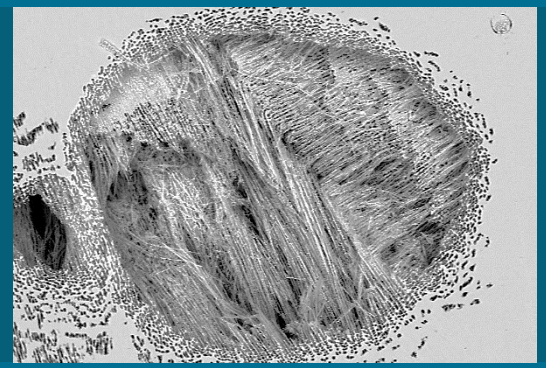
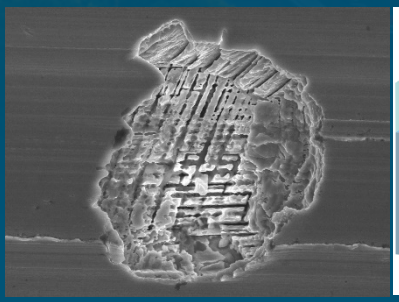
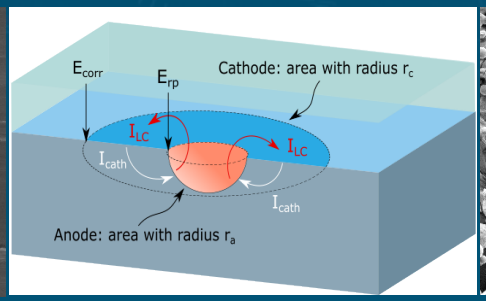
SAND2021-2457C

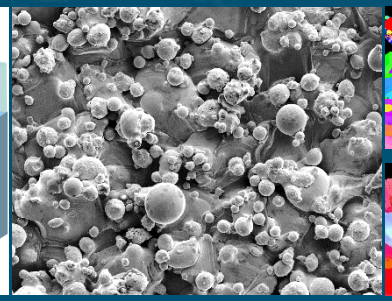
Sandia National Laboratories

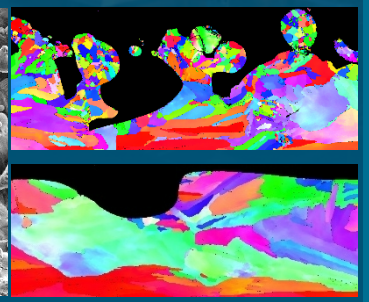
Disinfectant corrosivity with shipboard HY80 steel











PRESENTED BY

Michael Melia (SNL)

Co-author: Jay Taylor (SNL)

U.S. DEPARTMENT OF ENERGY NNSA

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Acknowledgements

Funding: SNL Laboratory Directed Research and Development (LDRD) Program.
This was a rapid response LDRD call roughly a month after the pandemic lockdowns went into place.

Many people to thank…
SNL: Rob Sorensen, Bruce Kelley, Patrick Burton, Christina Profazi, Jie Er Yang, Wahid Hermina, Edward Cole.
DECON Seven (D7): Dr. Mark Tucker.
NSCW Carderock Division: Dr. Matthew Draper.

Thanks to the symposium organizers for this opportunity.

COVID-19 spread freely aboard USS Theodore Roosevelt, report shows

Filed Under: COVID-19

Mary Van Beusekom | News Writer | CIDRAP News

US Navy, Dan Posey / Flickr cc

Ships as breeding grounds for outbreaks

In an invited commentary in the same journal, John Malone, MD, MPH, an epidemiologist with the San Diego County Health and Human Services Agency, noted that sailors on board the USS Theodore Roosevelt sleep and work in very close quarters with linear fan forced-flow ventilation, which can spread particles through the air.

In such settings, he said, COVID-19 will continue to cause outbreaks, because wearing face coverings, washing hands, and physical distancing are not enough to contain the spread.

The US military, Malone noted, now uses premovement sequestration, which is like a quarantine although the participants have no known exposure to COVID-19, with 14-day movement restrictions to lower the risk of outbreaks.

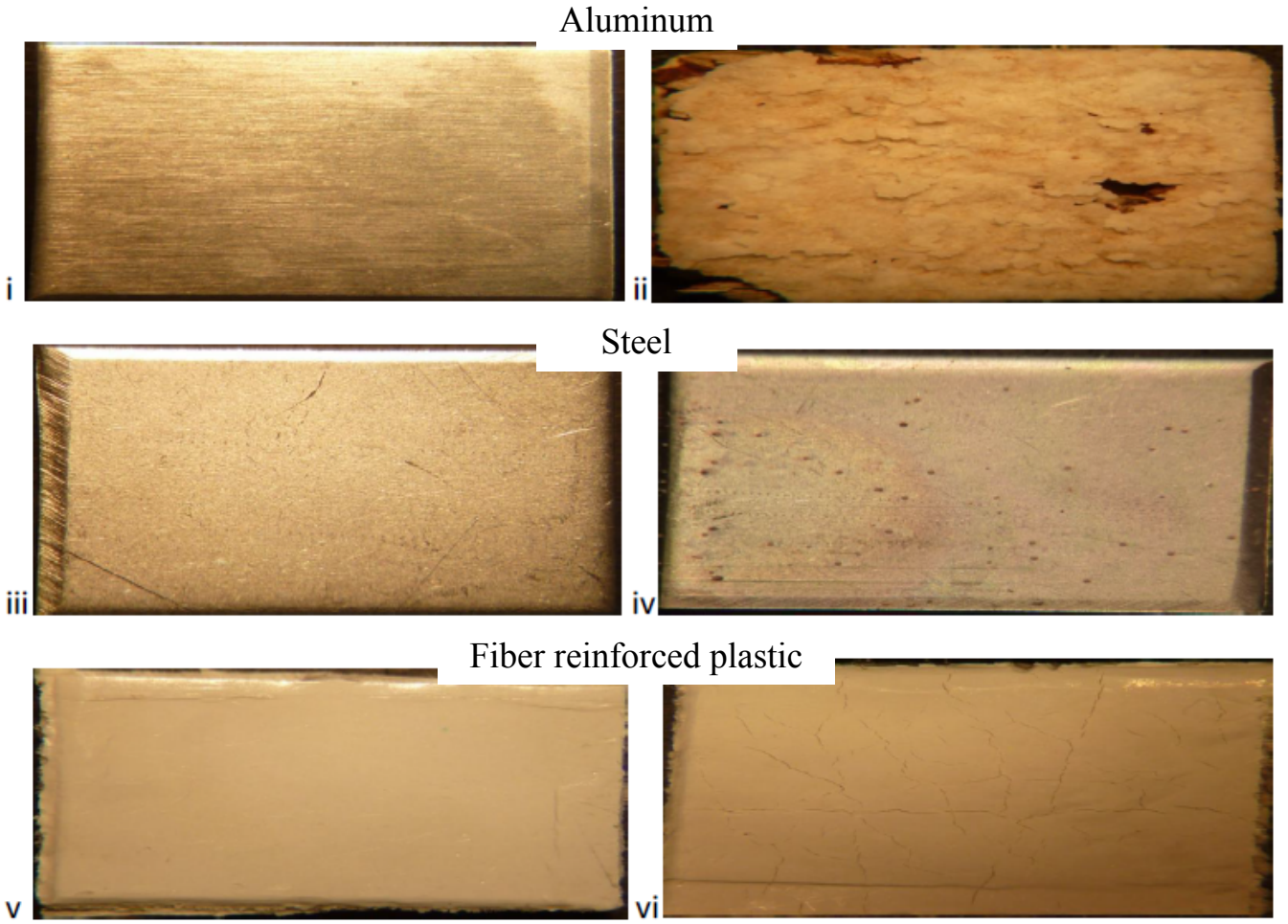
"Unfortunately, the COVID-19 outbreak on the USS Theodore Roosevelt will be remembered by the removal of the Commanding Officer and April 7, 2020, resignation of the Secretary of the Navy instead of the many lessons learned regarding a highly contagious respiratory virus in ships with closely confined spaces and linear airflow systems," he said.

