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# INSTALLATION MANUAL

For answers to installation Questions call 509-466-3545

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## Introduction

The following instructions are recommended by Travis Pattern & Foundry Inc. and should only be used as a guide for the installation of electrical connectors and fittings. The instructions provided here are intended to provide helpful reference information for three types of installation procedures; bolted, welded, and compression. Instructions are provided for both copper/bronze and aluminum alloy connectors.

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## Cleaning and Preparation of Electrical Connections

Although **copper/bronze** oxidation does not provide as much interference with the flow of electric current as the oxidation produced by **aluminum alloys**, it is advisable to follow the same procedures for installation of either material. Aluminum is more critical because aluminum oxide is known to insulate electrical potential and can therefore cause connectors to over heat and eventually fail. For copper/bronze as well as aluminum alloy applications, a properly cleaned surface with the correct oxide inhibitor applied maximizes conductivity and helps keep outside contaminants from promoting corrosion. This can cause a reduction of the current carrying capability and life of the connector. Once oxidation has been removed the use of an oxide inhibitor on all connections can prevent further oxidation from taking place.

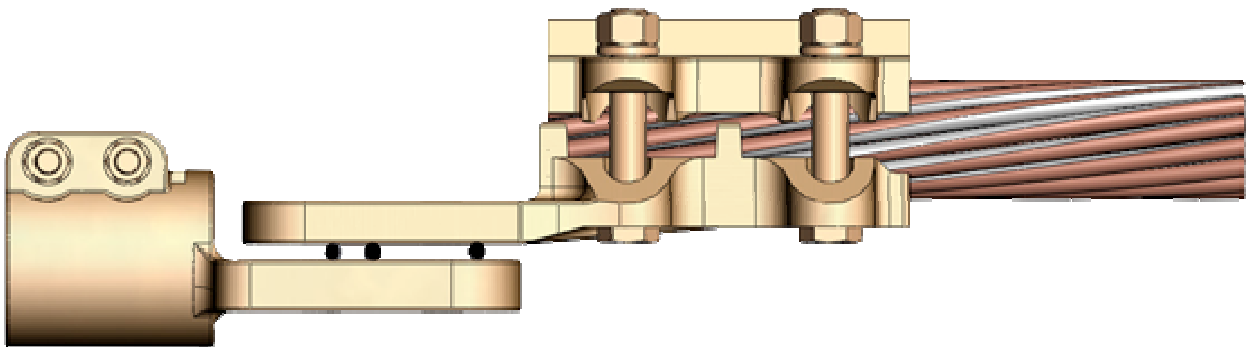
All contact areas of a connector, as well as the areas to which they will be connected, should be wire brushed to thoroughly remove any oxidation. The contact area is the part of a connector, cable, bus, or any other conducting surface that is intended to be joined together for the purpose of conducting electricity. Each contact surface should be cleaned with a wire brush and a generous portion of oxide inhibitor should be applied. Excess oxide inhibitor does not need to be removed from connections installed when corona is not an issue. **All excess oxide inhibitor must be removed from connectors installed in EHV applications.** When insulated cable is being connected, only non-petroleum based oxide inhibitor should be used.

After brushing the contact areas clean, immediately apply the correct oxide inhibitor that is designed for that application. Repeat the wire brushing a second time to work the inhibitor into the clean surface. The correct oxide inhibitor will depend on the material being connected and the contour of the conductor surfaces being connected.

**Plated surfaces** should be cleaned with a mild wire brush or mild abrasive like Scotch Brite being careful to remove as little of the plating as possible. Chemicals formerly available for cleaning plated surfaces have been found to be hazardous to human health and are no longer available. The correct oxide inhibitor should be applied in the same manner previously stated as if there were no plating.

## Selecting the Correct Oxide Inhibitor for Flat to Flat Connections

Oxide inhibitors containing suspended conductive particles **should not be used on flat to flat surfaces**, IE: **(ALCOA Filler Compound (AFC))**. As seen in the drawing below, particles prevent the two flat surfaces from coming together in order to maximize their contact area. They reduce the cross sectional area of the contact points. Only a **non-grit** type oxide inhibitor IE: **(ALCOA Electrical Joint Compound #2)** should be used for flat and other smooth surface connections such as rigid pipe conductor and terminal pads.

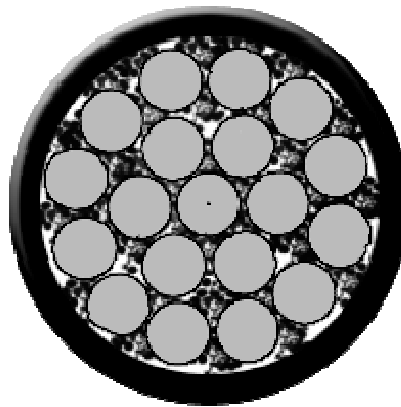


## Oxide Inhibitor (Filler Compound) for Cable Connections

The best job anyone can do at wire brushing a cable that is to be electrically connected is to clean only the outer surfaces of the outer strands of that cable. The inner strands are coated with aluminum oxide and it cannot be removed without unraveling the cable. Some oxide inhibitors are supplied with suspended conductive particles such as zinc, nickel, or other such hard conductive material. The function of these particles is to pierce through the aluminum oxidation covering the inner strands of a cable and to make contact with clean aluminum between each strand of the cable. The particles act as small shunts connecting the inner strands of a cable to each other as well as to its outer strands. This permits more of the strands to participate in the current carrying function of the cable thus maximizing the efficiency of the connection.

The oxide inhibitor should be worked in-between the strands so that the conductive particles that are suspended in the oxide inhibitor can make contact with each cable strand. Note that all oxide inhibitors do not contain suspended particles so it is important to select an oxide inhibitor with particles (**grit**) when making a connection to a cable. Oxide inhibitors containing particles should be used in all applications involving a cable. Oxide inhibitors that contain **suspended particles should not be used on flat to flat surfaces** such as rigid pipe conductor and terminal pads.

