

FNSS

AVT-373 Research Specialists' Meeting “Emerging Technologies for Proactive Corrosion Maintenance”

**A TRADE-OFF BASED ASSESSMENT STUDY on
POSSIBLE COATING ALTERNATIVES for ARMORED COMBAT VEHICLES**

Aylin Selvi,

Elif S. Yıkılmaz,

Barış Çetin

FNSS Savunma Sistemleri A.Ş.
Ankara, TÜRKİYE

Nuri Durlu

TOBB University of
Economics and Technology
Ankara, TÜRKİYE

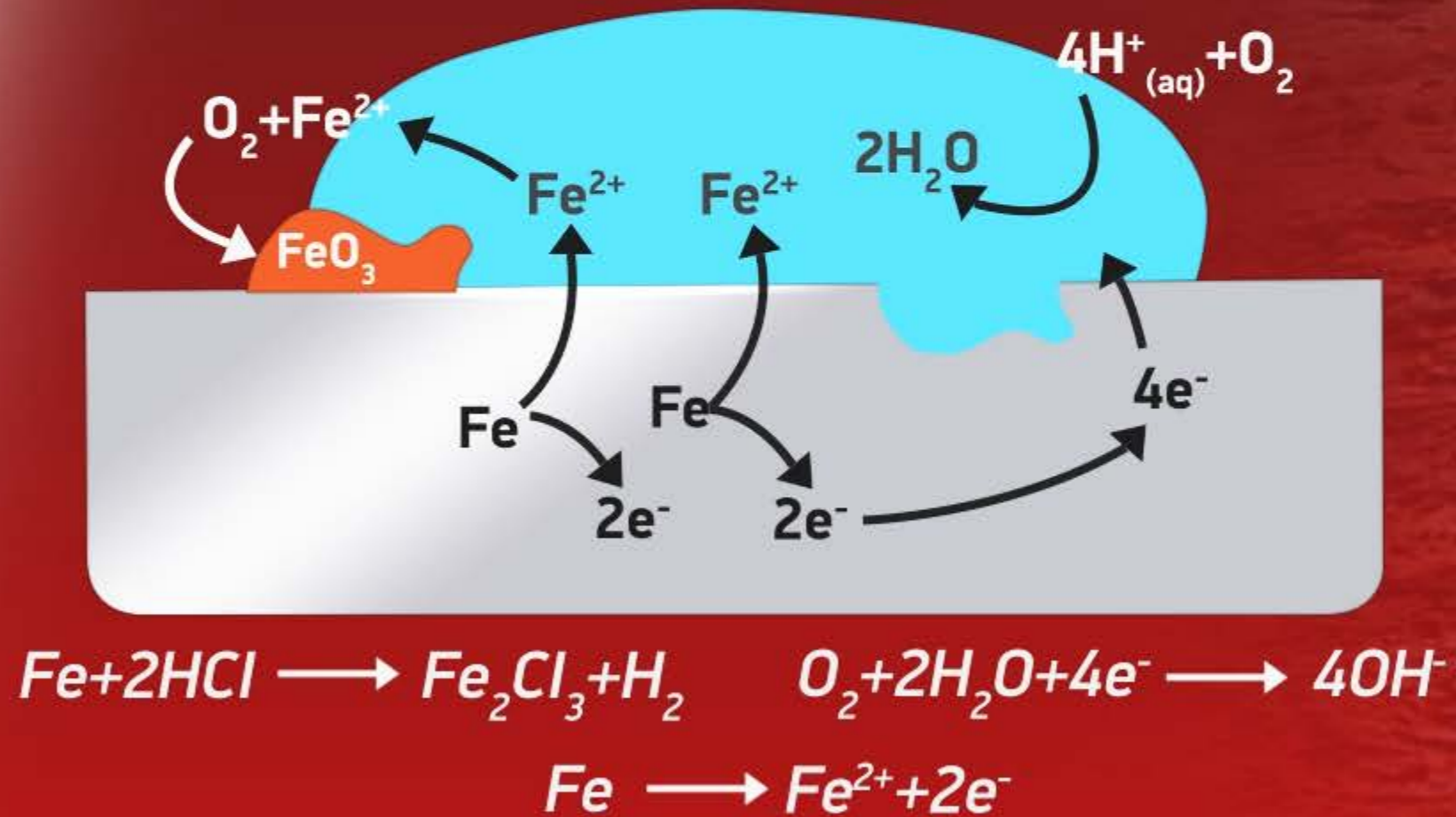


FNSS

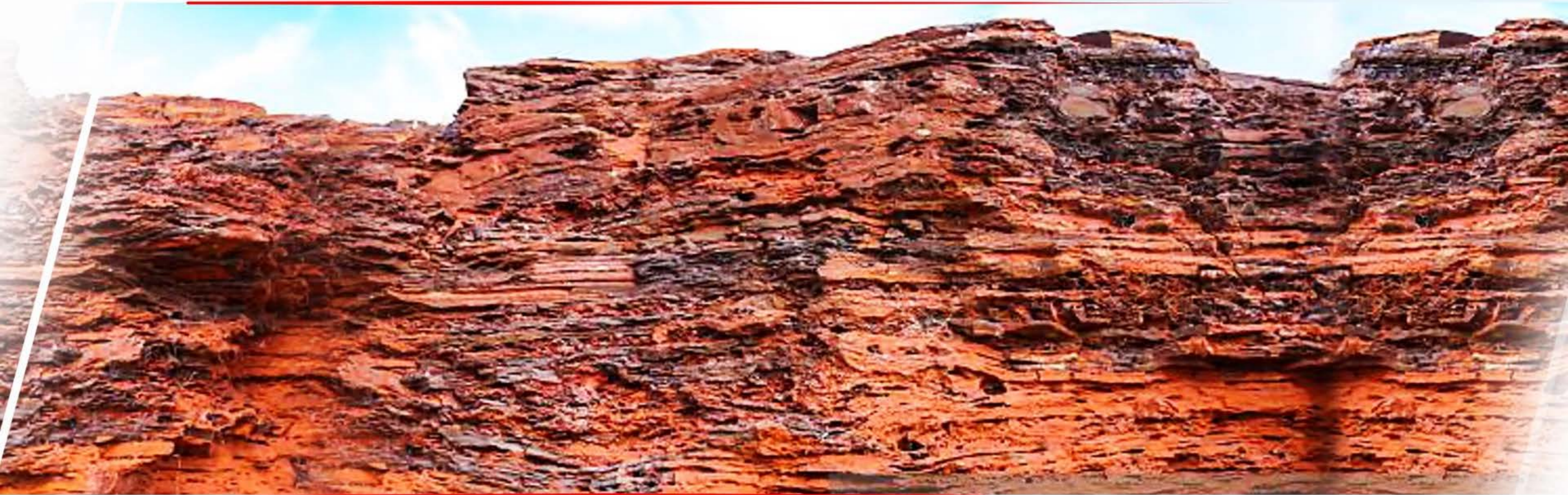


PROTECTED MOBILITY AT YOUR SERVICE!

WHAT IS **CORROSION**?

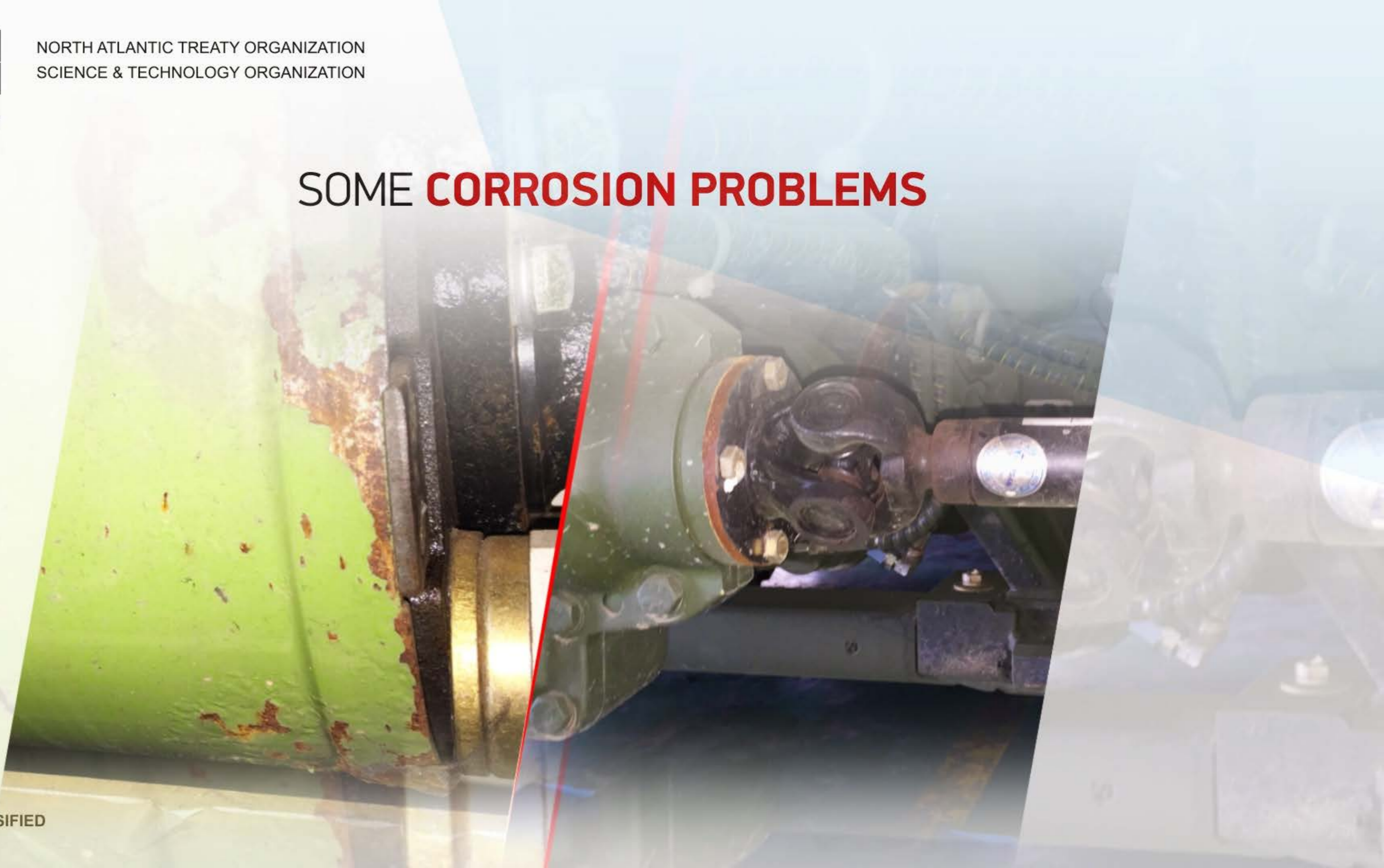


WHAT IS **CORROSION**?





