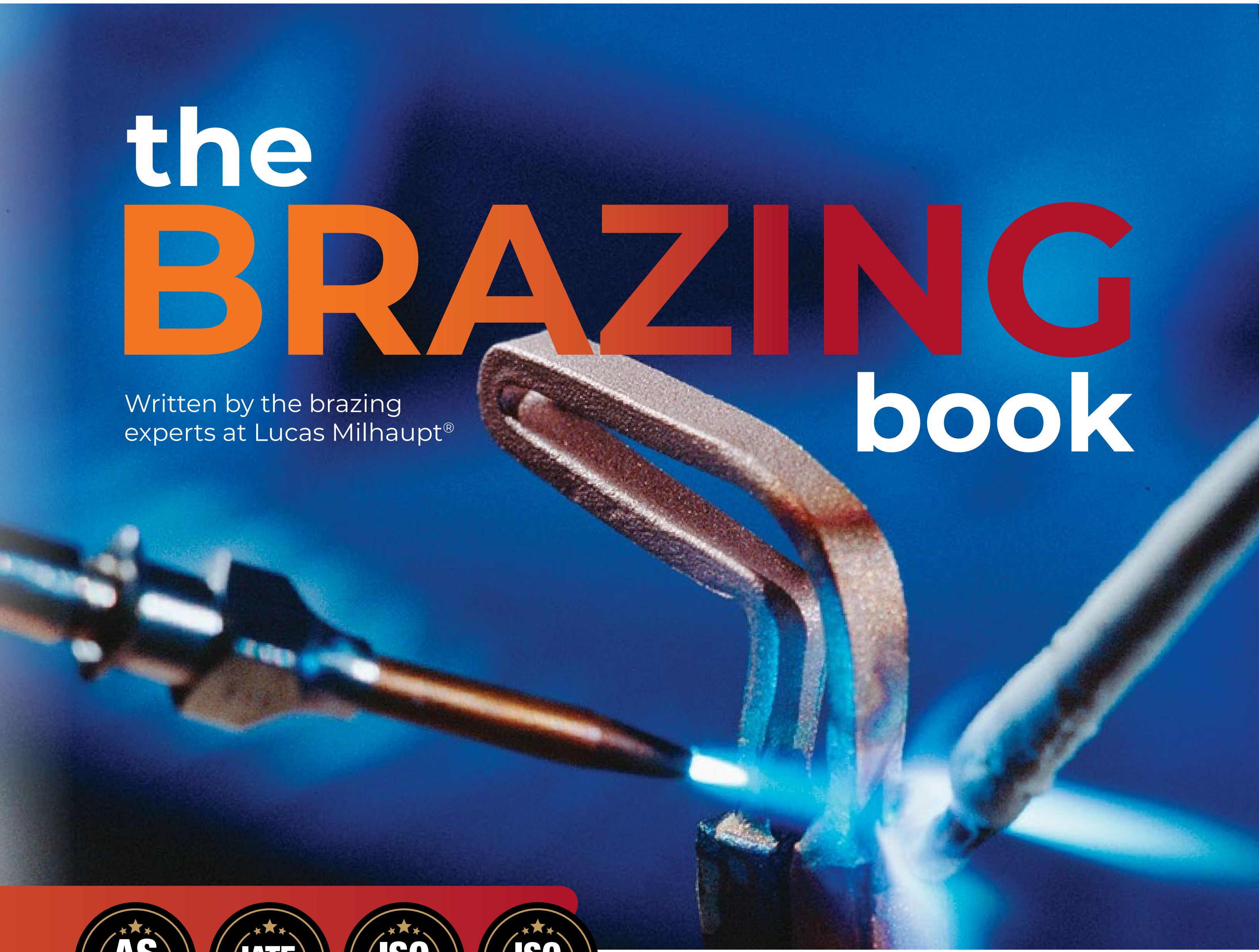
LucasMilhaupt®
A STEEL PARTNERS COMPANY
Join with the Best™

the BRAZING book

Written by the brazing experts at Lucas Milhaupt®



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ISO 9001 CERTIFIED
ISO 14001 CERTIFIED

An educational resource for novice brazers and seasoned engineers.

the BRAZING book

The Brazing Book is designed to assist both novice brazers and seasoned engineers by providing comprehensive information on the brazing process. Lucas Milhaupt, Inc. has updated this publication to reflect the many advancements in the industry, while maintaining its core purpose: to expand the applications of brazing by highlighting its many advantages and acknowledging its limitations. This guide also showcases the people and industries that use brazing to enhance manufacturing efficiencies.

For clarity, the book is divided into four main sections:

- **Section One, "The Idea of Brazing,"** explains what brazing is, where to use it, and how to perform it properly.
- **Section Two, "Products to Meet Your Brazing Needs,"** features newly developed products and their current applications.
- **Section Three, "Choices In Brazing Materials,"** lists and describes various brazing products from Lucas Milhaupt, including selection charts for the best filler metals and fluxes.
- **Section Four, "The Lucas Milhaupt Advantage,"** provides an overview of the R&D capabilities in the Center of Excellence, as well as the technical services and brazing solutions available through Lucas Milhaupt.

We know you'll find The Brazing Book informative and helpful. We hope you'll find it interesting as well.

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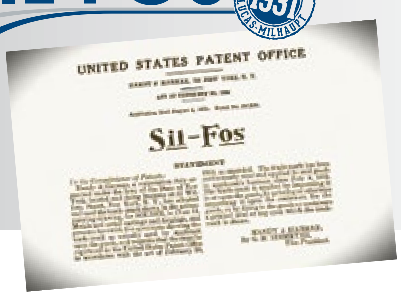
A Legacy of Innovation with Lucas Milhaupt

Founded in 1942 as a tool manufacturer, Lucas Milhaupt pivoted to producing silver alloy brazing preforms during World War II. The company expanded its product line over the decades to include copper, brass, and aluminum brazing preforms. In 1967, Lucas Milhaupt was acquired by Handy & Harman®, enhancing its brazing products and services. Joining Steel Partners in 2018, Lucas Milhaupt embraced operational excellence to boost efficiency and customer satisfaction. Today, it offers the industry's most extensive inventory of alloys and forms, backed by a dedicated technical support team.

1867 *Handy & Harman founded.*

1931 *SIL-FOS® trademark acquired.*



1942 *Donald Lucas and Howard Milhaupt established Lucas Milhaupt as a cutting tools manufacturer.*

1967 *Lucas Milhaupt acquired by Handy & Harman.*

1984 *New Formulated Paste / Flux Value Stream Introduced.*

2002 *HANDY ONE® product line launched.*

2004 *Protechno S.A. in Ribérac, France acquired.*

2008 *First facility located in Suzhou, China industrial park.*

Lucas Milhaupt acquired OMNI.

2009 *All brazing companies unified under a single brand name – Lucas Milhaupt.*

2013 *Wolverine Joining Technologies, Warwick, Rhode Island acquired.*

2017 *Received AS9100 Certification.*

2018 *Lucas Milhaupt officially became a Steel Partners Company.*

2023 *Lucas Milhaupt launched new state-of-the-art facility in Cudahy, WI.*

Lucas Milhaupt acquired Braze Alloy.

