

Bonding Technologies – Resilience to mechanical, electrical and environmental stress

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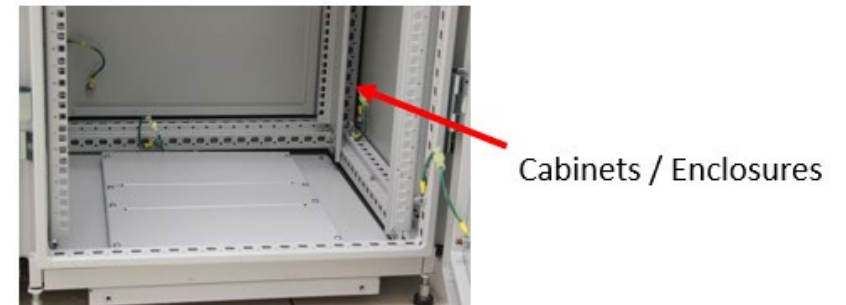
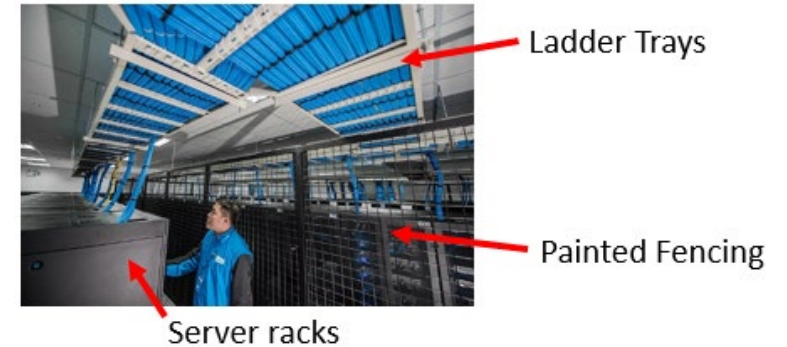
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Bonding of Metallic Surfaces with Non-Conductive Coatings

- Bonding metallic objects is required to provide a continuous, low-resistance path to ground for safety and performance of equipment.
- Metallic objects are typically coated to prevent exposure to corrosive environments and for aesthetics
- The most common coatings and for metallic objects are nonconductive
 - Powder Coat, Anodizing, Paints, Enamels, etc.
- Nonconductive coatings can create a challenge when trying to properly bond metallic objects
 - Create safety and performance issues if not done properly.
- Failures can occur due to any of the below:
 - Improper installation, Connector loosening, corrosion, electrical failure (insufficient current carrying capacity)



Existing Installation Methods and Technology



- Scratch Brushing
- Wire wheel
- Sandpaper
- Etc.

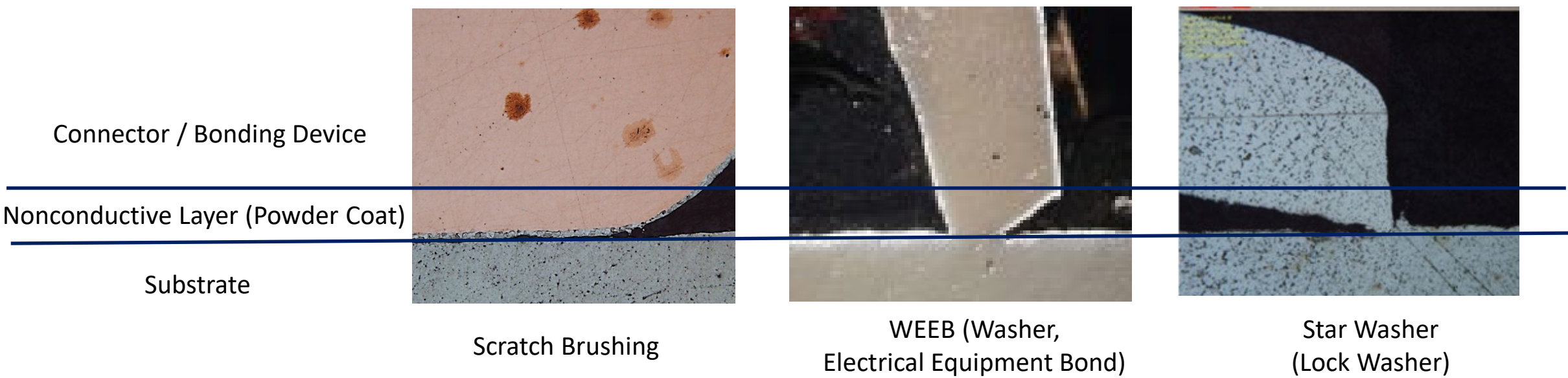


- WEEB (Washer, Electrical Equipment Bond)
- Listed / Recognized Bonding washer



- Star Washer
- Lock Washer (internal tooth / external tooth)

A Closer Look....



