

Wide-Gap Brazing: A Practical Approach to a Difficult Process

By Dientje Fortuna, Oerlikon Metco (US) Inc.

There are many essential processing ingredients for achieving a “good” braze joint. The ingredients include proper fixturing, using the right heat source, selection of the best braze alloy and cleanliness of the parts. Another important factor is the gap size or the distance between the surfaces to be joined.

The gap size is determined by the alloy chosen to braze the component. Copper brazing, because the alloy is very fluid in the liquid state, is typically done with a gap of 0.0005 to 0.002 inches. Other alloy classes (see Table 1) have similar joint gap requirements that will yield the best braze joint possible. Each alloy in the various classes has its own unique melting characteristic. The design and manufacture of components must take into account the thermal expansion of the base metals, how

fluid the braze alloy is at temperature and the depth of the joint to achieve a strong, solid joint in the completed component.

Why less is better

When the joint fit-up is correct, less braze alloy is needed for the braze joint. This results in reduced costs for the braze alloy and labor to apply the alloy. With less alloy flow, the need for stop-off is reduced and this equates to lower labor costs for the application and removal of the stop-off. And last, but probably most important, the smaller gap will generate the strongest joint. The relationship between strength and joint size is clear in Figure 1. As the joint size increases, the strength is proportionally reduced. Without testing it is possible to manufacture a component that can be brazed but will not survive in service. Too often the optimum joint conditions for

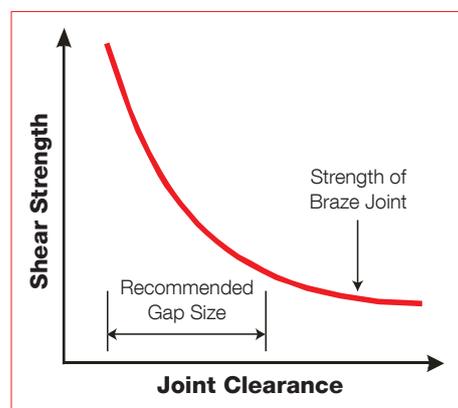


Figure 1. Shear strength vs. joint clearance

brazing a component are not achievable. The gap size is not the desired 0.001 to 0.004 inch size, but closer to 0.010 inches or greater. This is referred to as a wide-gap condition.

Table 1. Recommended Joint Clearances at Brazing Temperature

(From the Brazing Handbook by the American Welding Society)

Filler Metal AWS Classification Group	Joint Clearance* (inches)
BAISI	0.000 – 0.002 for furnace brazing in a vacuum atmosphere and clad brazing sheet in salt bath
	0.002 – 0.008 for length of lap less than 0.25 in.
	0.008 – 0.010 for length of lap greater than 0.25 in.
BCuP	0.001 – 0.005 no flux and for flux brazing for joint length under 1 in.
	0.007 – 0.015 no flux and for flux brazing for joint length greater than 1 in.
BAG	0.002 – 0.005 flux brazing
	0.000 – 0.002 ** atmosphere brazing
BAu	0.002 – 0.005 flux brazing
	0.000 – 0.002 ** atmosphere brazing
BCu	0.002 – 0.005 ** atmosphere brazing
BCuZn	0.002 – 0.005 flux brazing
BMg	0.004 – 0.010 flux brazing
BNi	0.002 – 0.005 general application (flux/atmosphere)
	0.000 – 0.002 free-flowing types, atmosphere brazing

* Clearance is measured on the radius when rings, plugs or tubular members are involved. On some applications it may be necessary to use the recommended clearance on the diameter to assure not having excessive clearance when all clearance is on one side. An excessive clearance will produce voids. This is particularly true when brazing is accomplished in a high quality atmosphere.

** For maximum strength a press fit of 0.001 in. per in. of diameter should be used.

Why has this happened?

- Design of the part may be very complex. While the component looks simple enough on the drawing board, the reality of manufacturing the part may be such that the dimensions are difficult to maintain an results in a gap that is too wide for the braze alloy.
- The design may be good, but the capability of the shop does not make it possible to achieve the optimum gap size.
- During assembly of a part a component may not be seated properly so one side has too narrow a gap and the other side too wide. This can actually cause two problems, but of interest here is the wide-gap area.
- Dissimilar thermal expansion between component parts could result in a wide-gap situation. The cause of the dissimilarity can be from two different metals being used in one component or thick and thin sections being joined.
- The type of fixturing used could also cause a wide gap depending on how it holds the part to be brazed.