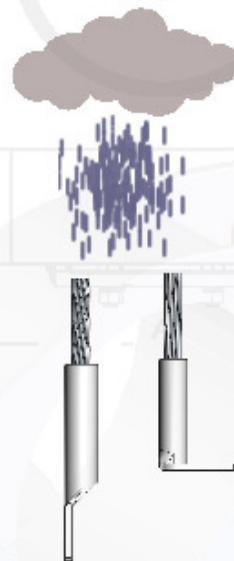
When installing a cable into a compression connector, the act of completely inserting the cable into a tube that has been properly filled with oxide inhibitor will cause the inhibitor to rise in the tube. This action will cause the oxide inhibitor to extrude itself into the cable thus filling many of the voids between the strands. The drawing below demonstrates how the particles fill in between the strands in a cable. The same method is used for both bolted and compression connections involving a cable.



**Compression connectors** should be properly filled with filler compound so that there is no empty space after the conductor is inserted. This is especially important if the terminals are to be installed with the barrels in the upright position. If there are any cavities not filled with filler compound water will eventually find its way into these voids and later freeze and expand making the cavity even larger. After a number of these cycles the cavity can grow to the point of connector failure. External contact areas such as the terminal pad need to be cleaned and have **non-grit** type oxide inhibitor applied as described earlier.

**Filler compound is required for all installations.**

**Note:** In applications that require the open end of a terminal barrel to point towards the sky it is imperative that additional filler compound be used to fill the entire cavity area.



### Common Crimping Dies

Die index	Kearney	Alcon	Bumdy	T&B
0.840	5/8	73 AH	243	-
0.840	840 or 845	74 AH	248	78
1.000	1.000	75 AH	251	-
1.125	1 1/8	78 AH	490, 547, 318	96
1.312	1 5/16	20 AH	327, 317, 428, 300	106
1.500	1 1/2	24 AH	318, 261, 608	125
1.843	1 5/8, K8030AH	30 AH	282, 302, 352, 579	150
2.125	2 1/8	34 AH	422, 575	160, 181
2.375	2 3/8	38 AH	478, 728	189
2.937	2 15/16	48 AH	740	-

## **Bolted Connections**

The hardware material that is generally supplied with bolted connectors is in keeping with the avoidance of using dissimilar metals. This is done for protection against electrolysis and other corrosion. The standard hardware on bronze connectors is silicon bronze and aluminum anodized hardware is standard on aluminum alloy connectors. Aluminum anodized hardware is sometimes substituted with stainless steel or galvanized steel hardware for use on aluminum alloy connectors. **The primary reason for selecting one hardware material over another should be the environment in which it will be installed and personal experience.** Some harsh environments are more susceptible to corrosion with one material or another. Examples of this might be when connectors are installed near paper mills, chemical plants, salt water or any other environment that could promote or even accelerate corrosion. The same selection process can be employed when determining the pad mounting hardware to be used to fasten a connector to equipment or another connector.

Each clamping bolt that goes through the body of the connector and clamps down on the conductor is usually supplied with a nut and lock washer. The purpose of the lock washer is to prevent loosening due to vibration and to compensate for expansion and contraction of metals. Pad mounting hardware should also include a nut and a washer that provides some means of compensation for expansion and contraction. This can either be a lock washer or a Bellville washer.

Bolts used in the connector body as well as those used for pad to pad mounting should be **tightened evenly** and a **torque wrench** should be used in accordance with the torque tables below. PDU connectors are supplied with **non-lubricated** silicon bronze hardware, stainless steel hardware **w/anti-seize** and **lubricated** aluminum hardware. Using oxide inhibitors, especially those containing particles, as a lubricant can interfere with the tightening of bolts resulting in a poor connection.

<b>Recommended Torque Values in ft/lbs</b>			
<b>Bolt Diameter</b>	<b>Silicon Bronze</b>	<b>Stainless Steel (w/anti-seize)</b>	<b>(Lubricated) Aluminum</b>
<b>5/16-18</b>	11	11	N/A
<b>3/8-16</b>	20	20	15
<b>1/2-13</b>	40	40	25
<b>5/8-11</b>	55	55	40

## **Selection of Compensating Washers**

Whether a washer is being used on a clamping or a pad mounting bolt of an electrical connection, its purpose is to compensate for the expansion and contraction of the materials being connected due to temperature changes, and to protect against loosening due to vibration. The two most common types of washers used for this purpose are SS 304 lock washers and SS 304 Bellville washers. Lock washers are generally provided by the manufacturer for use with the clamping bolts because they are generally smaller in diameter and therefore fit in the connector body more compactly. Both can provide needed protection.

When selecting a washer there are three major factors to consider. All washers are not equal and quality can make the difference between a connector operating correctly and one that fails.

1. **Material** – All washer materials do not provide the same ability to spring back to their original position. The best grade of stainless steel washer may not be the best selection for a particular application. A washer that has very high resistance to corrosion may also be very low in its ability to retain its spring.
2. **Curing** – Some type of heat treating, pre-stressing, or curing is needed in order to provide necessary resilience in any washer, by the manufacturer. All washers are not necessarily prepared in the same fashion and the results can be different.
3. **Corrosion resistance** – A balance must be found that provides both corrosion resistance for the particular application, and still be able to provide necessary spring ability. When considering corrosion resistance of hardware, there are two issues to evaluate. The first issue is to make sure that electrolysis is minimized by not introducing dissimilar metal hardware that will promote electrolysis. (See also “SELECTION OF MOUNTING HARDWARE”) The second issue to be aware of is the environment in which the connector will be installed.
4. **Length of travel** – The amount of necessary travel must be considered to ensure that compensation for expansion and contraction are both considered. Although some washer manufacturers recommend installing washers close to or at the flattened position, consideration must be given to how the connection will perform when heat is applied and expansion takes place. Cold flow may result because the aluminum body of the connector is not allowed to expand and may also lead to a loose connection.
5. **Pressure** – The amount of torque that is applied to a mounting bolt will determine how much pressure will be developed on the connecting surfaces. High pressure decreases electrical resistance, but this pressure must be maintained as temperature increases and decreases. If a washer is installed too tight initially the resistance may decrease. Then the temperature will increase and cold flow will begin to occur.