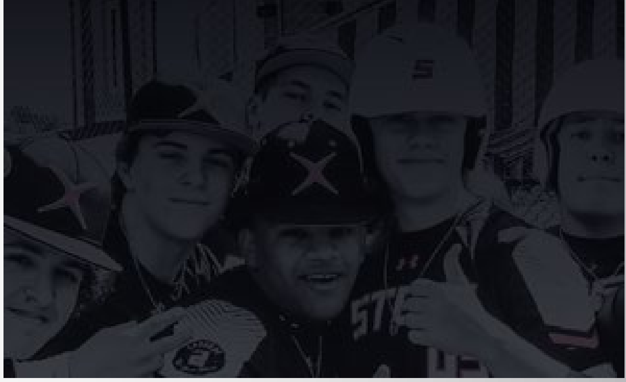
STEEL PARTNERS

STEEL PARTNERS

The Strength of Steel

In 2018, Lucas Milhaupt officially became a part of the Steel Partners family. Steel Partners is a diversified global holding company, dedicated to strengthening the competitive advantage and increasing the profitability of its operating businesses, while enabling them to achieve operational excellence and enhanced customer satisfaction.

Founded in 1990, Steel Partners has steadily grown its portfolio to include operations in diversified industrial products, energy, defense, supply chain management and logistics, banking, and youth sports.



Section 1: The Idea of Brazing

What brazing is all about.

What is brazing?

Brazing is the joining of metals through the use of heat and a filler metal—one whose melting temperature is above 840°F (450°C) but below the melting point of the metals being joined. This heat is typically imparted via torch, furnace, induction, or resistance methods.

Brazing is probably the most versatile method of metal joining today for a number of reasons:

- Brazed joints are strong. On nonferrous metals and steels, the tensile strength of a properly made joint will often exceed that of the metals joined. On stainless steels, it is possible to develop a joint whose tensile strength is 130,000 pounds per square inch. (896.3 megapascal [MPa]).
- Brazed joints are ductile, able to withstand considerable shock and vibration.
- Brazed joints are usually easily and rapidly made, with relatively simple to acquire operator skills.
- Brazing is ideally suited for joining dissimilar metals. You can easily join assemblies that combine ferrous with nonferrous metals, and metals with widely varying melting points.
- Brazing is essentially a one-operation process. There is seldom any need for grinding, filing or mechanical finishing after the joint is completed.
- Brazing is performed at relatively low temperatures, reducing the possibility of warping, overheating or melting the metals being joined.
- Brazing is economical. The cost-per-joint compares quite favorably with joints made by other metal joining methods.
- Brazing is highly adaptable to automated methods. The flexibility of the brazing process enables you to match your production techniques very closely to your production requirements.

The Versatility of Brazing

- Strong, ductile joints
- Ease of operation
- Suited for joining dissimilar metals
- One-operation process
- Requires low temperatures
- Economical
- Highly adaptable to automation

With all its advantages, brazing is still only one of the ways in which you can join metals. To use brazing properly, you must understand its relationship to other metal joining methods.

What are some of those methods and which should you use where?

There are many ways to join metals.

Brazing, as we've noted, relies on heat and a filler metal to join metals.

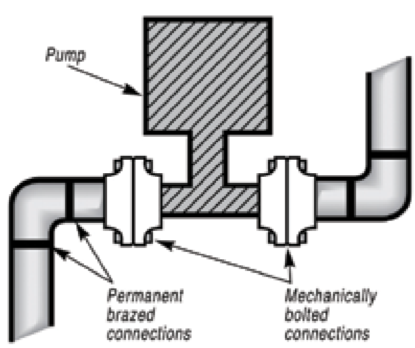
There is nothing unique about this. Welding and soldering are similar in these respects. And, metals can also be joined efficiently and economically without the need for heat or a filler metal at all, by mechanical fastening or adhesive bonding.

When would you use brazing, rather than one of these other methods? It depends on the circumstances.

Let's start our evaluation of brazing as a metal joining method by eliminating those situations where brazing is generally unsuitable.

The first of these situations is the non-permanent joint. This is the joint that's made with future disassembly in mind.

For example, a pump connected to a piping assembly.



The pipes won't wear out—but some day the pump will. It's easier to disassemble a threaded or bolted pump connection than a brazed connection. (You can "de-braze" a brazed joint if you have to, but why plan on it?) For the typical non-permanent joint, mechanical fastening is usually the most practical method.

There's another kind of joint where brazing will likely be your last, rather than your first, consideration. And that is the permanent, but low-strength joint. If you're joining metal assemblies that won't be subjected to much stress or strain, there are frequently more economical ways to join them than by brazing. (Mechanical fastening, for example, or soft soldering or adhesive bonding.) If you are selecting a method to seal the seams of tin cans, there is nothing to stop you from brazing. Yet soft-soldering would be perfectly adequate for this low-stress type of bond. And soft-soldering is generally less expensive than brazing.

In these two areas—the non-permanent joint and the permanent but low-strength joint—other joining methods are adequate for the job and usually more economical than brazing.

Where does brazing fit in?

Consider brazing when you want permanent and strong metal-to-metal joints.

Mechanically-fastened joints (threaded, staked, riveted, etc.) generally don't compare to brazed joints in strength, resistance to shock and vibration, or leak-tightness.

Adhesive bonding and soldering will give you permanent bonds, but generally neither can offer the strength of a brazed joint—strength equal to or greater than that of the base metals themselves. Nor can they, as a rule, produce joints that offer resistance to temperatures above 200°F (93°C).

If you want metal joints that are both permanent and strong, it's best to narrow down your consideration to welding and brazing.

Welding and brazing both use heat. They both use filler metals. They can both be performed on a production basis. But the resemblance ends there. They work differently, and you need to understand the nature of that difference to know which method to use where.

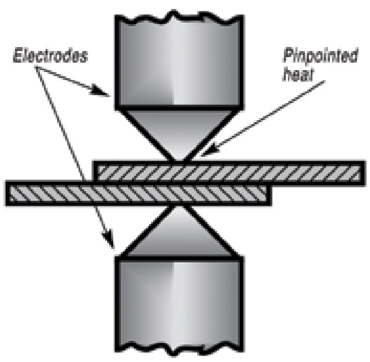
How welding works.

Welding joins metals by melting and

fusing them together, usually with the addition of a welding filler metal. The joints produced are strong, usually as strong as the metals joined or even stronger.

In order to fuse the metals, a concentrated heat is applied directly to the joint area. This heat is high temperature. It must be—in order to melt the “base” metals (the metals being joined) and the filler metals as well. So welding temperatures start at the melting point of the base metals.

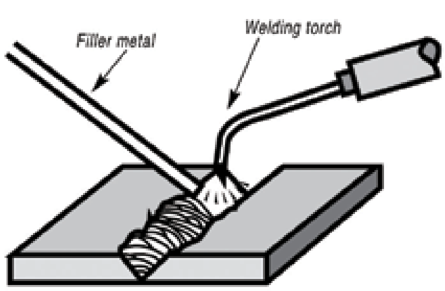
As welding heat is intense, it is impractical to apply it uniformly over a broad area. Welding heat is typically localized, pinpointed heat. This has its advantages. For example, if you want to join two small strips of metal at a single point, an electrical resistance welding setup is very practical.



This is a fast, economical way to make strong, permanent joints by the hundreds and thousands.

However, if the joint is linear, rather than pinpointed, problems arise. The localized heat of welding tends to become a disadvantage. For example, suppose you want to butt-weld two pieces of metal—start by beveling the edges of the metal pieces to allow room for the welding filler metal. Then weld, first heating one end of the joint area to melting temperature, then slowly traveling the heat along the joint line, depositing filler metal in synchronization with the heat.

This is a typical conventional welding operation. Let’s look at its characteristics.



It offers one big plus—strength. Properly made, the welded joint is at least as strong as the metals joined. But there are minuses to consider. The joint is made at high temperatures, high enough to melt both base metals and filler metal. High temperatures can cause problems, such as possible distortion and warping of the base metals or stresses around the weld area.

These dangers are minimal when the metals being joined are thick. But they may become problems when the base metals are thin sections.

High temperatures are expensive as well since heat is energy, and energy costs money. The more heat you need to make the joint, the more the joint will cost to produce.

