# BRAZING Q&A

BY R. L. PEASLEE

**Q: We have purchased a vacuum furnace to braze aircraft assemblies in a $10^{-3}$ to $10^{-5}$ vacuum atmosphere. The question has come up as to how fast can assemblies be heated within the furnace.**

**A:** Since you indicate that you are going to have different assemblies of different sizes and masses, it is not possible to give a definitive answer. Basically, each assembly is a beast unto itself and it behaves its own way. So, in reality, we have to take the cue from the assembly itself, how big is the assembly, how massive is it, how complicated is it, how much difference in metal thickness in various locations of the assembly? All of these items will have a bearing on the allowable heating rate, and also the cooling rate, of the assembly.

The first thing we will look at is distortion. Many times we hear people say that the brazement is going to distort in the furnace because there are a lot of welding stresses, machining stresses, or forming stresses. While there may be a lot of stresses in the assembly, if we heat and cool the assembly using the proper furnace cycle, there will be no distortion, or minimum distortion, of the final brazement. The main cause of distortion is the differential temperatures throughout the assembly. We have to look at the assembly and try to understand, from the shape of the assembly, what differential temperatures will occur and what the assembly can tolerate. If we have a heavy inner and outer band with very lightweight veins between the bands, with the blades tacked in place, we would have to heat the assembly much slower than we would a small two-in.-round fuel nozzle assembly. The fuel nozzle assembly, being small and fairly uniform in thickness, could be heated as fast as the furnace can go up to heat. So, the heating rate is dependent on the size and shape of the assembly.

When in doubt as to how the assembly is going to respond to heating and cooling, it is desirable to attach thermocouples to the areas that will be the hottest and the section that will be the coolest during heating and cooling. The coolest section is going to be the heaviest section, probably where it is setting on the supporting fixture. The hottest area is going to be the thinnest metal, near the elements of the furnace, where the radiant heat can strike the thin section.

Attaching a thermocouple to an assembly, to get the proper temperature information feedback, is not as easy as one might suspect. Frequently, we have a person make up the thermocouple by twisting the two ends together of an alumel/chromel thermocouple, then melting the end into a bead and placing the bead at the work area. Unfortunately, when the leads are twisted, the temperature is not read at the bead end but is read at the last twist away from the bead end. It is therefore desirable to butt weld the two ends of the thermocouple wire together with as small a bead a possible, so that this is the only area where the thermocouple wires touch each other. This junction can then be wired to the assembly and a small piece of insulating material placed on top of it, so that the junction does not see the radiant heat from the furnace elements, but gets the heat directly from the metal.

While it is not always possible, if the separate wires of the thermocouple can be spot welded to the assembly with a capacitor discharge welder, so that the assembly base metal then becomes the junction of the thermocouple, this will give the best results for many applications. In other assemblies where there are drilled holes, it may be possible to put the thermocouple in the hole, not allowing the leads to touch the sidewalls of the hole, but allowing the junction to touch the bottom of the hole.

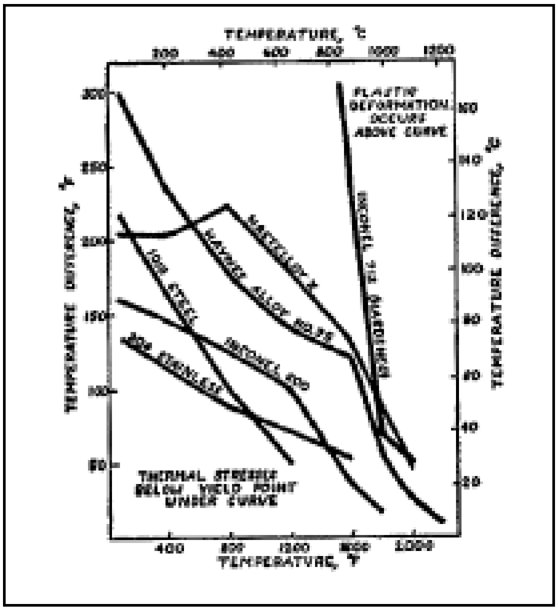

*Fig. 1 — Temperature difference at which thermal stresses equal the yield point of various materials. At temperature differences below the curve, the thermal sresses are less than the yield point of the material. Temperature differences above the curve indicate the occurrence of plastic deformation. This chart applies to the special case of a thin member rigidly connected at its ends to a relatively thick member. Use double the temperatue difference shown for two rigidly connected members of the same cross section (see text for additional information).*

When any of this is not possible, it may be necessary to use blocks of metal to simulate the thickest and the thinnest sections of the assembly. Tack weld thermocouples wires separately to each of these blocks of base metal and use this as a differential-temperature indicator.