Simply selecting a lock washer over a Bellville or the other way around is not enough. Either washer can do the job if it is made correctly. Once a washer has been selected, it must be installed in a way that will maximize its efficiency. A flat washer should always be used between the spring washer and the body of the connector. This is especially important on aluminum because it is a soft metal and the washer can dig into the part being fastened.

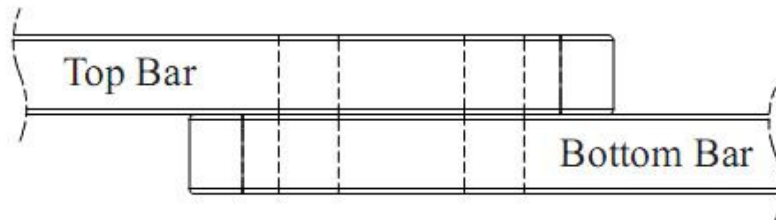
Nuts should be tightened evenly with a torque wrench. Torque tables for the specific hardware material should be followed closely. Excessive torque can reduce the washer's ability to compensate for expansion of the material being fastened. Cold flow can occur as the connected material tries to increase in volume due to changes in temperature, but is restricted from increasing because a washer has lost its ability to expand and contract. The result is the washer material being fastened appears to be imbedded into the connector, but in fact it is the material being fastened that has escaped from under the washer, thus reducing its thickness and possibly loosening.

When using a Bellville washer it is the manufacturer's recommendation that it be installed at no less than 80-90% of its being flattened. If the required travel is greater than the washer can offer, more than one washer may be needed. If this is the case, sets of two washers should be installed with the concave surfaces facing each other in that set. It should be understood that as a Bellville washer approaches the flattened position, it begins to lose its ability to fully return to the original position.

Consideration should be given to the material being fastened. Aluminum compression connectors are made of pure aluminum, so they are softer than a similar bolted or welded connector. Excessive tightening only displaces more material and does not necessarily make a better connection.

# Recommended Pad Mounting Hardware

The table below illustrates the recommended mounting hardware material for applications involving both similar and dissimilar metals.



TOP BAR	CU	AL	AL	GS	GS
BOTTOM BAR	CU	CU	AL	CU	AL
Recommended Hardware Options	BR	SS	AL	BR	AL
	SS	GS	SS	SS	SS
	GS		GS	GS	GS

Copper	CU
Aluminum	AL
Galvanized Steel	GS
Stainless Steel	SS
Silicon Bronze	BR

## **Connecting Dissimilar Metals**

Although it is best to avoid making connections using different metals like copper and aluminum there are times when this cannot be avoided. There are a few steps that can be taken to minimize potential problems.

### **A. Electrolysis (see section on Electrolysis)**

This is the most commonly known problem that occurs when two different metals are forced to cohabitate together in a potentially corrosive environment. This is called galvanic corrosion. It is the action of one material giving off molecules (anode) to another material (cathode). The result can cause a failed connection.

#### **Possible prevention**

1. **Tin plating** the aluminum or the copper/bronze component of the connection can help reduce the effects of electrolysis. It can also help slow down corrosion caused in some environments.

2. A **transition plate** is a plate that electronically bonds aluminum to copper in the form of a washer-like plate. This plate is usually supplied in the same size as the terminal being connected and can be drilled for either two or four hole applications. It is then positioned between the two dissimilar metals like a washer would be.

## **Electrolysis**

Electrolysis is sometimes also described as galvanic corrosion, both are the same. This is the same phenomenon through which a battery can exist. By placing two dissimilar metals in a corrosive environment a difference in electrical potential is created. The most common example of this may be the high school science experiment where zinc and copper strips are placed in a beaker containing sulfuric acid. Using a voltmeter a voltage can be measured across the two strips.

In a controlled environment this energy can be harnessed and put to good use. Electrolysis does not always occur in a controlled environment and its effects are not always desirable. There are conditions and situations when an electrical circuit design may require the use of either a copper or aluminum conductor. Both have benefits that may be desirable under certain conditions. There are also times however, when these two dissimilar metals must be connected together. The result is similar to the creation of a battery in an uncontrolled environment.

Voltage itself is not the primary concern, but the physical effects of electrolysis are. When a condition causing electrolysis exists, one of the two dissimilar metals becomes the anode and the other becomes the cathode. To determine which metal will become the anode and which will become the cathode refer to the Galvanic Series table in this section. The metal listed with the most relatively positive voltage is the cathode and the metal with the relatively more negative voltage is the anode. When electrolysis is taking place the anode gives off some of its molecules to the cathode. After the period of time that this action has taken place the anode eventually has no more molecules to give off. This is sometimes called galvanic corrosion. When this occurs with an electrical connector, failure eventually results.

By understanding how various factors can influence electrolysis on electrical connections made with dissimilar metals, its corrosive effects can be minimized.

## Electrolysis Factors

### 1. Voltage

The higher the relative voltage difference of the two different metals the faster the anode will deteriorate or corrode. By keeping the relative voltage between the two metals on the Galvanic Series table to a minimum, corrosion of the anode slows down. Using the Galvanic Series table for example we find that copper has a relative voltage of -0.20 volts. On the same table aluminum has a relative voltage of -0.80. Therefore the relative voltage between the two metals is the difference between copper and aluminum, or about -0.60 volts (difference between -0.20 and -0.80). Notice that tin-plate has a relative voltage of -0.50 volts. By plating one of the metals the relative voltage can be reduced to -0.30 volts.

