Best Practices for Outdoor Grounding & Bonding Terminations

Connector Technology

Electrical Connector

- In their simplest form, join two or more conductors in a continuous, electrically conductive path

Grounding Connection Types

Compression

Mechanical

Exothermic

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Outdoor Connection Longevity

Connector Selection

- Selecting a connector that is design to be used for the application.
  - Proper **wire size / wire range** & designed to connect to the surface you are bonding
  - Proper connector **materials and plating** (high copper content, tin plating, SS or silicon bronze hardware)

Installation

- Install per the manufacturer's recommendations
  - **Compression** - Tool, Die, No. of crimps
  - **Mechanical** - Proper Installation Torque
  - **Exothermic** - Cleaning / drying exothermic mold & conductors, proper shot and conductor size
- Minimize corrosion opportunity's that can be controlled
  - **Cleaning** conductor and connection surface
  - **Avoid dissimilar metals** when possible
  - Use **proper oxide inhibitor** on conductor and mounting surface
  - Use **corrosion resistant mounting hardware** (SS or Silicone bronze)

Bare copper connector designed for flat surface on a round steel pipe,

Fully tin-plated connector designed to be used on round pipe

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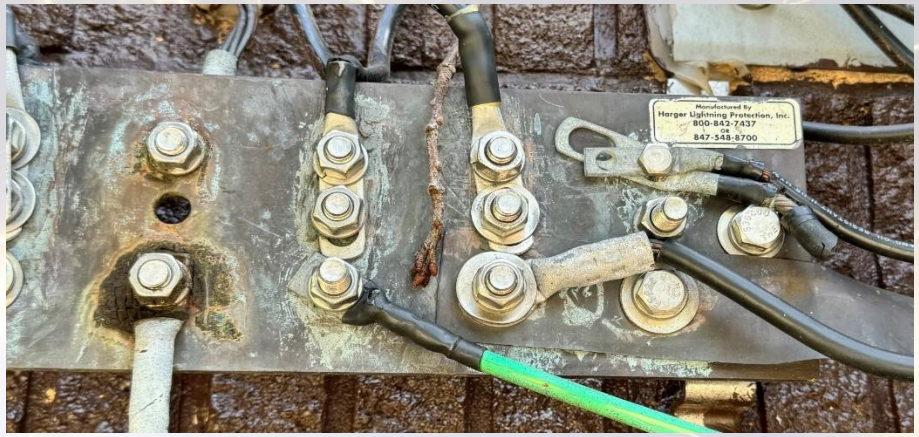
Preferred Connection Methods (Telecom industry)

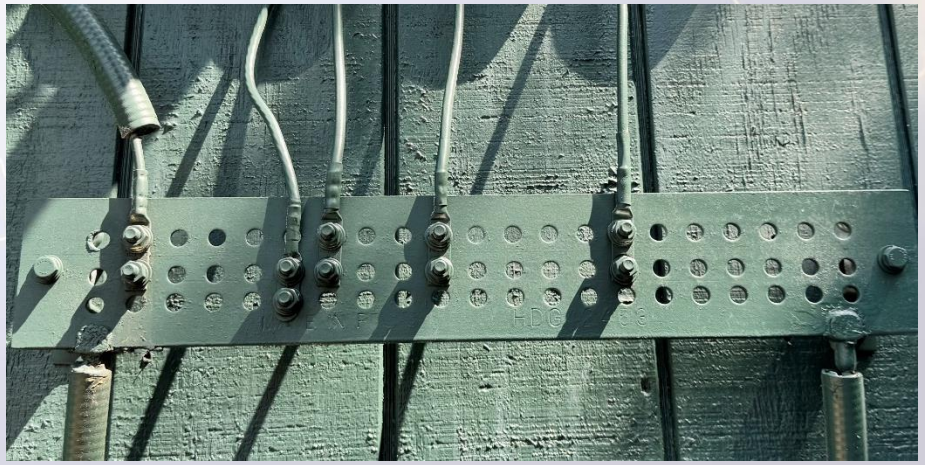
Compression / 2 – hole long barrel lugs

- Irreversible
- Inability to rotate which can cause hardware to loosen
- Larger contact surface when compared to a single hole lug
- Able to utilize more crimps (Lower resistance & higher mechanical strength)