Beusekom, Mary Van, October 2020, CIDRAP News, accessed: Feb. 20th, 2021.
https://www.cidrap.umn.edu/news-perspective/2020/10/covid-19-spread-freely-aboard-uss-theodore-roosevelt-report-shows

More than a dozen sailors are home quarantining in San Diego after catching the coronavirus on the USS Lake Champlain.

*Carlisle, Cassie, **Feb. 20th, 2021**, ABC 10 News – San Diego, accessed: Feb. 20th, 2021.*
https://www.10news.com/news/local-news/coronavirus-outbreaks-affecting-navy-ships

Testing of disinfectant corrosivity of structural metals



S. Abban, et al., African Journal of Biotechnology, (2013) 3689-3698

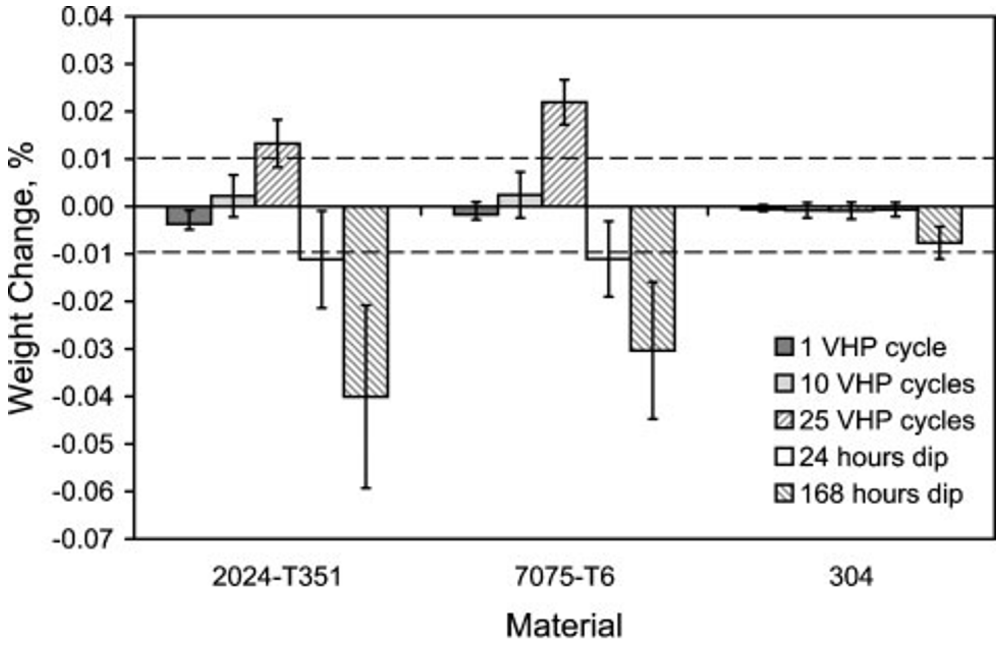
Current testing uses full immersion corrosion exposures (typically ASTM G31 -72).

This approach is non-sensical when you consider how disinfectants are typically applied.

Would you immerse an entire ship in bleach for 30 days?

Testing of disinfectant corrosivity of structural metals

Demonstration of decontamination of entire wide body airliner cabin using VHP.



W.F. Gale, et al., Mater. Sci. Technol., 25 (2009) 76-84.

Application of some disinfectants (hydrogen peroxide based) is done through vaporization of the solution, such as **vaporized hydrogen peroxide (VHP)**.

This study by Gale et al. starts to look at a more realistic application of a disinfectant showing a rather large difference in mass gain/loss when compared to immersion testing.

What else should be considered?

General electrochemical testing

HY80 steel in the cast and forged condition.

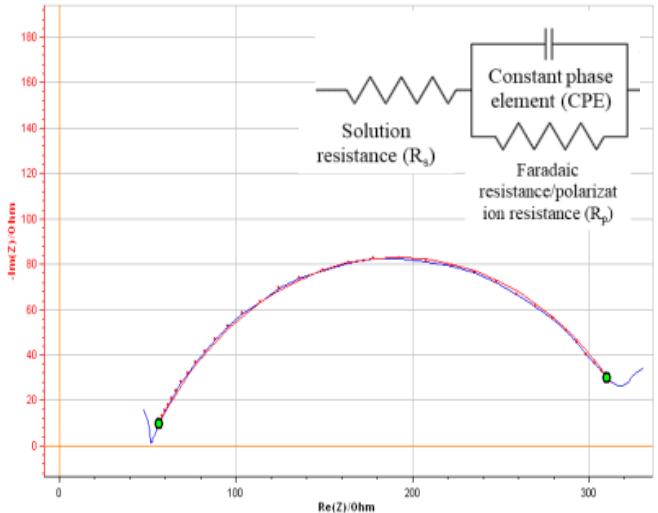
The disinfectants to be tested:

- 10% bleach:
  - 0.825% sodium hypochlorite
- 10% DF-200 formulation:
  - 0.16% n-Alkyl(C12-16)-N, N-dimethyl-N-benzylammonium chloride (CAS 85409-22-9) ← **Detergents**
  - 0.399% Hydrogen peroxide (CAS 7722-84-1) ← **H_2O_2**
  - 0.1% Diacetin (Glycerol diacetate – CAS 25395-31-7)

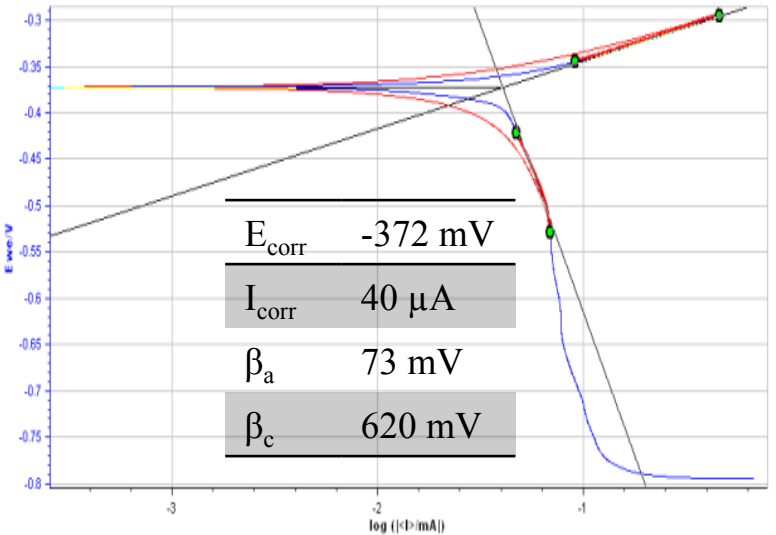
HY80 nominal composition (wt%)

Iron, Fe	93.1
Nickel, Ni	3.23
Chromium, Cr	1.80
Copper, Cu	≤ 0.25
Molybdenum, Mo	0.60
Silicon, Si	0.35
Carbon, C	0.18
Manganese, Mn	0.40
Phosphorous, P	≤ 0.025
Sulfur, S	≤ 0.025
Titanium, Ti	≤ 0.020
Vanadium, V	≤ 0.030

Electrochemical impedance spectroscopy (EIS)

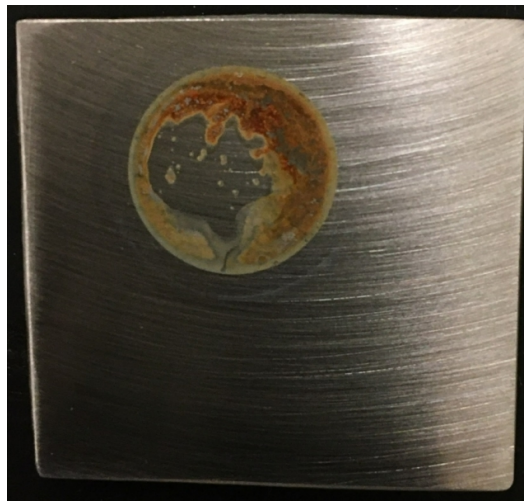


Linear polarization resistance (LPR)

