Ogden Air Logistics Center

U.S. AIR FORCE

Zinc Nickel Update 2023

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Agenda

- Corrosion Test Data
- Cadmium History and Limitations
- LHE Zn-Ni Performance
  - Potential to move beyond cadmium
- LHE Zn-Ni Process Challenges
- Proposed Expansion of Thickness Range
- Fasteners

Historical LHE Zn-Ni Testing

Panel #	Average Thickness (mil)	Time to Red Rust (hrs)
17	0.17	1496
18	0.19	2456
15	0.26	3128
16	0.29	4544
10	0.31	5400
9	0.33	6000
8	0.35	6000
7	0.38	5000
2*	0.39	5000
1*	0.41	5000
12	0.44	5000
14	0.48	6000
13	0.5	6000
11	0.51	6400
5	0.58	5000
6	0.6	5400
19	1.11	4472
20	1.14	2264
21	2.08	5000
22	2.16	5000

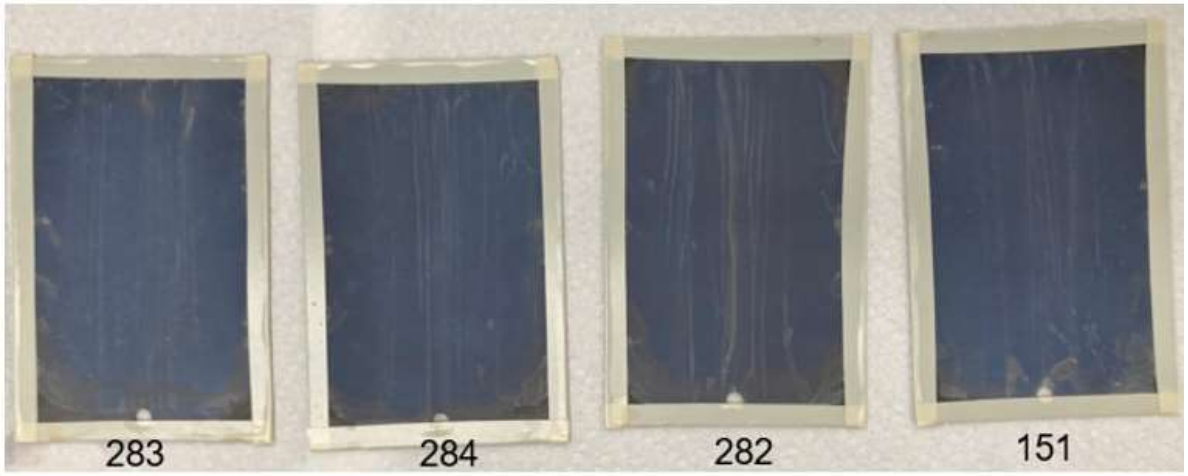
2022 Thin LHE Zn-Ni and Cadmium Performance Tests

- **ASTM B117 Salt Fog Results**
  - **Industrial plating solutions currently used in B505**

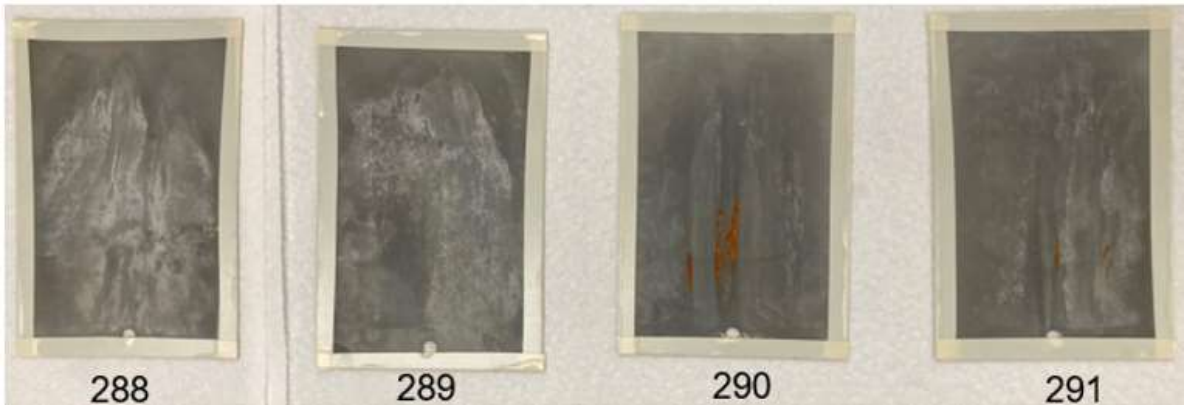
Specimen #	Coating	Avg Thickness (0.001”)	XRF Scan Results	Time to Red Rust (hours)	Notes (Dates are 2022)
151	LHE Zn-Ni	0.2	24.0 % Zn	4728	Nov 8th -started from the bottom
283	LHE Zn-Ni	0.18	20.5 % Zn	3072	Aug 31st -started from the bottom
282	LHE Zn-Ni	0.08	13.7 % Zn	2520	Aug 8th -started at top edge and quickly spread to center area
284	LHE Zn-Ni	0.1	16.2 % Zn	3936	Oct 6th -started at top edge and quickly spread to center area
288	Cadmium	0.18	21.7 % Cd	432	May 13th -started in center area
289	Cadmium	0.2	26.2 % Cd	504	May 16th -started in center area
290	Cadmium	0.12	9.4 % Cd	168	May 2nd -started in center area
291	Cadmium	0.12	10.4 % Cd	168	May 2nd -started in center area

