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Galvanic Corrosion Study on SS Cartridge Design

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Outline

- Background
- Objective
- Procedure
- Results
- Conclusions
- Future Work

Background

- Lightweight Cartridge for Small Arms program at Picatinny
  - Designing/developing stainless steel cartridge case
  - For structural support inserting Al plug
- Galvanic corrosion
  - Dissimilar metals that are in electrical contact while immersed in a solution electrolyte[1]
- 3 main galvanic couples of concern shown below:

Courtesy of Wikimedia Commons (public domain)

1.	Plug Insert 7075 T6 Aluminum	Cartridge Case 305 Stainless Steel
2.	Bullet Jacket Cu Alloy 220	Cartridge Case 305 Stainless Steel
3.	Cartridge Links 1045 Carbon Steel	Cartridge Case 305 Stainless Steel

1. Jones, D.A., Principles and Prevention of Corrosion, ©1996, Prentice-Hall, Inc., Upper Saddle River, NJ, pg. 168-198.

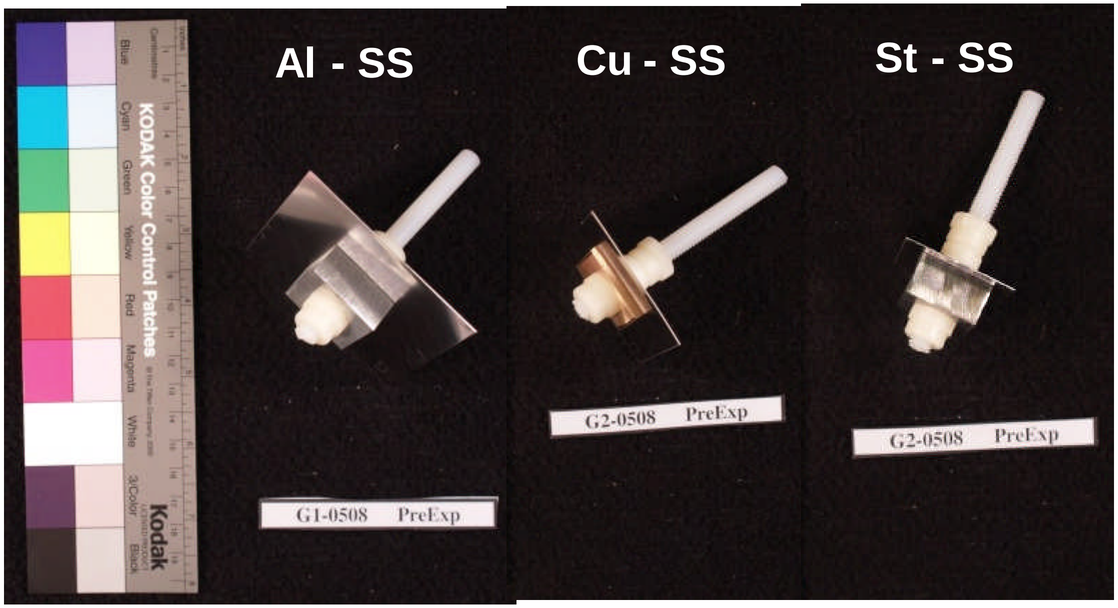
Objective

- To investigate the galvanic interaction between the materials used in the new ammunition design under aggressive conditions to determine if the there will be a corrosion issue in the future.

Photo courtesy of U.S. Army (taken by Sgt. Tierney Nowland)

Procedure

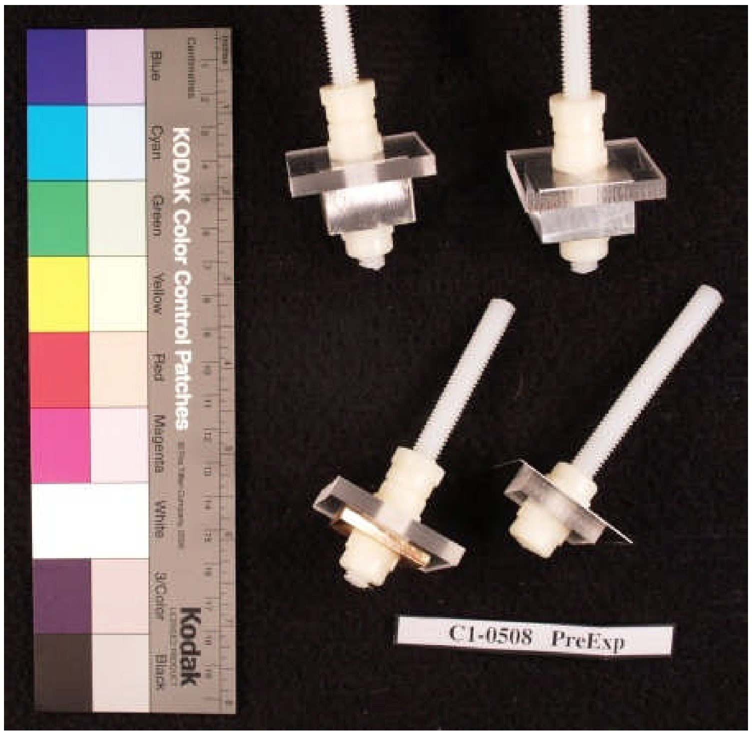
- **Materials/Configuration**
  - Area ratio calculation (based on "ASTM G71"[2])
    - SS cartridge to aluminum insert = **5 to 1**
    - SS cartridge to copper jacket = **4 to 1**
    - SS cartridge to steel links = **1 to 1**
  - Small pieces of each material were cut, drilled, polished and cleaned
  - Each couple was assembled using a nylon threaded rod and bolts



