BY TIM HIRTHE

Q: We have been brazing a tube to fitting joint for several years. Both components are 304 stainless steel and we use a 50% silver braze alloy and black flux. We use induction generators to braze the parts. Our customer wants to evaluate these assemblies using 3003 aluminum rather than stainless steel and has asked us to provide prototypes. They have asked us to use BAlSi-4 as the filler metal. We have no funds for new equipment and would like to keep it in-house so we want to do the brazing with our existing induction equipment. Can this be done?

A: This is a great question. It is a difficult thing to do but not impossible. If you reference the most recent (Fifth) edition of the AWS *Brazing Handbook,* it would seem to be out of the realm of possibility. Looking at the chapter on Induction Brazing (Chapter 13), no mention of aluminum applications or materials is to be found. Similarly, in Chapter 20 on Aluminum and Aluminum Alloys, there is one sentence that says induction heating can be used for special applications but then it is not mentioned in the section on Applicable Brazing Processes later in the chapter. These are not omissions, but rather, they highlight the scarcity of use of induction heating in the brazing of aluminum.

Having said this, I have seen it used successfully. Induction heating is chosen where rapid and localized heating is desired. In the case of stainless steel for example, induction is often selected over torch brazing to minimize heat discoloration and the resultant cleaning effort. The location heated and amount of heat used can be carefully controlled. Heating is achieved by resistance to the flow of an induced current in the components to be brazed. A basic process requirement is that the components be electrical conductors. The induced current is produced by placing the parts in an electromagnetic field created by an alternating current (AC) flowing in an induction coil. Figure 1 (taken from the *Brazing Handbook,* 5th Edition, Chapter 13, Fig. 13.1), shows a typical induction coil and the flows of current. In this example, the parts to be brazed would be placed inside the circular coil.

There are several factors that affect the way components will heat in any particular setup. These include the frequency setting of the induction generator, the electrical resistivity of the materials being brazed, the configuration of the components being heated and the design of the induction coil used. The heating is directly related to the frequency of the generator

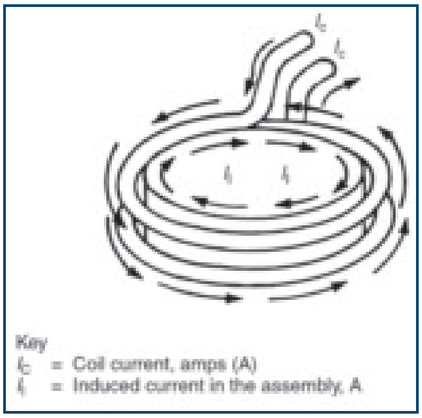

*Fig. 1 — Induced current, (I_i), produced by an electromagnetic field in a conducting assembly. (*Brazing Handbook, *5th edition, Fig. 13.1.)*

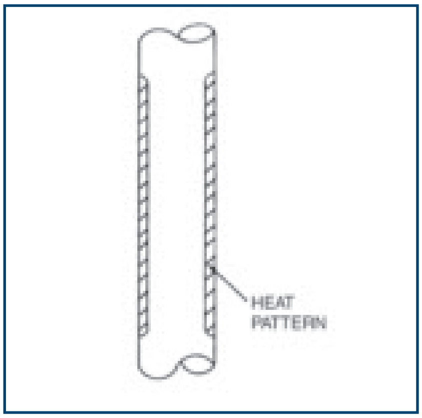

*Fig. 2 — Heat pattern created by resistance to the flow of the induced current. (*Brazing Handbook, *5th edition, Fig. 13.2.)*

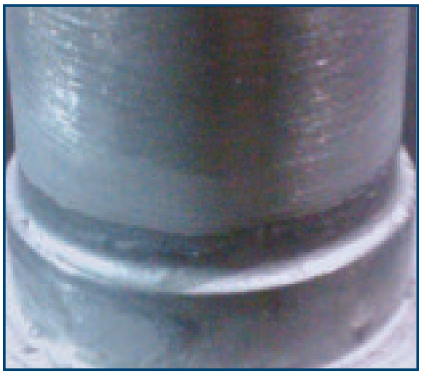

Fig. 3 — Aluminum tube-to-fitting joint using induction heating and AWS A5.8 BAlSi-4 filler metal.