The first steps to take to eliminate a wide-gap problem are to review the design, assembly, machining/manufacturing process and the base metals to see where the process can be improved. If the review does not yield a way to improve the gap size, use of a wide-gap alloy or gap filler may be the only solution. While wide-gap brazing should not be the first choice solution, it is an acceptable method in today's market. Remember the parts must meet the designed service requirements.

Wide-gap alloys

For the Aluminum-Silicon, Copper-Phos and Nickel base braze alloys wide-gap powders are available. There are two kinds: The first are alloys whose chemical make-up result in a sluggish flowing alloy that is able to bridge slightly wider than standard gaps. For example in the nickel alloy family, AMS 4776 and AMS 4779 are able to bridge gaps up to 0.010 inches. In the Copper-Phos alloys, BCuP-5 is available for brazing wider gaps of 0.005 to 0.006 inches (see Table 2 for alloy details). To help make this bridging possible, brazing at or below the liquidus temperature or for shortened periods of time are suggested. This will keep the braze alloy from becoming too liquid and flowing more than necessary. The aim is to keep the alloy slushy so that it fills the wider area of the joint because the flow is retarded.

Table 2. Examples of Wide-Gap Braze Alloys

Braze Alloy	Chemistry
AMS 4776, BNi-1a	Ni 14Cr 3.15B 4.5Si 4.5Fe
AMS 4779, BNi-4	Ni 2B 3.5Si
BCuP-5	Cu 15Ag 5P

The second type of wide-gap alloy is a blend of a braze alloy plus a filler powder. The filler material, in a wide-gap product, can be a pure metal, such as nickel or an alloy like NiCr, NiSiB, stainless steels, superalloys or other metal powders, as long as they are compatible with the base metal and the braze alloy and suitable for the intended service of the part. Figure 2 shows how the filler material is the bridgework for the braze alloy to use in brazing a wide-gap joint.

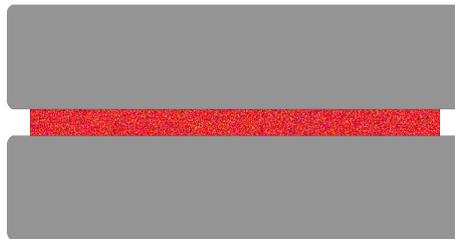


Figure 2. Wide-gap braze joint filled with a commercial or custom wide-gap braze alloy.

The filler powder chosen for the wide-gap alloy should melt at a higher temperature than the braze alloy. Some wide-gap braze alloys are available commercially. In the nickel alloy family, products such as Amdry™ 103, Nicrogap 108 and 118, NI-568 and Vitta-Braz 1142 can be used as they are delivered from the manufacturer for wide-gap brazing. The wide-gap products are applied in the same manner as other braze alloys. The form of the alloy will depend on the joint configuration and forms available. Some application details are discussed later in the paper.

Custom wide-gap alloys can be made by blending a braze alloy plus a filler powder in various ratios creating an optimum braze alloy to fill the joint. When making these blends, it is important to use the proper equipment and sufficient time to insure a homogeneous blend. Blending time is also very important in the success of wide-gap brazing. A minimum of 30 minutes and a maximum of 60 minutes of blending is necessary to get a homogeneous blend of the two powders. Less than 30 minutes and

the powders may not be mixed well. Over 60 minutes and the powders may actually begin to separate again. A “V” blender is the recommended equipment for blending powders, but other options are available for thorough powder blending. The success of wide-gap brazing, or any brazing where more than one powder is used, is dependent on how well the powders are blended before application to the part.

When making custom blend wide-gap alloys, some consideration must be paid to the mesh size of the powder components. Braze alloys and filler powders are usually available as coarse and fine powders. Table 3 shows the powder combinations that are possible for wide-gap brazing. A study of the actual joint configuration will help in choosing the best combination of powder mesh sizes to create a dense and completely filled joint area. According to a paper by Fritz Lenel¹ about spherical powder particle density (see Figure 3) the optimum density is when a maximum of 40% -325 mesh powder is used in a powder mixture. While “optimum” density may not be achievable, it is still possible to get a wide-gap joint with better density by taking the mesh size of the powder into consideration.