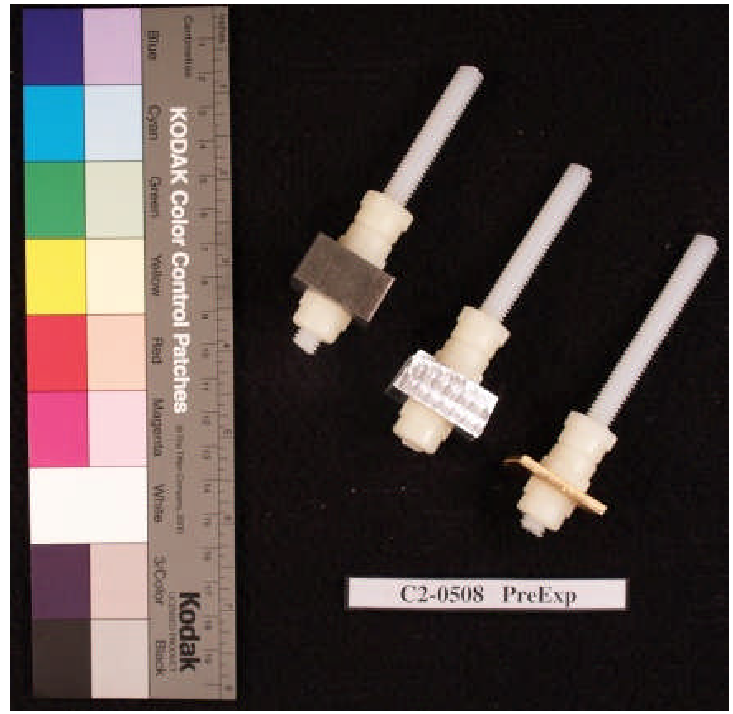
2. ASTM G71, "Conducting and Evaluating Galvanic Corrosion Tests on Metals"

Procedure

- **Control Specimens**



Specimens with plastic backing

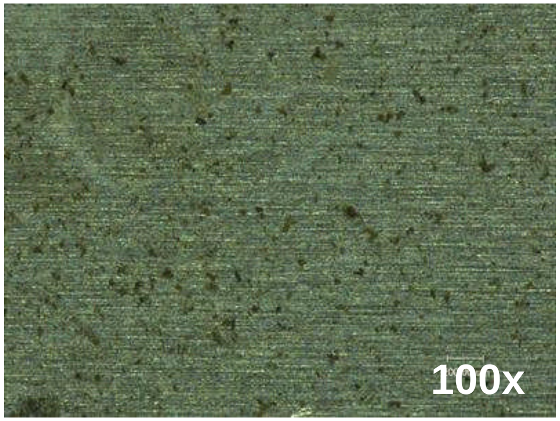


Specimens without plastic backing

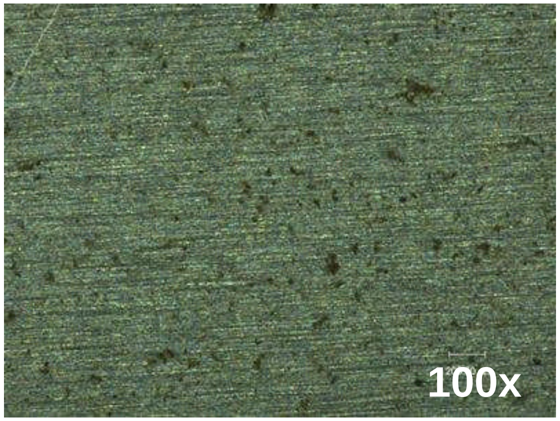
Results – Atmospheric Exposure

- No significant difference was visible between the Al-SS coupled and uncoupled materials after 3 months of exposure.
- This was expected because both Al and stainless steel form strong passive oxide layers in the presence of oxygen in the atmosphere.
- Only slight discoloration on the Al was noticed on the face that was mated with the stainless steel.

Slight discoloration on Al backside that was mated with the stainless steel



(a)

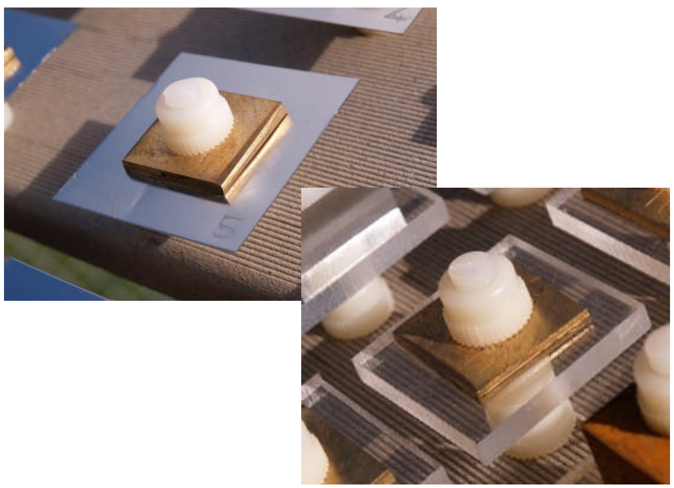


(b)

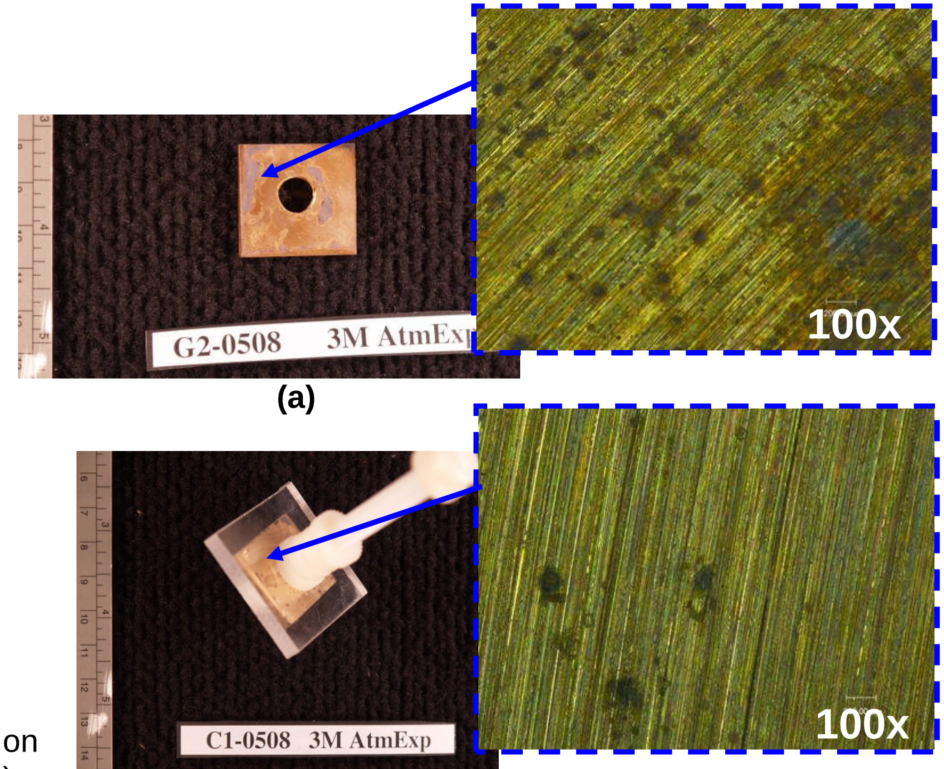
Pitting of stainless steel in crevice formed from (a) galvanic couple with Al and (b) plastic backing.