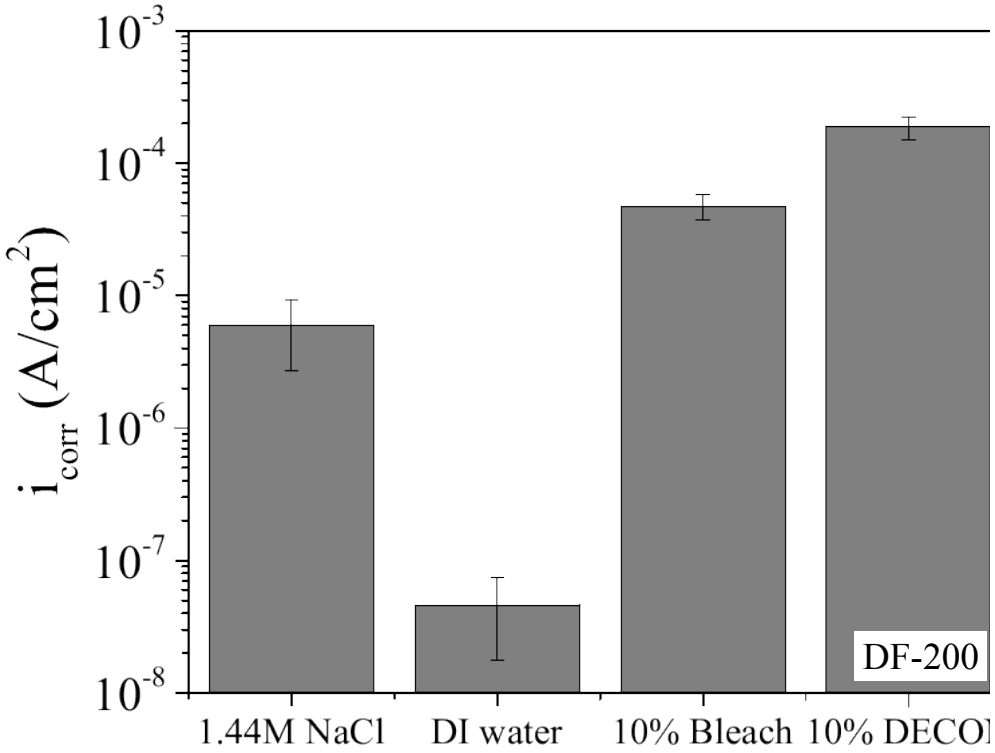


E_{corr}	-372 mV
I_{corr}	40 µA
β_a	73 mV
β_c	620 mV

After 1 hour test in 10% bleach



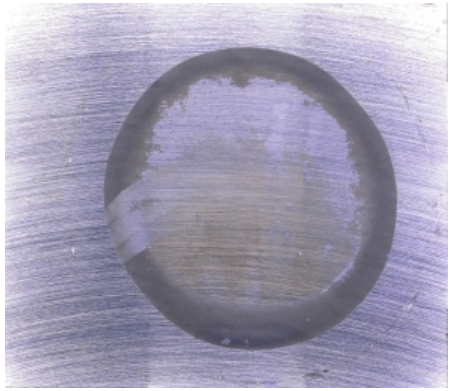
Observations after **1 hour** immersion electrochemical tests



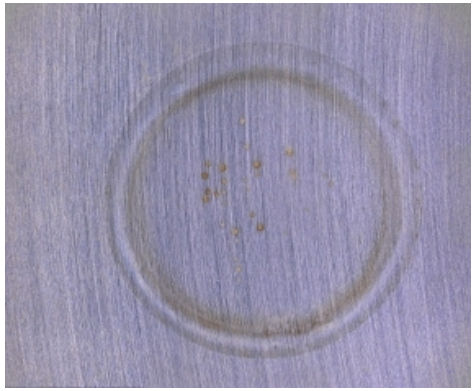
1. The **corrosion rates** of HY80 steel when immersed for an hour in 10% Bleach and 10% DF-200 disinfectants **are similar**.
2. The corrosion rate caused by the NaCl solution was **~1 order of magnitude less** than the disinfectants after 1 hour immersion.
3. Deionized water caused the smallest corrosion rate.