### 2. Anode size

Relative physical size of the anode to that of the cathode in an electrical connection can contribute to the life expectancy of the connection. Since the anode will be giving off molecules to the cathode it stands to reason that when the mass of the anode is significantly greater than that of the cathode its life expectancy of the connection is improved.

### 3. Environment

In the previous high school experiment, sulfuric acid was used for the environment of the zinc and copper strips. The Galvanic Series table uses salt water. A change in the environment that the two metals used in making the electrical connection can also change the effects of galvanic corrosion.

## Galvanic Series

Metallurgical Category	EMF	
Gold, solid and plated; gold-platinum alloys; wrought platinum	+0.15	Cathode
Rhodium plated or silver-plated copper	+0.05	
Silver, solid or plated; high alloys	0	
Nickel, solid or plated; Monel metal, high nickel-copper alloys	-0.15	
<b>Copper</b> , solid or plated; low brasses or bronzes; silver solder; German silver; high copper-nickel alloys; nickel-chromium alloys; austenitic corrosion-resistant steels	-0.20	
Commercial yellow brasses and bronzes	-0.25	
High brasses and bronzes; naval brass; Muntz metal	-0.30	
18 % chromium type corrosion-resistant steels	-0.35	
Chromium, plated; tin plated; 12% chromium type corrosion-resistant steels	-0.45	
<b>Tin plated</b> terneplate; tin-lead solder	-0.50	
Lead, solder plated; high lead alloys	-0.55	
Aluminum wrought alloys of the duralumin type	-0.60	
Iron, wrought, gray, or malleable; plain, carbon and low alloy steels, armco iron	-0.70	
Aluminum, wrought alloys other than duralumin type; aluminum case alloys of the silicon type	-0.75	
<b>Aluminum</b> , cast alloys other than silicon type; cadmium, plated and chromated	-0.80	Anode
Hot-dip-zinc plate; <b>galvanized steel</b>	-1.05	
Zinc, wrought; zinc based die-casting alloys; zinc plated	-1.10	
Magnesium and magnesium-base alloys, cast or wrought	1.60	

## **Corrosion**

No metal is totally immune from corrosion from any chemical. Corrosion can lead to the deterioration of the mass of a connector or conductor which eventually leads to failure of the electrical connection.

### Possible preventions

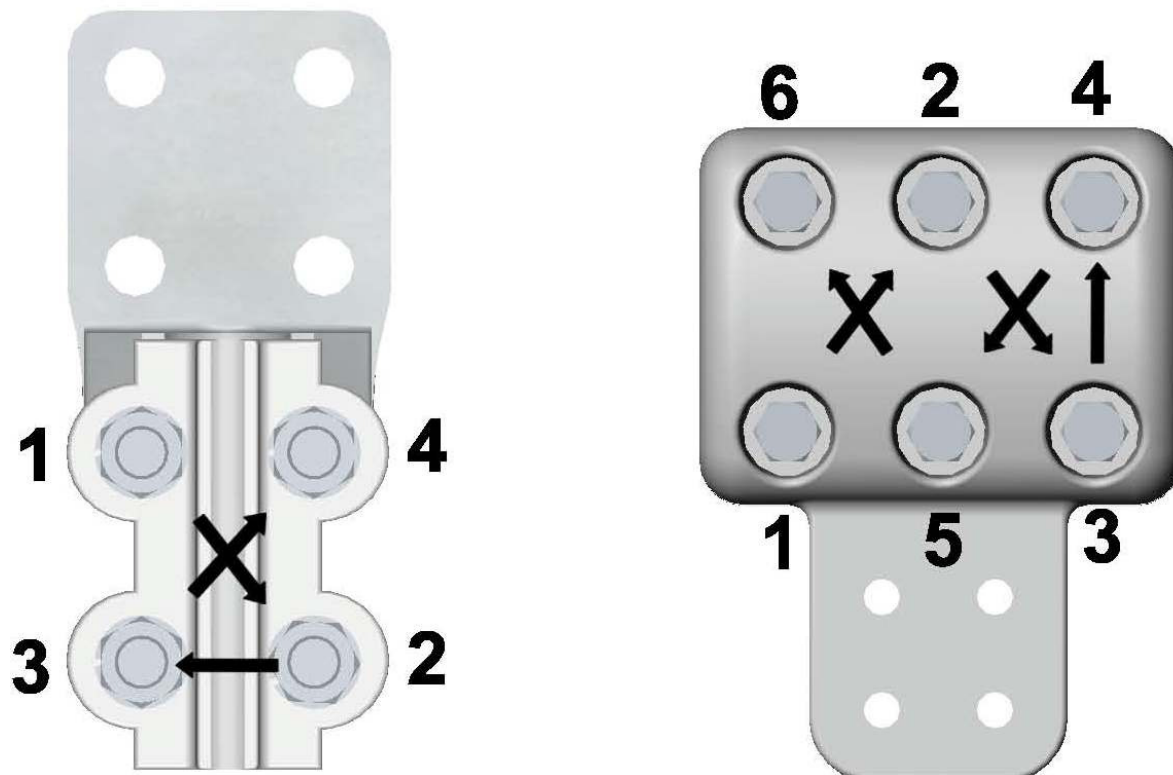
1. Always be aware of the environment in which a connection is being made as well as its compatibility with that environment. For example, will this connection be made near salt water, a paper mill, a chemical plant or any other toxic environment? Through the use of corrosion tables and personal experience, one material can be found that will work better than another.
2. When connecting aluminum to copper, always make sure that the aluminum is physically above the copper. Copper salts can accelerate corrosion of aluminum.