Results – Atmospheric Exposure

- As in the case of the Al-SS couples, the Cu alloy-SS materials did not corrode significantly different when coupled vs. uncoupled.
- The corrosion on the backside of the galvanic couple specimen was more evident than that of the plastic-backed specimen. The crevice formed in both setups appears to have contributed to the degradation but the galvanic couple provided a stronger driving force.
- The stainless steel specimens (both coupled to the Cu alloy and the plastic) exhibited pitting from the crevice formed.



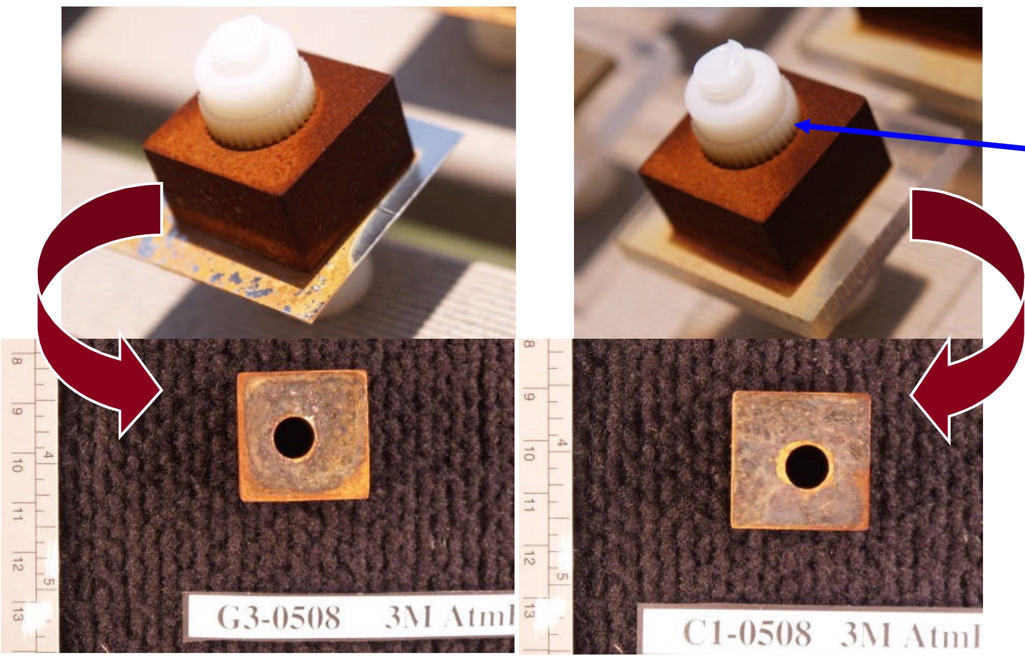
Slight tarnish on surfaces after 1 month of exposure



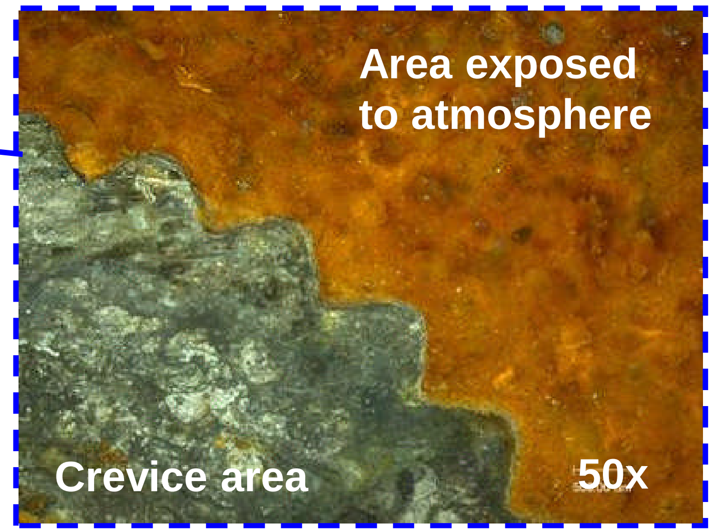
After 3 months atmospheric exposure on Cu alloy (a) face coupled to SS and (b) face coupled to plastic backing.

Results – Atmospheric Exposure

- As expected, the carbon steel specimens exhibited the most atmospheric corrosion.
- General corrosion was apparent on the surface of all carbon steel specimens after 1 week of atmospheric exposure.
- However, the corrosion was not significantly different in the coupled as compared with the uncoupled arrangement.



Carbon steel specimens during atmospheric exposure (a) galvanic couple (St-SS) after 3 months, and (b) control with plastic backing after 3 months



Border of crevice created by nylon nut on front face of carbon steel.

