Do Bolted Joints and Connections Get You Uptight?

Most mechanical bolted joints and connectors come with the appropriate hardware, but what happens when you have to provide your own?

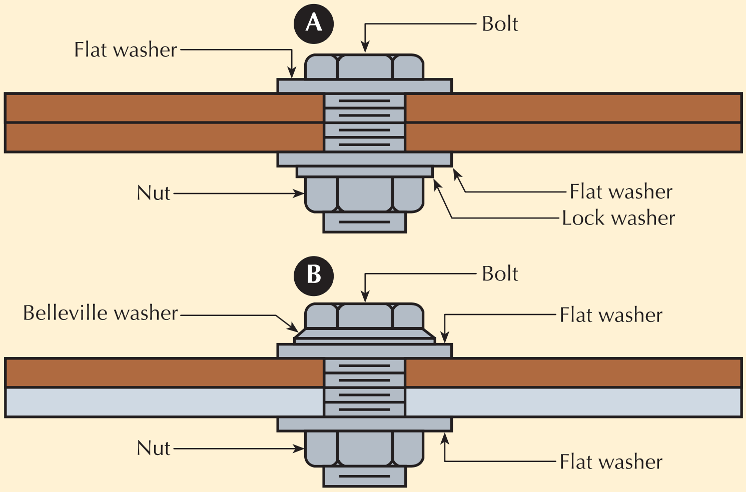

Fig. 1. *Shown are the two choices of bolted-joint configurations. Your choice depends on the connection composite. Use the Fig. 1A configuration for copper-to-copper joints and Fig. 1B configuration for copper-to-aluminum and aluminum-to-steel joints. Depending on the type of metal in the hardware you're using, you can also use Fig 1A or Fig. 1B for aluminum-to-aluminum and copper-to-steel joints. See* ***Table 1****, on page 48.*

By John DeDad, Editorial Director

What's in a bolted joint? This seems like a simple question. You obviously need a bolt, a nut, and some washers. But, there's more to it when it comes to joining different conducting materials. Depending on the kinds of materials you're joining, you may need some special hardware. Let's walk through a set of steps that will help you choose the right hardware for your particular joint or connection.

Step 1: Verify bus bar conducting metals. Typically, you'll find these conducting metals used for bus bars:

- Tin-plated aluminum;
- Silver-plated copper; and
- Bare copper.

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In switchyards, you may also find steel used at certain connection points.

Step 2: Verify connection composite. Based on the types of conducting metals you're connecting, you'll need specific hardware. Therefore, you must verify the connection composite. Typical scenarios include copper-to-copper; copper-to-aluminum; and aluminum-to-aluminum. As a general rule, you're less likely to have a copper-to-steel or aluminum-to-steel connection, but it's possible.

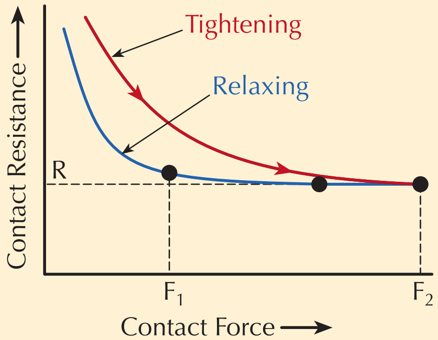

Fig. 2. *Shown is a bolt force relaxation curve. Although the materials relax to a contact force of F2, the contact resistance remains relatively constant. This indicates a stable connection throughout the F1-to-F2 contact force range.*

Step 3: Choose hardware materials. Using the proper hardware material for the specific connection composite helps ensure the connection's integrity will last. Your choices include silicon bronze; aluminum; stainless steel; and galvanized steel.

- For *copper-to-copper* joints, you should use silicon bronze or stainless steel hardware.
- For *copper-to-aluminum* joints, use tin-plated silicon bronze hardware or stainless steel hardware.
- For *aluminum-to-aluminum* joints, you should use aluminum or stainless steel hardware.
- For *copper-to-steel* joints, you can use silicon bronze, stainless steel, or galvanized steel hardware.

> Using the proper hardware material for the specific connection composite helps ensure the connection's integrity will last.

- For *aluminum-to-steel* joints, you can use tin-plated silicon bronze hardware, as well as stainless and galvanized steel hardware.

See Table 1, on page 48, for a list of recommended hardware materials for connection composites.