Now consider the automated process. What happens when you join not one assembly, but hundreds or thousands of assemblies? Welding, by its nature, presents problems in automation. We know that a resistance weld joint made at a single point is relatively easy to automate. But once the point becomes a line—a linear joint—the line has to be traced. It’s possible to automate this tracing operation, moving the joint line, for example, past a heating station and feeding filler wire automatically from big spools. But this is a complex and exacting setup, warranted only when you have large production runs of identical parts.

Of course, welding techniques continually improve. You can weld on a production basis by electron beam, capacitor discharge, friction and other methods. But these sophisticated processes usually call for specialized and expensive equipment and complex, time-consuming setups. They’re seldom practical for shorter production runs, changes in assembly configuration or—in short—typical day-to-day metal joining requirements.

How brazing works.

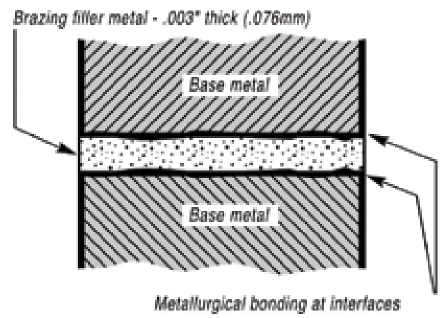
A brazed joint is made in a completely different way from a welded joint.

The first big difference is in temperature. Brazing doesn’t melt the base metals. So brazing temperatures are invariably lower than the melting points of the base metals. And, of course, always significantly lower than welding temperatures for the same base metals.

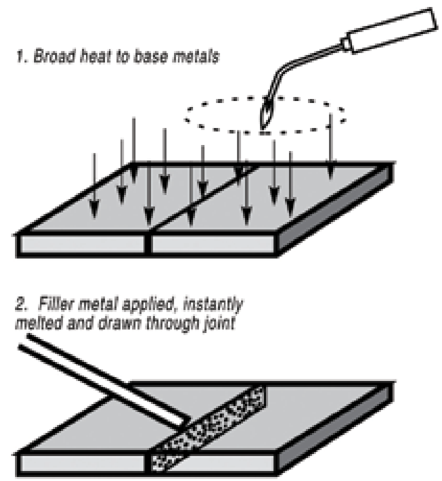
If brazing doesn’t fuse the base metals, how does it join them?

It joins them by creating a metallurgical bond between the filler metal and the surfaces of the two metals being joined.

The principle by which the filler metal is drawn through the joint to create this bond is capillary action. In a brazing operation, you apply heat broadly to the base metals. The filler metal, which is in



contact with the heated parts, is melted instantly by the heat in the base metals and drawn by capillary action completely through the joint.



This, in essence, is how a brazed joint is made. What are the advantages of a joint made this way?

Advantages of a brazed joint.

First, a brazed joint is a strong joint. A properly made brazed joint (like a welded joint) will in many cases be as strong or stronger than the metals being joined.

Second, the joint is made at relatively low temperatures compared to welding. There are several considerations for brazing temperature and primarily will depend on the filler metal chosen and the heating method used.

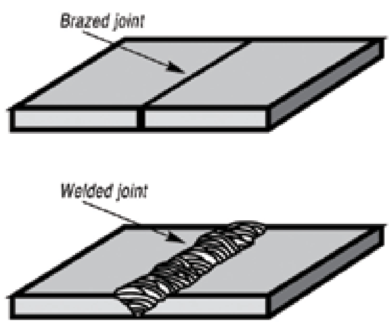
Since the base metals are not melted, they can typically retain most of their physical properties. And this “integrity” of the base metals is characteristic of all brazed joints, of thin-section as well as thick-section joints. Also, the lower heat minimizes any danger of metal distortion or warping. (Consider too, that lower temperatures need less heat which can be a significant cost-saving factor.)

An important advantage of brazing is the ease with which it joins dissimilar metals. If you don’t have to melt the base metals to join them, it doesn't matter if they have widely different melting points. You can braze steel to copper as easily as steel to steel.

Welding is a different story. You must melt the base metals to fuse them. So, if you try to weld copper (melting point 1981°F/1083°C) to steel (melting point 2500°F/1370°C), you have to employ rather sophisticated, and expensive, welding techniques.

The total ease of joining dissimilar metals through conventional brazing procedures means you can select whatever metals are best suited to the function of the assembly—knowing you'll have no problem joining them no matter how widely they vary in melting temperatures.

Another advantage of a brazed joint is its good appearance. The comparison between the tiny, neat fillet of a brazed joint and the thick, irregular bead of a welded joint is like night and day.



This characteristic is especially important for joints on consumer products, where appearance is critical. A brazed joint can almost always be used as-is, without any finishing operations needed. And that too is a money-saver.

Brazing offers another significant advantage over welding in that brazing skills can usually be acquired faster than welding skills. The reason lies in the inherent difference between the two processes. A linear welded joint must be traced with precise synchronization of heat application and deposition of filler metal. A brazed joint, on the other hand, tends to "make itself" through capillary action. (A considerable portion of the skill involved in brazing actually lies in the design and engineering of the joint.) The comparative quickness with which a brazing operator may be trained to a high degree of skill is an important cost consideration especially when brazing with a manual process.

Finally, brazing is relatively easy to automate due to the many heating method options and filler metal forms, which helps eliminate the potential for problems. Because of this, brazing operations can easily be automated to the extent needed for almost any level of production.

Brazing Advantages

- Joint strength
- Lower temperatures/lower cost
- Maintains integrity of base metals
- Dissimilar metals easily joined
- Good joint appearance
- Operator skill easily acquired
- Process easily automated

Which joining method is the best?

As we've indicated, when you want to make strong and permanent metal joints, your choice will generally narrow down to welding or brazing.

So, which method is best?

It depends entirely on the circumstances. The key factors in making a decision will boil down to the size of the parts to be joined, the thickness of the metal sections, configuration of the joint, nature of the base metals, and the number of joints to be made and the service requirements. Let's consider each of them.

How big is the assembly?

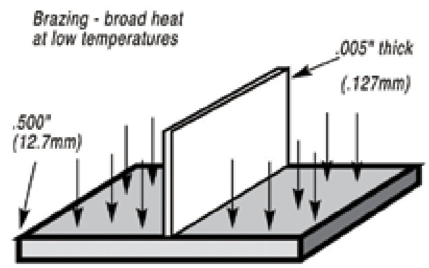
Welding is usually more suited to the joining of large assemblies than brazing. Why? Because in brazing the heat must be applied to a broad area, often to the entire assembly. And, if the assembly is a large one, it's often hard to heat it to the flow point of the filler metal as the heat tends to dissipate faster than you build it up.

You don't meet this limitation in welding. The intense localized heat of welding, sometimes a drawback, becomes an advantage in joining a large assembly. So does welding's ability to trace a joint.

There's no way to establish exactly the point at which size of assembly makes one metal joining method more practical than another. There are too many factors involved. For example, if the assembly is unable to be brazed in open air (torch, induction, etc.) due to size, a furnace or dip brazing process may eliminate the size consideration. However, you can still use this rule-of-thumb as a starting point: Large assembly—weld, if the nature of the metals permits. Small assembly—braze. Medium-sized assembly—experiment.

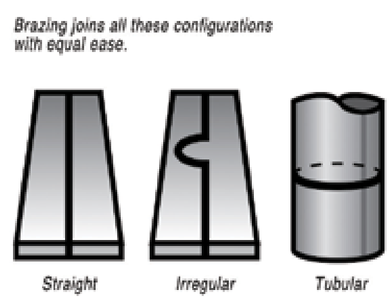
How thick are the base materials?