2022 Thin LHE Zn-Ni and Cadmium Performance Tests

- **ASTM B117 Salt Fog Results**
  - **Industrial plating solutions currently used in B505**



Zn-Ni after
168 Hours



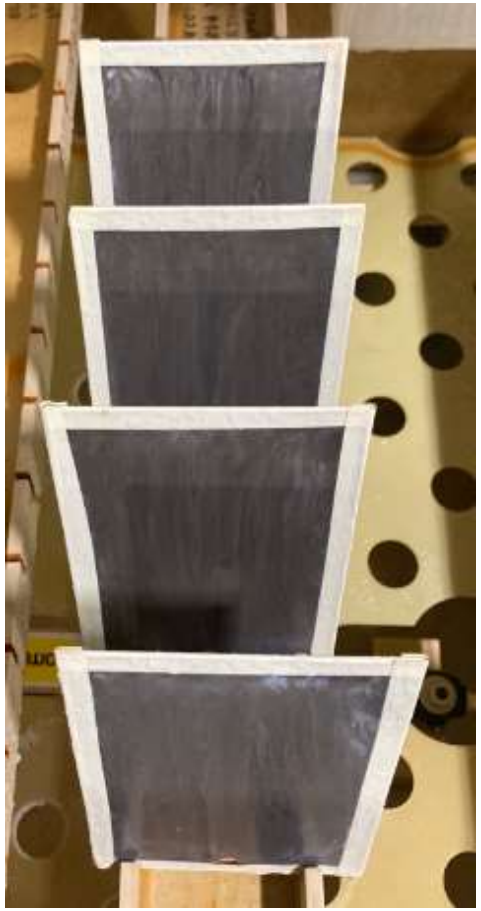
Cadmium after
168 Hours

2022 Thin LHE Zn-Ni and Cadmium Performance Tests

- **ASTM B117 Salt Fog Results**

Last two Cd and four Zn-Ni panels after 504 Hours salt fog

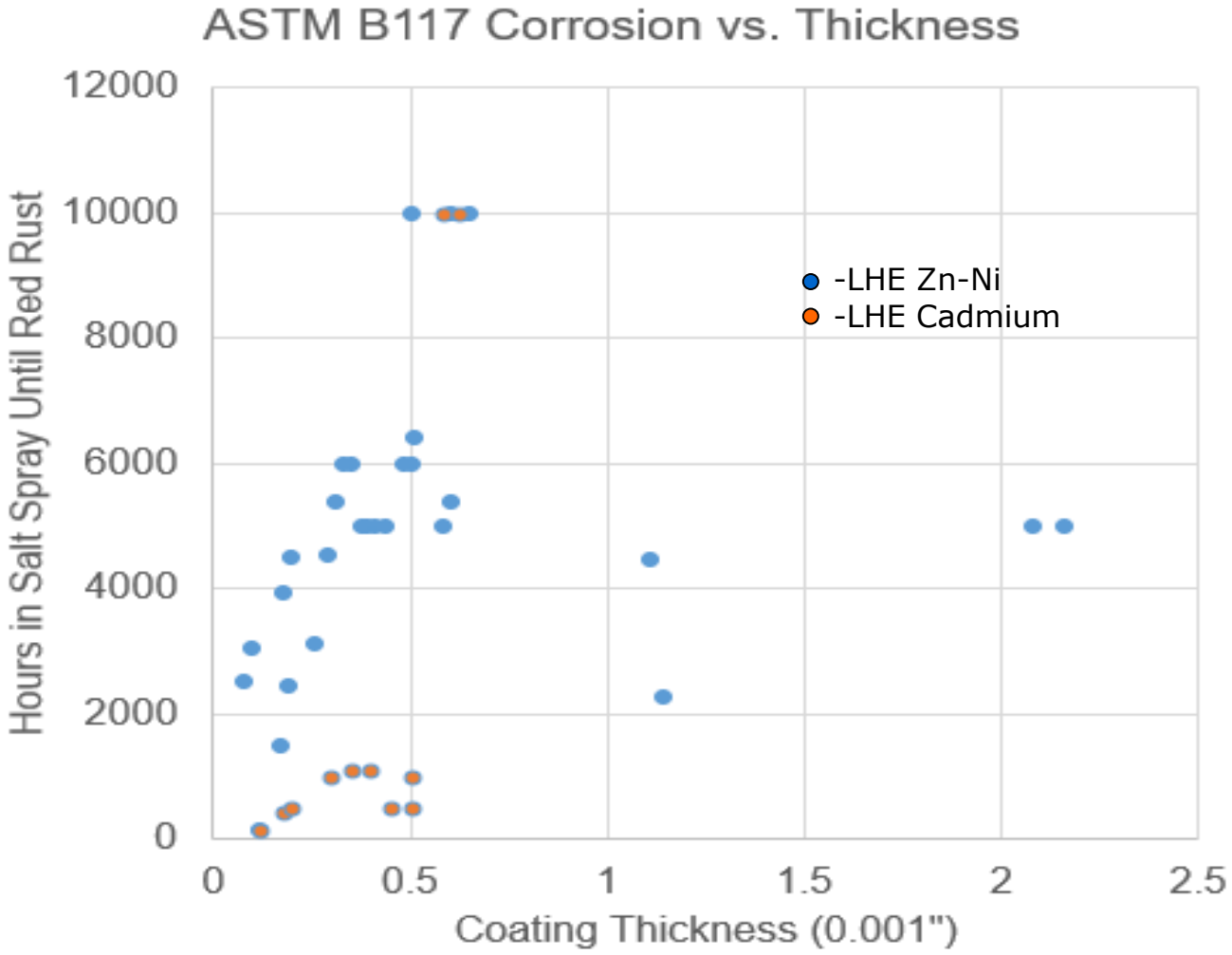
2022 Thin LHE Zn-Ni and Cadmium Performance Tests