Step 4: Choose bolted joint configuration. According to Framatone Connectors International (FCI), you have two choices of bolted joint configurations, as shown in Fig. 1, on page 44. Your choice depends on

Table courtesy of FCI.

Materials Being Joined	Bolt	Nut	Flat Washer	Lock Washer	Belleville Washer	Reference Figure
Copper to copper	SB SS	SB SS	SB SS	SB SS	NR NR	1A 1A
Copper to aluminum	SB* SS	SB* SS	SB* SS	NR NR	SS SS	1B 1B
Aluminum to aluminum	AL SS	AL SS	AL SS	AL NR	NR SS**	1A 1B
Copper to steel	SB SS GS	SB SS GS	SB SS GS	SB SS GS	SS** NR NR	1A or 1B 1A 1A
Aluminum to steel	SB* SS GS	SB* SS GS	SB* SS GS	NR NR NR	SS SS SS	1B 1B 1B

SB=silicon bronze; SS=stainless steel; AL=aluminum; GS=galvanized steel; NR=not required.

Table 1. *Recommended hardware materials for specific joint composite (quantity per bolt). Key: NR = not required; SB = silicon bronze; AL = aluminum; SS = stainless steel; GS = galvanized steel. Single asterisk (*) denotes tin-plated; double asterisk (**) denotes alternate recommendation in place of lock washer.*

the connection composite, as mentioned above. Note that both configurations (Fig. 1A and Fig. 1B) include a bolt, nut, and flat washer. However, Fig. 1B also includes a Belleville washer.

Use the Fig. 1A configuration for copper-to-copper joints. Depending on the type of metal in the hardware, you can also use this configuration for aluminum-to-aluminum and copper-to-steel joints.

Use the Fig. 1B configuration for copper-to-aluminum and aluminum-to-steel joints. Depending on the type of metal in the hardware you're using, you can also use this configuration for aluminum-to-aluminum and copper-to-steel.

See Table 1 for joint configurations, per connection composites.

Throughout the industry, opinions vary as to what the "correct" method is to install Belleville washers. According to FCI, the following is a successful, time-tested procedure (refer to Fig. 1B):

- First, place a flat washer between the *concave* side of the Belleville washer and the surface of the member you're joining. By doing so, you capture the Belleville between the bolt head and large flat washer. *(Make sure you use a flat washer having an outside diameter greater than that of the flattened Belleville so there is no overhang. Also, choose a flat washer that's twice the thickness of the Belleville.)*

Probably the most important task in making a bolted joint is applying the correct torque to tighten the components.

- Second, fit the assembly (bolt, Belleville, and flat washer) into its hole. *(Make sure there's no interference with washers of adjacent bolts and no overhang over surface edges.)*
- Third, tighten the nut (with a washer of its own) onto the bolt until you feel a sudden and noticeable increase in torque. The Belleville is now flat; it's not necessary to "back off" the nut after you've tightened to this point.

Table courtesy of FCI.

Bolt Size*	Torque (lb-in.) Durium® (silicon bronze) stainless steel galvanized steel	Torque (lb-in.) Aluminum
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

Table 2. *Recommended tightening torque per specific bolt size. Single asterisk (*) denotes hardware threading of UNC-2A (external) and UNC-2B (internal) thread series.*

Step 5: Apply correct torque. Probably the most important task in making a bolted joint is applying the correct torque to tighten the components. Remember, every field termination (from the smallest low-voltage screw terminal to the largest lug) has an optimum torque value that produces the most reliable, low-resistant joint. See optimum torque values for the most common materials and sizes of hardware used in making electrical connections in Table 2.

One common question is: "Does torquing a bolt beyond its optimum torque value make for a better connection?" The answer is an emphatic "NO!" The only effect is possible damage to the bolt and connection itself. The better practice is to initially install hardware to the recommended torque values, and then periodically check for signs of loosening or overheating *before* making any adjustments.

So, how does the tightening of a connection affect contact resistance anyway? Let's say you torque a bolt to produce a contact force of F1. By doing so, you reduce the contact resistance to a lower value, R1. But, through creep and temperature cycling, the connection materials may relax and result in a different contact force (F2).

Looking at Fig. 2, on page 47, you can see that the relaxation curve *differs* from the tightening curve. Although the materials relax to a contact force of F2, the contact resistance remains relatively constant. This indicates a stable connection throughout the F1-to-F2 contact force range.

If you make sure you have the right hardware for your particular joint or connection, you can keep bolted joints and connections from getting you uptight. EC&M