$$\textbf{Corrosion rate} \propto \frac{1}{R_p} \propto i_{corr}$$

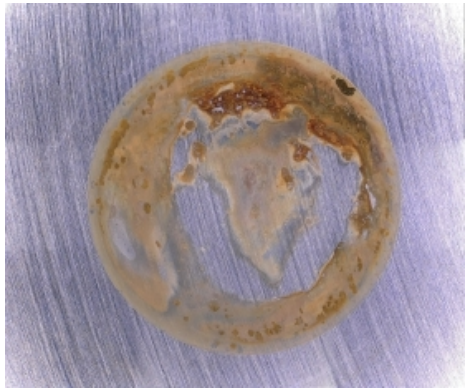
1.44 M NaCl



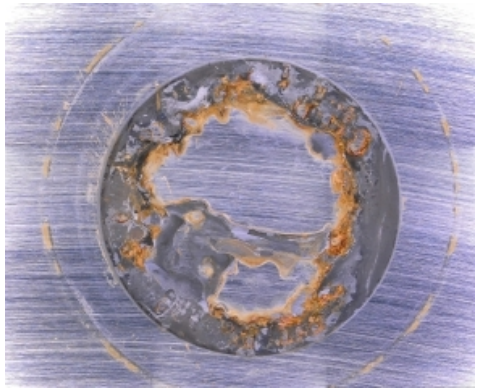
DI water



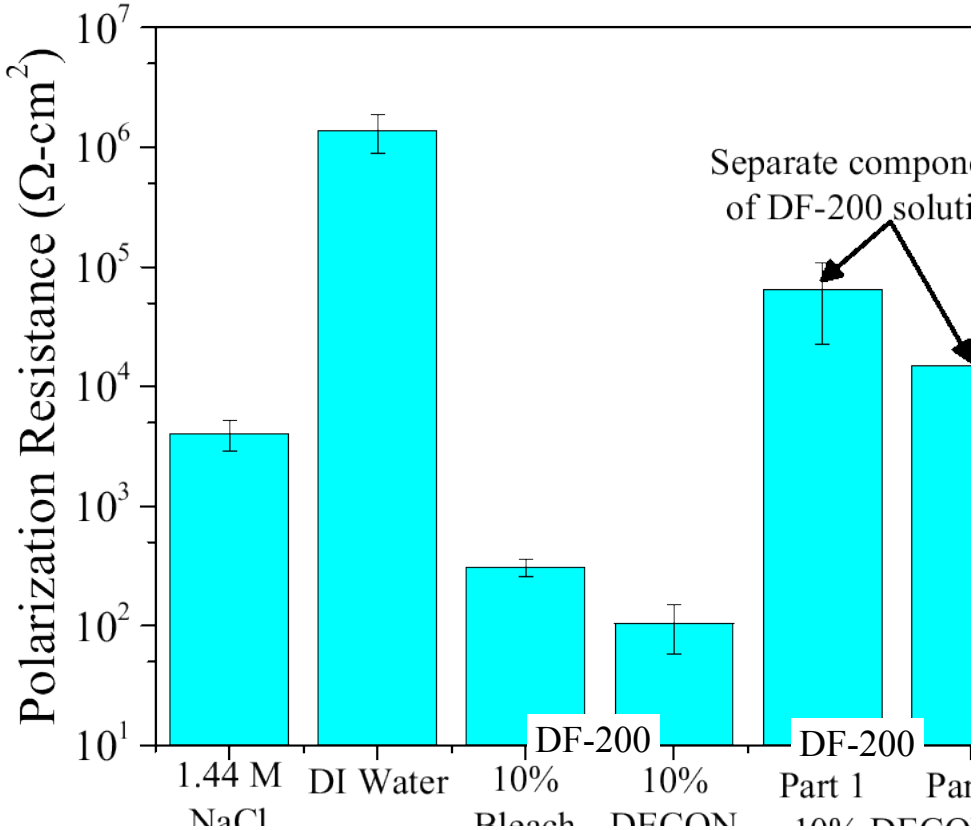
10% Bleach



10% DF-200



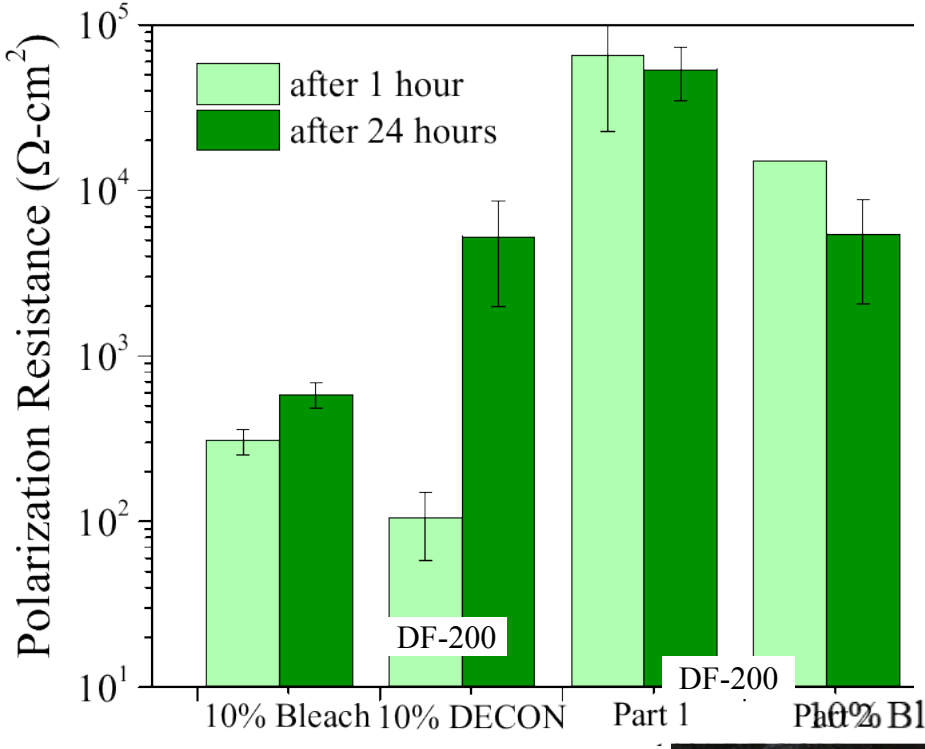
Observations after **1 hour** immersion electrochemical tests



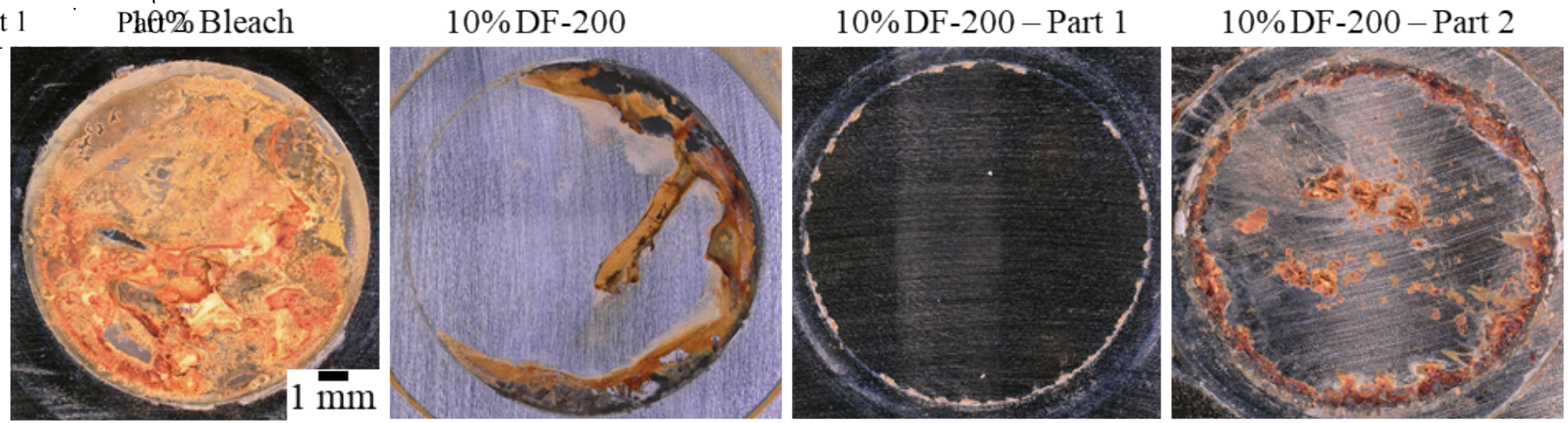
$$\text{Corrosion rate} \propto \frac{1}{R_p} \propto i_{corr}$$

1. The corrosion rate determined by **polarization resistance (R_p)** corresponds to i_{corr} values.
2. Samples were immersed in the separate parts of the DF-200 solution:
   - Part 1 – Detergents.
   - Part 2 – Hydrogen peroxide.
   - The corrosion rate caused by **part 1** was 2 orders of magnitude less than the combined solution.
   - The corrosion rate caused by **part 2** was ~ 2 orders of magnitude less than the combined solution.
     - ➢ This rate diminished over time but corrosion product was prevalent on the surface.

Observations after **1** and **24 hours** immersion tests



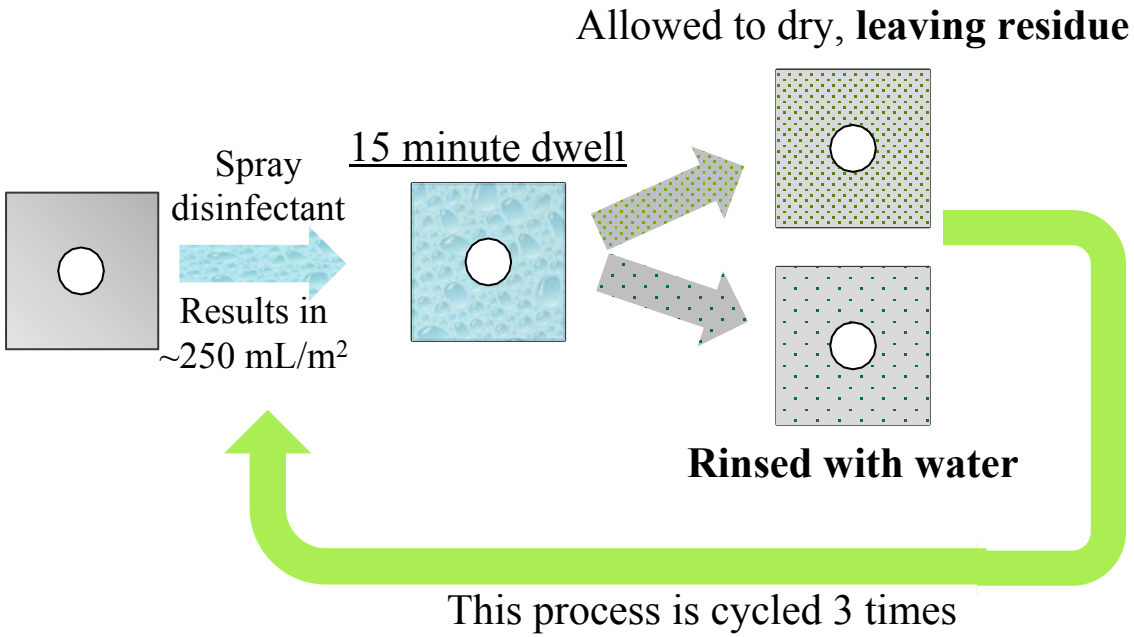
1. After 24 hours, the samples immersed in DF-200 saw **~2 orders of magnitude reduction** in corrosion rate (This is caused by the concentration of H_2O_2 diminishing with time – result was somewhat expected).
2. After 24 hours, the samples immersed in bleach saw **minimal change in corrosion rate.**
3. The Part 1 and Part 2 of DF-200 both exhibited lower corrosion rates at all times than 10% DF-200 with all parts.



Decontaminant residue/crevice humidity-controlled corrosion experiments

Disinfectants sprayed onto HY80 samples after grinding to 400 grit finish.