Zn-Ni at 1704 Hours

Zn-Ni at 2400 Hours

Cadmium/LHE Zn-Ni Comparison



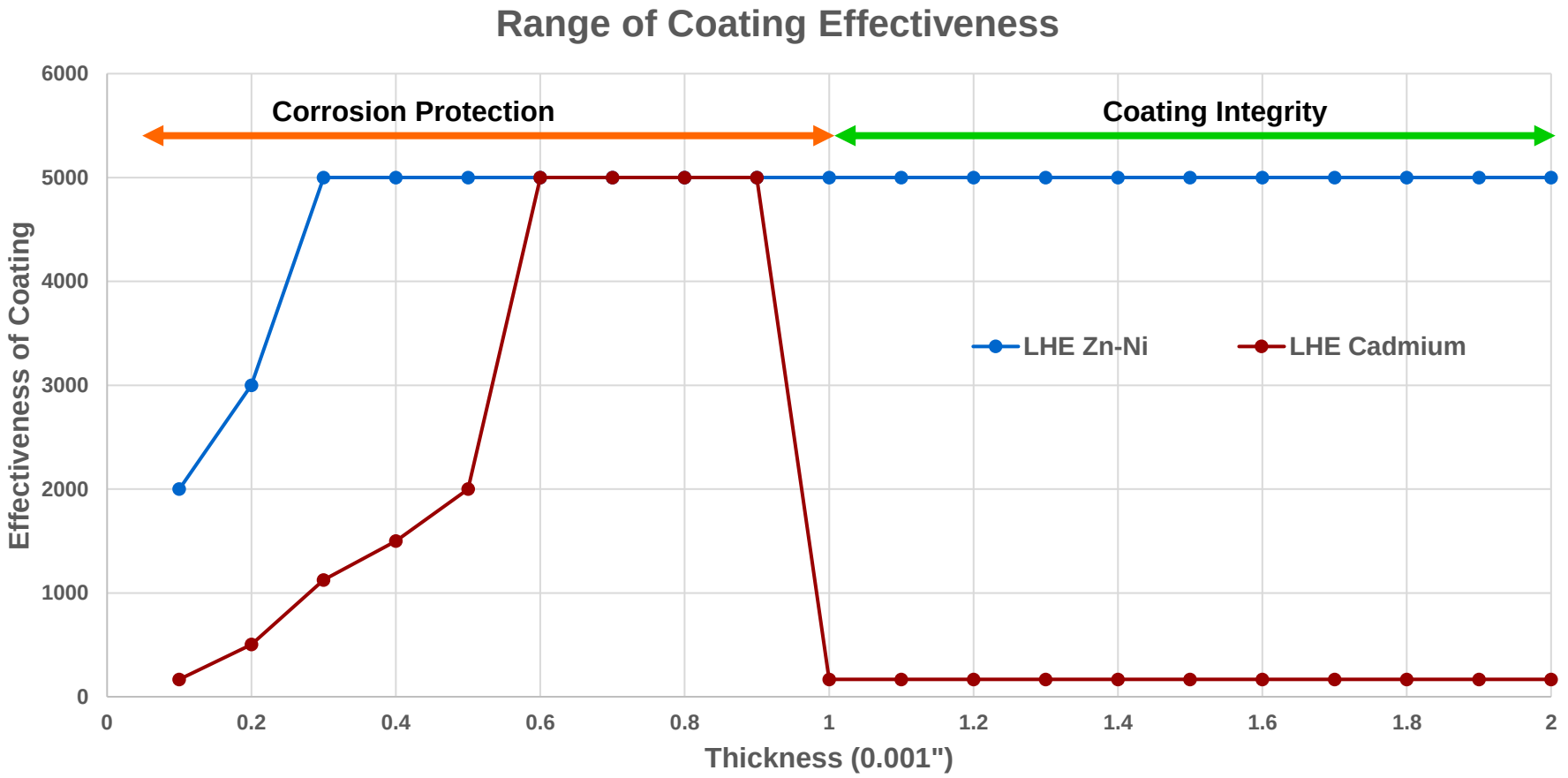
Cadmium History and Limitations

- Used for 70 years to inhibit corrosion of steel
- Very thin band of performance
  - Below 0.0003” –little corrosion protection
    - 0.0001” provided 168 hours of salt fog resistance
    - Notably, porous cadmium required for high strength steels
  - Above 0.001” -poor cohesion and unpaintable
  - Cadmium at any thickness:
    - Easily damaged and compromised
    - Galling of threads
    - Not compatible with titanium
    - Not compatible with high strength steels above 400 °F.
- Cadmium specifications tailored thicknesses to fit the narrow performance band.

LHE Zn-Ni Performance

- Used for 13 years on high strength steel
- Very wide band of performance.
  - 0.0001” provided ~2000 hours salt fog resistance
  - Areas that can’t be touched by .75” sphere…
  - Adhesive, cohesive, and dense up to 0.0027”
    - Bond Strength > 10,000 psi
    - Coating 0.0015” thick used as a pneumatic sealing surface
- LHE Zn-Ni is more robust than cadmium and has a much wider performance band; why treat it like cadmium?
  - Thickness control not as critical for LHE Zn-Ni.

LHE Zn-Ni Performance



LHE Zn-Ni Performance (continued)

- Compatible with titanium up to 650 °F
- Tested with H11 steel up to 900 °F
  - Corrosion protection up to 850 °F
- LHE Zn-Ni could be more than a substitute for cadmium
  - Galvanic corrosion inhibition for titanium fasteners?
  - Higher temperature applications