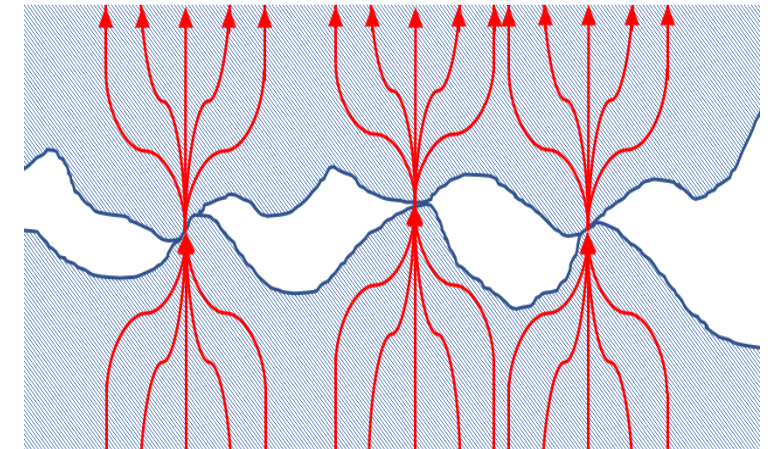
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Electrical Considerations

- Total contact area (Number / Size of A-spots)
 - A-Spots (points of physical contact) carry current between substrate and connector
 - Added clamping force creates more A spots over a given area
- Piercing connectors concentrate the clamping force of the bolt onto a smaller contact area
 - The increase in pressure in those locations increases concentration and size of the A-Spots
 - Allows smaller embedment points to carry high levels of current



Microscopic depiction of A-Spots

Mechanical Considerations

- Resistance to rotation and loosening of connection
 - Will reduce A-Spots and increase connection resistance
 - 2-Hole lugs are always recommended but are not always able to be used
- Clamping force of installation hardware (function of hardware size / torque)

Connector	None (Wire Brush)	WEEB	Star Washer
Connection Geometry	Flat on flat	Deep embedment points	Shallow surface depressions
Primary Resistance to Rotation	Friction force (large area, lower pressure)	Shear force (teeth embed into lug and metallic surface)	Friction force (small area / increased pressure)
Strength of Connection	Moderate	High	Low

Environmental Considerations

- Corrosion is caused by variety of factors
 - Salt spray testing is a good indicator of corrosion resistance but limited to observing resistance to alkaline corrosion
- Corrosion causes increased contact resistance and can lead to failure
 - Corrosion leads to reduction of A-Spots and decreases the lifespan of the connection



Overview of Testing – Electrical

Test Category	Description	Substrate	Groups
Electrical	Short-time current	Powder Coated Steel	WEEB
			Star Washer
			WEEB w/ Oxide Inhibitor 1
			Star Washer w/ Oxide Inhibitor 1
			WEEB w/ Oxide Inhibitor 2
			Star Washer w/ Oxide Inhibitor 2
	Anodized Aluminum	WEEB	
		Star Washer	
	Resistance Readings	Powder Coated Steel	WEEB
			Star Washer
			WEEB w/ Oxide Inhibitor 1
			Star Washer w/ Oxide Inhibitor 1
			WEEB w/ Oxide Inhibitor 2
			Star Washer w/ Oxide Inhibitor 2
Anodized Aluminum		WEEB	
		Star Washer	

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Overview of Testing – Mechanical

