BY TIM P. HIRTHE

Q: We are torch brazing 304 stainless steel "u" tubes to flared socket joints of the same base material. We are brazing with a black flux and a filler metal ring made from a 50% silver filler metal recommended for stainless steel. We do not seem to have any problems with wetting the stainless steel, and leaks are no problem as the filler metal is quite fluid and does a good job filling the tight joint. If anything, the alloy is too fluid as it travels out of the joint and well onto the surface of the "u" tube. From a process perspective, the only issue we have is that the fit-ups are very tight, we get inconsistent tube size, and we sometimes need to force the parts together. It can prove difficult from time to time. The problem is that, fairly often, we get a "u" tube that cracks wide open during heating. It's not a hairline crack or a leak in the joint, but rather, a catastrophic tube failure. We have been in contact with our tube supplier and can find no issues with tube quality. What may be causing this, and what can we do about it?

A: There are a number of mechanisms that can cause the base metal failure as you are describing. Some are related to the service conditions the braze joint is subjected to and some are caused by the braze process. Yours, obviously, is the latter. There is detailed information about these and other joint failure mechanisms in the AWS *Brazing Handbook,* Fifth Edition, Chapter 7, Corrosion of Brazed Joints.

In cases where normally sound base metal fails with catastrophic cracking during the brazing process, tensile stresses in the material are normally blamed. There is, however, almost always a corrosion component that goes along with it. If you were to heat these assemblies without braze filler metal and/or flux, you would most likely not see this cracking occur. The parts would be stress relieved and no failure would occur. It is the combination of stress and corrosive material that causes the failure. The corrosive agent may be the flux, the filler metal, or both. Because you need flux and filler metal to make your braze joints, the things you need to eliminate are the causes of stress.

The two most common mechanisms we see in this regard are stress corrosion cracking and liquid metal embrittlement. They both involve tensile stresses in the base metal and a corrosive environment.

Stress corrosion cracking normally refers to failure in service after a brazed assembly is exposed to service conditions. The phenomenon you are experiencing is most likely liquid metal embrittlement. The flow of the molten filler metal on the stainless steel disrupts the equilibrium of stresses on the surface, initiating the catastrophic cracking.

We saw this problem many years ago with similar types of parts. A quick test we did to get a fix on the problem was to heat the parts without braze alloy being added. We assembled and fluxed the components as usual, then ran them through the heating process. No cracking was observed. On some joints we overstressed them by excessively bending them before assembly. There was still no cracking when only flux was applied. After running a significant number of joints in this fashion, we began adding braze alloy in our testing. On the parts that were overstressed, the tubing split wide open when the molten braze filler metal was applied to the areas of highest stress.

There is a significant number of ways stress can be found in your base metal tubing during the brazing process. Some are inherent in the process used to fabricate the parts and some may be introduced during the assembly and brazing process. Identifying and eliminating them will be keys to overcoming the cracking issue.

Liquid metal embrittlement is found most commonly in high-strength materials such as the stainless steel you are using. You have chosen it for a reason, but if you could change to a base metal with less susceptibility to this failure mechanism, it would help. In most cases, this is not an acceptable solution. Looking for an alternative braze filler metal might also be an option, but it's doubtful that enough research could be uncovered to help in the search, leaving you most likely to a frustrating trial-and-error process.

The first place to look is in the tube fabrication. Any mechanical working of the tubing will put stress into the metal. Bending and end forming are the most common processes. You do not mention in your question whether or not you use annealed parts, but annealing the parts would eliminate residual stresses built up during the fabrication processes and may help.

Using annealed material would be a good start but there are several ways that stress can be induced during the brazing process. These could counter the positive effects of annealing. You mention that the part fitups are not ideal. Forcing these parts together is an obvious source of stress. Improving part dimensional consistency would seem to be in order. Parts can also be constricted by fixturing. When heated, brazed assemblies grow, and the fixtures need to allow for this growth. Otherwise, stress can be induced during heating.

There is another component that adds to the problem — heat. The cracking would not occur if heat was not applied. Sometimes the rate of heating can contribute also. Fast heating rates may not allow enough time for the parts to stress relieve before the filler metal melts. You can also look at a higher-temperature braze filler metal. It is possible that the parts would be stress relieved prior to filler metal flow if a high enough temperature was reached prior to filler metal flow. Nonuniform heating can also be a factor if it contributes to a buildup of stress across the assembly. The down side to some of these heating-related ideas is that they cause you to take longer to heat the parts and take you to higher temperatures. Production rate goes down while energy and other process costs go up.

While there are many ways to approach this, the main objective is to use stress-free parts to start with then keep them as stress-free as possible during the brazing process. In your situation, this may mean annealing the parts before brazing and improving part fitup. The rest of the process may be fine. The details of your situation will dictate the optimum implementation of these ideas.♦

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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.