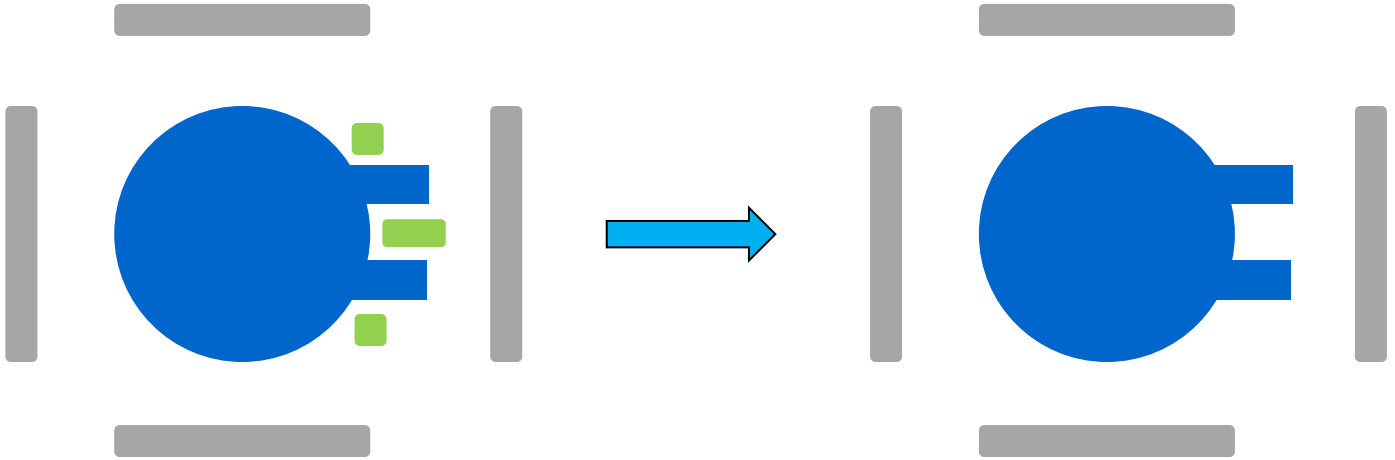
LHE Zn-Ni Process Challenges

- Lower throwing power than cadmium
  - LHE Zn-Ni is more prone to bare spots than cadmium
  - Difficult to meet narrow range of thickness on irregular surfaces.
- The alkaline LHE Zn-Ni plating solution dissolves the coating once the current is turned off.
  - Traditional techniques such as wanding are more difficult to perform.
  - The ID and OD must be plated simultaneously.
- Very complicated fixturing required
  - High percentage of components need unique tools
  - Often very low anode to cathode distances required
    - 0.25” in some cases

Possible LHE Zn-Ni plating allowance.

- A wider thickness range such as 0.0002” – 0.0012” could be implemented many areas and provide superior protection than Class 2 cad (0.0003” 0.0006”
  - Would allow for simplified fixturing and eliminate complex fixturing for some components
    - Would allow increased distance from anode to cathode
    - The anode wouldn’t need to mimic the exterior of the component as closely
  - Applications such as fasteners should continue to use traditional thickness bands.