Samples are laid out in hood



Conditions	
Disinfectant	Salt (NaCl)
No disinfectant	None
10% Bleach	None
10% Bleach - rinsed	None
10% DF200	None
10% DF200 - rinsed	None
Full DF200	None

No disinfectant	50 ug/cm²
10% Bleach	50 ug/cm²
10% Bleach - rinsed	50 ug/cm²
10% DF200	50 ug/cm²
10% DF200 - rinsed	50 ug/cm²
Full DF200	50 ug/cm²

Recommended disinfecting conditions

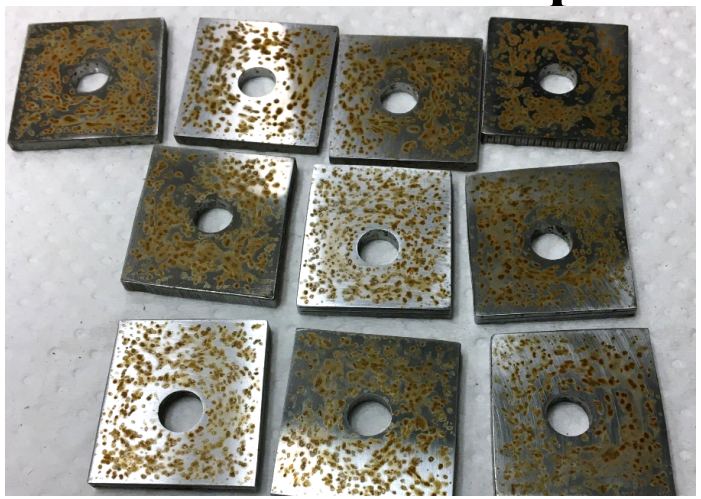
Contact time: 15 min.

Disinfectant loading: 250 mL/m²

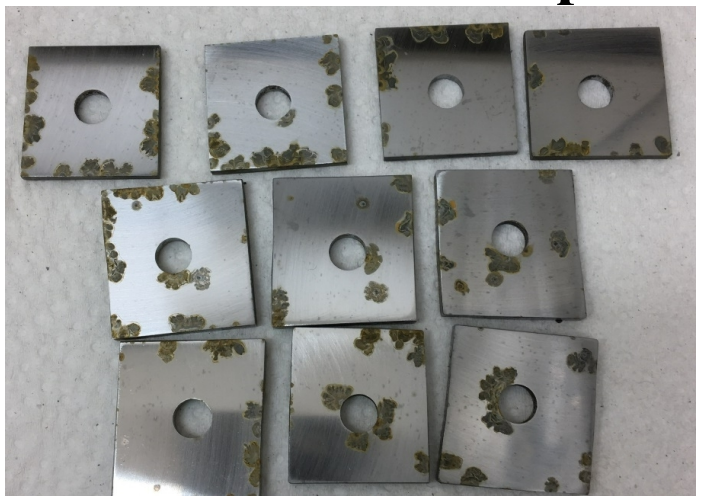
1.44 M solution with a WL thickness of 6.3 um

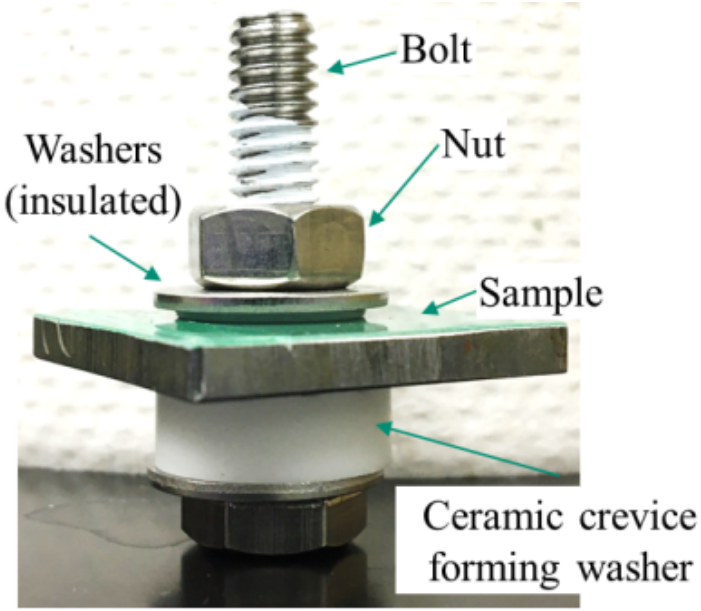
Decontaminant residue/crevice humidity-controlled corrosion experiments