The size of the gap is another reason why it is important to choose an appropriate mesh size of the filler powder for a wide-gap application. If a coarse mesh filler powder is used for a slightly wide-gap joint, 0.010” for instance, it is possible that only a small amount of the filler powder will make it into

Table 3

Coarse Braze Powder + Coarse Parent Metal Powder	Coarse Braze Powder + Fine Parent Metal Powder
Fine Braze Powder + Coarse Parent Metal Powder	Fine Braze Powder + Fine Parent Metal Powder

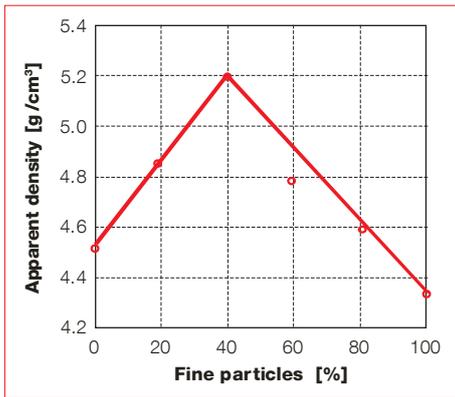


Figure 3. Effect of adding fine (–325 mesh) spherical powder to coarse (–100 +150 mesh) stainless steel powder on apparent density. From "Mechanical Fundamentals of Consolidation" by Fritz Linel.

the joint. Some of the coarse particles could be as large as 0.007 inches and these particles will not flow easily into the joint with the braze alloy. Figure 4 is a photograph of a 0.010 inch wide-gap where little of the nickel filler powder flowed into the joint. Most of it stayed clumped up at the joint entrance. Though the joint is filled, the strength of the joint is in doubt. The abundance of nickel and lack of braze alloy at the joint entrance, and with only braze alloy "cast" into the joint, the part could fail under service conditions. This same condition, lack of filler, could occur if there is not sufficient time at heat for the braze alloy to flow and carry the filler powder with it. For wide-gap applications where the gap is only slightly larger than recommended, the right decision might be to use a finer (–325) mesh filler powder. Testing is the best way to develop an alloy product for specific wide-gap applications.

How the wide-gap alloy is applied should also be considered. Making a paste or slurry and then extruding it through a small needle like those used on standard braze alloy pastes can also create problems. Just as large powder particles can have difficulty flowing into a joint that is too small, the particles will have problems flowing through small needles. A separation of the powders can occur if the pressure on the applicator is increased to overcome the low flow of the paste from the container. You can literally squeeze the smaller braze alloy and binder out of the needle and leave the large filler particles behind. This could also make too much binder flow out leaving the remaining paste or slurry too dry to flow from the container at all. In the extreme, the braze deposit will not contain sufficient alloy and

voids will appear in the braze joint. The paste remaining in the tube may be too dry to extrude and is usually discarded. No matter which of the component powders is coarser, to help guarantee success, choose the application equipment or alloy form carefully and tailor it to the size of the powder particles as well as the joint design.

When the wide-gap alloy uses a fine filler powder, the braze alloy can have a retarded flow. The fine mesh filler powder has a much greater surface area, which can require more braze alloy. If there is not sufficient braze alloy, there can be underfill or voids in the joint. Pre-placement of the wide-gap alloy so minimal flow is required, or an adjustment to the amount of braze alloy used in the wide-gap alloy would solve this problem.

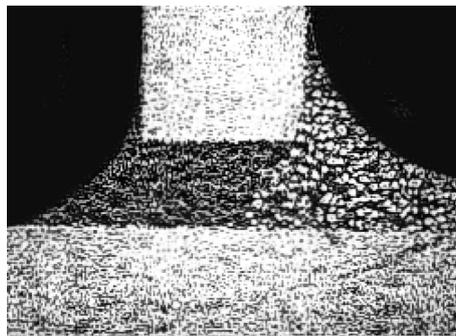


Figure 4.

If the wide-gap joint to be brazed is also deep as well as oversized, the filler powder can be applied directly into the joint (Figure 5 depicts this application). The filler powder should be packed into the joint as well as possible. When the braze alloy becomes liquid, it will flow between the filler particles and fill the wide-gap braze joint. be sure to pick a braze alloy whose flow characteristics is sufficient to penetrate the packed powder through the entire length of the joint.