Results – Atmospheric Exposure

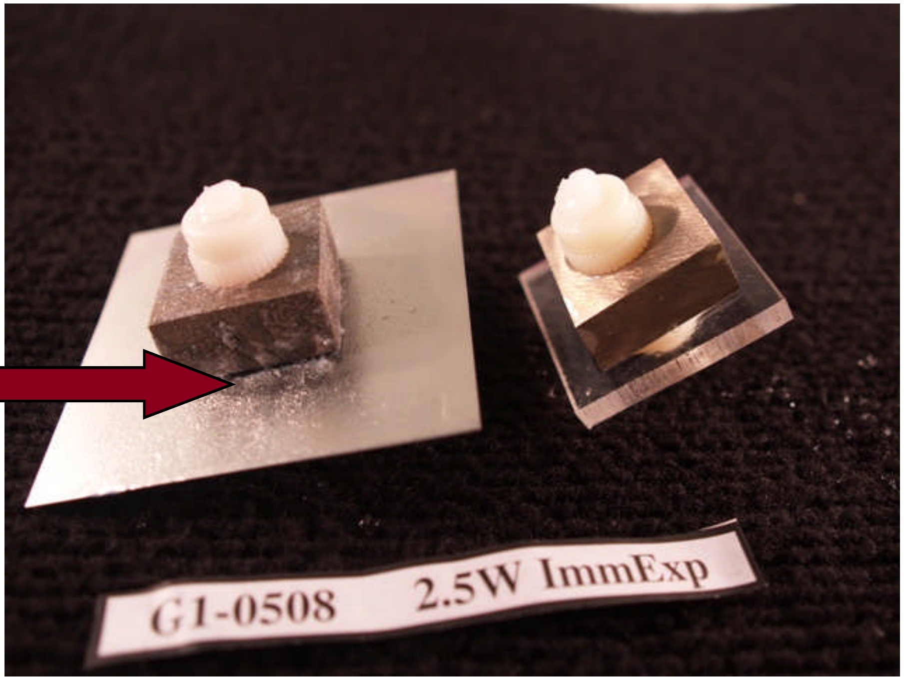
- For the atmospheric exposure specimens in general, it can be stated that the effect of being coupled to stainless steel did not significantly accelerate the corrosion rate.
- More time-of-wetness and a greater exposure to corrosive agents (chloride ions, sulfur dioxide, etc.) may have provided a more noticeable difference between coupled and uncoupled specimen degradation.
- The final set of specimens will continue to be exposed and monitored over the next year.
- Weight loss will be measured upon removal of final specimens however localized corrosion such as pitting can be misleading .

Atmospheric exposure rack at Picatinny Arsenal

Results – Constant Immersion

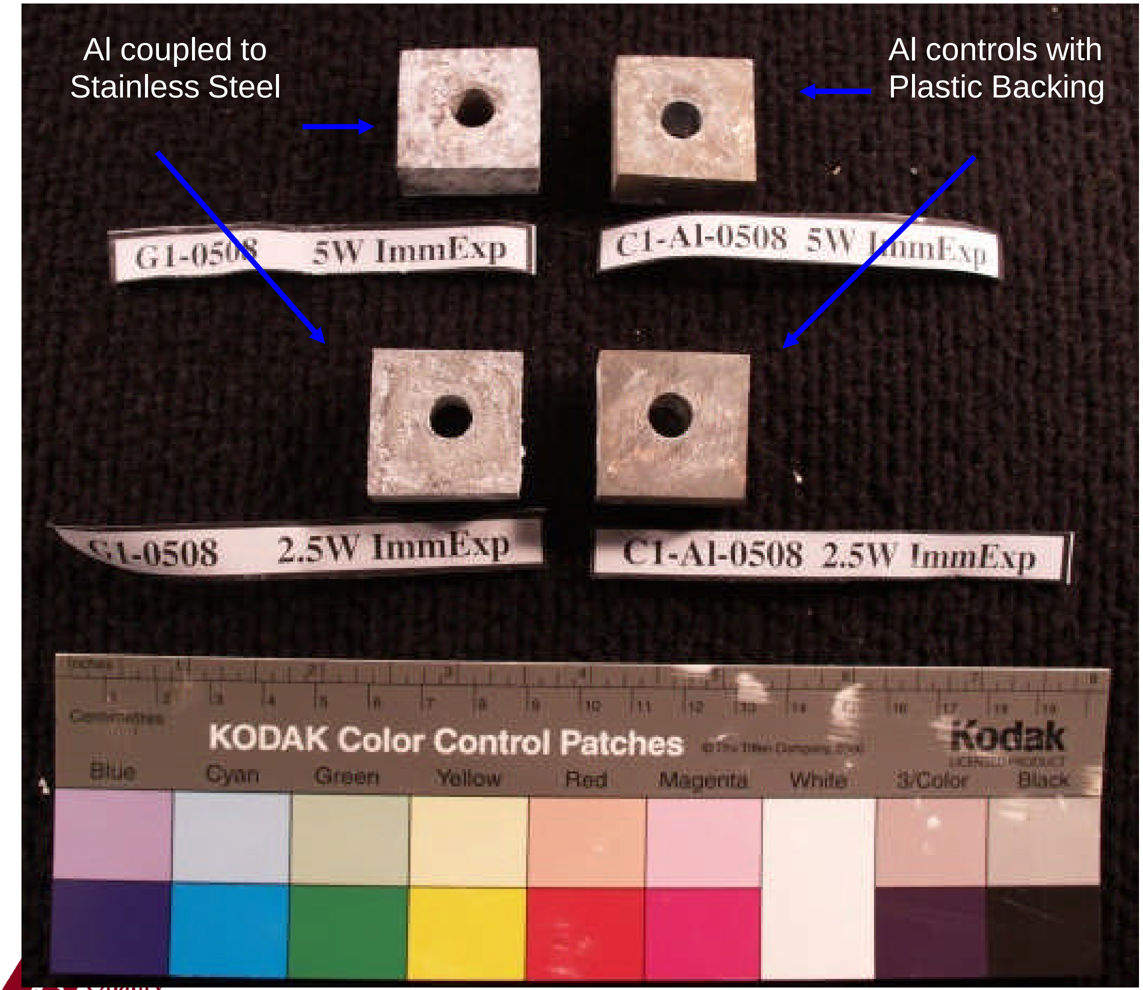
- **After 2.5 weeks of immersion** in artificial seawater, the galvanic coupled Al had a considerably large amount of white corrosion product.
- When the couples were separated for further examination, it was very clear that the galvanic couple had accelerated the Al corrosion rate.