Thickness of base material is an important consideration in selecting a metal joining method. If both sections are relatively thick—say .500" (12.7mm)—either welding or brazing can produce a strong joint. But if you want to make a T-joint, bonding a .005" (.127mm) thick sheet metal section to half-inch stock, for example, brazing is the better choice. The intense heat of welding is likely to burn through, or at least warp, the thin section. The broader heat and lower temperature of brazing allows you to join the sections without warpage or metal distortion.



What's the joint configuration?

Is the joint a "spot" or a "line"? A spot joint made at one point can be accomplished as easily by welding as by brazing. But a linear joint—all other things being equal—is more easily brazed than welded. Brazing needs no manual tracing. The filler metal is drawn through the joint area by capillary action, which works with equal ease on any joint configuration.



What metals are you joining?

Suppose you're planning a two-section metal assembly. You want high electrical conductivity in one section, high strength and corrosion resistance in the other. You want to use copper for conductivity, and stainless for strength and corrosion resistance.

Welding this assembly will present problems. As we've seen, you have to melt both metals to fuse them. But stainless melts at a much higher temperature than copper. The copper would completely melt and flow off before the stainless came anywhere close to its melting temperature.

Brazing these dissimilar metals offers no such obstacle. All you have to do is select a brazing filler metal that is metallurgically compatible with both base metals and has a melting point lower than that of the two. You get a strong joint, with minimal alteration of the properties of the metals.

The point to remember is that brazing joins metals without melting them, by metallurgically bonding at their interfaces. The integrity and properties of each metal in the brazed assembly are retained with minimal change.

If you plan to join dissimilar metals—think brazing.

How many assemblies do you need?

For a single assembly, or a few assemblies, your choice between welding and brazing will depend largely on the factors discussed earlier—size of parts, thickness of sections, joint configurations, and nature of base metals. Whether you braze or weld, you'll likely do the job manually if joining in open air. But when your production volume needs run into the hundreds, thousands, or more, production techniques and cost factors become a critical factor.

Which method is best—for production metal joining?

Both methods can be automated. But they differ greatly in flexibility of automation. Welding tends to be an all-or-nothing proposition. You weld manually, one-at-a-time, or you install expensive, sophisticated equipment to handle very large runs of identical assemblies. There's seldom a practical in-between.

Brazing is just the opposite. You can braze "one-at-a-time" manually, of course. But you can easily introduce simple production techniques to speed up the joining of several thousands of assemblies. As an example with torch brazing, many assemblies may be pre-fluxed and simultaneously heated and brazed on a conveyor which can run the assemblies past banks of heating torches. In this scenario, brazing filler metal can be applied to the joint in a premeasured amount. You may also choose to furnace braze with a continuous belt furnace or in a large chamber batch furnace. And there are endless "in-between" possibilities, a good many of which you can accomplish with relatively inexpensive production devices.

The point to keep in mind is that brazing is flexible. You can automate it on a step-by-step basis, at each step matching your automation investment to your production requirements.

Welding vs. Brazing Considerations

- Size of assembly
- Thickness of base metal sections
- Spot or line joint
- Metals being joined
- Final assembly quantity needed

When do you think brazing?

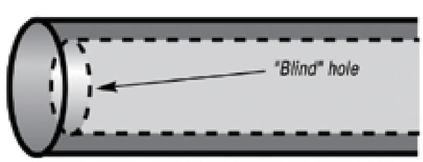
Brazing as a means to make a part.

So far, we've been talking about brazing as a way of joining two or more metals into a permanent assembly. And we've limited our discussion to the situations where you have a metal assembly in mind from the outset, from initial product concept through finished piece.

Now let's discuss brazing from a very different point of view. Think about the parts your company fabricates, and consider whether any of those parts now made as monolithic units, might not be made more efficiently as brazed assemblies.

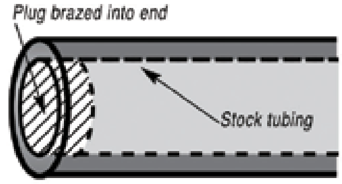
Consider this real-life story...

A company was fabricating thousands of small, closed-end metal cylinders. The part looked like this:



For years the cylinders were machined out of solid bar stock, with considerable labor required to drill and bore the blind holes. Finally, someone suggested that the cylinder was actually two parts—a tube and a plug.

Now the cylinders are made as assemblies—bar stock cut-offs brazed into lengths of stock tubing:



The assembly is a lot less expensive to make than the machined part—and it works just as well.

Think brazing at the beginning.

The time to consider brazing is at the beginning when you're first planning or designing any metal component.

Ask yourself if the part should be made as a single unit, or if it can better be made as an assembly of simple components.

The "assembly" approach may help you eliminate expensive casting, forging and machining operations.

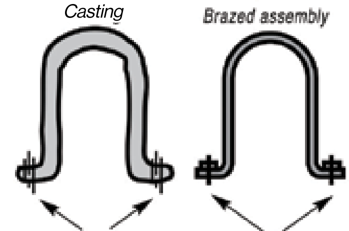
It may save materials. It may enable you to use low-cost stock forms—sheet, tube, rod, stampings, or extrusions.

It will almost invariably be lighter in weight than the monolithic part, and will probably work better as the metals in the assembly can be selected to match their functions.

Let's look at some typical metal "parts." First we'll see how they're made by conventional casting, forging and machining methods. And then we'll see how they could be made better and more economically as brazed assemblies.

From casting to sheet metal.

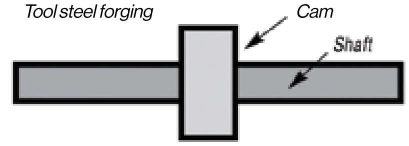
You're designing a housing, with threaded holes in the flange. You could make it as a casting. But consider instead making it as a brazed assembly, joining bar stock sections to a sheet metal deep draw:



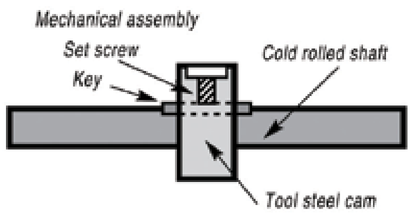
The brazed assembly works just as well as the casting. And it's a lot cheaper to make, because you're putting the thickness only where you really need it—in the flange and not the shell. You save weight, materials, and labor.

From forging to brazing.

You're planning a part—a hardened cam on a steel camshaft. Should you machine the unit out of a solid bar of tool steel?

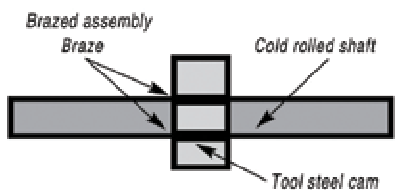


That's a lot of lathe chips. Perhaps forge the piece, and then finish-machine it?



Still a lot of work. After hardening, the cam has to be drawn and the shaft ends annealed. How about making the cam and shaft separately—and then joining them mechanically as an assembly?

You're on the right track. By substituting cold rolled for tool steel in the shaft, you're saving on material cost. But machining is still somewhat involved, and a locking device, such as a set screw, is subject to loosening under vibration.

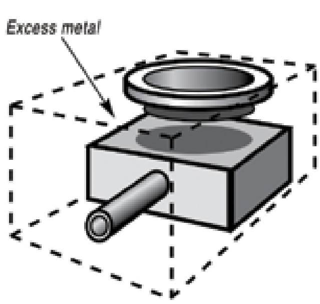


Now try the "assembly" approach again, but this time use a brazed joint instead of a mechanical one.

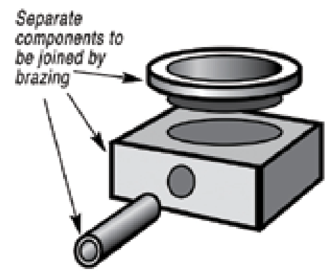
Simplest of all. No keyway, no key, no set screw. Minimum material, minimum labor—and a strong, permanent, vibration-proof bond.