Exothermic

- Molecular bond between the two conductors
- Strong, low resistance connections when done properly
- Highly corrosion resistant as there is no ability for water or air to enter the connection



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Grounding Electrodes

Ground Rods

Ground Plates

Ground Enhancement Material (GEM)

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Oxide Inhibitors

Overview and Benefits

- Oxide Inhibitors typically utilize an oil base, a thickener and suspended additives or particles (“grit”)
- **Seal the connection** from air and moisture to **prevent oxidation** and **improve the service life of the connection**
- May aid in **penetrating an existing oxide layer**
- Acts as a **lubricant for inserting conductor** into a connector or **on threads to prevent galling or seizing**

Common Types of Oxide Inhibitors

- Petroleum or synthetic base
- “Non-grit” or “Grit” versions
- “Grit” typically consists of suspended Zinc, Copper or Aluminum Oxide particles

Considerations

- **Connector, conductor** and **mountain surface** materials
- **Operating temperature range** (not a major issue with grounding connections)
- **Compatibility** with conductor **insulation or PPE** (gloves) being used during installation.

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Oxide Inhibitors (Cont.)

Reference Studies

Data

Summary

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Lug Selection Considerations

Inspection Window

- Allows for **visual inspection** of the wire ensuring **full wire insertion** and no visible strand damage
- Creates an area for **moisture and other contaminants** to enter the connection

No Inspection Window

- Connection is **less vulnerable to moisture and contamination**
- **No ability to visually inspect wire** before or after crimping

Two - Hole

- Lug is unable to rotate preventing hardware to loosen
- Large contact surface with additional clamping force

Single - Hole

- Can fit in a more confined space
- Potential for hardware to loosen over time from lug moving

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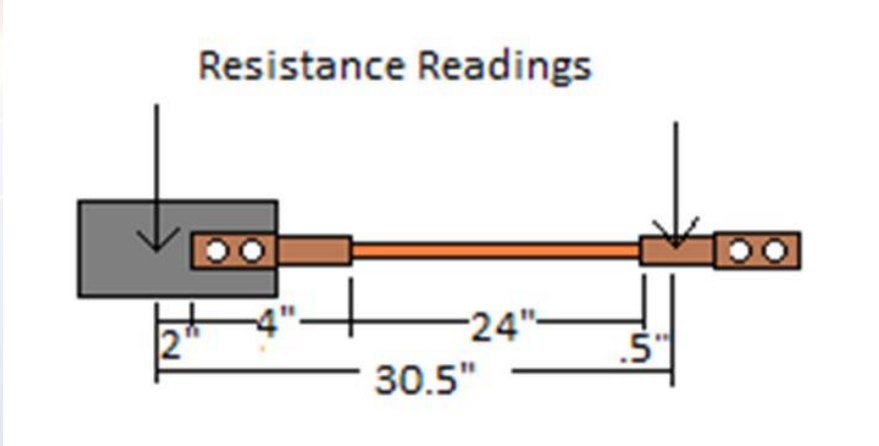
Connector Comparison – Experimental Data

ASTM B117 – Salt Spray (Fog) 1008 - hour exposure test

- 6 sample groups were tested to compare plating, mounting surface and the use of oxide inhibitor
- Resistance measurements were taken 6 separate times through the 1008 hours

Connector	Platting	Mounting Surface	Oxide Inhibitor
YGHA262NTN	Tin	Steel Plate	N/A
YGHA262NTN	Tin	Copper Plate	N/A
YGHA262N	N/A	Steel Plate	N/A
YGHA262N	N/A	Copper Plate	N/A
YGHA26-2NTN	Tin	Steel Plate	Penetrox- E
YGHA26-2NTN	Tin	Copper Plate	Penetrox- E

Sample Groups



Test Setup

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Connector Comparison – Experimental Data (Cont.)