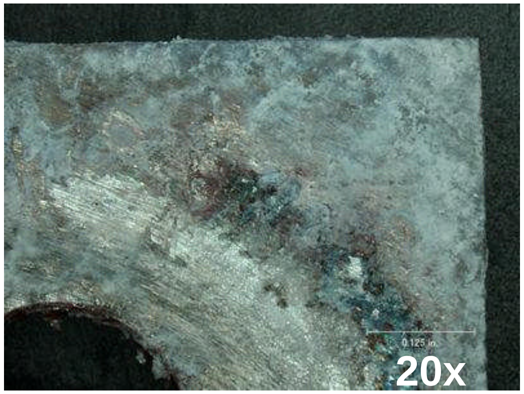
Corrosion product



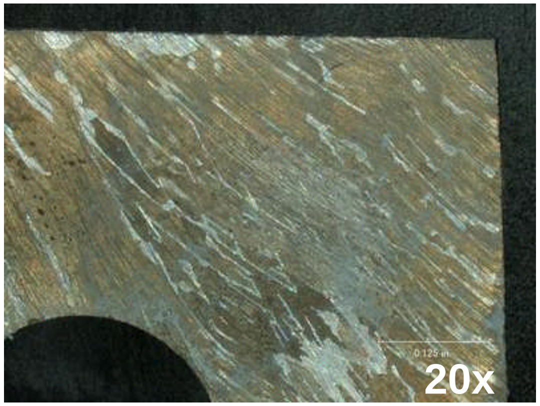
Results – Constant Immersion

- **After 5 weeks of immersion**





(a)

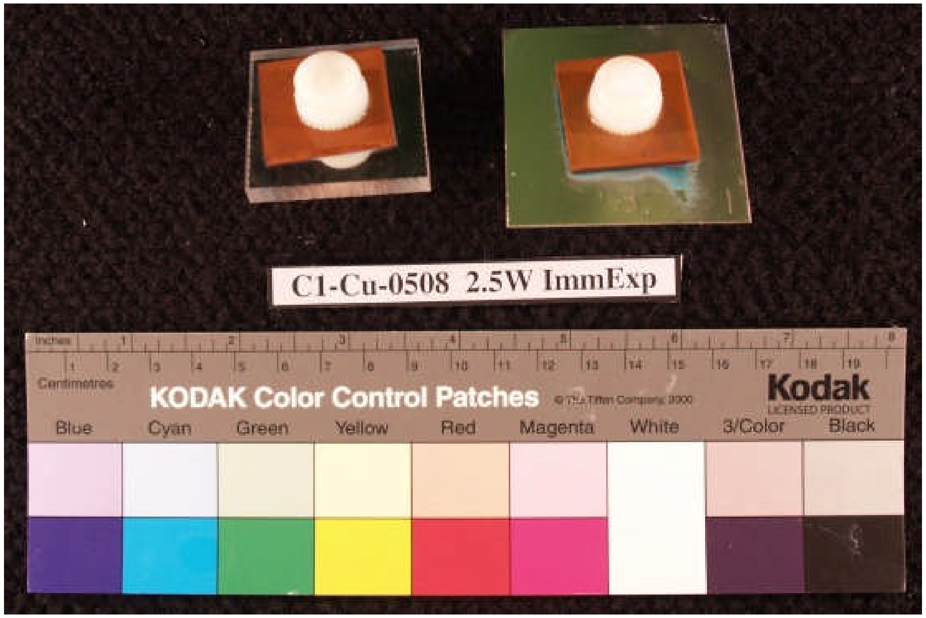


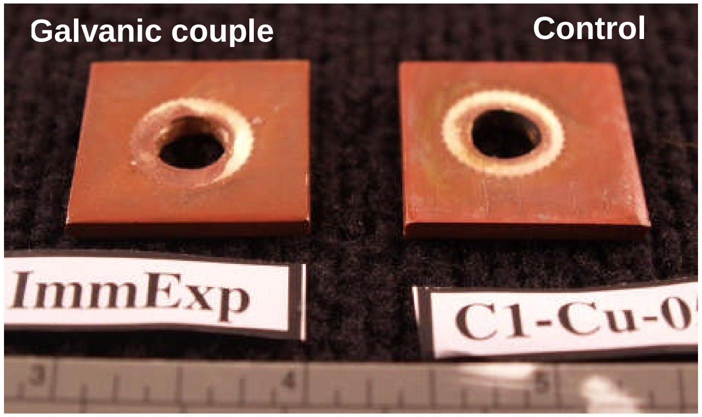
(b)

Digital microscope images of Al specimens after 5 weeks of constant immersion in artificial seawater (a) coupled with stainless steel and (b) with plastic backing

Results – Constant Immersion

- **After 2.5 weeks** of immersion in artificial seawater, one set of specimens was removed for inspection.
- It was already apparent that the galvanic couple Cu alloy was corroding more than the plastic-backed specimen.
- The area underneath the nylon nut is still untarnished.