## Installation instructions

### Bolted Connectors

1. Thoroughly clean all contact surfaces of the connector and the conductor with the aid of a stiff stainless steel wire brush. **Do not use a stiff wire brush on plated surfaces. Plated surfaces** should be cleaned with a mild wire brush or mild abrasive like Scotch Brite being careful to remove as little of the plating as possible.
2. Apply a generous amount of oxide inhibitor to conductor and connector as described previously. (See **Applying Correct Oxide Inhibitor for Cable Connections** pg. 5)
3. Install power connector and hand tighten hardware.
4. Tighten hardware in sequence shown below with a torque wrench in order to get the correct torque for the particular alloy hardware. (See Torque Table pg. 7)

**Note: All excess oxide inhibitor must be removed from connectors installed in EHV applications.**



## **Compression Connectors**

1. Insert conductor into connector until the end of conductor reaches the bottom of the barrel. Mark the conductor where it comes out of the mouth of the barrel.
2. With a wire brush thoroughly clean the conductor from the mark made in step (1) to the end.
3. Apply a generous amount of oxide inhibitor with particles IE:(Alcoa Filler Compound (AFC)) into the conductor barrel and onto the conductor to ensure that excess filler compound will protrude from the connector barrel when the conductor is inserted. (See **Applying Correct Oxide Inhibitor for Cable Connections** pg. 5 & 6)
4. Select the correct die based on the connector recommendations, not on the cable size. Over compressing a connection can damage cable strands and cause the connector to fail. Under compressing can cause a loose connection that will also lead to failure. Ensure that the die does not have excessive wear and that the recommended outside diameter is attained after crimping. Dies can wear either through normal use or for example: (Leaving them in the compression tool and hanging it on a hook, especially on a line truck.)
5. Apply the first compression at the end of the barrel nearest to the pad on the line marked (START) and continue compression crimps toward the mouth of the barrel being careful to overlap the compressions by approximately  $\frac{1}{4}$ ".
6. File off all of the flashing formed by the compression tool so that the barrel of the connector is smooth.
7. Clean off all excess filler compound leaving a smooth finger size fillet where the conductor exits the mouth of the now compressed connector barrel.

## **Welded Connections**

PDU recommends the following welding methods for installing aluminum weldment fittings to aluminum bus pipe and/or aluminum wire:

Welding Apparatus: TIG or MIG

Filler rod (welding wire): 4043 aluminum alloy

Shielding Gas: Argon, Helium or combination of both

### **Welded Cable connections**

1. Remove all oxides, grease, oil, and moisture from the surfaces that are to be welded. Clean the welding surfaces of both the conductor and the connector by brushing vigorously with a stainless steel brush.
2. Slide the conductor into the weldment cavity of the connector until it is within 1/8" to 3/16" of the rear of the cavity.
3. Before welding the connection, a test weld should be made on an aluminum casting to check weld settings.
4. Begin welding the inner wall of the casting and moving toward the center of the conductor.
5. Wire brush the original weld if more than one pass is needed.

### **Welded Tubular connections**

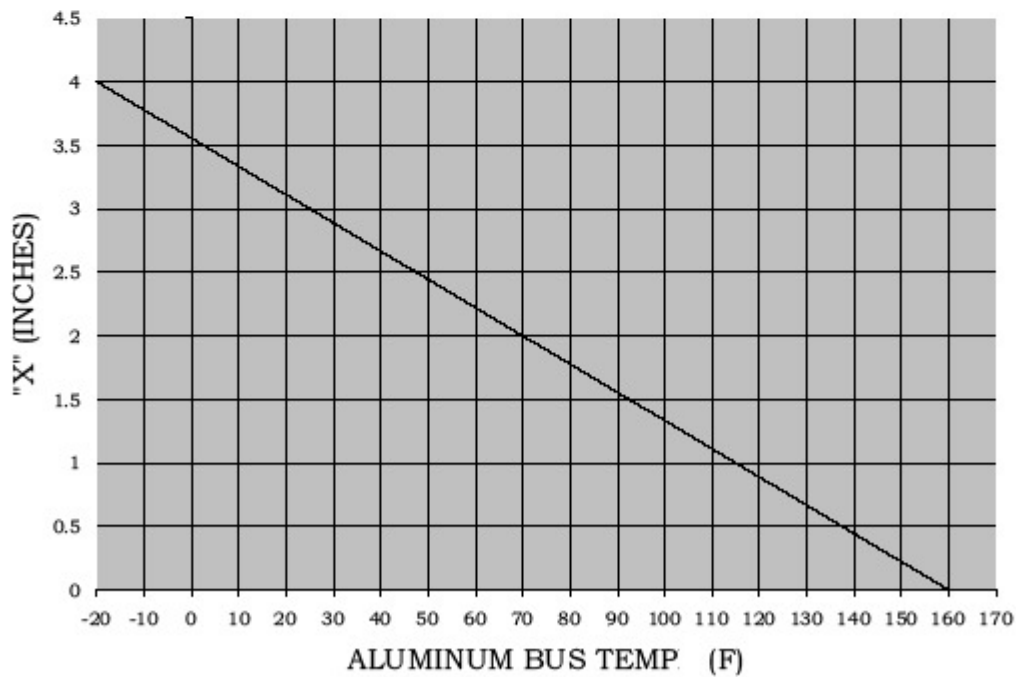
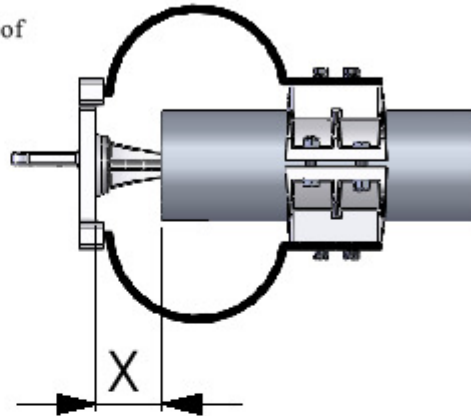
1. Remove all dirt, grease, oil, and moisture from the surfaces that are to be welded. Clean the welding surfaces of both the conductor and the connector by brushing vigorously with a stainless steel brush.
2. Before welding the connection, a test weld should be made on an aluminum casting to check the weld settings.
3. It is recommended that the tubular bus be positioned in the weldment cavity and tack welded before final welding.
4. Begin the final weld by burning into the original weld then passing over the entire contact surface.
5. When possible welds should encompass entire perimeter of connector, excluding bus supports and end plugs where tack welds may be sufficient.