The awkward elbow.

Extensions or projections on metal parts require excessive material (expensive!), and then a lot of work to machine away the unwanted metal (twice as expensive!). Consider what happens when you make an elbow-shaped part from solid stock...



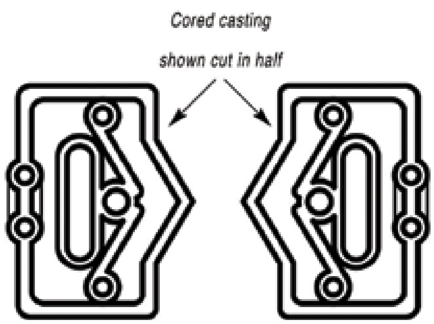
You're paying for metal you don't want, and the labor of getting rid of it. There's an easier way. Make the "part" as a brazed assembly, joining together standard tubing and bar stock components:



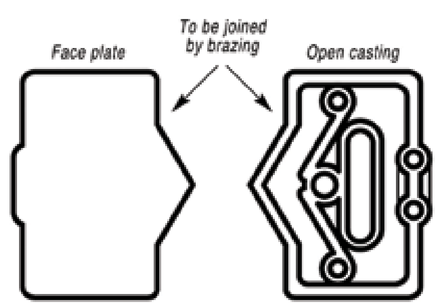
The assembly will be just as strong as the machined part. And you'll save materials, labor and weight. (The more awkward and complex the extension, the more you'll save.)

From hard to easy.

You have to design a leak-tight component with complex configuration. You can plan it as a cored casting...



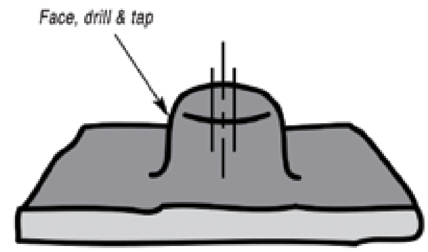
It will be leak-tight, but a cored casting is an expensive one. An open casting is a lot cheaper to make. So why not make it that way?



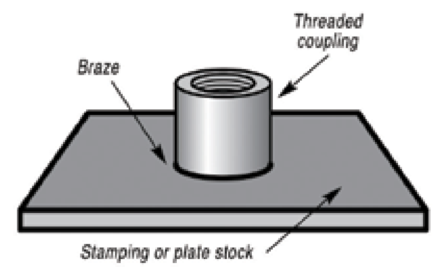
By using brazing, you've replaced the complex cored casting with a simple open casting—and a metal stamping. Machining is easier, and brazing's capillary action assures you of a leak-tight bond.

From casting to stock parts.

Let's say you're designing a base plate with a threaded coupling. You can make it in one piece as a casting...



Material cost is low, but material choice is limited. Weight is excessive, machining extensive, and the finished part may be weak and brittle.

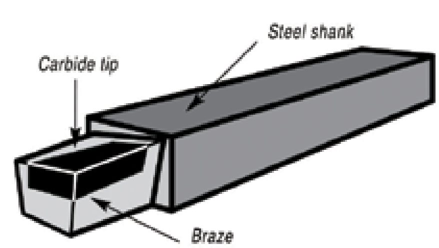


Consider making the part as a brazed assembly of stock elements. The plate is a stamping and the coupling a screw machine part. Weight is down to the bone, too, because the thickness is only where it's needed, in the threaded coupling. Material can be matched to function. And the assembly will undoubtedly be stronger than the casting.

Two metals are better than one.

The ability of brazing to join dissimilar metals is helpful in many applications, but in some instances it's quite critical. A classic example is the carbide metal-cutting tool. The tool could be made entirely of carbide. But carbide is expensive. What's more, though carbide is fine for the cutting tip, you don't really want to use it for the tool shank. It's too hard and brittle to withstand shock.

Brazing solves the problem. By brazing, you've reduced material cost—obviously. But even more—you're now using metals perfectly suited to their functions. Hard carbide at the cutting edge, and shock-resistant tool steel for the shank.



Freedom for the designer.

We started this section with a question: "When do you think brazing?" And we've indicated, through just a few of the many possible examples, that you think brazing at the beginning—at the design stage.

The fact is—brazing liberates the designer. It enables him to design for function, for light weight, for selective use of metals, and for production economy. The designer who's fully aware of the possibilities of brazing thinks less and less in terms of castings, forgings, and parts machined from solid metal. He thinks more and more in terms of brazed assemblies, which combine plate or sheet stock, standard tubing and bar, stampings, and screw machine parts.

Assemblies based on the use of such elements are generally lighter in weight, less expensive to fabricate, and at least equal in performance to metal parts made as monolithic units.

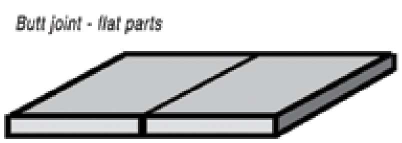
The principles of joint design.

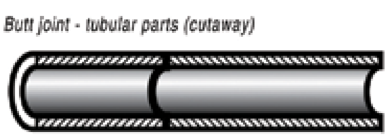
Types of brazed joints.

What type of brazed joint should you design?

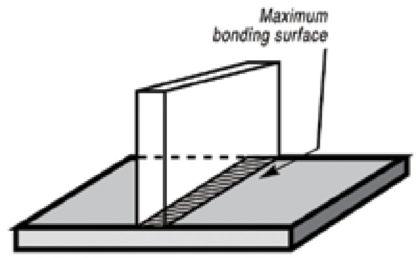
There are many kinds of joints. But our problem is simplified by the fact that there are only two basic types—the butt and the lap. The rest are essentially modifications of these two.

Let's look first at the butt joint, both for flat and tubular parts.



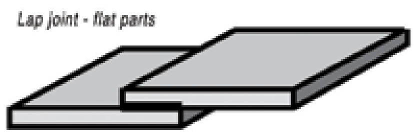


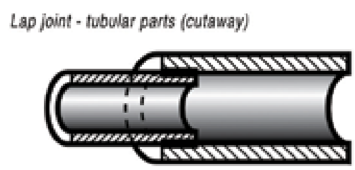
As you can see, the butt joint gives you the advantage of a single thickness at the joint. Preparation of this type of joint is usually simple, and the joint will have sufficient tensile strength for many applications. However, the strength of the butt joint does have limitations. It depends, in part, on the amount of bonding surface, and in a butt joint the bonding area can't be any larger than the cross-section of the thinner member.



Now let's compare this with the lap joint, both for flat and tubular parts.

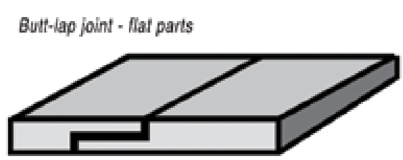
The first thing you'll notice is that, for a given thickness of base metals, the bonding area of the lap joint can be larger than that of the butt joint—and usually is. With larger bonding areas, lap joints can usually carry larger loads.

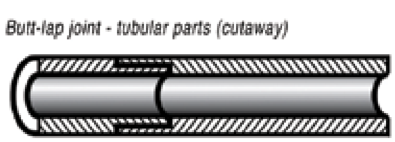




The lap joint gives you a double thickness at the joint, but in many applications (plumbing connections, for example) the double thickness is not objectionable. And the lap joint is generally self-supporting during the brazing process. Resting one flat member on the other is usually enough to maintain a uniform joint clearance. And, in tubular joints, nesting one tube inside the other holds them in proper alignment for brazing.

However—suppose you want a joint that has the advantages of both types: single thickness at the joint combined with maximum tensile strength. You can get this combination by designing the joint as a butt-lap joint.





