Troubleshooter's checklist: sound joints every time

Sometimes it's poor joint design; sometimes it's the wrong choice of alloy; practically always it's one of five key areas that causes the problem, and sparks off the telephone enquiry.

The callers are everyone from government departments and large fabricators to model builders and hobbyists. There are 10-20 of them per day ringing Johnson Matthey Metals at Harlow for advice in solving problems with brazed joints.

That may seem surprising. After all, brazing is supposed to be a relatively simple procedure. So what can go wrong?

JMM thought they could answer that question exactly when they invited me to Harlow. The idea was to make some joints for myself, sometimes deliberately choosing the wrong materials or the wrong heating conditions to see the effect on the finished item.

My guides to good brazing practice were Mike Pocklington, product manager metal joining, and Jack Willingham, supervisor metal joining. Both are enthusiastic prophets of brazing as a joining process and no mean exponents of the craft itself.

The keys to making a successful joint, they told me, were: joint design; pre-cleaning; fluxing; heating of the joint and applying the alloy; and removing flux residues. If all those were done correctly nothing could go wrong.

Before I lifted a brush loaded with flux paste or took control of a brazing torch, we discussed each of the problem areas.

Joint design

The majority of user problems stem from poor joint design.

Designers often fail to recognise that a brazed joint is made by flow of brazing alloy through a capillary gap between the parts to be joined.

If the joint gap is too wide — as it often is—flow will not occur, and the joint will not be formed.

The joints made most successfully by brazing are lap joints between flat components, or sleeve joints between tubular components.

In making a lap joint the optimum gap is 3 to 4 times the thickness of the thinnest base material. For tube, an overlap of one pipe diameter will generally ensure good bonding.

Both provide extremely strong joints. Don't be fooled into thinking of brazing as an inferior joining technique to welding — your joints will be stable and strong.

Five guidelines will help you make better brazed joints. And to prove it, W&MF's John Pearson swopped his notebook for a brazing torch and, with expert guidance, showed that even a journalist can get it right

On the other hand, brazed butt joints will not generally be as strong as their welded equivalents and should be designed out of components where possible.

In industrial design, a butt can be converted to a lap by making a lip on the 'vertical" member of the joint.

Alloy selection

An essential part of joint design is correct alloy selection.

The operator will always tend to pick easy-to-use low melting point, high silver content alloys; the accountant will pick low silver poorer flowing but cheaper consumables.

Flux paste, torch, alloy wire — and intense concentration

It's up to the production engineer to strike the right balance between cost, time taken to make the joint, and joint quality.

Generally the higher the brazing temperature or the longer the range of temperatures over which the alloy melts the more difficult it will be for the operator to use.

But this type of poor flowing alloy can be advantageous when wide gaps have to be filled — instead of flowing freely, it will bridge the joint as discrete globules. However, the amount of alloy deposited is consequently large. As Pocklington says, "The alloys are cheap to buy and expensive to use."

Pre-cleaning

It is good practice to clean the surfaces to be joined, even if they look ready for joining without preparation.

Typical contaminants are oil, grease and paint. The former two should be removed by solvent degreasing. The latter, together with other contaminants, like surface oxides, are best removed with abrasives such as emery paper (30-40 grit).

An added advantage of abrasive cleaning is that it roughens the joint surface. However, it is best to use the emery paper in the direction that alloy will flow. Scratches cutting across flow direction may result in voiding.

Fluxing

In choosing the right flux, you must ensure that its working range matches that of the brazing alloy you have selected.

That is to say the flux must melt and become active below the temperature of brazing, removing surface oxides and creating a path along which the alloy can flow.

Care must be taken not to overheat, otherwise the flux ceases to do its job of dissolving oxides and becomes exhausted. The brazing alloy will then fail to flow properly and the joint will fail.

One or two general purpose fluxes will answer most requirements, but for special applications, special formulations are needed. JMM market some 10 brazing fluxes.