**Note: The final judgment of any welding should always be left to the project supervisor and/or engineer.**

# EXPANSION TERMINAL INSTALLATION INSTRUCTIONS

## CHART INSTRUCTIONS

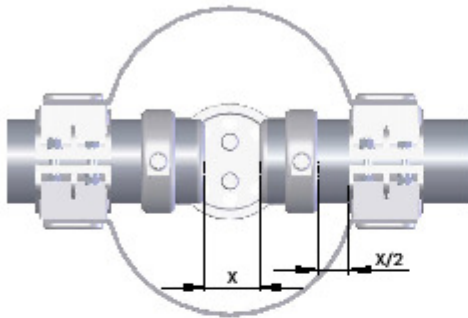
1. Locate bus temperature at bottom of chart
2. Using the diagonal line for maximum bus length of 140ft. find the appropriate dimension "X".
3. The chart may only be used for bus lengths less than 140ft.



PRODUCT DESIGN UTILITY - Manufactured by: **TEVA** Pattern & Foundry, Inc.

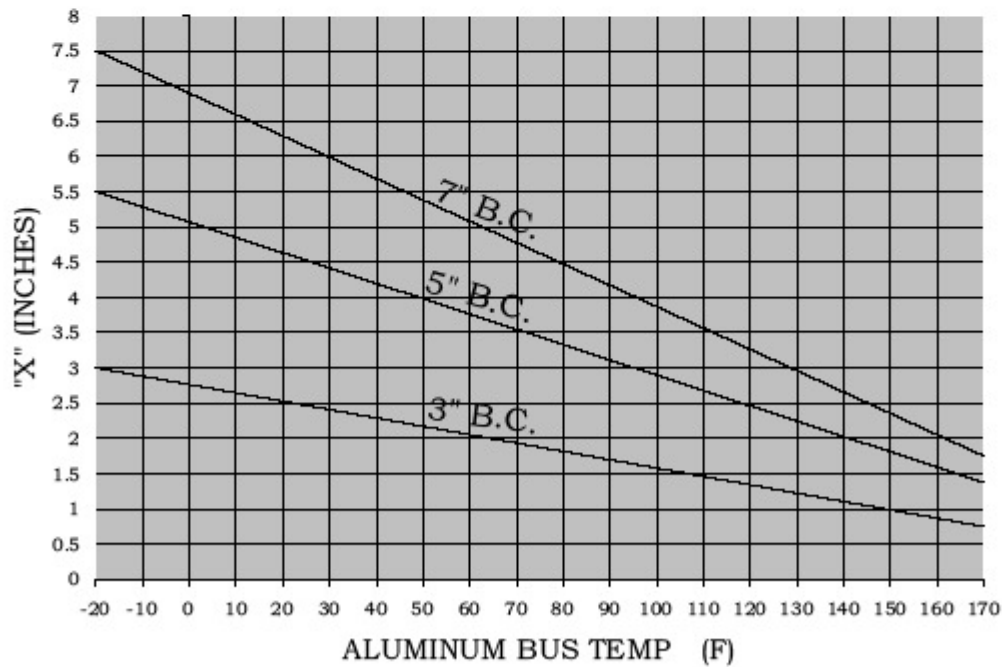
# EXPANSION SUPPORT INSTALLATION INSTRUCTIONS

## CHART INSTRUCTIONS



1. Locate bus temperature at bottom of chart
2. Using the diagonal line for maximum bus length of  
 240ft.(120ft per side)-----7"B.C.  
 160ft.(80ft. per side)-----5"B.C.  
 80ft. (40ft per side)-----3"B.C.  
 Find the appropriate dimension "X"
3. "X" measurement to be taken with the end plugs in stalled.

(Extended to conserve phase spacing.)

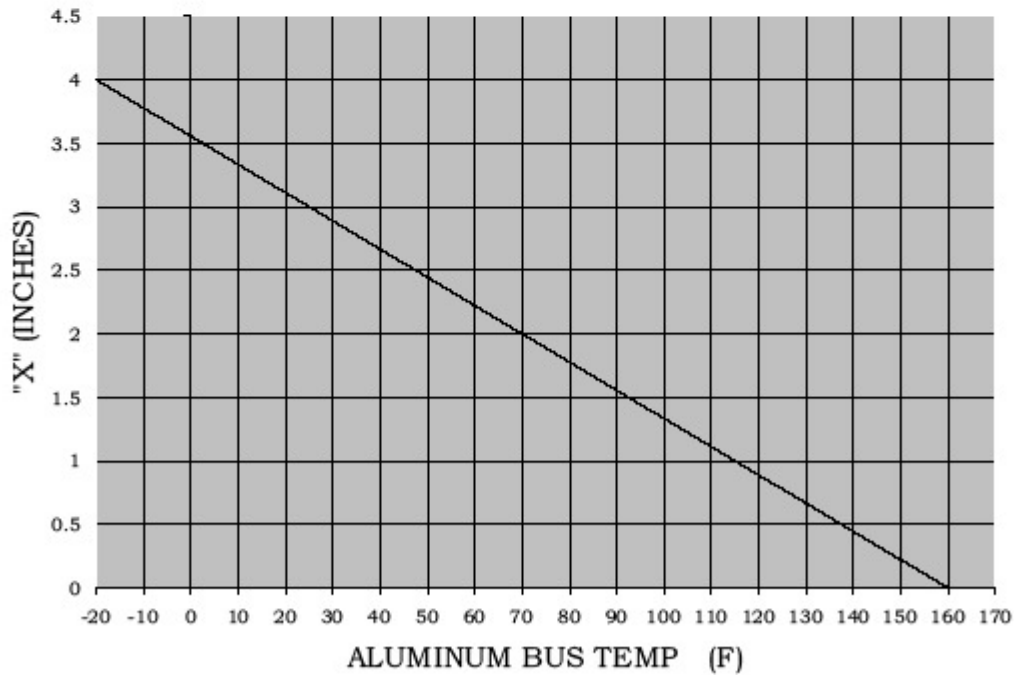
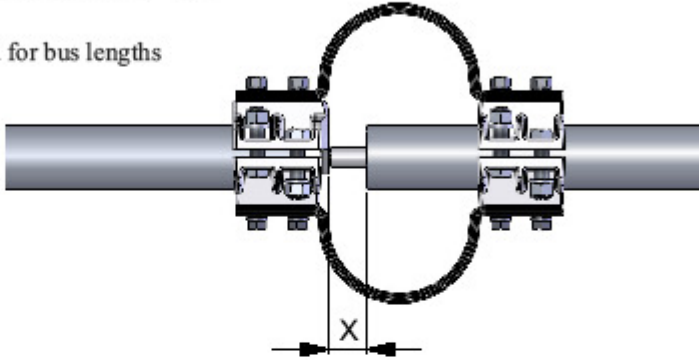


