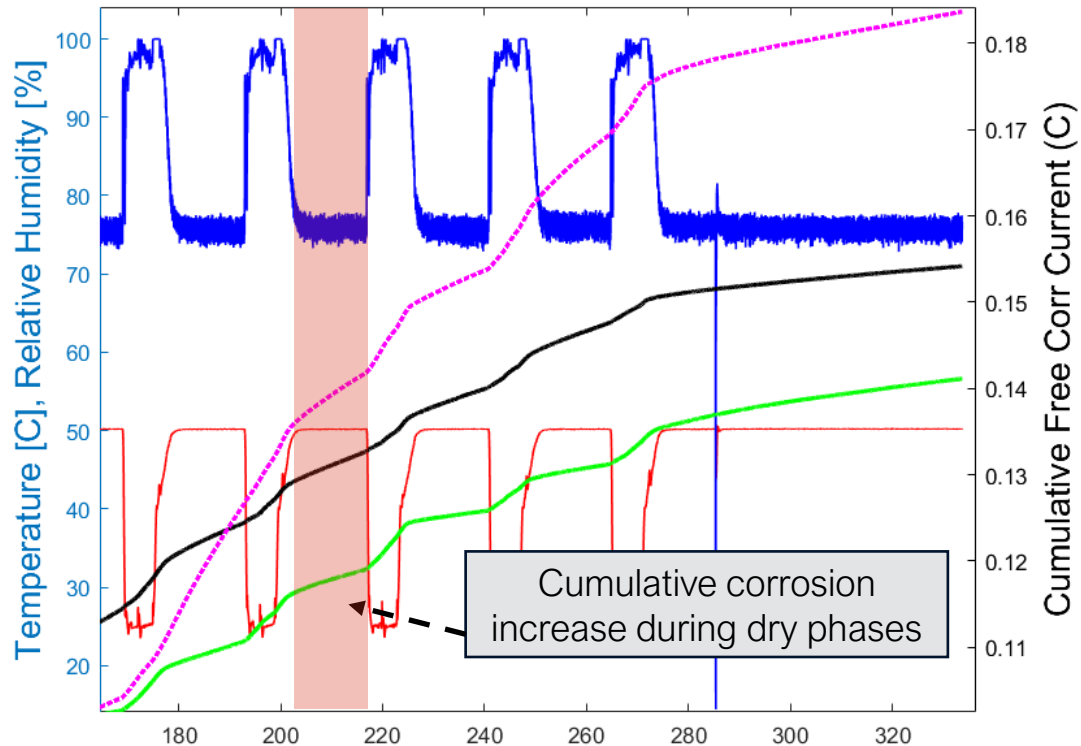
- (a) Free corrosion decreases due to increased R from Al passivation or/and pitting progression

- (b) Free corrosion current peaks as an indicator of increased conductance

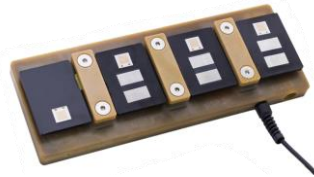
Results: Comparison of Cumulative Free Corrosion for Lab vs On-vehicle conditions on week two