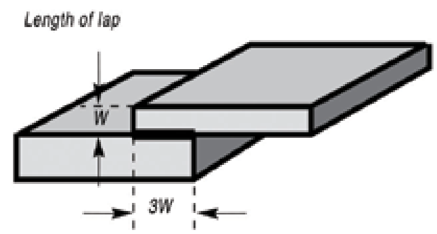
True, the butt-lap is usually a little more work to prepare than straight butt or lap, but the extra work can pay off. You wind up with a single-thickness joint of maximum strength. And the joint is usually self-supporting when assembled for brazing.

Figuring the proper length of lap.

Obviously, you don't have to calculate the bonding area of a butt joint. It will be the cross-section of the thinner member—and that's that.

Butt lap joints are often variable. Their length can be increased or decreased. How long should a lap joint be?

The rule of thumb is to design the lap joint to be three times as long as the thickness of the thinner joint member.



A longer lap may waste brazing filler metal and use more base metal material than is really needed, without a corresponding increase in joint strength. And a shorter lap will lower the strength of the joint. For most applications, you're on safe ground with the "rule of three."

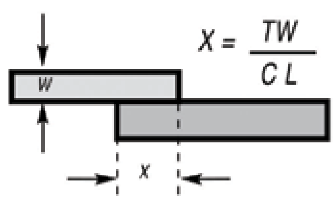
More specifically, if you know the approximate tensile strengths of the base members, the lap length required for optimum joint strength in a silver brazed joint is as follows:

If you have a great many identical assemblies to braze, or if the joint strength is critical, it will help to figure the length of lap more exactly, to gain maximum strength with minimum use of brazing materials. The formulas given below will help you calculate the optimum lap length for flat and for tubular joints.

Tensile Strength of Weakest Member		Lap length = factor x W (W = thickness of weakest member)
35,000 psi	241.3 MPa	2 x W
60,000 psi	413.7 MPa	3 x W
100,000 psi	689.5 MPa	5 x W
130,000 psi	896.3 MPa	6 x W
175,000 psi	1,206.6 MPa	8 x W

NOTE: psi x 6.8948 = 1 MPa

Figuring length of lap for flat joints.



X = Length of lap
T = Tensile strength of weakest member
W = Thickness of weakest member
C = Joint integrity factor of .8
L = Shear strength of brazed filler metal

Let's see how this formula works, using an example.

Problem: What length of lap do you need to join .050" annealed Monel sheet to a metal of equal or greater strength?

Solution:
C = .8
T = 70,000 psi (annealed Monel sheet)
W = .050"
L = 25,000 psi (Typical shear strength for silver brazing filler metals)

$$X = \frac{70{,}000 \times .050}{.8 \times 25{,}000}$$

X = 18" lap length

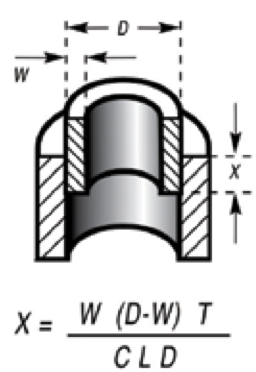
Problem in Metric: What length of lap do you need to join 1.27 mm annealed Monel sheet to a metal of equal or greater strength?

Solution:
C = .8
T = 482.63 MPa (annealed Monel sheet)
W = 1.27 mm
L = 172.37 MPa (Typical shear strength for silver brazing filler metals)

$$X = \frac{482.63 \times 1.27}{.8 \times 172.37}$$

X= 4.5 mm (length of lap)

Figuring length of lap for tubular joints.



X = Length of lap area
W = Wall thickness of weakest member
D = Diameter of lap area
T = Tensile strength of weakest member
C = Joint integrity factor of .8
L = Shear strength of brazed filler metal

Again, an example will serve to illustrate the use of this formula.

Problem: What length of lap do you need to join 3/4" O.D. copper tubing (wall thickness .064") to 3/4" I.D. steel tubing?

Solution:
W = .064"
D = .750"
C = .8
T = 33,000 psi (annealed copper)
L = 25,000 psi (a typical value)

$$X = \frac{.064 \times (.75 - .064) \times 33{,}000}{.8 \times .75 \times 25{,}000}$$

X = .097" (length of lap)

Problem in Metric: What length of lap do you need to join 19.05 mm O.D. copper tubing (wall thickness 1.626 mm) to 19.05 mm I.D. steel tubing?

Solution:
W = 1.626 mm
D = 19.05 mm
C = .8
T = 227.53 MPa (annealed copper)
L = 172.37 MPa (a typical value)

$$X = \frac{1.626 \times (19.05 - 1.626) \times 227.53}{.8 \times 19.05 \times 172.37}$$

X = 2.45 mm (length of lap)

Designing to distribute stress.

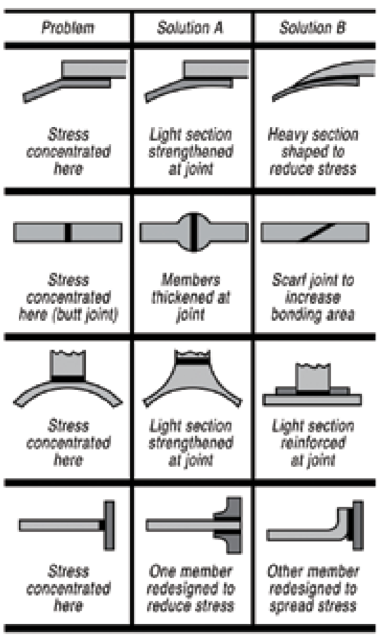
When you design a brazed joint, obviously you aim to provide at least minimum adequate strength for the given application. But in some joints, maximum mechanical strength may be your overriding concern.

You can help insure this degree of strength by designing the joint to prevent concentration of stress from weakening the joint.

Motto—spread the stress. Figure out where the greatest stress falls. Then impart flexibility to the heavier member at this point, or add strength to the weaker member.

The illustrations below suggest a number of ways to spread the stress in a brazed joint.

Designing to distribute stress

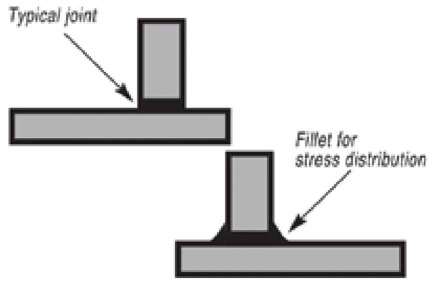


To sum it up—when you're designing a joint for maximum strength, use a lap or scarf design (to increase joint area) rather than a butt, and design the parts to prevent stress from being concentrated at a single point.

There is one other technique for increasing the strength of a brazed joint, frequently effective in brazing small-part assemblies. You can create a stress-distribution fillet, simply by using a little more brazing filler metal than you normally would, or by using a more "sluggish" alloy.

Usually you don't want or need a fillet in a brazed joint, as it doesn't add materially to joint strength. But where it contributes to spreading joint stresses, it pays to create using a little more brazing filler metal than you normally would, or by using a more "sluggish" alloy.

Usually you don't want or need a fillet in a brazed joint, as it doesn't add materially to joint strength. But where it contributes to spreading joint stresses, it pays to create the fillet.



Designing for service conditions.

In many brazed joints, the chief requirement is strength. And we've discussed various ways of achieving joint strength. But there are frequently other service requirements which may influence the joint design or filler metal selection.