PRODUCT DESIGN UTILITY • Manufactured by: **GRAVIL** Pattern & Foundry, Inc.

# EXPANSION COUPLER INSTALLATION INSTRUCTIONS

## CHART INSTRUCTIONS

1. Locate bus temperature at bottom of chart
2. Using the diagonal line for maximum bus length of 140ft. find the appropriate dimension "X".
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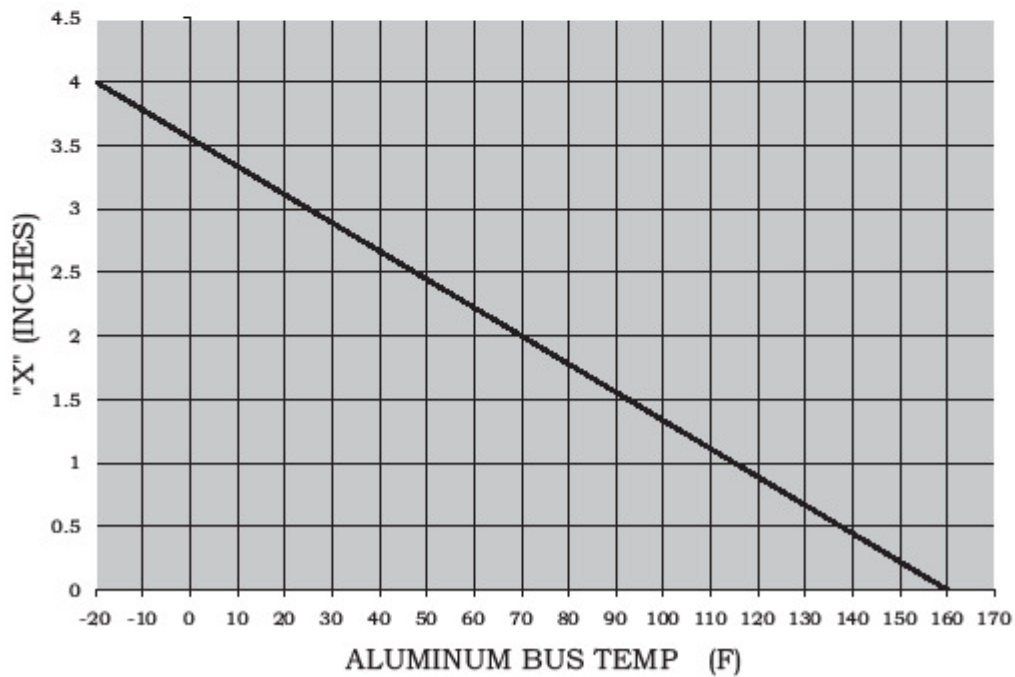
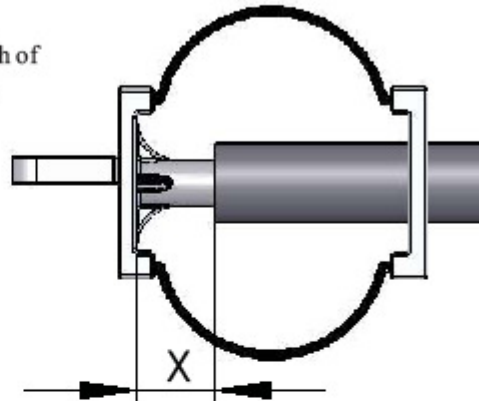


<sup>P</sup><sub>D</sub><sub>U</sub> PRODUCT DESIGN UTILITY • Manufactured by: **GRAVIG** Pattern & Foundry, Inc.