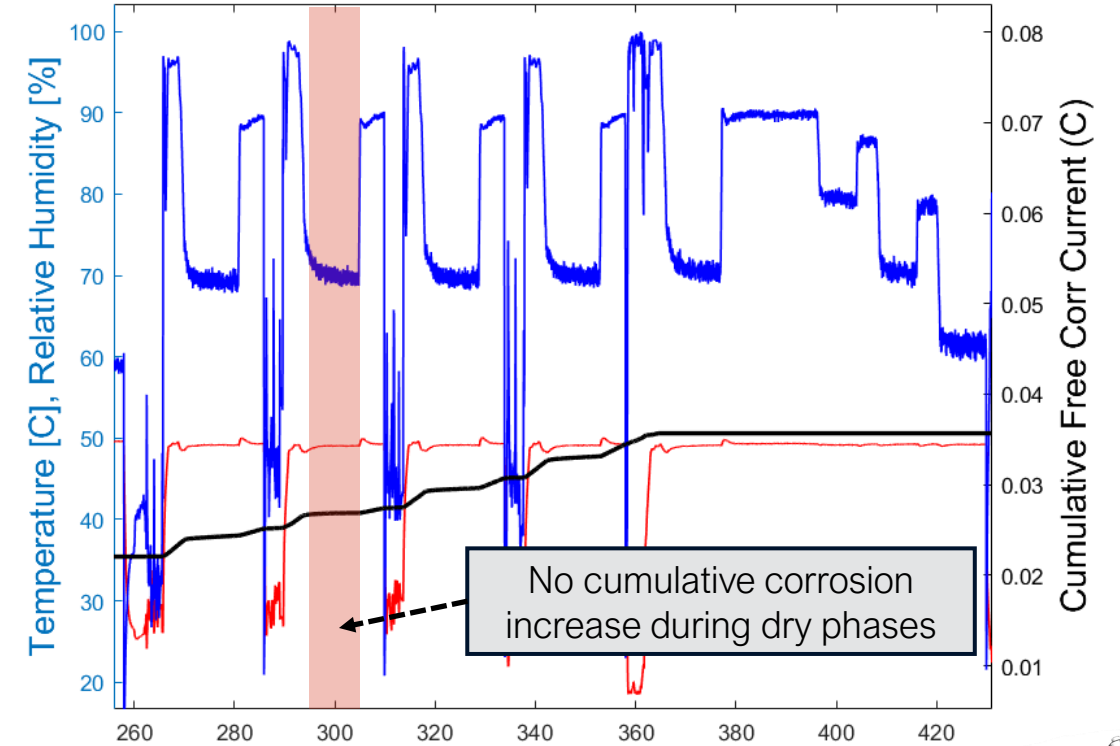
Lab corrosion conditions



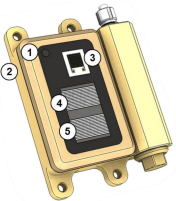
— Air Temp
— Relative Humidity
— MSP1
— MSP2
— MSP3 } AA6111 - Cumulative Free Corrosion



On-vehicle corrosion conditions



— Air Temp
— Relative Humidity
— AA6111 - Cumulative Free Corrosion
— MSP3

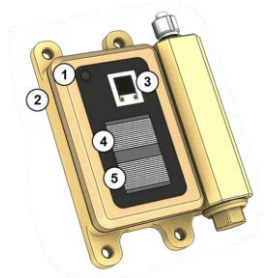
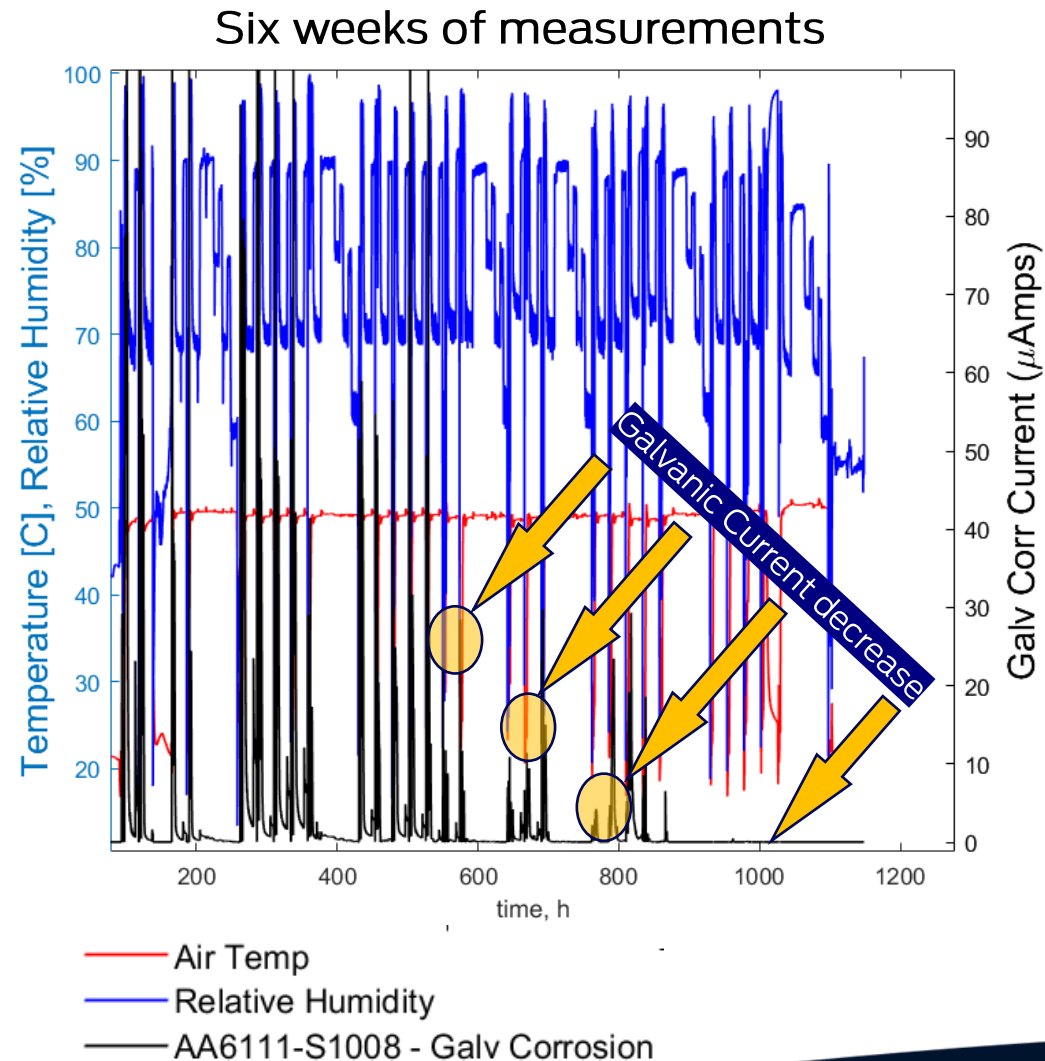