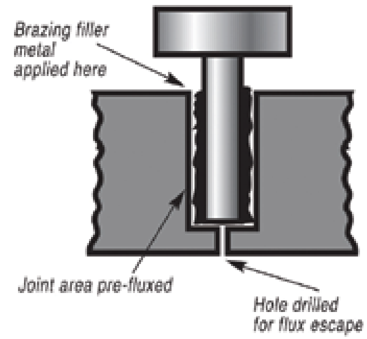
For example, you may be designing a brazed assembly that needs to be electrically conductive. A silver brazing filler metal, by virtue of its silver content, has very little tendency to increase electrical resistance across a properly brazed joint. But you can further insure minimum resistance by using a close joint clearance, to keep the layer of filler metal as thin as possible. In addition, if strength is not a prime consideration, you can reduce length of lap. Instead of the customary "rule of three," you can reduce lap length to about 1-1/2 times the cross-section of the thinner member.

If the brazed assembly has to be pressure-tight against gas or liquid, a lap joint is almost a must, since it withstands greater pressure than a butt joint. And its broader bonding area reduces any chance of leakage.

Another consideration in designing a joint to be leak proof is to vent the assembly. Providing a vent during the brazing process allows expanding air or gases to escape as the molten filler metal flows into the joint. Venting the assembly also prevents entrapment of flux in the joint. Avoiding entrapped gases or flux reduce the potential for leak paths.

If possible, the assembly should be self-venting. Since flux is designed to be displaced by molten filler metal entering a joint, there should be no sharp corners or blind holes to cause flux entrapment. The joint should be designed so that the flux is pushed completely out of the joint by the filler metal. Where this is not possible, small holes may be drilled into the blind spots to allow flux escape. The joint is completed when molten filler metal appears at the outside surface of these drilled holes.

To maximize corrosion-resistance of a joint, select a high purity brazing filler metal. These filler metals contain filler elements such as silver, gold or palladium, which are inherently corrosion-resistant.



Keep joint clearances tight and use a minimum amount of filler metal, so that the finished joint will expose only a fine line of brazing filler metal to the atmosphere.

These are a few examples of service requirements that may be demanded of your brazed assembly. As you can see both the joint design and filler metal selection must be considered.

Fortunately, there are many filler metals and fluxes available to you—in a wide range of compositions, properties, and melting temperatures. The selector charts that appear later in this book can help you choose filler metals and fluxes that best meet the service requirements of the joints you design.

The Technical Services Department at Lucas Milhaupt is available to help answer any questions you may have with regard to your specific brazing application, joint design, and/or filler metal selection.

The importance of correct procedures.

We've said that a brazed joint "makes itself"—or that capillary action, more than operator skill, insures the distribution of the filler metal into the joint. The real skill lies in the design and engineering of the joint. But even a properly-designed joint can turn out imperfectly if correct brazing procedures are not followed.

These procedures boil down to six basic steps. They are generally simple to perform (some may take only a few seconds), but none of them should be omitted from your brazing operation if you want to end up with sound, strong, neat-appearing joints.

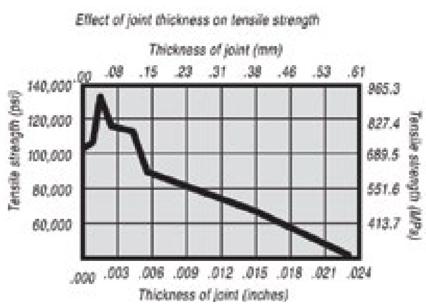
For the sake of simplicity, we'll discuss these six steps mainly in terms of "manual brazing," that is, brazing with hand-held torch and hand-fed filler metal. But everything said about manual brazing applies as well to mass production brazing. The same steps must be taken, although they may be performed in a different manner.

The six basic steps in brazing.

Step 1: Good fit and proper clearances.

Brazing, as we've seen, uses the principle of capillary action to distribute the molten filler metal between the surfaces of the base metals. Therefore, during the brazing operation, you should take care to maintain a proper clearance between the base metals to allow capillary action to work most effectively. This means, in almost all cases—a close clearance.

The following chart is based on open air brazing butt joints of stainless steel, using EASY-FLO® filler metal. It shows how the tensile strength of the brazed joint varies with the amount of clearance between the parts being joined.



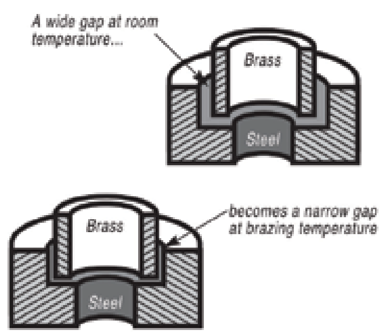
Note that the strongest joint (135,000 psi/930.8 MPa) is achieved when the joint clearance is .0015" (.038mm.) When the clearance is narrower than this, it's harder for the filler metal to distribute itself adequately throughout the entire joint—and joint strength is reduced. Conversely, if the gap is wider than necessary, the strength of the joint will be reduced almost to that of the filler metal itself. Also, capillary action is reduced, so the filler metal may fail to fill the joint completely—again lowering joint strength.

So, the ideal clearance for a brazed joint, in the example above, is in the neighborhood of .0015" (.038mm). However, in ordinary day-to-day brazing, you don't have to be this precise to get a sufficiently strong joint. Capillary action operates over a range of clearances, so you get a certain amount of leeway. When looking at the chart again, note that clearances ranging from .001" to .005" (.025 mm to .127 mm) still produce joints of 100,000 psi (689.5 MPa) tensile strength.

The general rule of thumb when thinking about joint fit up is to maintain a clearance of 0.015"-0.005" when open air brazing and 0.000"-0.002" when brazing in a controlled atmosphere or vacuum environment.

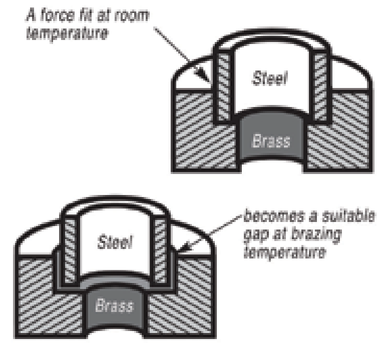
Translated into everyday shop practice, an easy slip fit will give you a perfectly adequate brazed joint between two tubular parts. And if you're joining two flat parts, you can simply rest one on top of the other. The metal-to-metal contact is all the clearance you'll usually need, since the average "mill finish" of metals provides enough surface roughness to create capillary "paths" for the flow of molten filler metal. (Highly polished surfaces, on the other hand, tend to restrict filler metal flow.)

However, there's a special factor you should consider carefully in planning your joint clearances. Brazed joints are made at brazing temperatures, not at room temperature. So you must take into account the "coefficient of thermal expansion" of the metals being joined. This is particularly true for tubular assemblies in which dissimilar metals are joined.



As an example, let's say you're brazing a brass bushing into a steel sleeve. Brass expands, when heated, more than steel. So if you machine the parts to have a room temperature clearance of .002"-.003" (.051 mm-.076 mm), by the time you've heated the parts to brazing temperatures the gap may have closed completely! The answer? Allow a greater initial clearance, so that the gap at brazing temperature will be about .002"-.003" (.051 mm-.076 mm).

Of course, the same principle holds in reverse. If the outer part is brass and the inner part steel, you can start with virtually a light force fit at room temperature. By the time you reach brazing temperature, the more rapid expansion of the brass creates a suitable clearance.



How much allowance should you make for expansion and contraction? It depends on the nature and sizes of the metals being joined and the configuration of the joint itself. Although there are many variables involved in pinpointing exact clearance tolerances for each situation, keep in mind the principle involved—different metals expand at different rates when heated and shrink at different rates when cooled. To help you in planning proper clearances in brazing dissimilar metals, the chart on the opposite page furnishes the coefficient of thermal expansion for a variety of metals and alloys.

Step 2: Cleaning the metals.

