Q: Can you explain strength vs. joint clearance?

A: As I visit many brazing shops around the world, and talk about joint clearances used for brazing, it is apparent that many people still operate with a misunderstanding about how tight a joint clearance can be before it becomes nonbrazable.

Due to its early and extensive use in articles, reports, talks, and more, the chart shown in Fig. 1, which was developed back in the late 1930s by Handy & Harman researchers in their laboratory in Fairfield, Conn., is apparently still being used today by many engineers around the world as the joint clearance standard for all brazing situations, whether in open air using torches or induction heating, or when furnace brazing using a nonoxidizing atmosphere or vacuum.

I even heard one PhD metallurgist at an international brazing conference a number of years ago use this same chart in his talk, telling the audience that joint clearances for correct brazing should not be less than about 0.0015 in. (0.04 mm) because joint strength obviously becomes less when joints were tighter than that. I was stunned. I asked him after his talk why he told the audience that, and he said that it was because that’s what the chart showed. When I asked him if he knew the history of the testing that led to the creation of that chart he said, “No.” So, I shared with him the rest of the story behind the testing at Handy & Harman in the late 1930s that led to the publication of that chart.

Even today, I still see brazing videos talk about an idealized joint clearance of 0.0015 in., and then hear people talk about using special shim stock to hold that kind of joint clearance for brazing. Let’s take a look at that chart and see how it actually should be used to help you understand joint clearances used for all kinds of brazing.

In Fig. 1, notice that as the joint clearance gets tighter and tighter (moving from right to left along the bottom axis), the tensile strength (as shown on the vertical axis on the left side of the chart) gets higher and higher. Although there is a lot of experience with this over the years, and general acceptance of this information is widespread, it must be pointed out that this chart is very specific only to the actual testing performed in making this particular chart, and may not be identical to tests performed by others today, since the actual test specimen shapes and tensile testing methods used for making this chart are no longer known (apparently the original lab reports and data were lost or destroyed when Handy & Harman’s laboratory was moved). But the general principal of increased joint strength with tighter gaps can be absolutely accepted. However there is much more to this chart than just that.

First of all, the test data used to create the chart was generated by flame brazing (torch brazing) two pieces of 304 stainless in a butt joint configuration, using BAg-1 silver-based brazing filler metal (BFM) and a brazing paste flux (because it was being brazed in air with a torch).

The actual stainless steel test pieces used in that testing were apparently...
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Fig. 1 — Strength of the brazing filler metal (BFM) vs. joint clearance. (Drawing developed by Handy & Harman in 1939, and is currently published in the AWS Brazing Handbook, 6th Ed., 2007, p. 92.)

Fig. 2 — Shear strength of silver brazed drill rod, induction brazed in a dry hydrogen/nitrogen atmosphere, where no flux was used. Notice the increased joint strengths shown below 0.001 in. (0.025 mm). (Source: AWS Brazing Manual, 3rd Ed., 1975, p. 79.)
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BFM were pulled apart in a tensile testing machine, will behave in service very differently when in the tight confines of a brazed joint, and that joint is subjected to tensile testing. Thus, the tensile strength of that BFM (inside the joint) now being modified by the constraints of the faying surfaces on each side of the gap, and the BFM can no longer deform/stretch along preferred slip planes inside the BFM’s structure, as it could when it was being tested out in the open as a bar/rod/wire. Within very tight joints, it appears that instead of slip planes operating, deformation can only occur by actual rupture of molecular bonding within the BFM, requiring far higher levels of force to accomplish that. Thus, the chart shows higher and higher strength levels for the BFM as the joint clearance becomes less than about 0.006 in. (0.15 mm) in Fig. 1, up to more than three times the levels of force that would be required to break that same BFM in a tensile machine.

There was the BFM in a nonconstrained rod form out in open air.

What about that strength “drop-off” below 0.0015 in. (0.04 mm)? The decline in tensile strength shown in Fig. 1 by joint clearances less than about 0.0015 in. is still greatly misunderstood by many people.

Remember that the chart in Fig. 1 was created based on test results of tensile specimens that were torch brazed in air, using a viscous brazing flux to prevent oxidation of the joint surfaces as well as the BFM. All braze-ments joined in air using flux will contain some entrapped flux residues.

There is really no such thing as a flux-free joint when production brazing in air with a flux. Yes, it is possible to reduce, to some extent, the amount of any entrapped flux voids in a brazed joint by a process called “wiping the joint,” but even then you won’t get rid of 100% of all flux voids. Even in lab testing, some flux is still present in the joint.

Therefore, when the test pieces used in creating the chart in Fig. 1 were being torch brazed with joint clearings at about 0.0015 in. or less, the inevitable flux entrapment (gas bubbles and physical flux chemical compounds) in the joint began to become a noticeable percentage of the total joint volume remaining inside the extremely thin brazed joint, and began to negatively affect the joint strength due to their presence (percentage wise). Had the joints been able to be wiped thoroughly (the