BY TIM P. HIRTHE

Q: We manufacture an aluminum heat exchanger for an automotive application. It is of a round tube-to-fin design. The open ends of the tubes in the circuit are joined with a U-bend, and are brazed with a flux bearing aluminum-zinc braze alloy. We use a relatively simple fixture with four torches. We have set up to use natural gas and oxygen. The design of the heat exchanger includes a mounting bracket that makes it difficult to heat the entire circumference of one of the braze joints. We are having significant leak issues in the area where accessibility is hindered. Is there equipment available or some technique that will allow us to get a quality braze in this joint? We are considering switching to an aluminum-silicon braze alloy, which we understand is a higher temperature, but which we are hearing is a better braze alloy to use. Early trials with it, however, have resulted in melting of the tubing. A photo of the joint in question is shown in Fig. 1.

A: To state the obvious, the best situation would be to not have the bracket in the way in the first place. You mentioned that it is an automotive application, so the odds of removing it from the design are probably quite low. An alternative would be to redesign the assembly to have the bracket able to be out of the way prior to brazing and bent into place after brazing. Using perforations that allow bracket bending is one method. This is common practice in a variety of heat exchanger applications. This type of approach is perhaps obvious, and you probably would have done it already if a design change was possible. For the purpose of the remainder of my response, I will assume that no design change is possible.

By not being able to get heat onto the back side of the joint where the bracket is located, you are relying on the thermal conductivity of the aluminum to transfer heat to obtain proper melting and wetting of the braze alloy on that side of the joint. I can't determine from Fig. 1 or the information provided what the joint clearances are. The problem is that the aluminum-zinc braze alloy requires a loose fit and a rather deep joint. The reason for this is that these joints tend to be porous due to the zinc content. Zinc is a high vapor pressure element that will boil off at these braze temperatures. Since the braze alloy requires a loose fit, the heat transfer characteristics will be poor. You usually end up overheating one part of the joint to get another part hot enough to accept the braze alloy properly. Even if you can achieve minimally acceptable brazing temperatures around the circumference of the joint, you will most likely overheat it such that you will get zinc vaporization.

Another difficulty I see is that you are using natural gas and oxygen. Using oxygen to combust the natural gas results in a flame that is relatively hot and difficult to control when brazing aluminum. When brazing aluminum, we prefer the fuel gas be combusted with air rather than oxygen. It produces a cooler, more controllable flame. We suggest a blower be used rather than plant compressed air as the latter typically contains a lot of moisture. If you are going to use plant air, you must assure that it is being dried before combusting the fuel gas. I am concerned about using natural gas also. Natural gas fluctuates greatly in Btu content from the supplier and, depending on the time of year, it also can contain a great deal of moisture. Propane or a similar fuel is preferred.

You mention you are considering moving to the aluminum-silicon braze alloy because you believe it is a better choice. It is attractive because it does not have the vapor pressure problem, and it is a stronger material than the aluminum-zinc. There are several issues, though, that must be addressed in considering switching to an aluminum-silicon braze alloy. The most obvious one is that the aluminum-silicon braze alloy melts at a significantly higher temperature. I am not sure which aluminum-zinc braze alloy you are using, but for reference, the 98% zinc/2% aluminum braze alloy has a melt range of 715° to 725°F (379° to 385°C). The aluminum-silicon alloy most commonly used is the 88% aluminum/12% silicon, which has a melt range of 1070° to 1080°F (577° to 582°C). I don't know which aluminum tubing material you are using, but I am sure it melts in the vicinity of 1200°F/649°C. There is significantly less room for overheating with the aluminum-silicon.

If you are trying to use the aluminum-silicon on a joint designed for aluminum-zinc, you will have a substantial problem. As mentioned earlier, aluminum-zinc requires a loose fitting joint (~0.005 in./0.127 mm) that has considerable depth (~0.250 in./6.4 mm). The way to compensate for the tendency to vaporize the zinc is to provide this very deep joint. The aluminum-silicon requires a tight fitting joint (~0.001 in./0.025 mm) with less depth (~3.0 mm). Your trials with aluminum-silicon ran into the fit problem. You are having a struggle getting heat to the back side of the joint with aluminum-zinc because of the loose fit since you must overheat the front to get proper heat transferred to the back. You get away with this due to the low melting point of the aluminum-zinc. When you use aluminum-silicon, you do not have that margin of error with the temperature. The result is melting of the aluminum tube as the difference between the melting point of the tubing and that of the braze alloy is too small to tolerate this overheating.

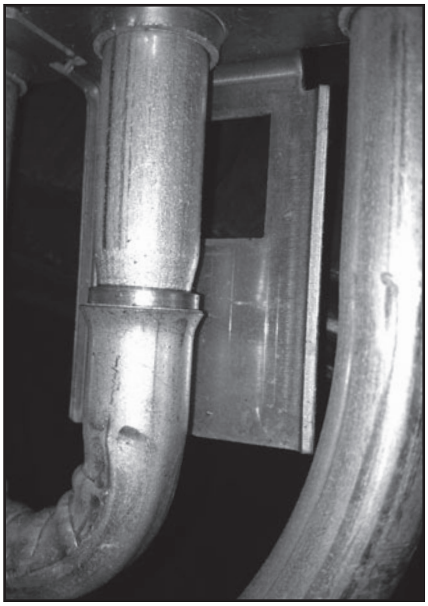

Fig. 1 — View of the customer's brazed aluminum heat exchanger.

Assuming again that no design changes can be made, it would seem that changing to the 88% aluminum/12% silicon alloy is not feasible. Considering that the bracket cannot be taken out of the equation, overheating will occur and most likely result in tube melting. If the joint could be redesigned to accept this alloy, i.e., tighter fit and shallower depth, it may be possible; but I have ruled out the option of changing the prints. Going forward then it seems the alloy must remain aluminum-zinc.

I would look at modifying your existing brazing setup to find a way to get more heat into the joint blocked by the bracket. Switching to air to combust the fuel will help. Using different torch tips that have a softer, broader, and longer flame condition that will allow heat to reach the backside of the joint will help. Adding more torches may help. In order to heat this particular joint, it may require a longer cycle time as you are allowing for the heat to transfer to the problematic area of the joint. You may also want to contact induction heating manufacturers as they may have heating coils that can preferentially heat different locations on the joint circumference. The lesson to be learned here is to take into account the joint accessibility when designing the assembly.♦

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

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