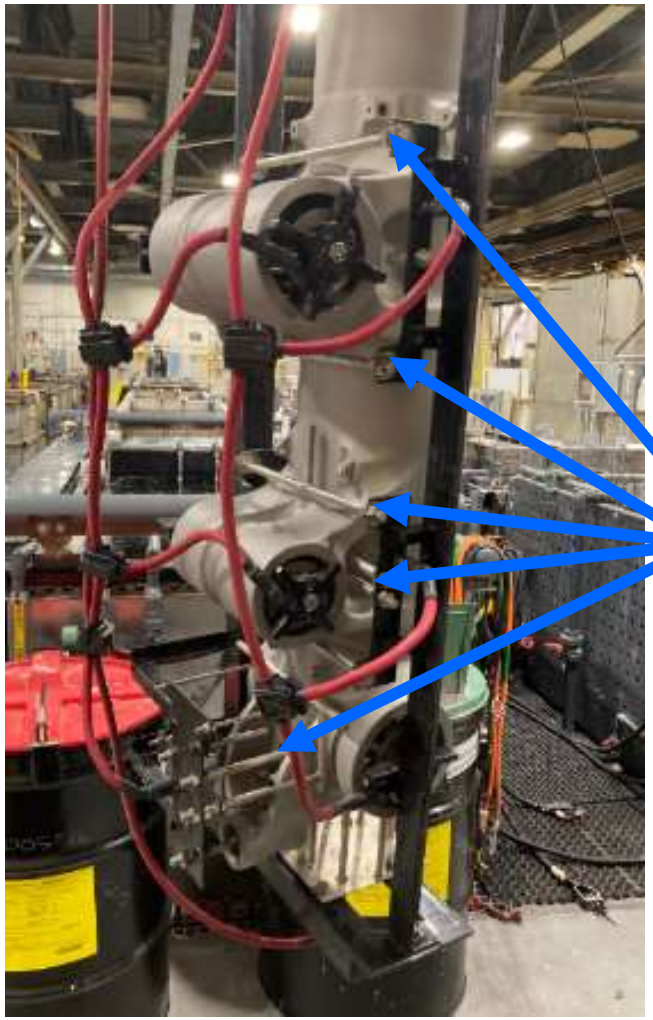
Fixturing Simplification



Current fixturing to meet 0.0003” to 0.0006” range.

Possible simplification with expanded range of 0.0002” to 0.0012”

Fixturing Simplification, B-1 Truck Beam



These exterior anodes could possibly be eliminated.

Fasteners

- Fasteners are used everywhere
  - Currently the only coating option for most alloy steel fasteners is cadmium.
- NASC is implementing Zn-Ni
  - AMS2461 Type II, Class 2, Grade B
- Logistics Challenges!
  - Parts Lists
  - Drawings and Specifications
  - Sources of supply
- Technical Challenges
  - Fatigue
  - Torque Tension

Fasteners

- **Fasteners are used *and reused* everywhere**
  - **Reuse of cadmium plated threaded fasteners**