SOME **CORROSION PROBLEMS**



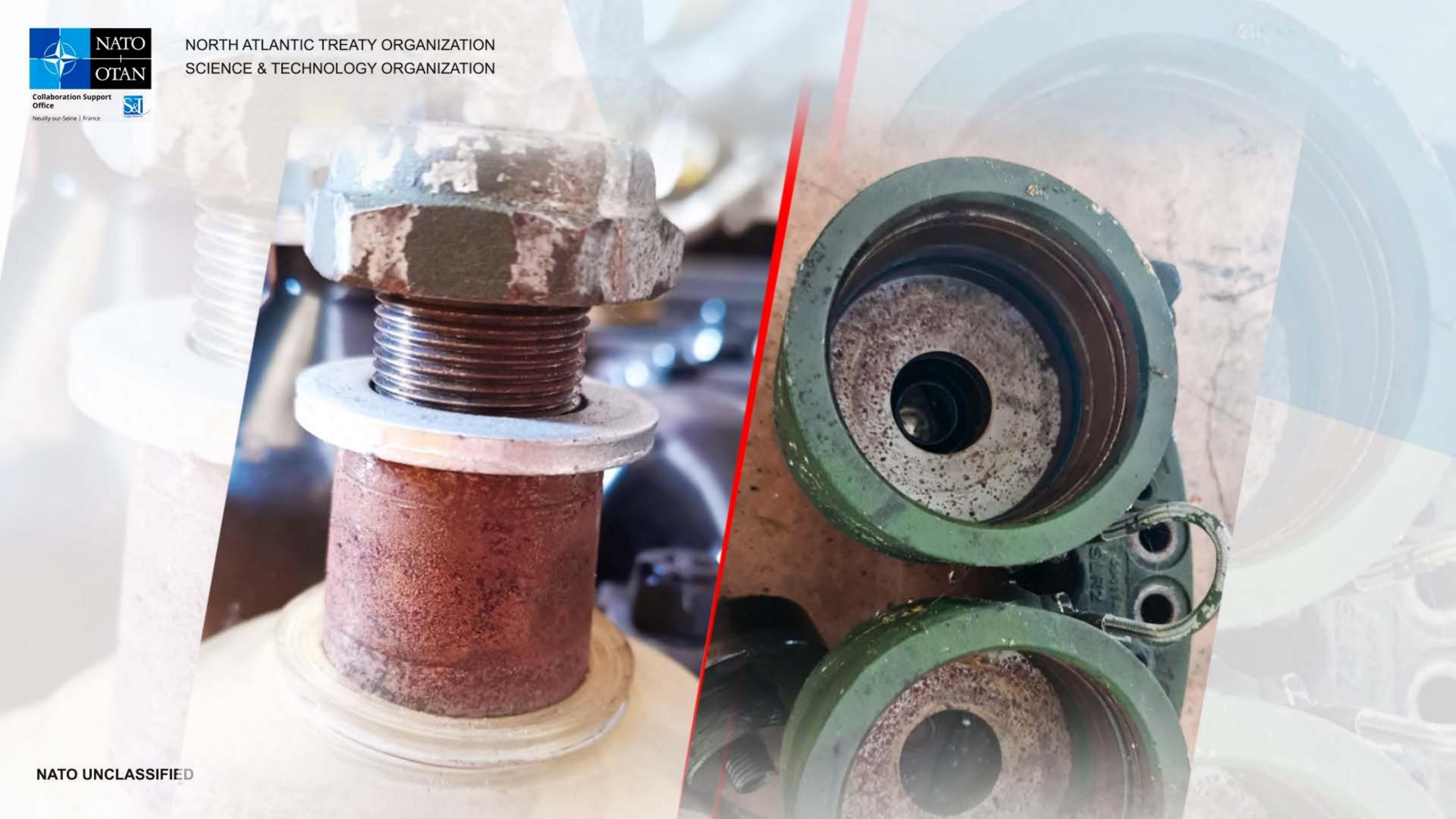
IMPROVED **PAINT SYSTEM**

**CORROSION
RESISTANCE**

**IMPACT
RESISTANCE**

**ABRASION
RESISTANCE**

**CHEMICAL
FLUID
RESISTANCE**



COATING SYSTEMS

MIL-DTL-16232: Phosphate Coating, Heavy, Manganese Or Zinc Base

SAE-AMS-QQ-P-416: Plating, Cadmium (Electrodeposited)

ASTM B841: Standard Specification For Electrodeposited
Coatings Of Zinc Nickel Alloy Deposits