Bleach/rinsed samples



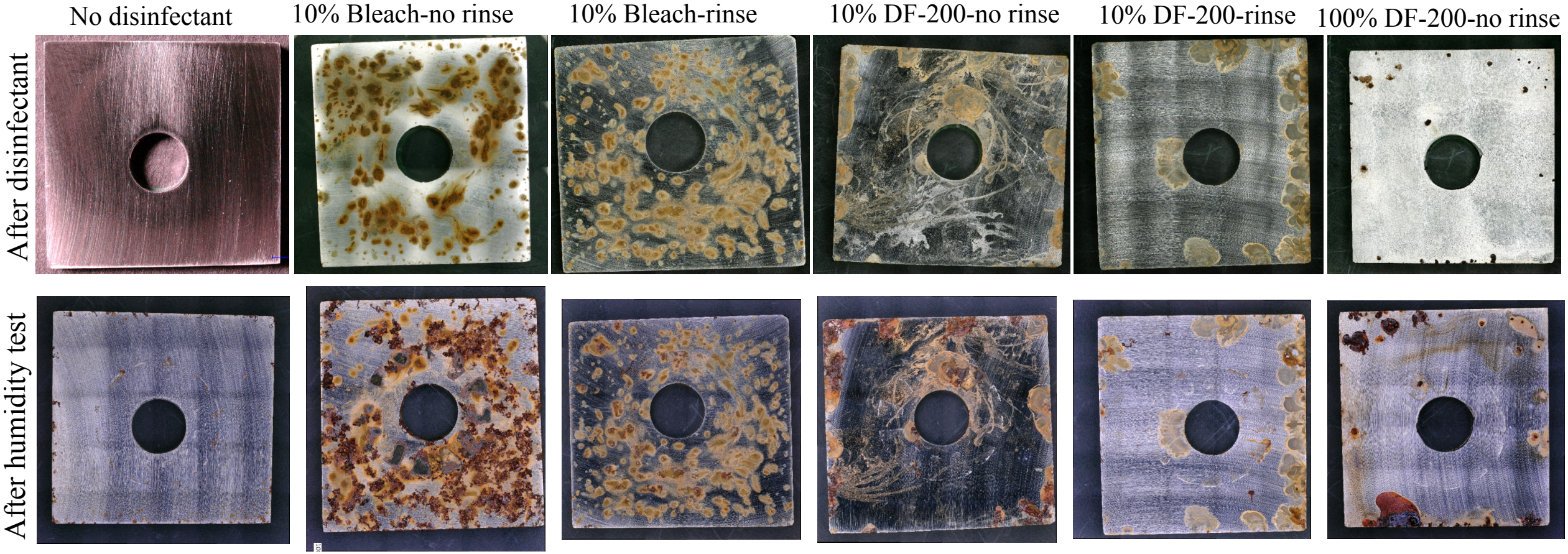
DF-200 rinsed samples





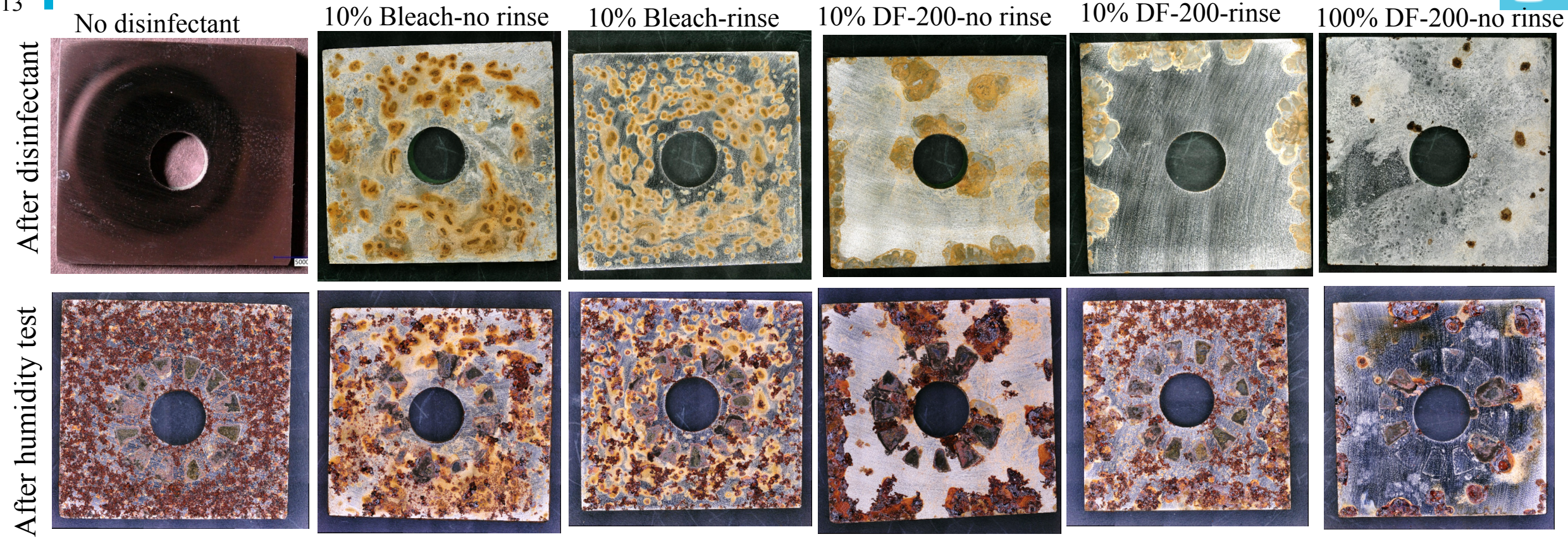
- Ceramic crevice washers were used (with a 316L fastener) to form crevices on both sides of the HY80 samples. A torque of 20 lbs./in was used.
- All 84 samples held at 95% relative humidity for 2 weeks.
- Corrosion rate was determined by mass loss. *(not shown)*
- Corrosion morphological analysis was performed as well:
  - *Did crevice corrosion occur? What form of corrosion occurs – pitting or uniform?*

General observations after humidity-crevice corrosion exposures **(NO NaCl)**



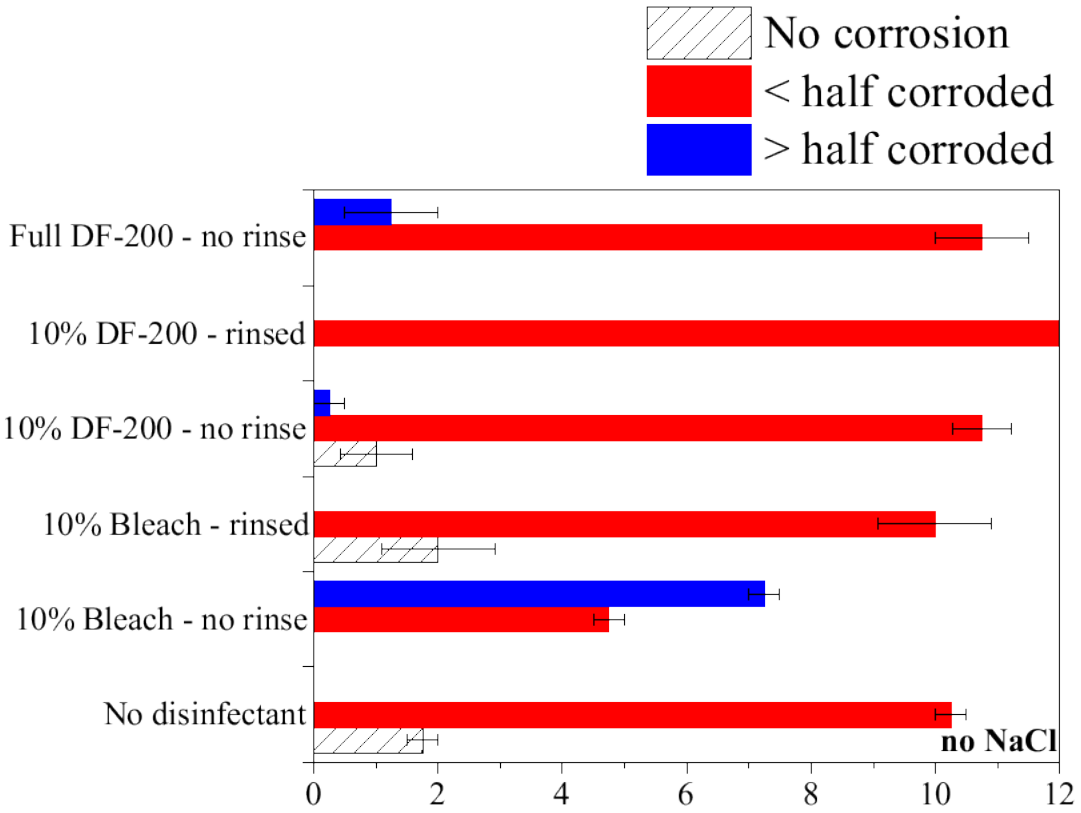
Prior to the humidity test - The corrosion that occurred around the edge of the samples, in particular for the DF-200 solution, was likely caused by a meniscus/droplet edge effect coupled with the oxidizing intensity of hydrogen peroxide. These edge regions become the main areas of corrosion initiation and are accelerated with an oxidizer.

General observations after humidity-crevice corrosion exposures **(with NaCl)**

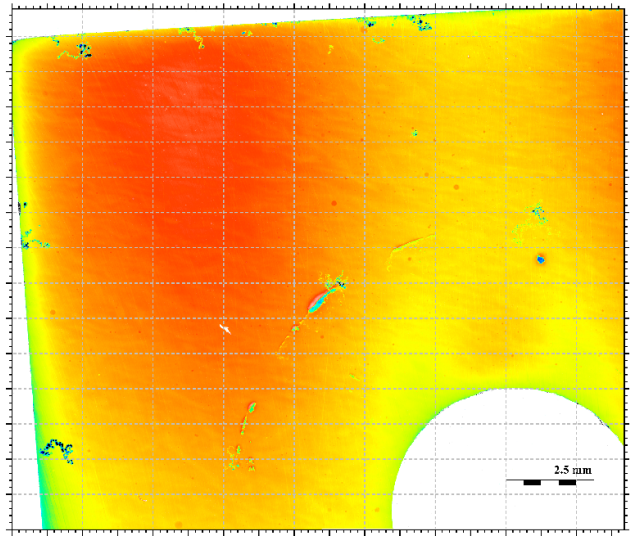


1. All samples with NaCl on their surface showed signs of crevice corrosion.
2. Corrosion morphology (crevice and general corrosion) for the rinsed samples were similar to the samples with **no disinfectant** applied to it.
   - ***The bleach sample that was not rinsed was also similar in morphology to this.***
3. The DF-200 samples that were not rinsed showed less general corrosion than the other samples, with most corrosion occurring at the previously corrosion regions.
   - ***This suggests there may be an inhibitor quality to this disinfectant after H_2O_2 dissipation*** (literature suggests solutions made of the salts in part 1 of the formulation may have this behavior).