- All measurements are given in micro-ohms corrected to 20 °C

YGHA Lug to Steel Plate										
Connector	Mounting Surface	Oxide Inhibitor	Initial Reading	168 Hours	336 Hours	504 Hours	672 Hours	840 Hours	1008 Hours	Max Resistance Change Measured
YGHA262NTN	Steel Plate	N/A	72.6	85.5	88.5	95.8	98.4	107.8	93.3	35.2
YGHA262N			101.5	109.1	117.0	125.2	135.8	154.2	125.4	52.7
YGHA26-2NTN		Penetrox- E	112.0	111.5	112.4	111.3	110.0	110.3	110.3	-1.7

YGHA Lug to Copper Plate										
Connector	Mounting Surface	Oxide Inhibitor	Initial Reading	168 Hours	336 Hours	504 Hours	672 Hours	840 Hours	1008 Hours	Max Resistance Change Measured
YGHA262NTN	Copper Plate	N/A	10.1	20.4	25.6	27.5	31.1	42.3	28.1	32.2
YGHA262N			25.8	28.4	28.7	36.6	38.6	41.8	38.4	16.0
YGHA26-2NTN		Penetrox- E	83.4	83.3	82.5	82.1	82.0	82.2	82.2	-1.3

Summary of Findings

- When connecting to steel, tin plating provided much better connection stability throughout the test
- Using an oxide inhibitor whether connecting to steel or copper greatly increased connection stability

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Mounting Hardware Considerations - Material

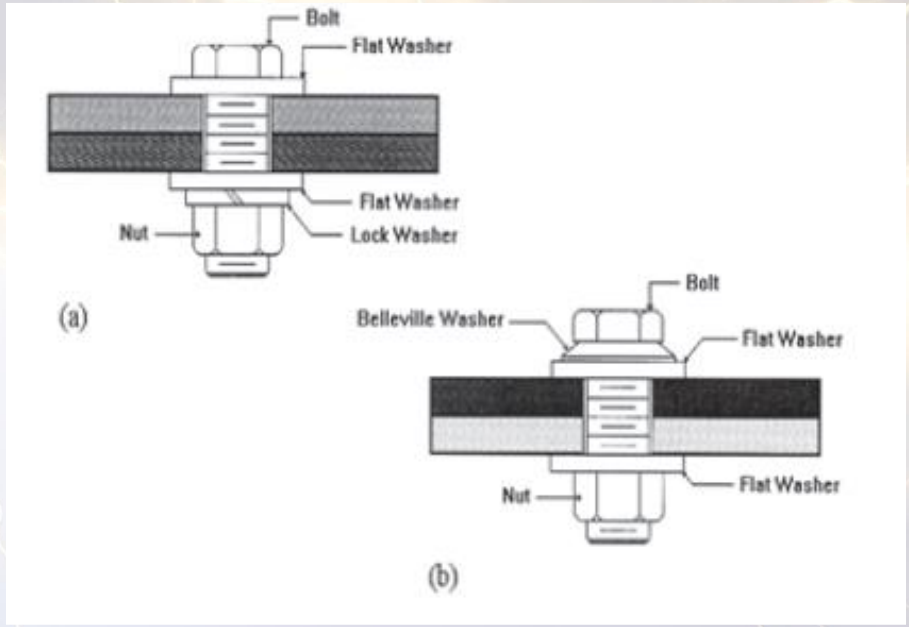
Bolted Joints
Table 3.1-1

Recommended Hardware Materials (Quantity per Bolt)

Materials Being Joined	Bolt (1 each)	Nut (1 each)	Flat Washer (2 each)	Lock Washer (1 each)	Belleville Washer (1 each)	Reference Figure 2.1-1
Copper to Copper	SB	SB	SB	SB	NR	(a)
	SS	SS	SS	SS	NR	
Copper to Aluminum	SB*	SB*	SB*	NR	SS	(b)
	SS	SS	SS	NR	SS	
Aluminum to Aluminum	AL	AL	AL	AL	NR	(a)
	SS	SS	SS	NR	SS**	(b)
Copper to Steel	SB	SB	SB	SB	SS**	(a) or (b)
	SS	SS	SS	SS	NR	(a)
	GS	GS	GS	GS	NR	
Aluminum to Steel	SB*	SB*	SB*	NR	SS	(b)
	SS	SS	SS	NR	SS	
	GS	GS	GS	NR	SS	