# EXPANSION TERMINAL INSTALLATION INSTRUCTIONS

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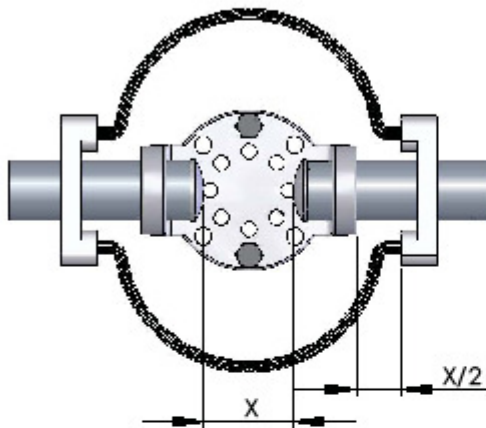
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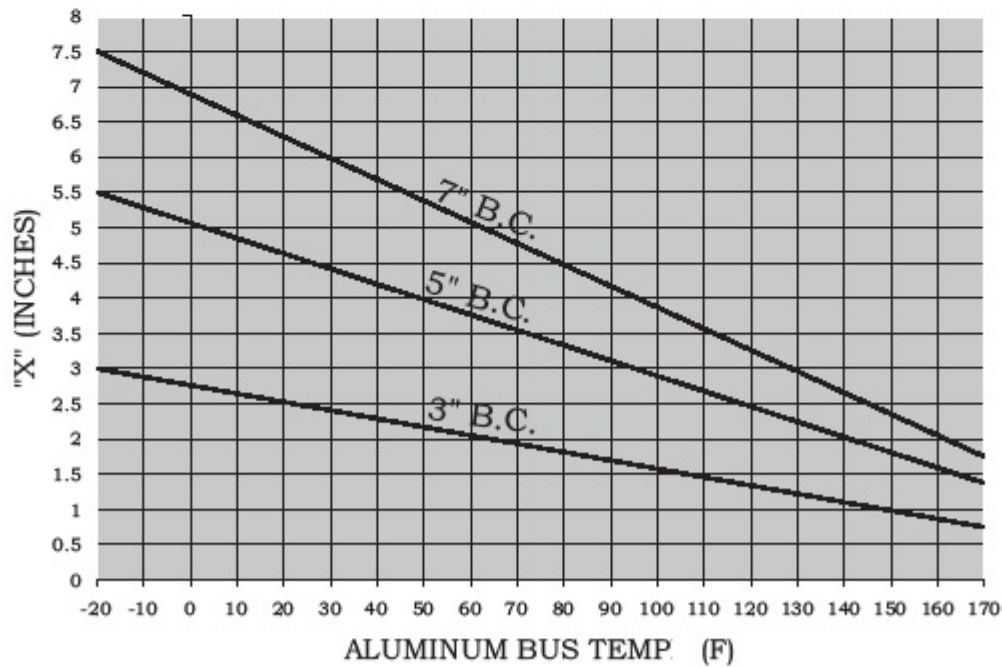
PRODUCT DESIGN UTILITY • Manufactured by: **TRAVIS** Pattern & Foundry, Inc.

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## CHART INSTRUCTIONS



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 240ft. (120ft. per side)-----7" B.C.  
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 Find the appropriate dimension "X"
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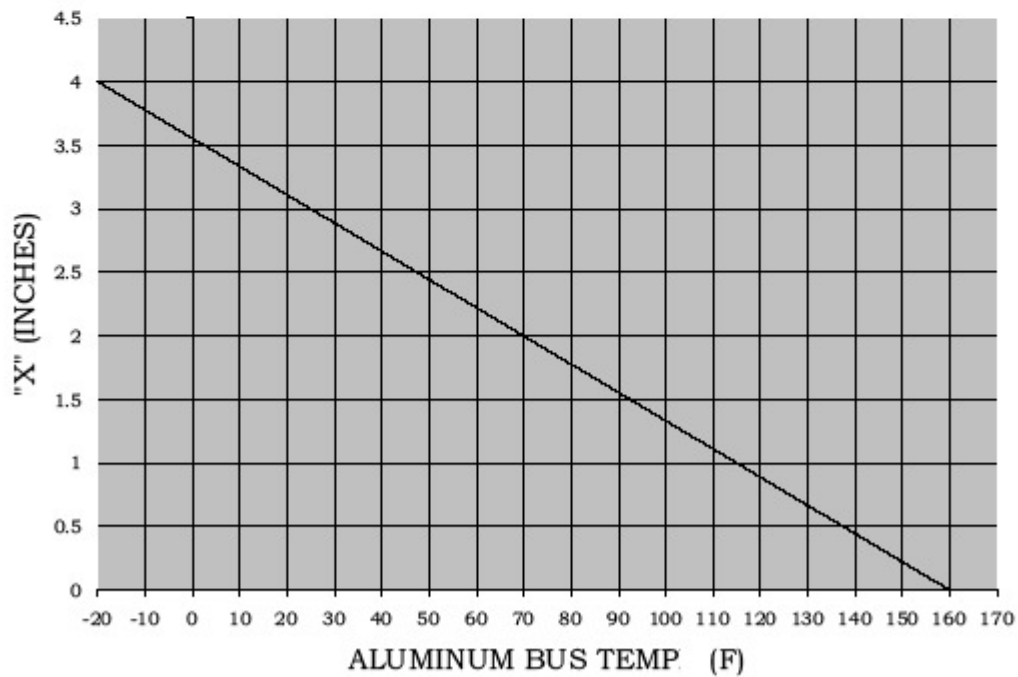
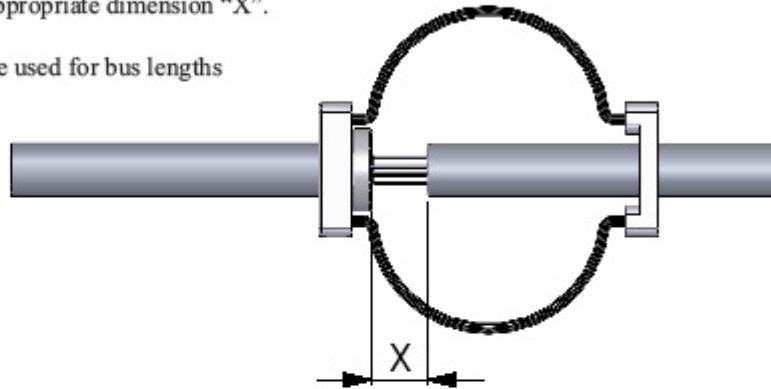



PRODUCT DESIGN UTILITY - Manufactured by: Pattern & Foundry, Inc.

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