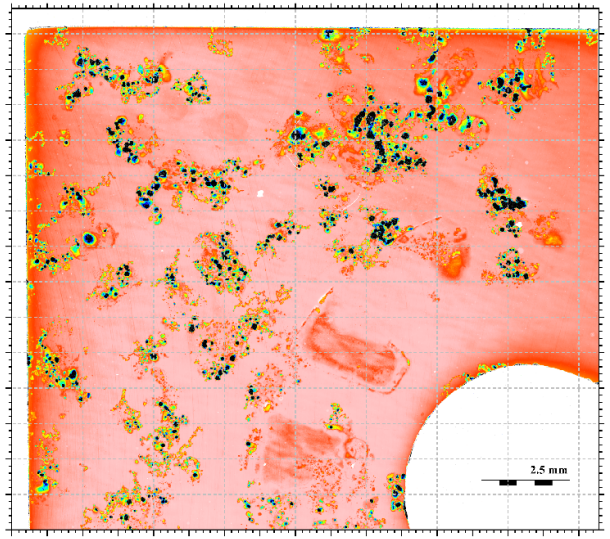
Quantifying crevice corrosion – without NaCl



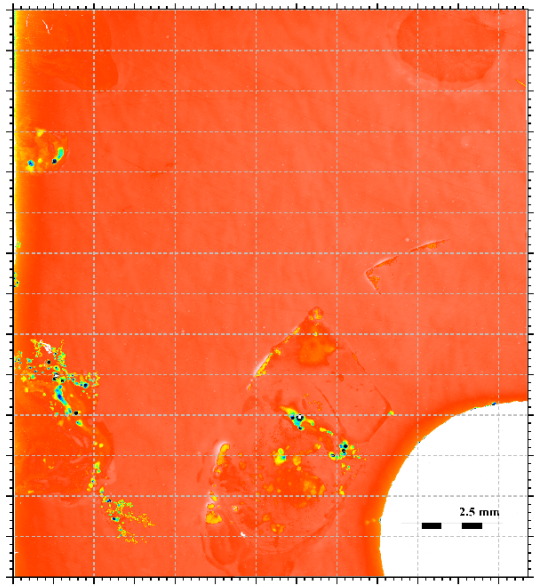
No disinfectant



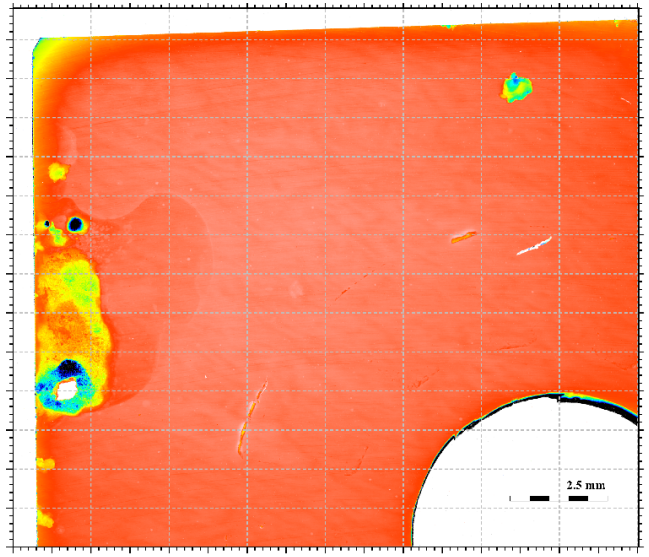
10% Bleach-no rinse

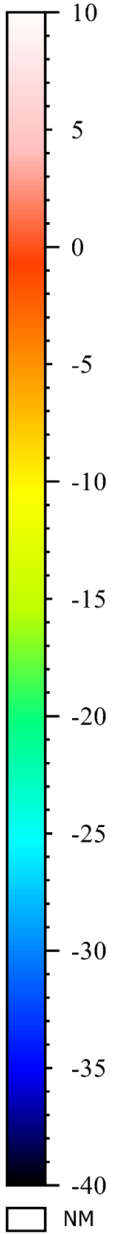


10% DF-200-no rinse

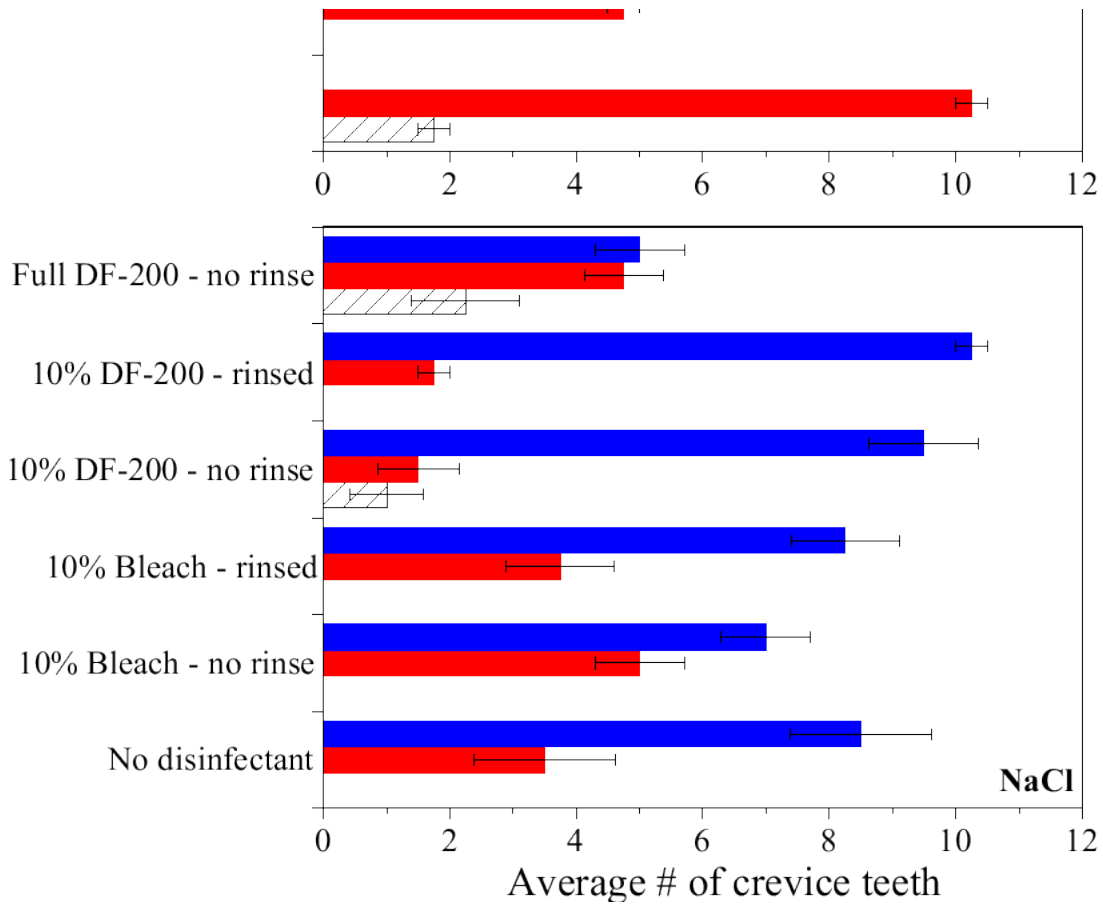


100% DF-200-no rinse

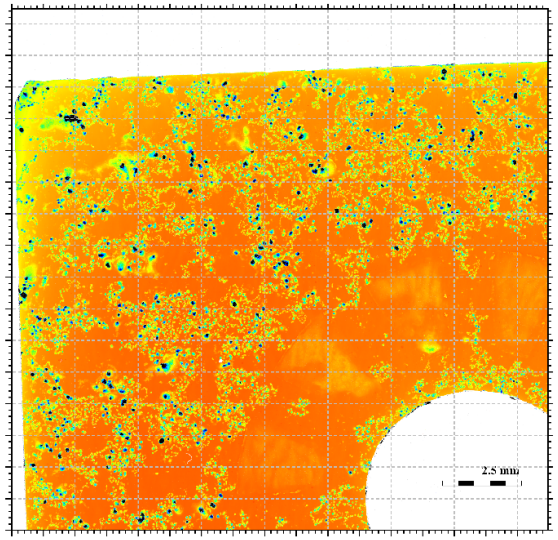




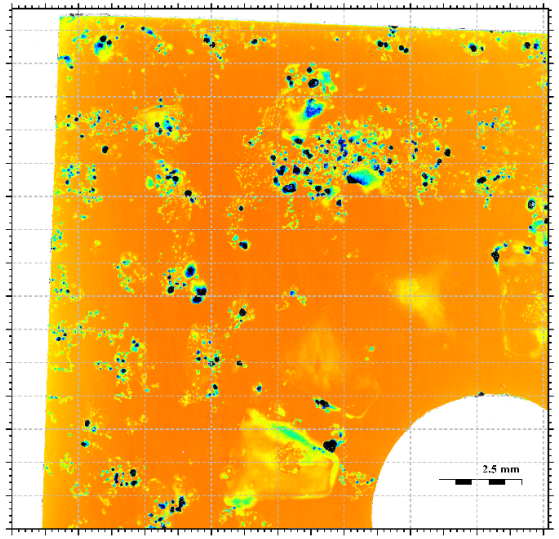
Quantifying crevice corrosion – with NaCl