Key:

NR Not Required
SB Silicon Bronze
AL Aluminum
SS Stainless Steel
GS Galvanized Steel
* Tin Plated
** Alternate recommendation in place of lock washer



- For outdoor connections **stainless steel** or **silicon bronze** hardware should be used
- **UL 467 requires stainless steel or silicon bronze hardware for Direct Burial Rating**

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Mounting Hardware Considerations - Torque

Properly Torqued Hardware

- Provides adequate clamping force for a low resistance, stable connection
- Creates a seal between the connector and mounting surface to help prevent entry of moisture and water

Industry Torque Recommendations

Recommended Tigtening Torque Table 3.1-2		
Bolt Size*	**DURIUM™ (silicon bronze) Stainless Steel Galvanized Steel (lb-in)**	**Aluminum (lb-in)**
1/4 - 20	80	—
5/16 - 18	180	—
3/8 - 16	240	168
1/2 - 13	480	300
5/8 - 11	660	480
3/4 - 10	960	650
* Thread classes are UNC-2A (external) and UNC-2B (internal)		

NEMA – CC1 *(Nominal Torque Values Table 4-4)*

Screw or bolt size		Tightening torque	
Metric	**SAE**	**N·m**	**(lbf·ft)**
–	No. 8 or smaller	2	(1.5)
–	No.10	3	(2.0)
M6	1/4	8	(6)
–	5/16	15	(11)
M10	3/8	26	(19)
–	7/16	41	(30)
M12	1/2	54	(40)
–	9/16, 5/8 or larger	75	(55)

UL 486A-B *(Table 24 – Tightening Torque for Connecting Hardware)*

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Dissimilar Metals Considerations – Galvanic Compatibility

Metallurgy	Index (V)
Gold, solid and plated, Gold-platinum alloy	0.00
Rhodium plated on silver-plated copper	0.05
Silver, solid or plated; monel metal. High nickel-copper alloys	0.15
Nickel, solid or plated, titanium an s alloys, Monel	0.30
Copper, solid or plated; low brasses or bronzes; silver solder; German silvery high copper-nickel alloys; nickel-chromium alloys	0.35
Brass and bronzes	0.40
High brasses and bronzes	0.45
18% chromium type corrosion-resistant steels	0.50
Chromium plated; tin plated; 12% chromium type corrosion-resistant steels	0.60
Tin-plate; tin-lead solder	0.65
Lead, solid or plated; high lead alloys	0.70
Aluminum, wrought alloys of the 2000 Series	0.75
Iron, wrought, gray or malleable, plain carbon and low alloy steels	0.85
Aluminum, wrought alloys other than 2000 Series aluminum, cast alloys of the silicon type	0.90
Aluminum, cast alloys other than silicon type, cadmium, plated and chromate	0.95
Hot-dip-zinc plate;galvanized steel	1.20
Zinc, wrought; zinc-base die-casting alloys; zinc plated	1.25

For ***harsh environments***, such as outdoors, high humidity, and salt environments fall into this category. humidity-controlled there should be not more than 0.15 V difference in the "Anodic Index". For example; gold -silver would have a difference of 0.15V being acceptable.

For ***normal environments***, such as storage in warehouses or non-temperature and humidity-controlled environments. Typically, there should not be more than 0.25 V difference in the "Anodic Index".

For ***controlled environments***, such that are temperature and humidity controlled, 0.50 V can be tolerated. Caution should be maintained when deciding for this application as humidity and temperature do vary from regions.
This serves as a basic qualitative guide only.

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Environmental Considerations

Temperature and Weather

Corrosive Environments

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