HYDROGEN EMBRITTLEMENT MECHANISM

- 1) ENVIRONMENTAL HYDROGEN EMBRITTLEMENT – EHE**
- 2) INTERNAL HYDROGEN EMBRITTLEMENT – IHE**

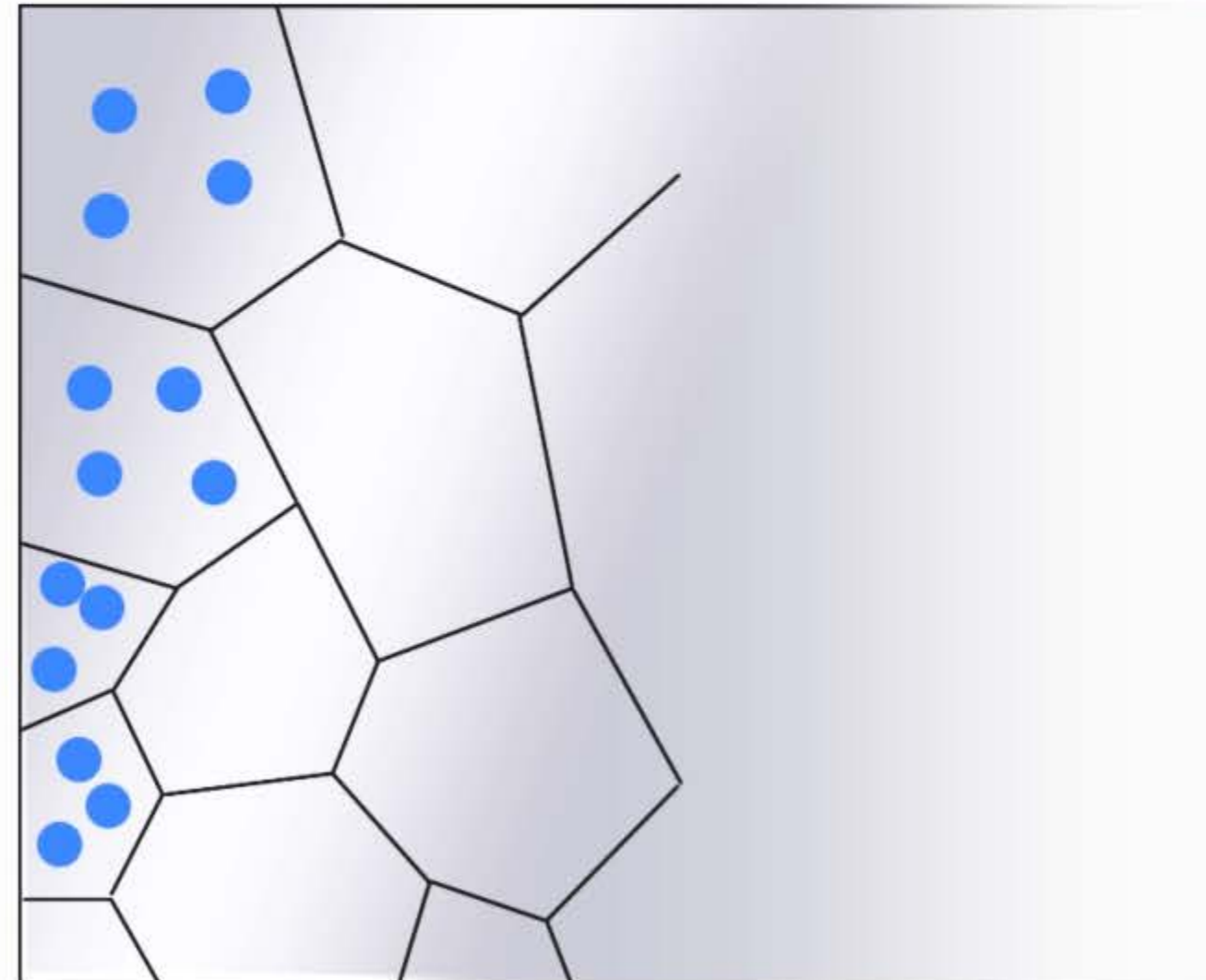
HYDROGEN



HYDROGEN EMBRITTLEMENT MECHANISM

- 1) ENVIRONMENTAL HYDROGEN EMBRITTLEMENT – EHE
- 2) INTERNAL HYDROGEN EMBRITTLEMENT – IHE

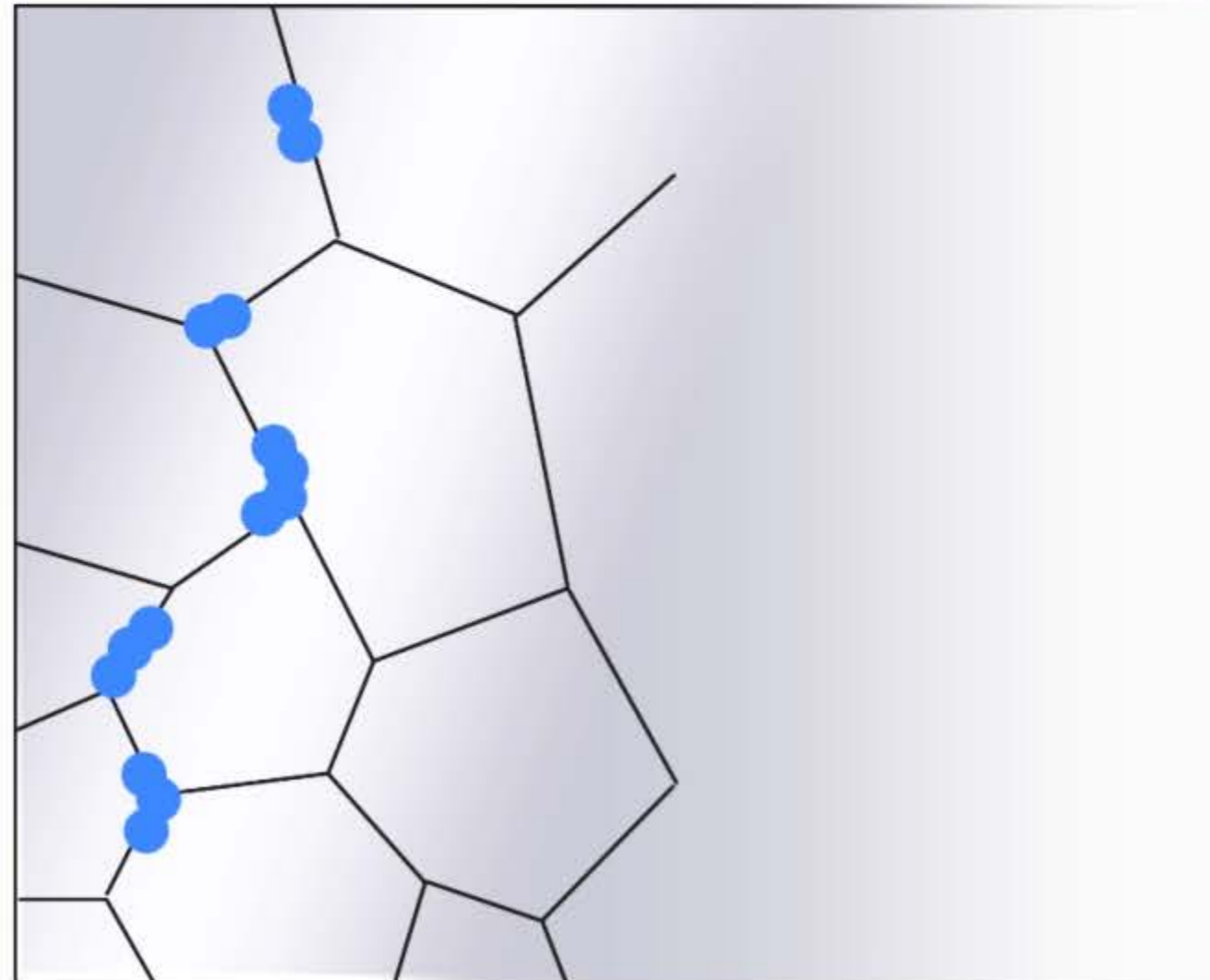
HYDROGEN
ABSORPTION



HYDROGEN EMBRITTLEMENT MECHANISM

- 1) ENVIRONMENTAL HYDROGEN EMBRITTLEMENT – EHE
- 2) INTERNAL HYDROGEN EMBRITTLEMENT – IHE

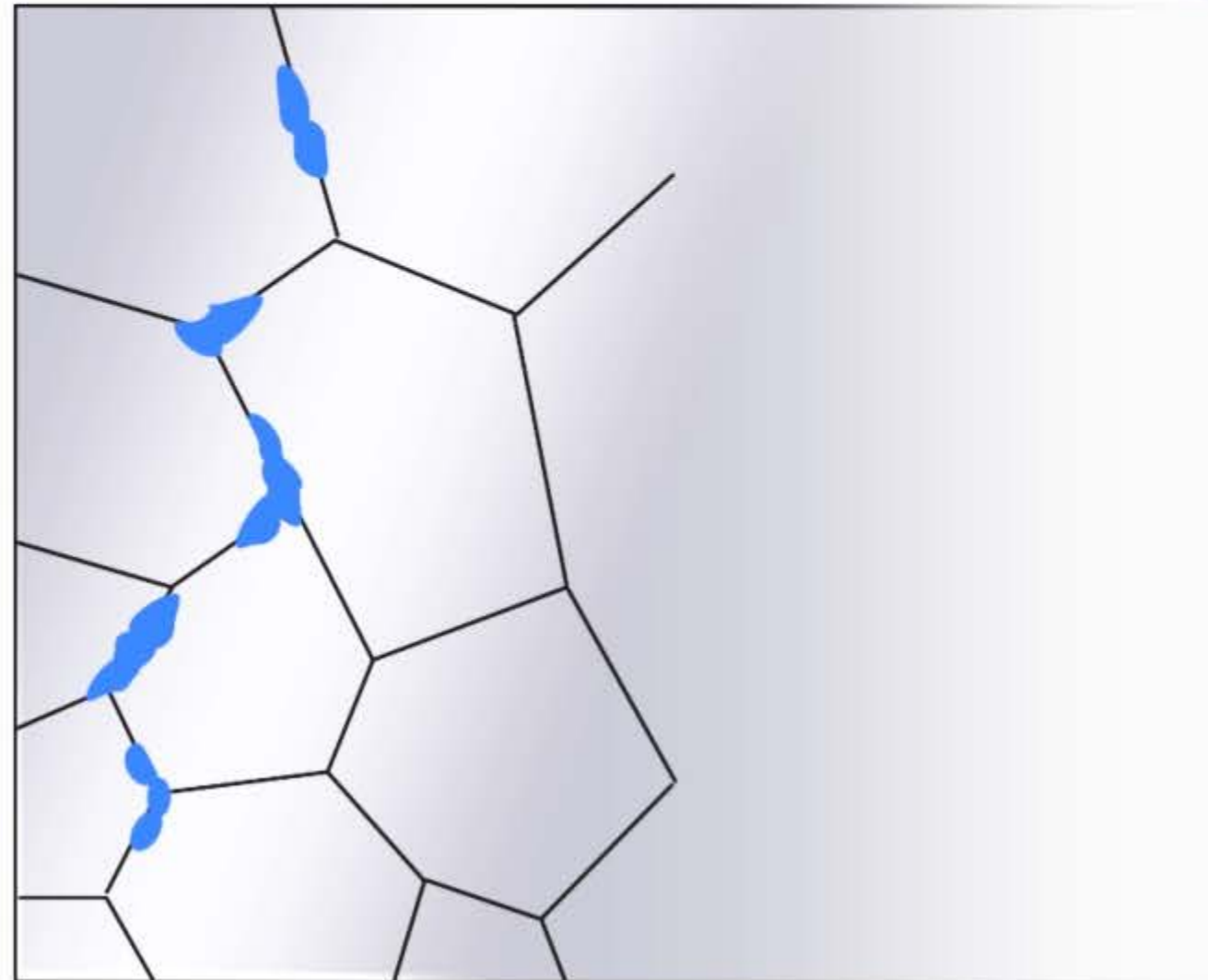
HYDROGEN IN
PREFERENTIAL SITES
LIKE GRAIN BOUNDARIES
DISLOCATIONS OR IMPURITIES



HYDROGEN EMBRITTLEMENT MECHANISM

- 1) ENVIRONMENTAL HYDROGEN EMBRITTLEMENT – EHE
- 2) INTERNAL HYDROGEN EMBRITTLEMENT – IHE

ATTACK GROWTHS AND
LEADS TO CRACKING
UNDER STRESS



HYDROGEN **EMBRITTELEMENT**