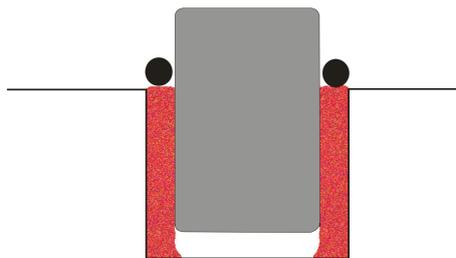


Figure 5. Wide-gap braze joint pre-filled with filler powder.

The last example of a wide-gap application is brazing of two large flat surfaces where the fit between the surfaces exceeds the recommended gap size (Figure 6). In this case it may be necessary or more effective to add a shim of the base metal in the joint. Prior to insertion of the shim, braze alloy is applied to both sides in powder, tape or foil form. The shim, with alloy applied, is then sandwiched between the components being brazed. An alternative to using a shim is a screen-like mesh or felt metal made from the base metal or a compatible metal. Braze alloy in paste, tape or foil form is applied with the mesh. This method would also work for filling wide-gaps around tubular braze joints where the mesh and braze alloy are pushed in to fill the area around the tube. In all cases, there must be sufficient braze alloy to flow into the mesh and still wet the surface of the components to complete the joining.

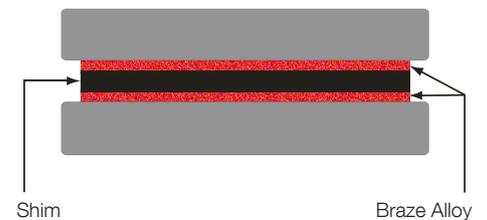


Figure 6. Wide-gap filled with base metal shim and braze alloy.

Most braze alloys (not pure metals) form some type of brittle eutectic phases. These brittle areas can reduce the joint strength. The larger the gap the more alloy is needed, the lower the strength. Refer to Figure 1 where the relationship between the joint size and strength is clearly shown. Testing should be done if the wide-gap condition is a continuing problem in the production of parts, to insure that joint strength of the brazed component meets the design criteria. If the strength cannot be met then other steps must be taken to have the joint tolerance meet the drawing requirements.. For critical components, wide gap brazing may not be an option.

Many of the braze alloys used today will increase in remelt temperature when held at the braze temperature for slightly longer periods of time. Often the higher remelt temperature is essential in order to meet the service requirements for the parts. When the gap is smaller, and less alloy is present, less time and lower temperatures are required to increase the remelt temperature of the braze alloy. With wide-gap situations,

where the additional alloy is required, it may be difficult to achieve a higher remelt temperature unless an extended furnace cycle is performed. Unfortunately, if the component is to perform in a high temperature environment, a longer braze cycle must be added to the processing plan. If this longer cycle is not performed, there is a risk of remelting the braze alloy in subsequent thermal cycles or in service, causing failure or at the very least, damage to the component.

Wider braze gaps are also more susceptible to cracking under certain conditions. This cracking could occur in service or in manufacturing steps occurring after the braze cycle. Cooling or quenching the parts can cause cracks in the wide-gap joints. Parts

made from base materials that have metallurgical transformations upon cooling require furnace cycles that minimize potential cracking of the wide-gap braze joints. Post-braze machining could also cause cracking in a wide-gap joint. Welding near braze joints is always potentially problematic. The risk of cracking the joint is exaggerated in wide-gap joints. It becomes very difficult to weld less than 3 inches away from the joint without having cracks form in the joint area. Since many parts are welded after brazing, other solutions than wide-gap brazing may be necessary.

Wide gap brazing is not a simple solution and should be avoided if possible. Before performing this braze operation on parts a

solution for the wide-gap situation should be sought through: redesign, improvement of manufacturing tolerances, better fixturing and careful assembly of parts. If no other solution is found, keep the following issues in mind when developing a wide-gap procedure:

- Mesh size of the wide-gap powder components
- Application of the alloy
- Chemistry of the braze alloy and base metal(s)
- Joint design
- Service requirements of the part
- Development of an appropriate process including the thermal cycle
- Post brazing processes

Notes

- Amdry is a registered trade mark of Oerlikon Metco
- Vitta-Braze is a trademark of Vitta Corporation
- Nicrogap is a registered trademark of Wall Colmonoy Corporation
- NI-568 is a product of Praxair Surface Technologies

Literature References

1. Lenel, Fritz, Mechanical Fundamentals of Consolidation

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www.oerlikon.com/metco
info.metco@oerlikon.com