so the higher the frequency, the faster the heating. Since the heating is accomplished by the resistance to current flow in the components, it follows that materials with higher electrical resistivity will heat more quickly than highly conductive materials. When placed in the electromagnetic field, the shape of components dramatically affects the heating. The closer a component surface is to the coil, the faster it will heat. Misalignment of the components when placed in the induction coil and differences in size and shape of components will cause one location to heat faster than others. The coil design has a significant effect also. Coils are typically designed per application, taking into account the variables mentioned here. For a more detailed review on the process, and to find references for additional information, refer to Chapter 13, Induction Brazing, in the 5th edition of the *Brazing Handbook.*

Aluminum is a material with high electrical conductivity. Materials such as this offer less resistance to the induced current. As a result, the first thing you will notice in attempting to heat aluminum with induction is that it heats more slowly than the stainless steel whose heating characteristics you are familiar with. Often, when you have an application with induction where the parts are heating more slowly than desired, you ramp up the power. With some materials this can work successfully. With aluminum, it can and most often will result in unwelcome base metal melting. First, consider how the heating occurs in the components. Figure 2 (taken from the *Brazing Handbook,* 5th Edition, Chapter 13, Fig. 13.2), shows how the parts heat when placed within the induction coil.

As with all brazing processes, the successful joining of the components relies on the conduction of heat through the joint. This results in thermal gradients in the brazed components. You provide more heat in some locations in order to have heat conducted through the joint to melt and flow the filler metal. With aluminum this is problematic because of the close proximity of the temperatures of the brazing filler metal and the base metal. In the case you have presented, the 3003 base metal has a melting range of 643° to 654°C (1190° to 1210°F) and the BAlSi-4 filler metal has a melting range of 577° to 582°C (1070° to 1080°F). When you consider that you must exceed the 582°C liquidus temperature of the filler metal to gain proper melt and flow of the braze filler metal, you only have a range of about 37°C (100°F) to work with.

To illustrate the situation, refer to the photo in Fig. 3. This is an aluminum tube-to-fitting joint that was successfully brazed with induction heating. I am not sure of the base metal used but the filler metal is BAlSi-4. A braze preform was placed on the ledge created on top of the fitting where the tube was inserted. Pressure testing of these joints resulted in bursting of the tubing while the braze joint retained its integrity. There were some preform and joint design considerations that I have not detailed here, but the application shows that it can be done with induction heating.

The biggest issue when brazing a part like the one shown will be heating rate, particularly when compared to stainless steel. As mentioned earlier, the aluminum has high electrical conductivity so it will inherently heat more slowly. Due to limitations on heating these parts, to avoid overheating them, you cannot readily increase the intensity of the heating. The fitting has a larger OD than the tube and will therefore be sitting closer to the ID of the induction coil. It will heat more quickly and there is a strong possibility that the edge of the fitting will melt during the process. Also, attention will need to be paid to location and alignment of the assembly in the coil. Misalignment will cause the differences in heating to be more pronounced. Some experimentation will be required with coil design but, generally speaking, a coil that heats more slowly and broadly will be needed. This may require that the coil be more loosely coupled to the parts, i.e., the distance between the OD of the parts and the ID of the induction coil may need to be greater than with stainless steel. More turns in the coil and less current through it may also be required to broaden the heating location and slow the heating rate.

My answer is that it most likely is possible to heat the components in an acceptable fashion with induction. Joint design and filler metal design will most likely need to be looked at to achieve an acceptable braze joint in your specific application. The heating rates will be much slower than what you are accustomed to seeing. Whether this is acceptable or not depends on your situation.♦

This column is written sequentially by TIM P. HIRTHE, ALEXANDER E. SHAPIRO, and DAN KAY. Hirthe and Shapiro are members and Kay is an adviser of the C3 Committee on Brazing and Soldering. All three have contributed to the 5th edition of AWS Brazing Handbook*.*

Hirthe (timhirthe@aol.com) *currently serves as a BSMC vice chair and owns his own consulting business.*

Shapiro (ashapiro@titanium-brazing.com) *is brazing products manager at Titanium Brazing, Inc., Columbus, Ohio.*

Kay (Dan@kaybrazing.com), *with 40 years of experience in the industry, operates his own brazing-training and consulting business.*

Readers are requested to post their questions for use in this column on the Brazing Forum section of the BSMC Web site www.brazingandsoldering.com.