- **ASTM B849:** Standard Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement
- **ASTM B850:** Standard Guide for Post-Coating Treatments of Steel for Reducing the Risk of Hydrogen Embrittlement
- **ASTM F1941:** Standard Specification For Electrodeposited Coatings On Mechanical Fasteners

TABLE 1 Classes of Embrittlement-Relief Heat Treatment (See Sections 4 – 6 for details on the Use of Table 1)

Hydrogen Embrittlement-Relief Treatment Classes for High-Strength Steels			
Class	Steels of Tensile Strength (R_m), MPa	Temperature, °C	Time, h
ER-0	not applicable		
ER-1	1701 to 1800	190–220	min 22
ER-2	1601 to 1700	190–220	min 20
ER-3	1501 to 1600	190–220	min 18
ER-4	1401 to 1500	190–220	min 16
ER-5	1301 to 1400	190–220	min 14
ER-6	1201 to 1300	190–220	min 12
ER-7 ^A	1525 or greater	177–205	min 12
ER-8	1101 to 1200	190–220	min 10
ER-9	1000 to 1100	190–220	min 8
ER-10 ^A	1250 to 1525	177–205	min 8
ER-11 ^A	1450 to 1800	190–220	min 6
ER-12 ^A	1000 to 1500	177–205	min 4
ER-13	1000 to 1800 unpeened items and for engineering chromium plated items	440–480	min 1
ER-14 ^A	surface-hardened parts <1401	130–160	min 8
ER-15 ^A	surface-hardened parts 1401 to 1800 plated with cadmium, tin, zinc, or their alloys	130–160	min 8
ER-16	surface-hardened parts <1401 plated with cadmium, tin, zinc, or their alloys	130–160	min 16

^AClasses ER-7, ER-10, ER-11, ER-12, ER-14, and ER-15 are traditional treatments used in Federal Standard QQ-C-320. They do not apply to any other standard.

TEST PLAN

•TEST METHODS:

ASTM F519: Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments

ASTM B117: Standard Practice for Operating Salt Spray (Fog) Apparatus

•Specimen Material:

AISI 4340 steel

•Specimen Coatings:

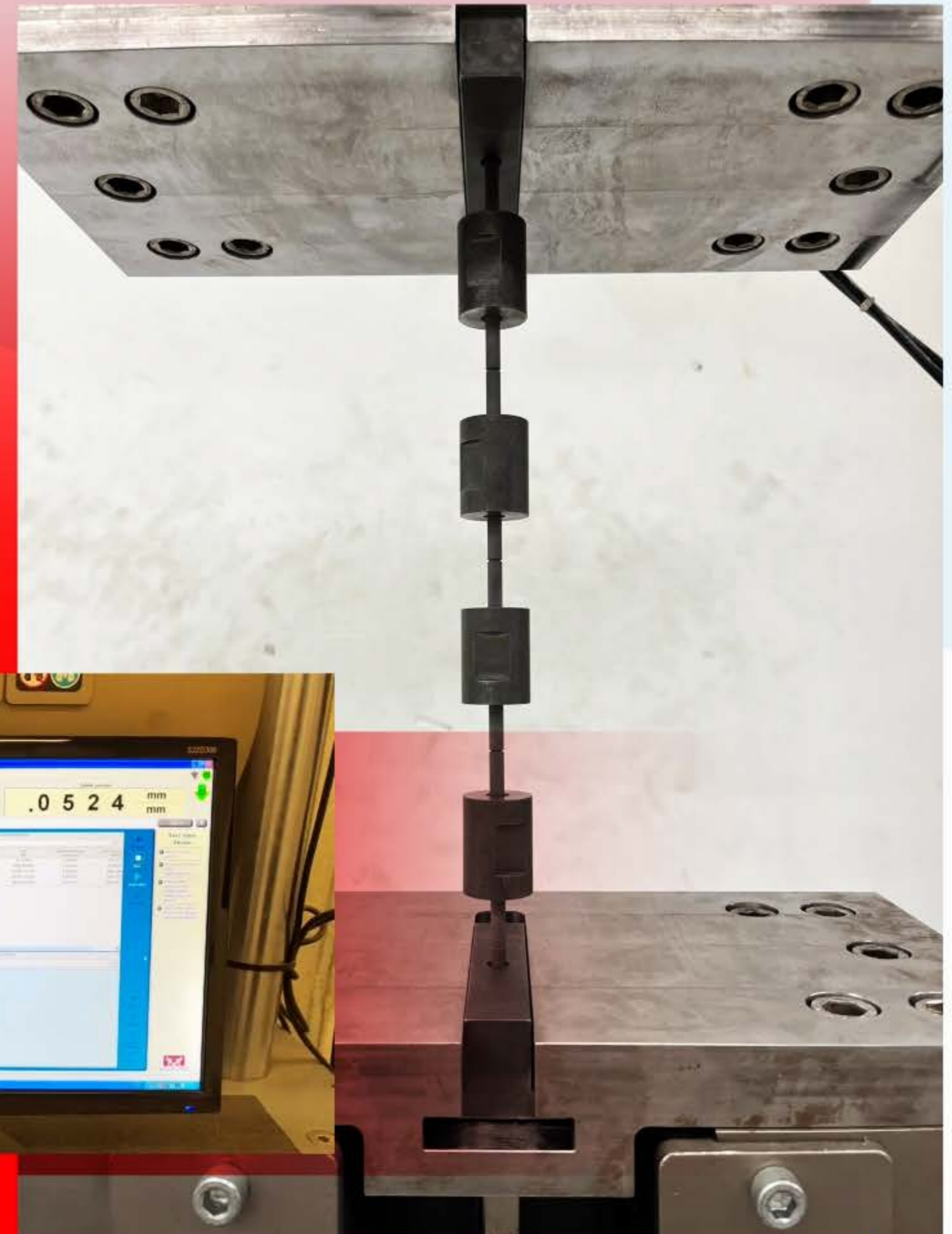
Zinc phosphate

Cadmium

Zinc-Nickel

•Hardness

51-53 Rockwell C (HRC)



TEST MATRIX

Coating	Standart	Process		Tests
		Pre HE treatment	Post HE treatment	
Zinch Phosphate	MIL-DTL-16232	-	-	ASTM F519 - 200hr
		5hr @ 160°C	23hr @ 160°C	ASTM F519 - 200hr
		5hr @ 160°C	23hr @ 160°C	ASTM B117 - 24hr ASTM F519 - 200hr
Cadmium	SAE-AMS-QQ-P-416	-	-	ASTM F519 - 200hr
		5hr @ 160°C	23hr @ 160°C	ASTM F519 - 200hr
		5hr @ 160°C	23hr @ 160°C	ASTM B117 - 96hr ASTM F519 - 200hr
Zinch-Nickel	ASTM-B841	-	-	ASTM F519 - 200hr
		5hr @ 160°C	23hr @ 160°C	ASTM F519 - 200hr
		5hr @ 160°C	23hr @ 160°C	ASTM B117 - 300hr ASTM F519 - 200hr



TEST RESULTS

Coating	Standart	Process		Tests	Tests Results
		Pre HE treatment	Post HE treatment		
Zinch Phosphate	MIL-DTL-16232	-	-	ASTM F519 - 200hr	Fractured
		5hr @ 160°C	23hr @ 160°C	ASTM F519 - 200hr	No Fracture
		5hr @ 160°C	23hr @ 160°C	ASTM B117 - 24hr ASTM F519 - 200hr	No Fracture
Cadmium	SAE-AMS-QQ-P-416	-	-	ASTM F519 - 200hr	Fractured
		5hr @ 160°C	23hr @ 160°C	ASTM F519 - 200hr	Fractured
		5hr @ 160°C	23hr @ 160°C	ASTM B117 - 96hr ASTM F519 - 200hr	On going
Zinch-Nickel	ASTM-B841	-	-	ASTM F519 - 200hr	Fractured
		5hr @ 160°C	23hr @ 160°C	ASTM F519 - 200hr	No Fracture
		5hr @ 160°C	23hr @ 160°C	ASTM B117 - 300hr ASTM F519 - 200hr	On going