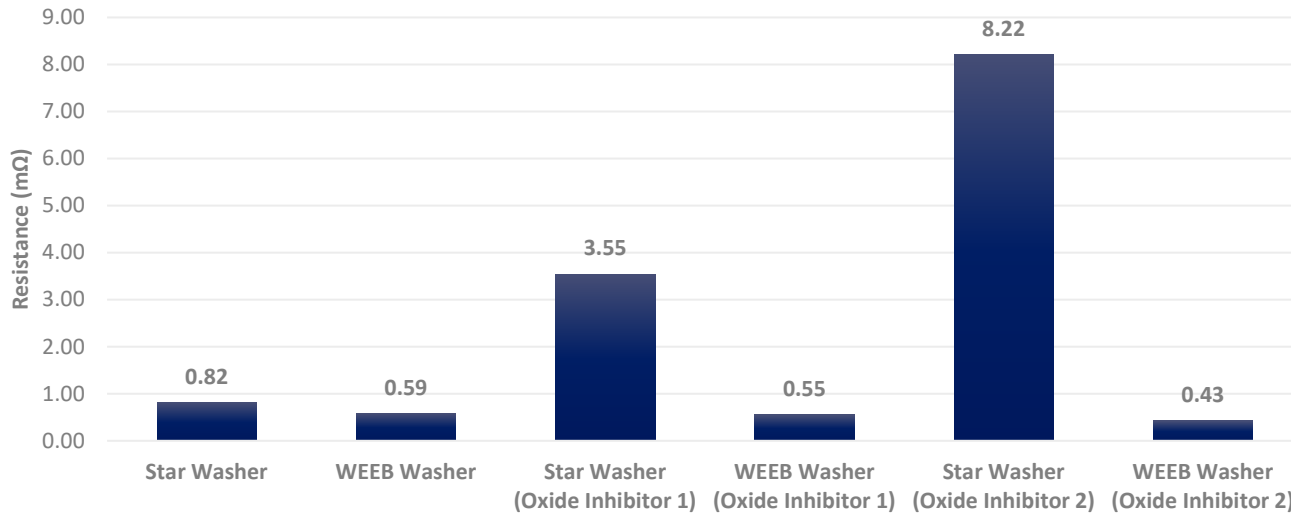
Test Category	Description	Substrate	Groups
Mechanical	Anti-Rotation	Powder Coated Steel	WEEB
			Star Washer
	Microscopic embedment analysis	Powder Coated Steel	WEEB
			Star Washer
		Anodized Aluminum	WEEB
			Star Washer

Overview of Testing – Environmental

Test Category	Description	Substrate	Groups
Environmental	Multi-Stress Sequence	Anodized Aluminum	WEEB
			Star Washer Material
	Salt Spray	Powder Coated Steel	WEEB
			Star Washer
			WEEB w/ Oxide Inhibitor 1
			Star Washer w/ Oxide Inhibitor 1
			WEEB w/ Oxide Inhibitor 2
			Star Washer w/ Oxide Inhibitor 2
	Annodized Aluminum	Annodized Aluminum	WEEB
			Star Washer

Electrical Results (Resistance)

Connection Resistance Prior to and Following Electrical Testing (Coated Steel)



Connection Type	Increase in Resistance
Star Washer vs WEEB	40 %
Star Washer vs WEEB (Oxide Inhibitor 1)	540% (5x)
Star Washer vs WEEB (Oxide Inhibitor 2)	1830% (18x)

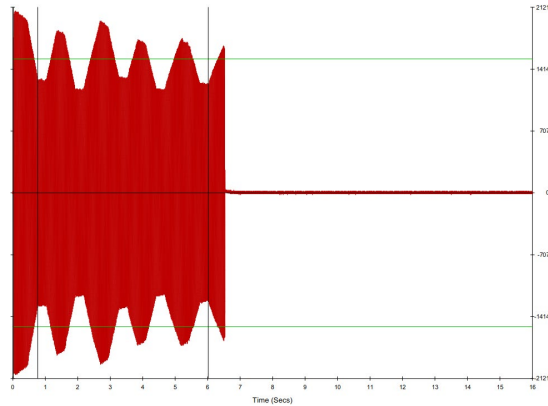
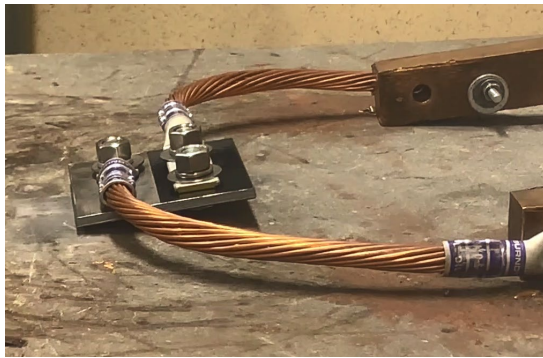
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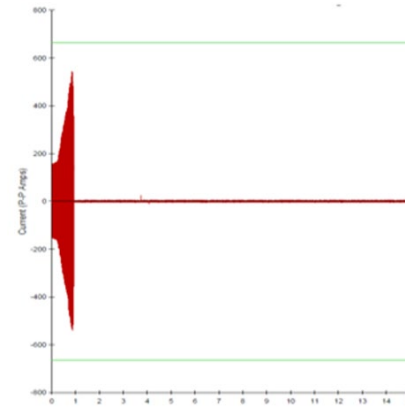
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Electrical Results (Short Circuit)