- Free corrosion current for the selected sensor location in On-vehicle test is 4-5 times lower than free corrosion in Lab test over 2 weeks

Interesting observation

Galvanic Corrosion currents for On-vehicle corrosion conditions

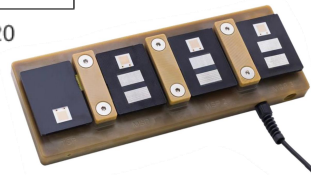
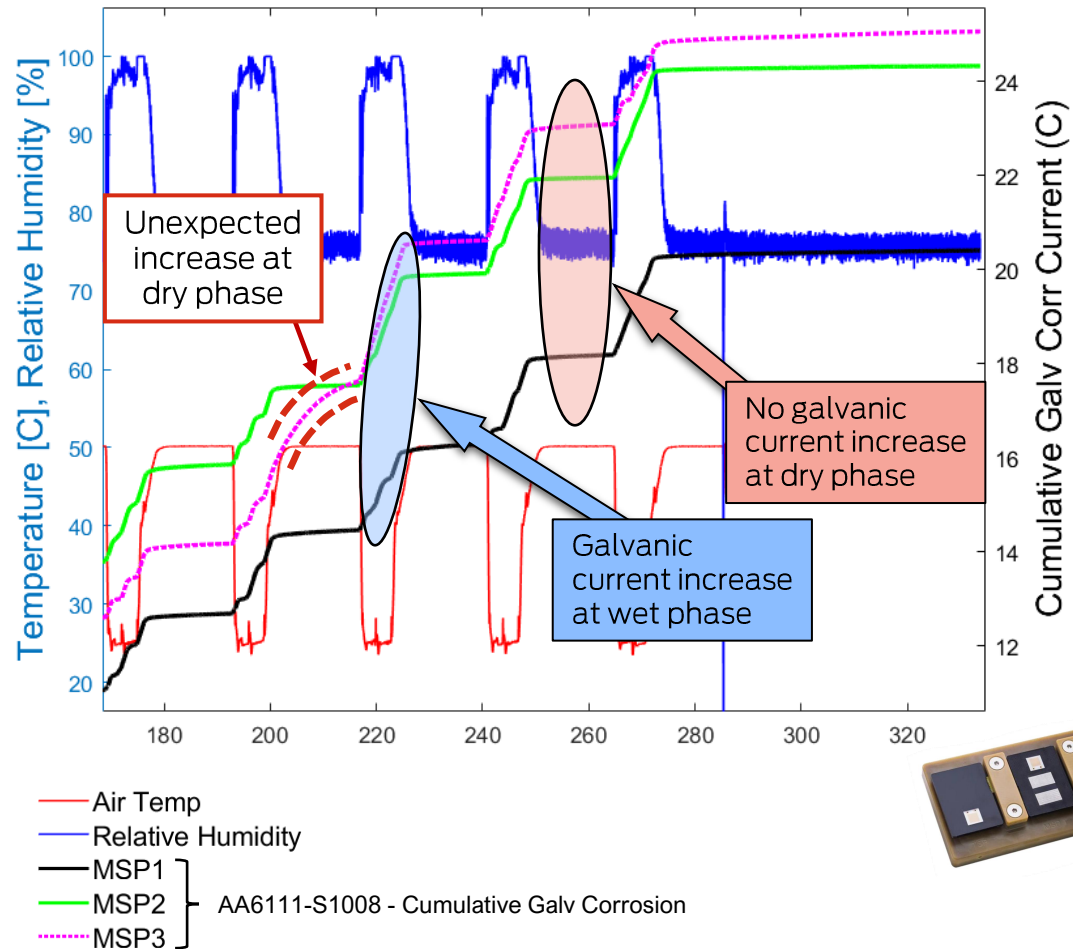
- Galvanic currents decreased even though wet phases increase starting from 3rd week.
- The decrease in galvanic current can result from steel (cathode) corrosion that may occur independently while the Al and steel do not have strong electrolyte connections.