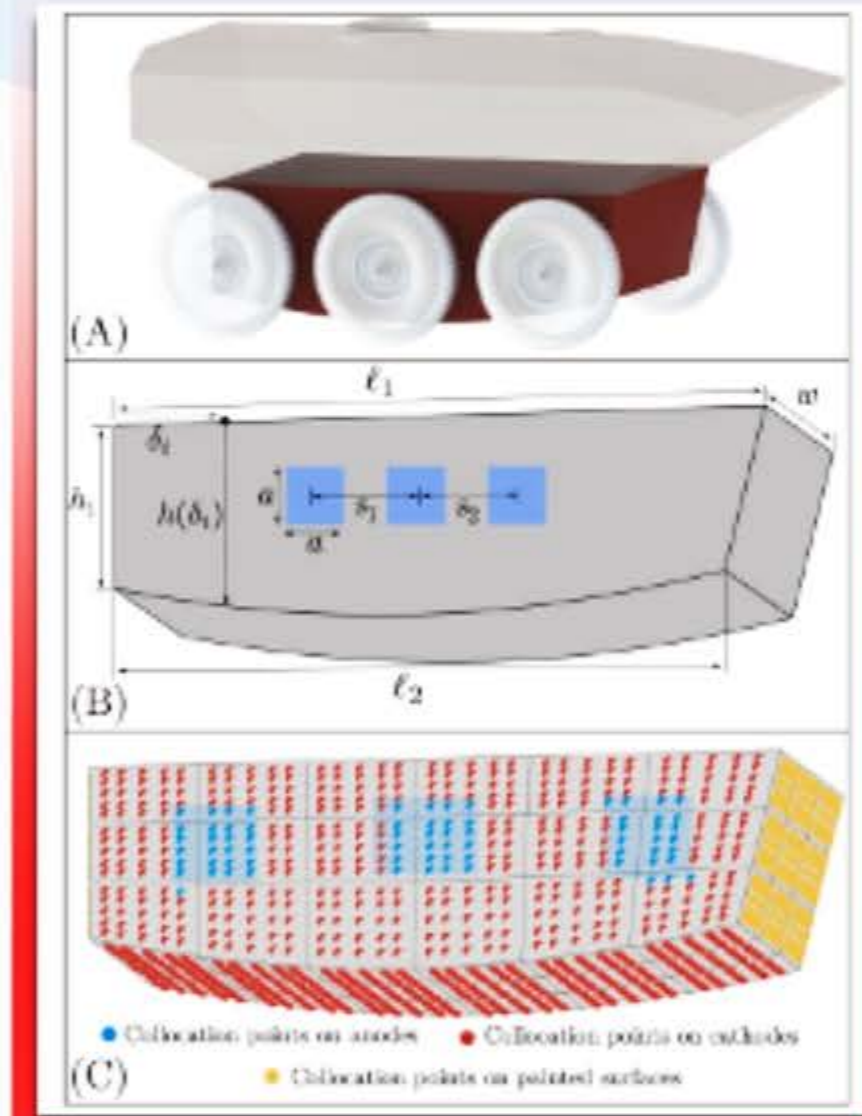
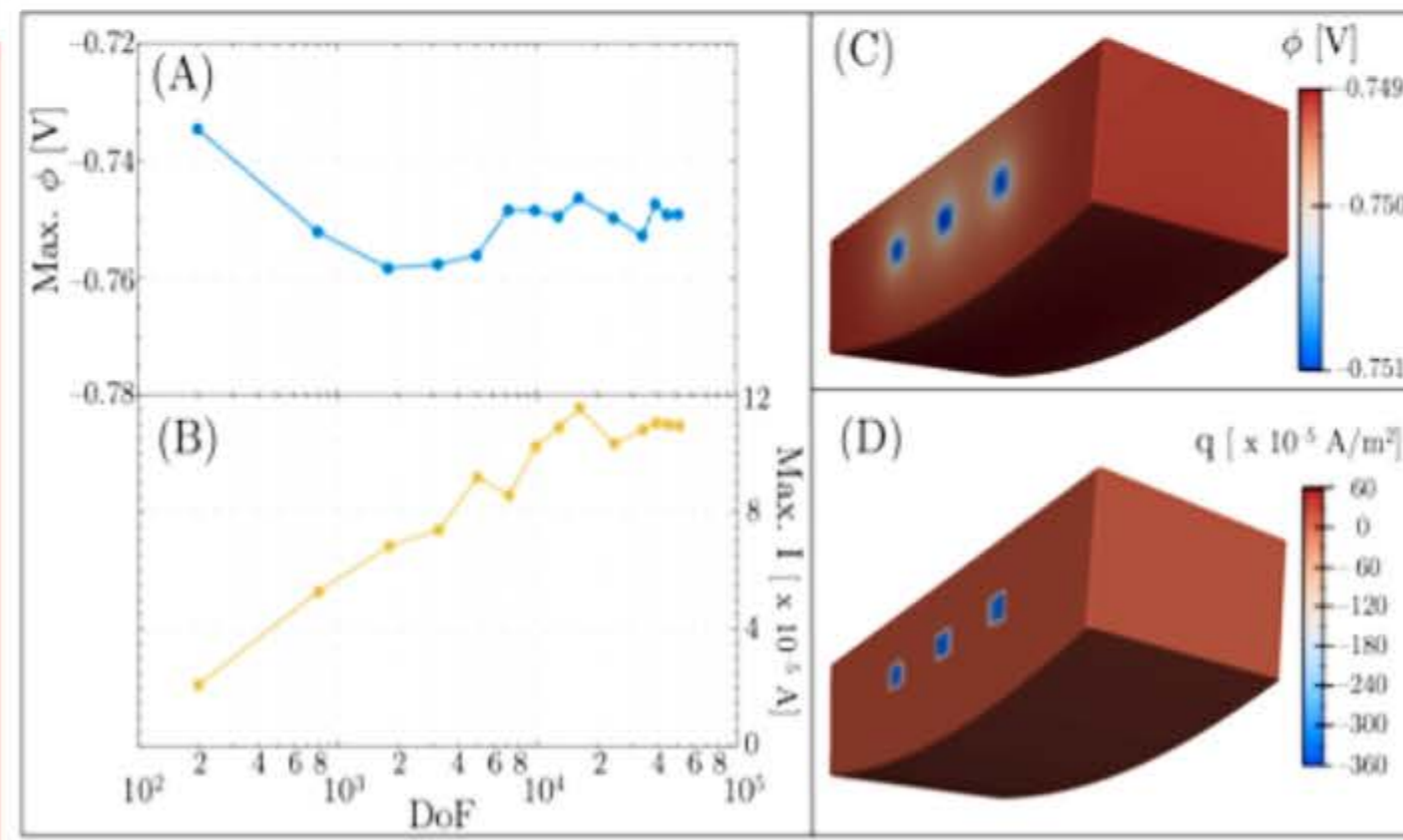


CONCLUSIONS

- You cannot paint everything
- Hydrogen causes fractures
- Not only for high-strength steels but also for fasteners
- Hydrogen embrittlement pre and post processes effects products' cost and process time
- Overheating can cause softening of material
- Process optimization is needed
- Limits should be studied for process failures
- Alternative coating systems ie. non-electrolytic processes

COMPUTATIONAL BASED R&D EFFORTS IN CORROSION PREVENTION

- Cathodic Protection systems with Isogeometric elements based numerical modeling in Boundary Element Method (BEM)
- First results was submitted to Journal of Engineering Analysis with Boundary Element related to this research.



FNSS

THANK YOU