WEEB Samples



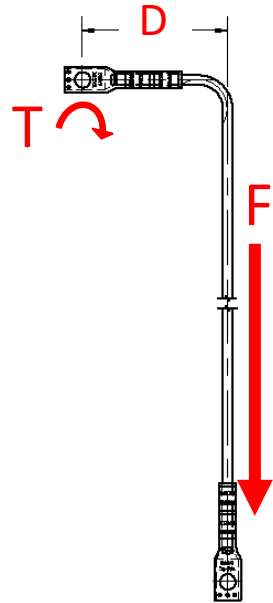
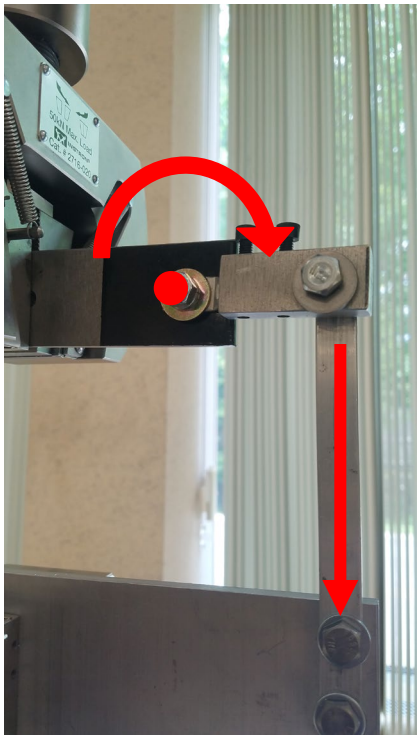
Star Washer Samples



- All WEEB samples carried the 6 AWG fault current for the full duration of the test
 - All samples had electrical continuity after the test

- 2 out of every 3 samples failed to carry the 6 AWG UL 467 fault current
 - Connection points fused causing loss of continuity

Mechanical Results

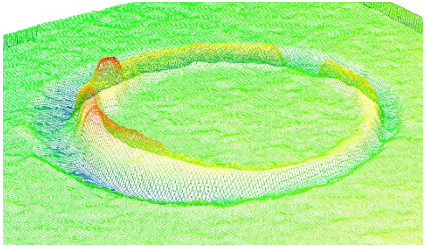


- Significant lug bending on samples 1 – 3
- Limited lug bend before rotation on samples 7 and 9
- Rotation of lug prior to noticeable lug deformation on samples 4 – 6 and sample 8



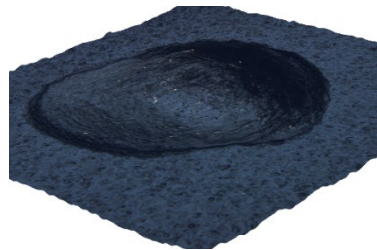
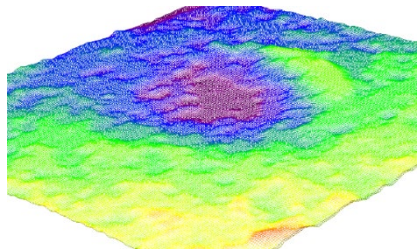
- Samples 1 – 3: WEEB-TC14
- Samples 4 – 6: External tooth lock washer
- Samples 7 – 9: Bare lug on plain steel

Mechanical Results



WEAB:

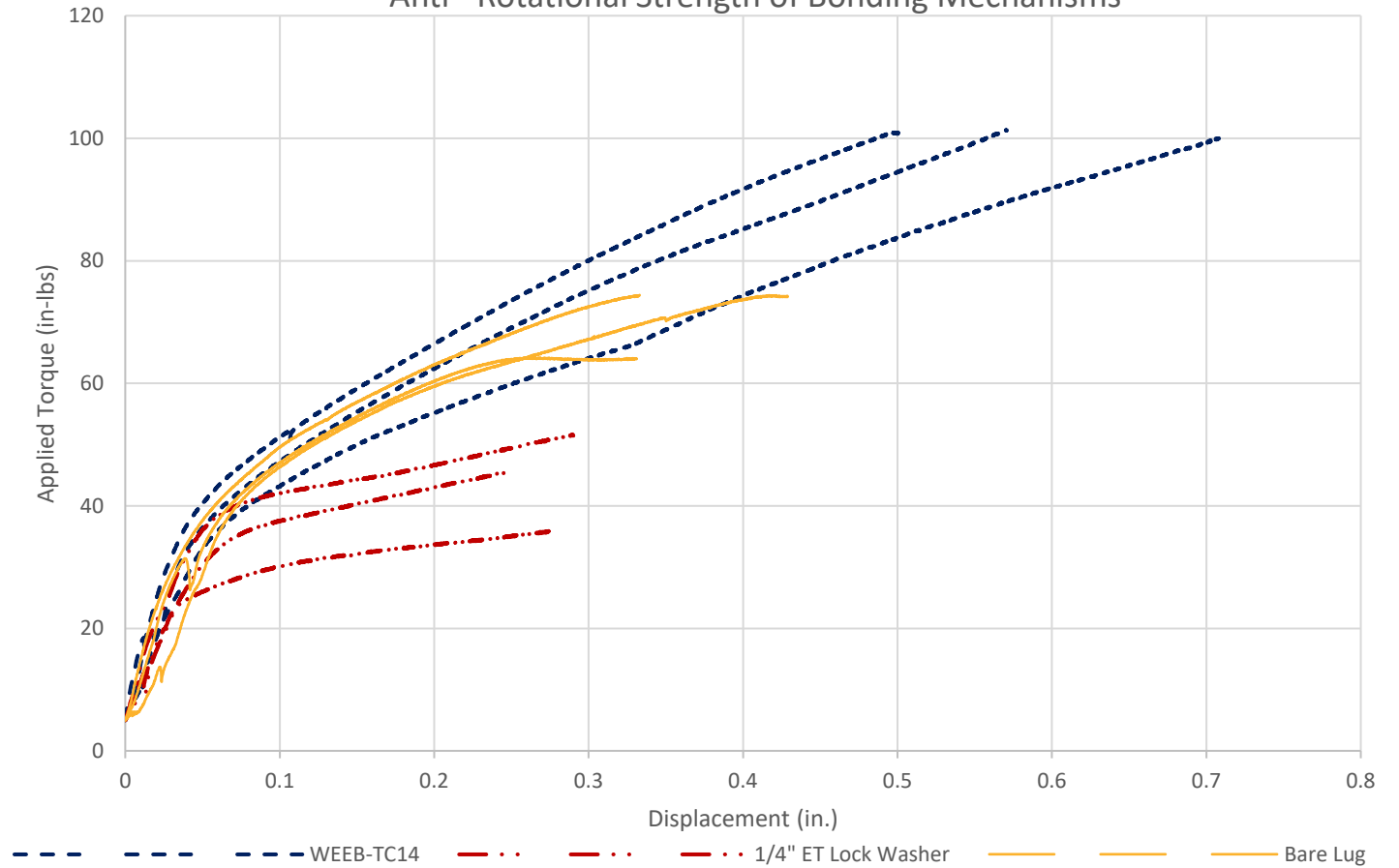
Significant embedment deformation – Shear at contact points



Star Washer:

Minor surface depressions – Minimal friction force

Anti - Rotational Strength of Bonding Mechanisms



Environmental Results – Multi Stress Sequence



vs.