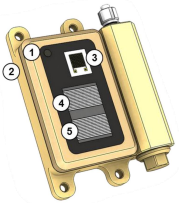
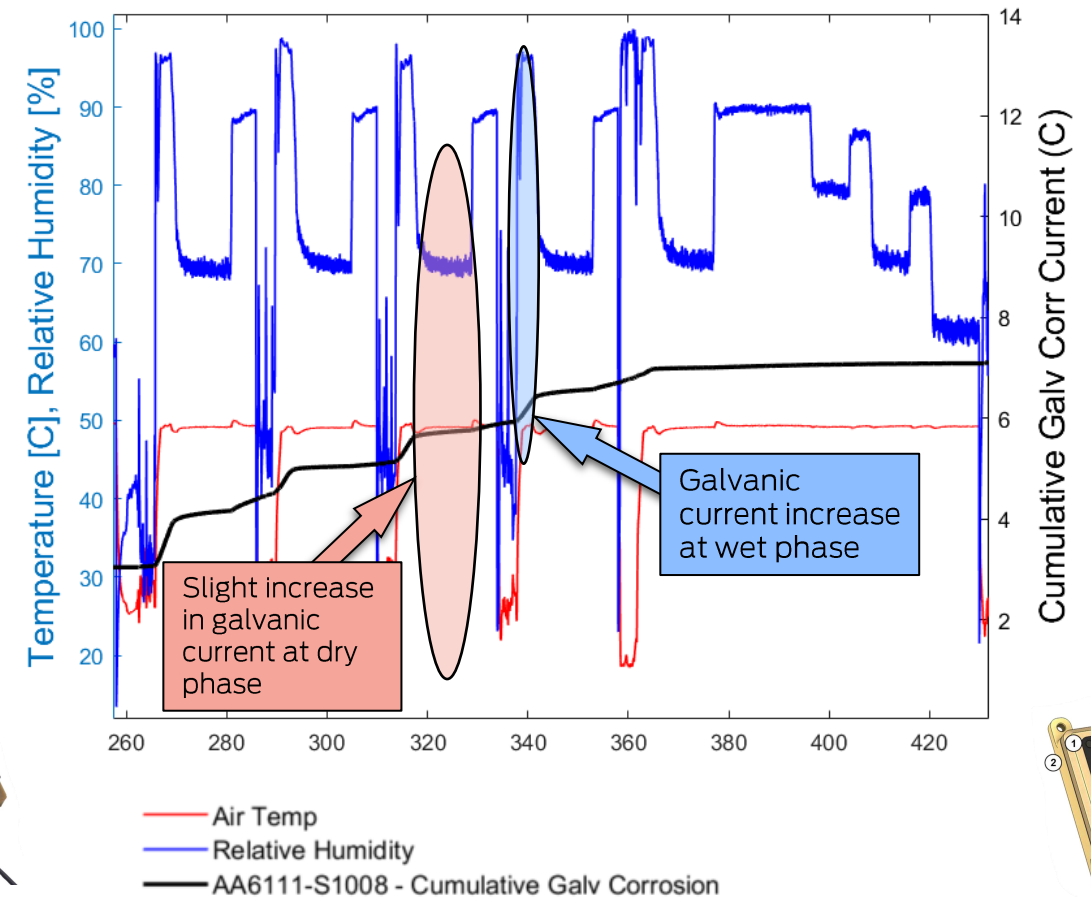
Comparison of Cumulative Galvanic Corrosion currents for Lab vs On-vehicle conditions on week two