    - **Galling**
    - **Bare areas**

Recap

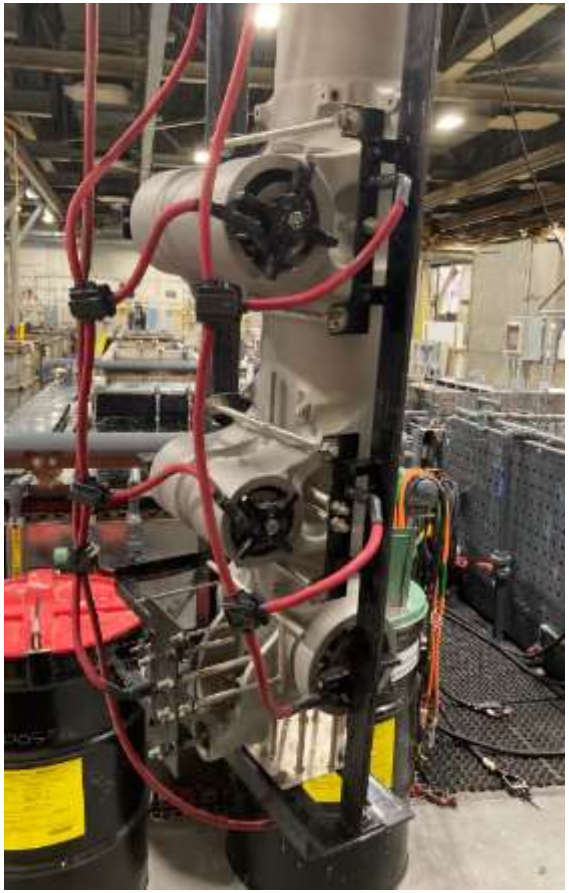
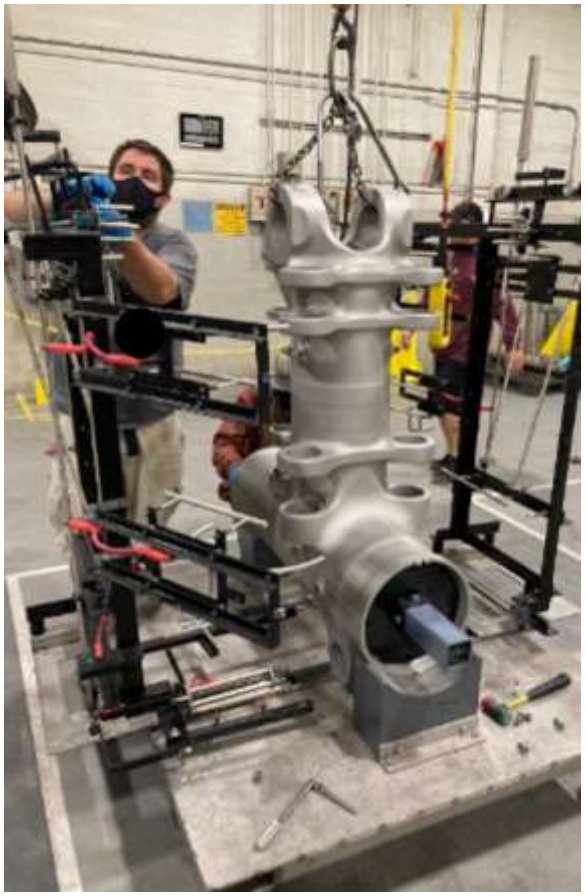
- LHE Zn-Ni does not have many of the performance limitations of cadmium
  - Gives excellent corrosion protection down to 0.0001”
  - Less susceptible to scratching or mechanical damage
  - >10,000 psi bond strength up to 0.0027” thickness
  - Dense and adherent at least up to 0.0027”
  - Used for pneumatic seal at 0.0015”
  - Does not embrittle steel up to 900 °F
  - Offers corrosion protection up to 850 °F
  - Does not embrittle titanium up to 650 °F
  - Could be used in new applications
- In many cases, the process could be simplified without loss of performance