WEEB

304 Stainless → no visible degradation

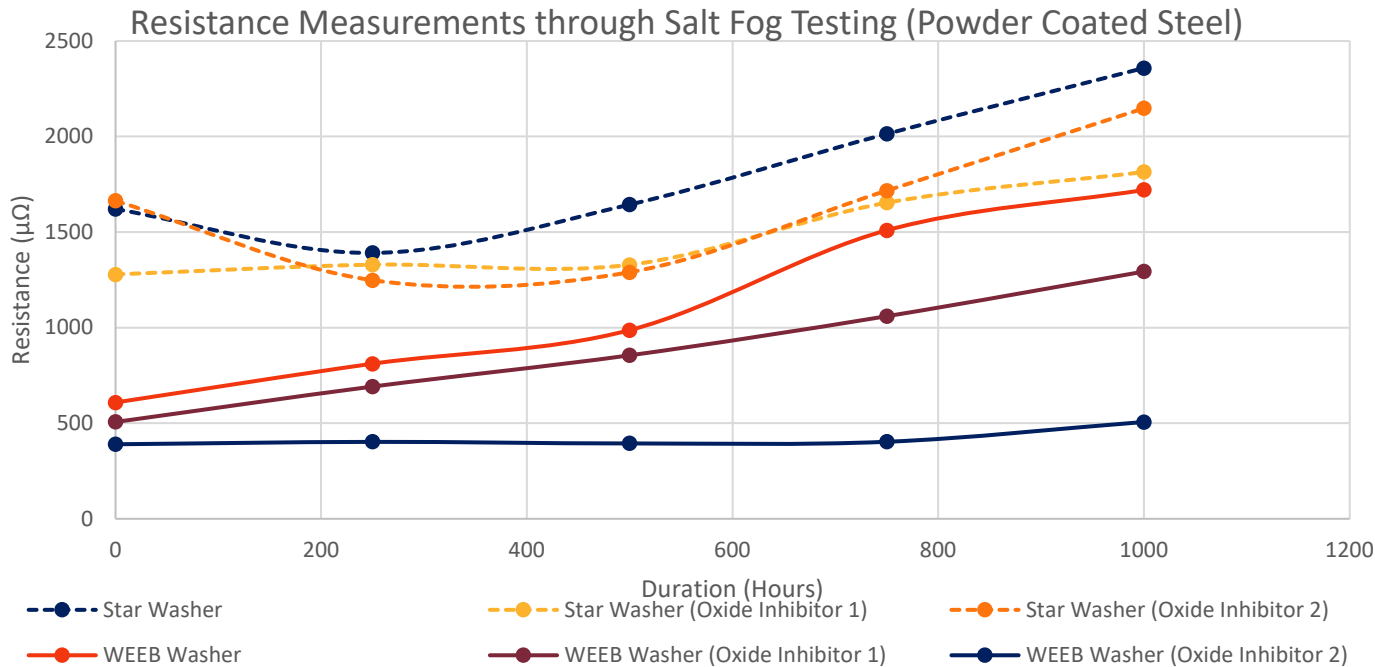
Low Carbon Steel → significant corrosion

HUMIDIFICATION												
HEATING												
DEMINERALIZED RAIN												
SALT FOG												
SOLAR RADIATION												
HOURS	2	4	6	8	10	12	14	16	18	20	22	24

- IN OPERATION
 - OUT OF OPERATION

IEC61109 - ENVIRONMENTAL SEQUENCE

Environmental Results – Salt Spray



- All WEEB samples provided low resistance, stable bonding connections
- Star washer samples that formed bonding connection also fairly stable, but less consistent initial connection with higher overall resistance

Summary

WEEB Washers

Star Washers

Electrical	UL467	All Samples Passed	Sporadic Failures
	Resistances	Comparatively Lower	Comparatively Higher
Mechanical	Anti-Rotation Strength	Higher than Control	Lower than Control
	Contact Points	Significant Embedment Points	Minor Depressions
Environmental	Multi-Stress Corrosion	High Corrosion Resistance	Significant Corrosion*
	Salt Fog	Consistent Resistance Readings	Sporadic Readings with Samples Losing Continuity

*star washer material analyzed

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Conclusion

- Bonding is vital to system safety and installation longevity
- WEEB washer properties support high quality and long-lasting bonding connections
- Star washer properties show inconsistent connection quality with unpredictable lifespan
- WEEB increases degree of installation safety by providing a connection that is tested to stand up to electrical, mechanical and environmental stress

References

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Questions?



Additional detail available in WEEB Theory Rev A – Available from Burndy