Lab corrosion conditions



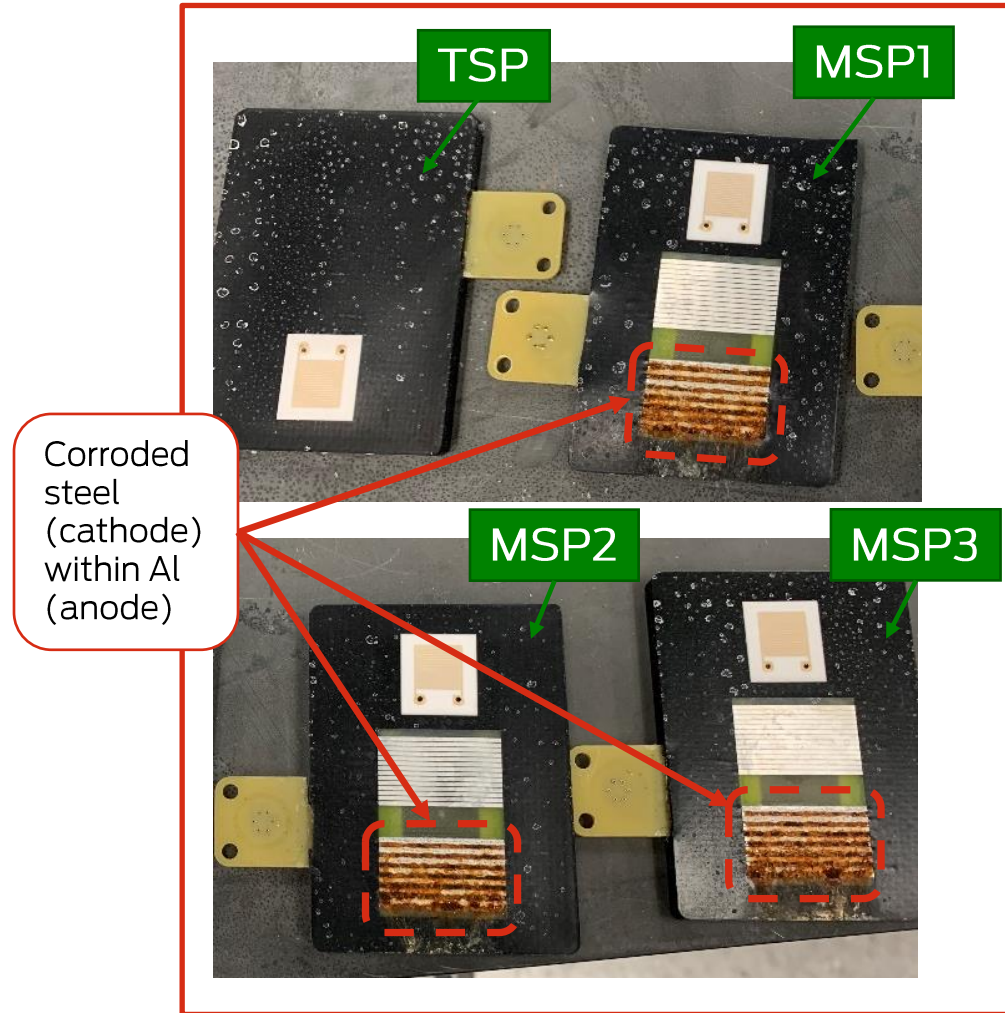
On-vehicle corrosion conditions



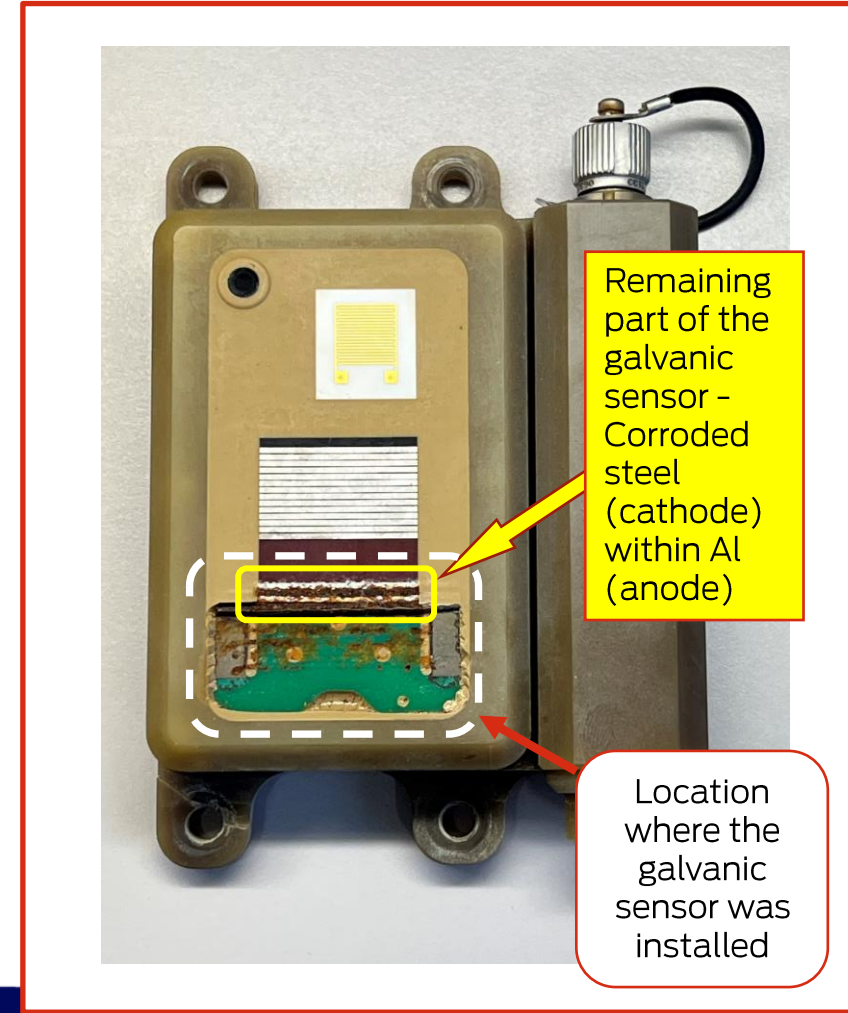
- Galvanic corrosion current for the selected sensor location in On-vehicle test is ~3 times lower than galvanic corrosion in Lab test over 2 weeks

View of Luna CorRES and Acuity LS sensors after Lab and On-vehicle test conditions

After Lab test – 2 weeks



After On-vehicle test – 6 weeks



- Both Luna CorRES and Acuity LS galvanic corrosion sensors rusted due to independent corrosion of steel during environmental cycles

Summary: Data Collected Over 2 Weeks Of Testing



Test	Sensor	Measured Parameters		
		Cumulative Conductance, (C/V)	Cumulative Free Corrosion, (C)*10 ⁻²	Cumulative Galvanic Corrosion, (C)
Lab	TSP	4036	N/A	N/A
	MSP1	3444	15.4	20.4
	MSP2	3905	14.1	24.3
	MSP3	7290	18.3	25.1
Proving Ground	Acuity	2803	3.6	7.1

The Corrosion Currents Measured In The Lab Test Were
3 – 4 Times Higher Than Those Measured On-Vehicle

Sensors Assessments



- The conductance measurements reflect T and RH changes programmed in the test cycles
- The free corrosion measurements in the lab test tracked with the environmental conditions generally, but diminished with exposure time
- The free corrosion measurement on-vehicle indicated a less-aggressive environment than the lab test for the selected sensor location
- The galvanic corrosion sensors were maxed out in wet phases of our tests
- The galvanic current does not account for self corrosion of the cathodic electrode

Careful Interpretation & Multiple Measurements
Required To Make Reliable Assessments

Acknowledge

Thanks to Jacob Meisberger for conducting experiments and Niamh Hosking, and Mark Nichols for supporting the data analysis work.

Thanks to Robert Garcia from MPG and Ken Redlin from Corrosion Engineering and Tony Misovski for getting the sensor installed at the proving ground.

Thanks to Luna Labs for supporting the project.

Happy to answer to your questions