QUESTIONS/DISCUSSION

- Thank you for your time

BACKUP SLIDES

- Fixturing for B-1 Truck beam and outer cylinder.


BACKUP SLIDES

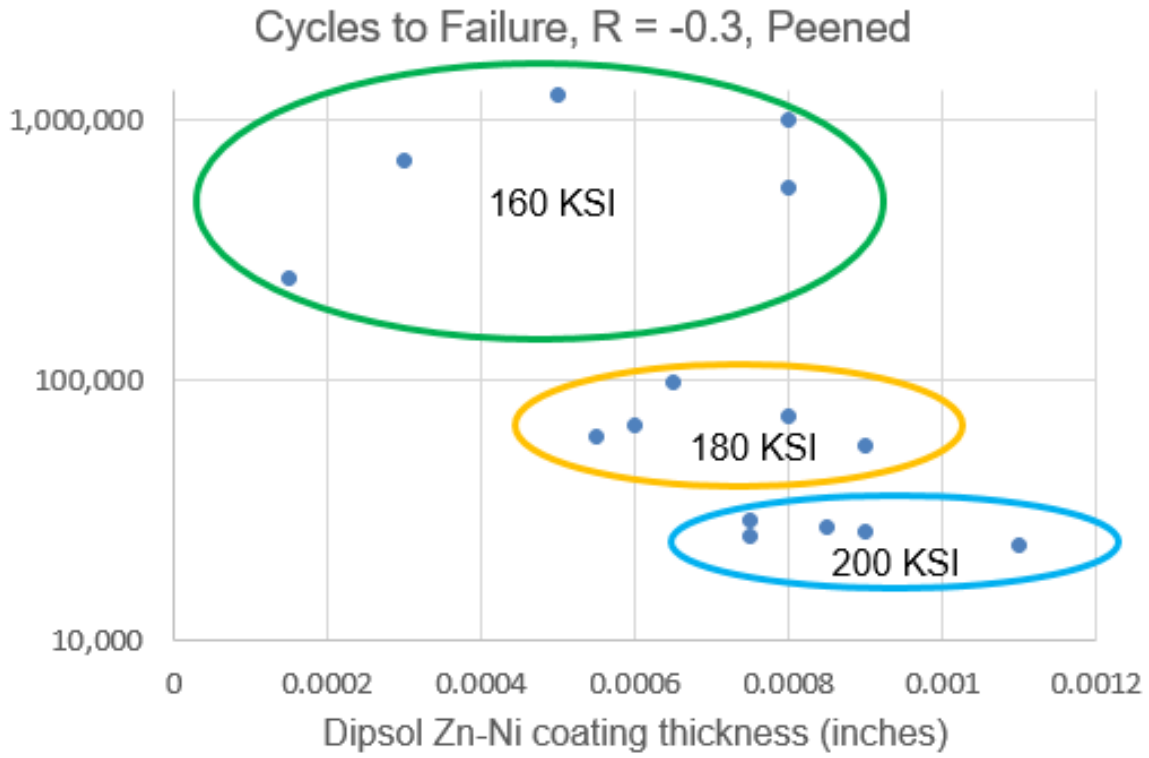


Figure 12: Fatigue data for 300M steel at 160 ksi, 180 ksi, and 200 ksi and various LHE Zn-Ni coating thicknesses