While, in general, you need to flux each joint you make, for copper-copper joints there is a range of phosphorus-containing alloys which are self-fluxing. These alloys contain either zero or 2% silver and so are inexpensive; they can also be applied (with flux) to brass joints.

Application

Flux should be applied as a paste, spread liberally over the joint components using a brush. Don't worry about applying too much — a sound joint will result; but too little and the joint will not be formed. This is a very common cause of joint failure.

Heating

To help judge when the fluxed joint has been raised to the correct temperature the operator should either take the colour of the metal as a guide or, better, the condition of the flux. At the correct temperature it will be fluid and clear.

In heating a lap joint, play the brazing flame on the lower plate first. That way conducted heat will enter the joint area and activate the flux. Similarly, in pipe-to-pipe joints, heat the sleeved section first to conduct heat into the joint zone.

Alloy application

When the joint is at the right temperature apply the alloy at one point and let capillary flow do the rest. Don't be tempted to move the alloy rod along the joint to build up a fillet. It's costly, and unnecessary.

Flux removal

Unremoved flux is corrosive. While it's rare for flux to corrode right through a metal, it will form bacterial growths and is responsible for the green colour sometimes seen around joints in copper.

But flux is comparatively easy to remove. Unspent residues will dissolve in warm water (>60°C). After soaking for 10-15 min joints can simply be scrubbed clean.

Where there is pipework in situ, either mechanical cleaning (eg, shotblasting) or flushing out with warm water will be successful. (When mechanical cleaning, choose a flux which does not become sticky.)

If the flux is exhausted, the only answer will be acid or caustic treatment to remove the residues.

Theory into practice

Most of the joints I made at JMM were butt joints. The guidelines worked: when they were followed, professional joints resulted; when they weren't the joints either didn't form or were weak mechanically.

As an unskilled brazer I had a tendency to hold the brazing rod in the flame too long. Compared with joints made by the experts, mine used about twice as much alloy. But that was a failing I had already started to overcome by the end of a morning's brazing.

Like most shop floor operators, I preferred easy flowing alloys, using a high melting point, poor flowing alloy to bridge a wide joint gap, I merely exhausted the flux.

Most fabricators believe that they know the ins and outs of brazing, yet many, apparently, make mistakes which are quite elementary.

Better joint design is probably the most pressing problem, and is something which should be tackled at college level.

Demonstrations. How JMM taught JP what not to do

1. Butt vs lapp	Flux used was Easy-flo paste; alloy wire was Silver-flo 55, a low melting, easy-to-use alloy with the advantage of being cadmium free, so there is no risk of harmful fumes. Joints were tested for strength by the simple means of hammering. In the case of butt joints it was sometimes possible to destroy the joint with sufficient (considerable) force; lap joints proved indestructable.
2. Bridging a wide joint gap	The alloy this time was Silver-flo 302, a higher melting point, less freely flowing material, which lays down in bead or globular form. The joint gap for this demonstration was 2-3 mm wide. Result was a sound, but not very professional-looking joint. Amount of material put down was considerably higher than for a free flowing alloy, and a "fillet" was built up along the butt edge.
3. Is flux necessary?	Demonstrations showed yes. Without flux joints were poor or patchy because surface oxides impeded alloy flow. The one exception was in making Cu-Cu joints with phosphorus-bearing low silver alloys (see text).
4. Which flux?	How to get it wrong. Take a high melting, copper-based ahoy like F bronze (890-930°C) and use it with Silver-flo flux paste which becomes active at about 800°C. Result is flux exhaustion, poor joint formation and difficult to remove flux residues. The reverse problem with a low melting point alloy meets a high temperature flux is equally as easy to achieve without care.
5. Single point application	The temptation to make fillets not only wastes money it also makes a less aesthetically-pleasing joint. So let capillary forces do the work.
6. Final assembly—getting it right	The final demonstration was a sleeve joint made of one brass and one copper component. Flux was Silver-flo paste and alloy was Silver-alloy 40. Result was a sound, attractive and economical joint.

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