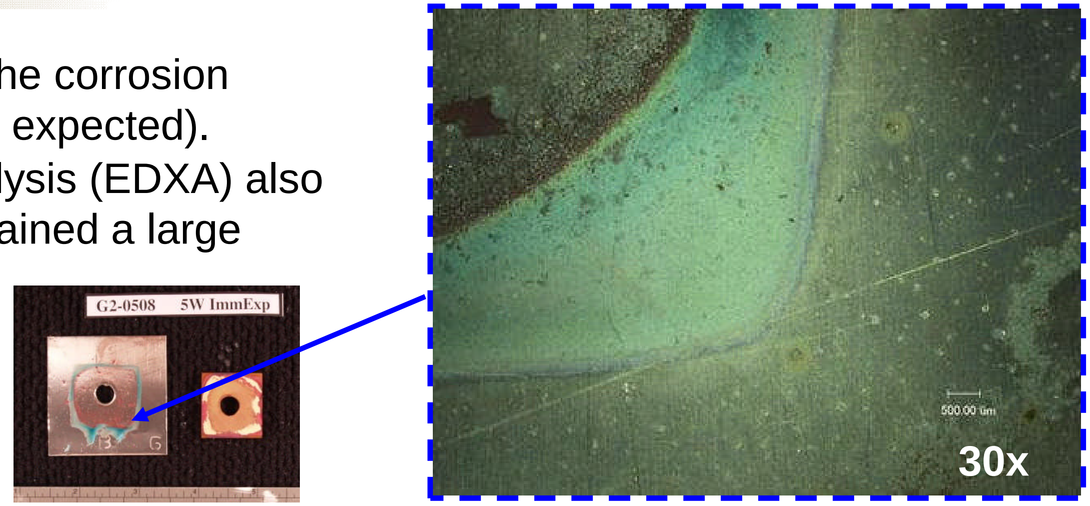




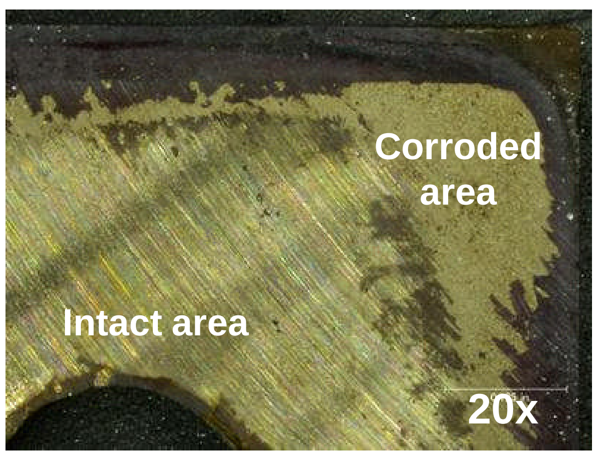
Front sides of Cu alloy specimens after being separated from coupling setups

Results – Constant Immersion

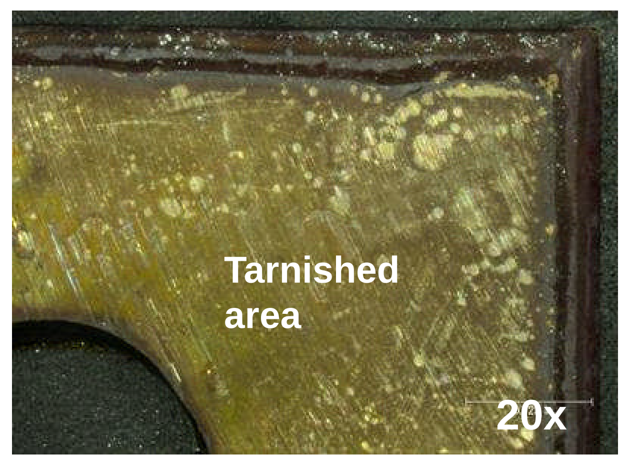
- Analysis supported the idea that the corrosion product was from the Cu alloy (as expected).
- The Energy Dispersive X-ray Analysis (EDXA) also showed that the red material contained a large amount of Ca and S.



Digital microscope image of corrosion product residue from the Cu alloy on the stainless steel specimen after 5 weeks of immersion in artificial seawater.



(a)



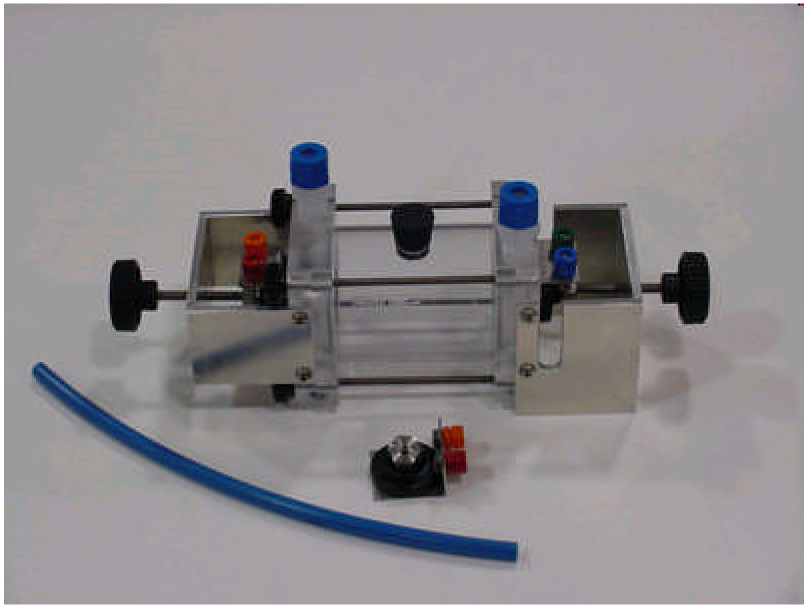
(b)

Digital microscope images of Cu alloy specimens after 5 weeks of constant immersion in artificial seawater (a) coupled with stainless steel and (b) with plastic backing.