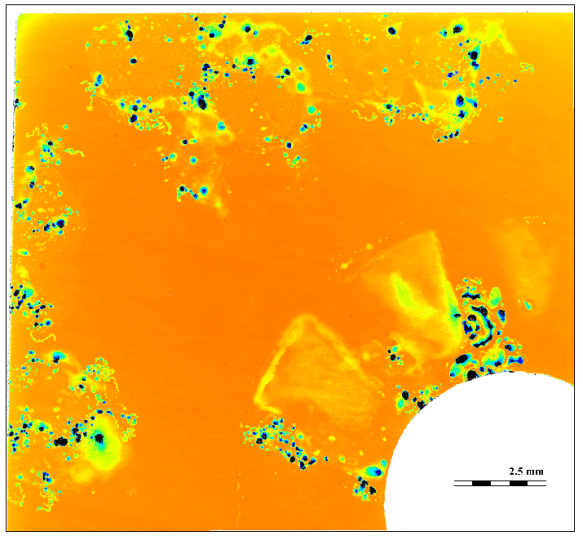
No disinfectant



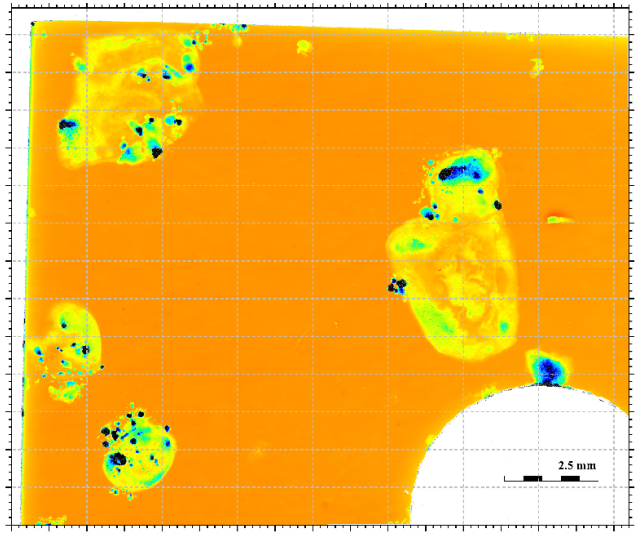
10% Bleach-no rinse

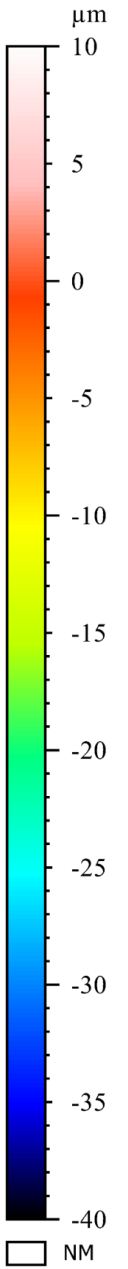


10% DF-200-no rinse



100% DF-200-no rinse





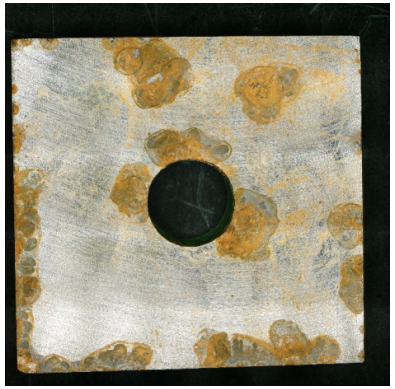
Conclusions

- All disinfectant formulations showed signs of local corrosion after 3 cycles of disinfecting and rinsing/drying.
- The corrosion caused by Bleach was more widespread and intense than the DF-200 formulation (in both dilute and fully concentrated conditions).
  - ➢ If rinsing of a surface occurs (best case scenario), then the corrosion rate and crevice corrosion susceptibility for bleach and DF-200 become comparable.
- After the atmospheric corrosion exposures, samples with Bleach solution residue showed signs of crevice corrosion and wide-spread coverage of localized corrosion.
  - ➢ Similar damage morphology, coverage, and mass loss to samples with NaCl.
- Corrosion damaged caused by the full concentration DF-200 samples covered less area than the 10% dilute samples, however this corrosion tended to be more localized, penetrating deeper.
- DF-200 residue showed signs of inhibiting crevice corrosion and the filament-like localized corrosion for specimens loaded with NaCl, a result requiring further investigation.

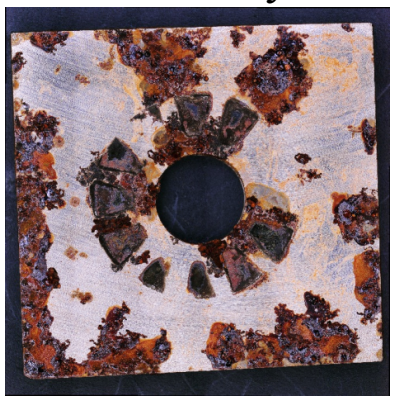
What is needed for future studies?

10% DF-200-no rinse

After disinfectant

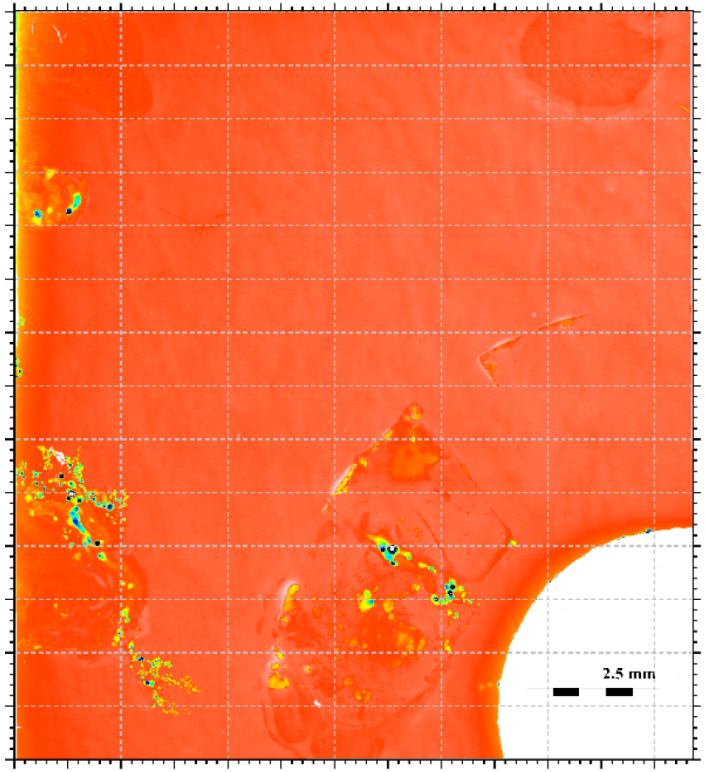


After humidity test



Future work for these and other disinfectants should consider ***organic carbon loading/detritus*** that will be found on most surfaces and show how it can impact the corrosion and efficacy response.

- Hydrogen peroxide is known to react with surface contaminates (organics, viruses, etc.), rapidly lowering its concentration.
- ***This is likely why anecdotal evidence suggests hydrogen peroxide-based disinfectants are considered relatively non-corrosive.***



The other obvious focus should be on increased breath of materials (coated and uncoated), disinfectant formulations, and component geometries.

Also, carful consideration of how relevant a full immersion study is.

They can be useful, but should not be the standard!

Backup slide - Mass loss data