Another technique for obtaining more uniform heating of a complex-shaped assembly is to put a heat shield around it, and sometimes a cover over the top of the assembly, so that the assembly cannot see the direct radiant heat from the elements or the fast loss of heat on cooling. This tends to slow down the heating, and provides much more uniformity of temperature throughout the assembly. When heating and cooling austenitic stainless steel assemblies, the problems are less severe than when heating and cooling base metals such as 410 martensitic stainless steel and the carbon steels, as these base metals can be hardened and go through transformation with a change in volume around the 1300°–1400°F (675°–787°C) range.

For example, if we braze a 410 stainless steel tube onto a 410 thick, heavy, flange on the inside of the tube, the thin stainless steel tube can transform and shrink on heating, while the heavier material on the inside is still expanding, thus causing a stretching of the thinner outer tube during the heating cycle. When the assembly reaches the brazing temperature, the outer thin tube is going to be larger than when it was assembled, so that the clearance is now excessive.

This is particularly true if the assembly is 12-in. in diameter. The braze may pull the thin tube into the flange, for most of the circumference, but at some point there will be an area that is unbrazed that is some distance away from the flange. In such a case, a heat shield is definitely in order; but it also may be necessary to hold off just before the transformation temperature. To equalize the temperature in the assembly, go through the transformation more slowly, and then speed up heating to get to the brazing temperature in a reasonable amount of time.

While the heating must be considered in the brazing cycle, the most critical portion of the cycle, as far as distortion is concerned, would be the cooling cycle. If we are brazing a complex assembly, such as the stator assembly mentioned earlier, with a nickel brazing filler metal at 1950°F (1066°C), and the cooling fan is turned on when the filler metal is still molten, the blades will cool very rapidly compared to the heavy inner and outer band. This can cause cracking at the braze joint by liquid metal embrittlement or stress corrosion cracking. In this case, it is necessary to slowly furnace cool to below the solidus temperature of the brazing filler metal, to assure that we do not highly stress the assembly before the filler metal becomes solid. If the fan is turned on at this point, the blade is going to cool much more rapidly than the heavy section, and thus it will get shorter as it cools down. While the big bands are hot and the joint solid braze, the blade would be stretched. When the assembly reaches room temperature and all the components are the same temperature, the stretched blade has to bow, or it will rotate the inner band so that the blades are no longer perpendicular to the sidewalls of the band. Here again, a heat shield with cover may be needed, and thermocouples would be best. Or, it may be that the assembly is so complex that it will be necessary to program furnace cool the assembly down below 1500° or 1000°F, depending on the requirements of the hardness.

As you can see, the heating and cooling cycle depends on the assembly to be brazed; the material it is made from, the size, the shape, the difference in thickness of the base metals, and so on. All have a profound effect on the brazing cycle that must be developed. Unfortunately, it is very hard to think like an assembly in the furnace, going up and coming down in temperature; the thermocouples will have to give us a better idea of how the assembly is actually responding to the furnace cycle.

To help understand the effect of the differential temperature, Fig. 1 shows the differential temperature allowable at various temperatures during the heating or cooling cycle. The curve for each base metal indicated is the point at which the yield strength of the base metal is reached, and if exceeded, some areas of the assembly will be stretched, resulting in distortion when the assembly is cooled to room temperature. Unfortunately, we do not have data for all base metals, and there are fewer data available at the higher temperatures, as the steel companies only obtain data up to the highest service temperature the base metal will see and brazing exceeds this temperature, sometimes by many hundreds of degrees.

Unfortunately, after you sit down and try to outguess the assembly requirements and program a cycle, you are going to have to braze an assembly and ask the brazement whether it likes the cycle you have developed. In many cases, for complex assemblies, you will find that the brazement does not agree with your engineering assessment, and you will have to correct your cycle, either at the high-temperature area, or at the transformation temperature, in order to braze the assembly without distortion. If the brazement distorts, we have not provided the proper furnace cycle for that specific assembly and must make corrections, in order to provide a cycle the assembly will like, so that there is no distortion, or an extremely small amount, in the final brazement.

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