Results – ZRA

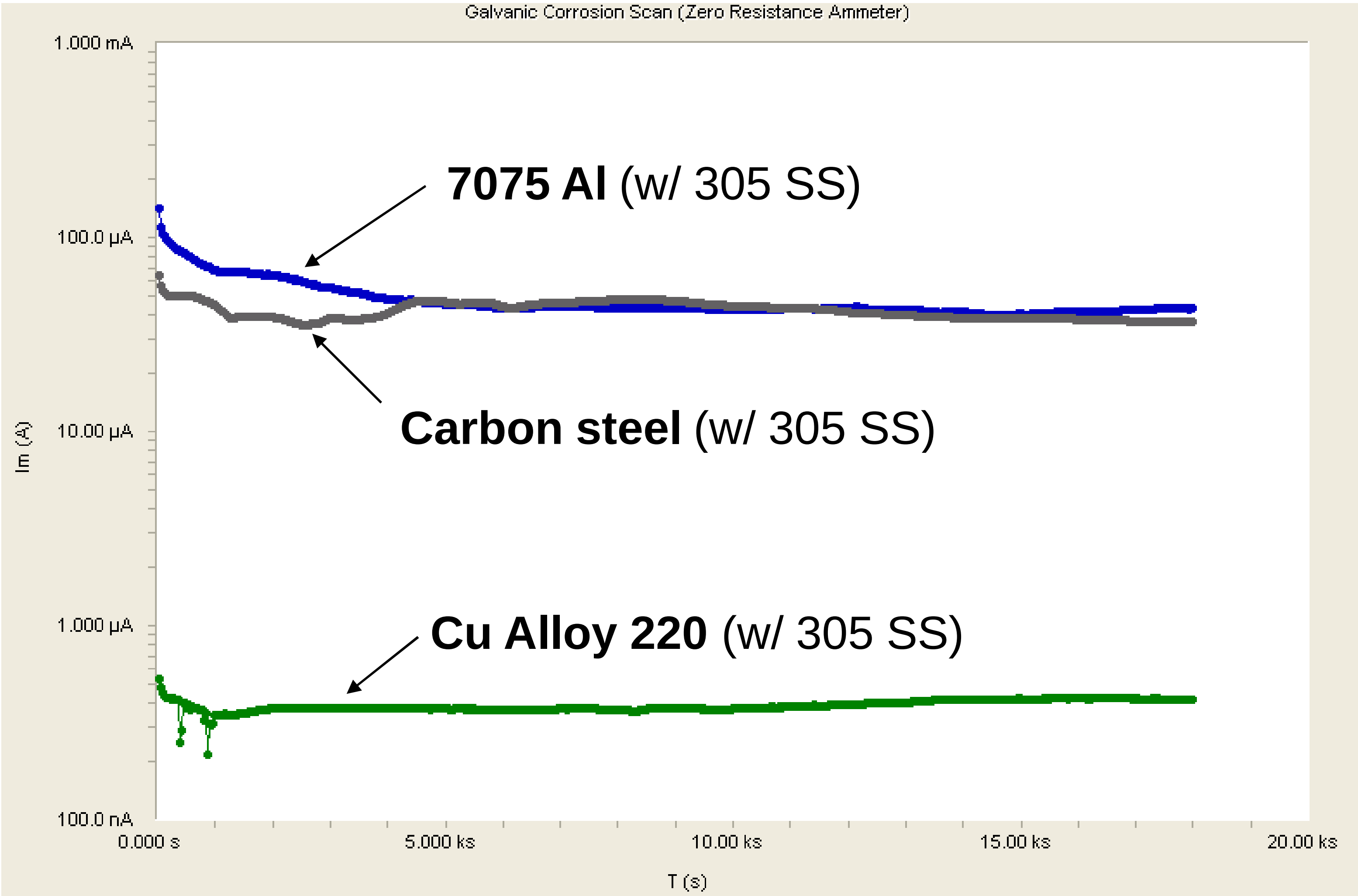
- **Zero Resistance Ammeter (ZRA) Test**

An additional test was conducted to compare the galvanic reactions of the different materials with stainless steel. In this electrochemical test, a zero resistance ammeter was used to maintain a constant potential difference of zero between the two materials of interest. The area ratios were kept equal to accommodate the test setup and the subsequent analysis.

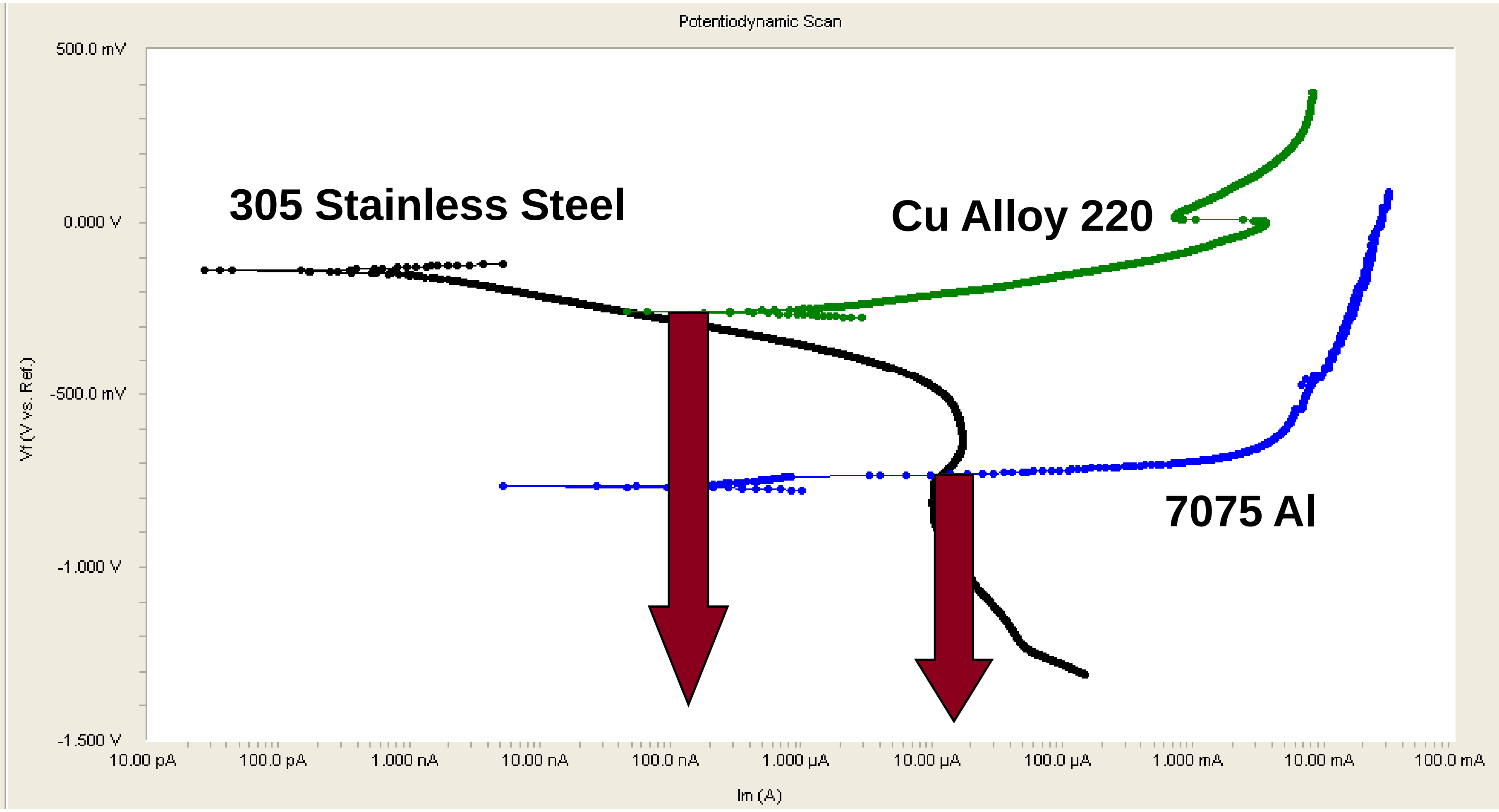


http://www.mpmtechnologies.com/MultiPurpose-Corrosion-Cell-Pic1.htm

Results - ZRA

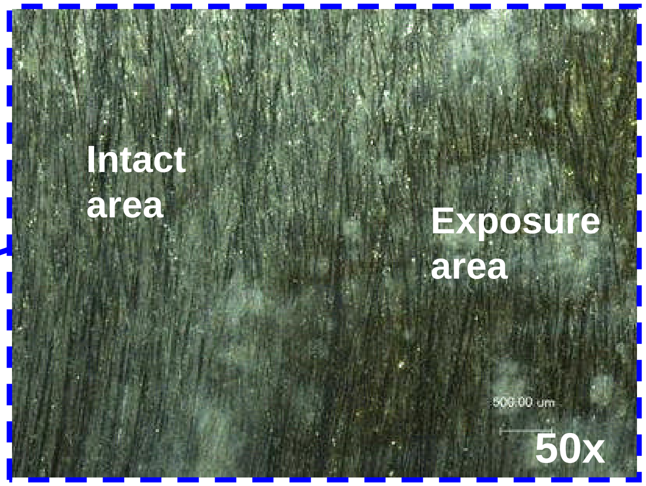

Galvanic Corrosion Scan (Zero Resistance Ammeter)
1.000 mA
100.0 µA
10.00 µA
1.000 µA
100.0 nA
Im (A)
0.000 s
5.000 ks
10.00 ks
15.00 ks
20.00 ks
T (s)
7075 Al (w/ 305 SS)
Carbon steel (w/ 305 SS)
Cu Alloy 220 (w/ 305 SS)

Results – Potentiodynamic Curves

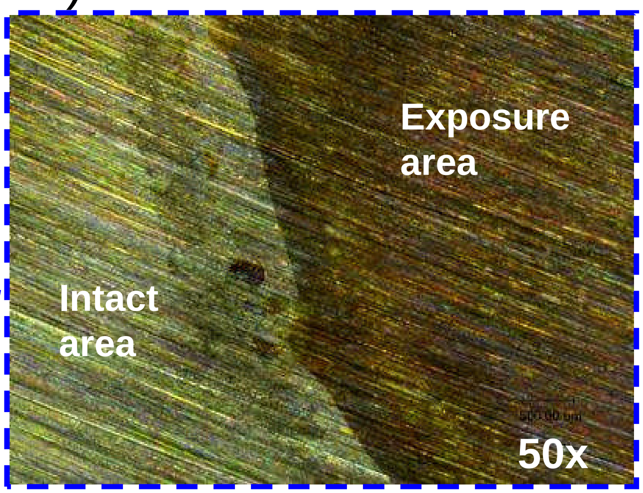


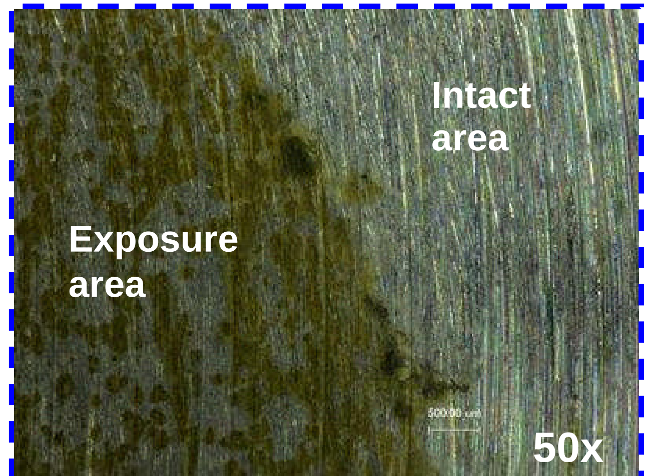
Results - ZRA

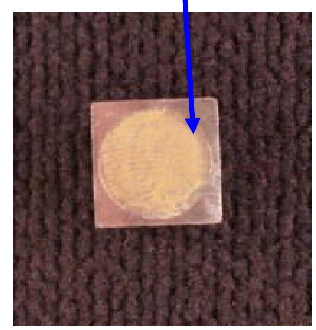
Al (w/ SS)



Cu Alloy (w/ SS)







Carbon steel (w/ SS)

Conclusions

- Testing results warrant the close monitoring of 7075 Al T6 plugs in the new design although it does not conclusively show that the plugs will corrode given the complicated environment within a cartridge case. A protective layer such as an anodized finish and/or somehow designing the plug so as not to create an electrical connection with the stainless steel cartridge case may provide further protection of the Al plug. Also, an alternate Al alloy may reduce the risk of stress corrosion cracking.
- By monitoring for evidence of blue/green corrosion product and maintaining proper storage of cartridges, the potential degradation of Cu Alloy 220 in contact with the stainless steel cartridge cases can be avoided and should not be of major concern.
- If carbon steel links are properly phosphated and treated with oil, there should not be a significant galvanic corrosion issue with the stainless steel cartridges. Any corrosion should be very visible as red corrosion product forming on the carbon steel links.

Conclusions

- The 305 stainless steel may be slightly vulnerable to pitting in any crevice conditions and should therefore be monitored.
- Materials and environments used in this study were chosen to represent the new cartridge design but surface treatments, manufacturing processes, actual environments, etc. can lead to unique results.
- Continued atmospheric exposure of several galvanic couples is underway. Any new pertinent information found upon further analysis will be reported.

Future Work

- **Focus**
  - Al and SS
  - Propellant (breakdown, chemical reactions, etc.)
  - Environment within cartridge
    - Determine humidity/moisture content of concern
- **Different alloys of Al**
- **Examine Actual Parts**
  - Materials
  - Manufacturing processes

Acknowledgements

- **PM Crew Served Weapons** (PM CSW)
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- **Armaments Research Development Engineering Center** (ARDEC)
  - **Don Skelton** (AMSRD-AAR-MEE-M) and the rest of the Organic Materials Corrosion Branch
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  - **Mark Leng** (AMSRD-AAR-MEM-I) Small Caliber Munitions Division

Photo courtesy of U.S. Army (taken by Spc. Richard Del Vecchio)

QUESTIONS ?

AP Photo