Capillary action will work properly only when the surfaces of the metals are clean. If they are "contaminated"—coated with oil, grease, rust, scale, or just plain dirt—those contaminants have to be removed. If they remain, they will form a barrier between the base metal surfaces and the brazing materials. An oily base metal, for example, will repel the flux, leaving bare spots that oxidize under heat and result in voids. Oil and grease will carbonize when heated, forming a film over which the filler metal will not flow. And brazing filler metal won't bond to a rusty surface.

Cleaning the metal parts is seldom a complicated job, but it has to be done in the right sequence. Oil and grease should be removed first, because an acid pickle solution aimed to remove rust and scale won't work on a greasy surface. (If you try to remove rust or scale by abrasive cleaning, before getting rid of the oil, you'll wind up scrubbing the oil, as well as fine abrasive powder, more deeply into the surface.)

Start by getting rid of oil and grease. In most cases you can do it very easily either by dipping the parts into a suitable degreasing solvent, by vapor degreasing, or by alkaline or aqueous cleaning.

If the metal surfaces are coated with oxide or scale, you can remove those contaminants chemically or mechanically. For chemical removal, use an acid pickle treatment, making sure that the chemicals are compatible with the base metals being cleaned, and that no acid traces remain

Comparisons of Materials: Coefficient of Thermal Expansion[a]

Material	10^{-6} in./in.*/°F		10^{-6} in./in.*/°C		Material	10^{-6} in./in.*/°F		10^{-6} in./in.*/°C	
	High	Low	High	Low		High	Low	High	Low
Zinc & its Alloys[c]	19.3	10.8	3.5	1.9	Nitriding Steels[d]	6.5	-	1.2	-
Lead & its Alloys[c]	16.3	14.4	2.9	2.6	Palladium[c]	6.5	-	1.2	-
Magnesium Alloys[b]	16.0	14.0	2.8	2.5	Beryllium[b]	6.4	-	1.1	-
Aluminum & its Alloys[c]	13.7	11.7	2.5	2.1	Chromium Carbide Cermet[c]	6.3	5.8	1.1	1.0
Tin & its Alloys[c]	13.0	-	2.3	-	Thorium[b]	6.2	-	1.1	-
Tin & Aluminum Brasses[c]	11.8	10.3	2.1	1.8	Ferritic Stainless Steels[c]	6.0	5.8	1.1	1.0
Plain & Leaded Brasses[c]	11.6	10.0	2.1	1.8	Gray Irons (cast)[c]	6.0	-	1.1	-
Silver[c]	10.9	-	2.0	-	Beryllium Carbide[d]	5.8	-	1.0	-
Cr-Ni-Fe Superalloys[d]	10.5	9.2	1.9	1.7	Low Expansion Nickel Alloys[c]	5.5	1.5	1.0	0.3
Heat Resistant Alloys (cast)[d]	10.5	6.4	1.9	1.1	Beryllia & Thoria[e]	5.3	-	0.9	-
Nodular or Ductile Irons (cast)[d]	10.4	6.6	1.9	1.2	Alumina Cermets[d]	5.2	4.7	0.9	0.8
Stainless Steels (cast)[d]	10.4	6.4	1.9	1.1	Molybdenum Disilicide[c]	5.1	-	0.9	-
Tin Bronzes (cast)[c]	10.3	10.0	1.8	1.8	Ruthenium[b]	5.1	-	0.9	-
Austenitic Stainless Steels[c]	10.2	9.0	1.8	1.6	Platinum[c]	4.9	-	0.9	-
Phosphor Silicon Bronzes[c]	10.2	9.6	1.8	1.7	Vanadium[b]	4.8	-	0.9	-
Coppers[c]	9.8	-	1.8	-	Rhodium[b]	4.6	-	0.8	-
Nickel-Base Superalloys[d]	9.8	7.7	1.8	1.4	Tantalum Carbide[d]	4.6	-	0.8	-
Aluminum Bronzes (cast)[c]	9.5	9.0	1.7	1.6	Boron Nitride[d]	4.3	-	0.8	-
Cobalt-Base Superalloys[d]	9.4	6.8	1.7	1.2	Columbium & its Alloys	4.1	3.8	0.7	0.68
Beryllium Copper[c]	9.3	-	1.7	-	Titanium Carbide[d]	4.1	-	0.7	-
Cupro-Nickels & Nickel Silvers[c]	9.5	9.0	1.7	1.6	Steatite[c]	4.0	3.3	0.7	0.6
Nickel & its Alloys[d]	9.2	6.8	1.7	1.2	Tungsten Carbide Cermet[c]	3.9	2.5	0.7	0.4
Cr-Ni-Co-Fe Superalloys[d]	9.1	8.0	1.6	1.4	Iridium[b]	3.8	-	0.7	-
Alloy Steels[d]	8.6	6.3	1.5	1.1	Alumina Ceramics[c]	3.7	3.1	0.7	0.6
Alloy Steels (cast)[d]	8.3	8.0	1.5	1.4	Zirconium Carbide[d]	3.7	-	0.7	-
Carbon Free-Cutting Steels[d]	8.4	8.1	1.5	1.3	Osmium & Tantalum[b]	3.6	-	0.6	-
Age Hardenable Stainless Steels[c]	8.2	5.5	1.5	1.0	Zirconium & its Alloys[b]	3.6	3.1	0.6	0.55
Gold[c]	7.9	-	1.4	-	Hafnium[b]	3.4	-	0.6	-
High Temperature Steels[d]	7.9	6.3	1.4	1.1	Zirconia[e]	3.1	-	0.6	-
Ultra High Strength Steels[d]	7.6	5.7	1.4	1.0	Molybdenum & its Alloys	3.1	2.7	0.6	0.5
Malleable Irons[c]	7.5	5.9	1.3	1.1	Silicon Carbide[e]	2.4	2.2	0.4	.039
Titanium Carbide Cermet[d]	7.5	4.3	1.3	0.8	Tungsten[b]	2.2	-	0.4	-
Wrought Irons[c]	7.4	-	1.3	-	Electrical Ceramics[c]	2.0	-	0.4	-
Titanium & its Alloys[d]	7.1	4.9	1.3	0.9	Zircon[c]	1.8	1.3	0.3	0.2
Cobalt[d]	6.8	-	1.2	-	Boron Carbide[e]	1.7	-	0.3	-
Martensitic Stainless Steels[c]	6.5	5.5	1.2	1.0	Carbon & Graphite[c]	1.5	1.3	0.3	0.2

* or mm / mm

[a] Values represent high and low sides of a range of typical values.

[b] Value at room temperature only.

[c] Value for a temperature range between room temperature and 212-750° F/100-390° C.

[d] Value for a temperature range between room temperature and 1000-1800° F/540-980° C.

[e] Value for a temperature range between room temperature and 2200-2875° F/1205-1580° C.

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in crevices or blind holes. Mechanical removal calls for abrasive cleaning. Particularly in repair brazing, where parts may be very dirty or heavily rusted, you can speed the cleaning process by using emery cloth, grinding wheel, or file or grit blast, followed by a rinsing operation.

Once the parts are thoroughly clean, it's a good idea to flux and braze as soon as possible. That way, there's the least chance for recontamination of surfaces by factory dust or body oils deposited through handling.

It's important to note that flux is only intended to remove oxides and should not be used as a substitute for precleaning. Additionally, while precleaning is an essential step of the brazing process in any case, it is especially important for furnace brazing, as there will likely be no flux to support removal of contaminations.

Step 3: Flux & atmospheres.

Flux is a chemical compound applied to the joint surfaces before brazing. Its use is essential in most open air brazing processes (with a few exceptions noted later.) The reason? Heating a metal surface accelerates the formation of oxides, the result of chemical reaction between the hot metal and oxygen in the air. These oxides must be prevented from forming or they'll inhibit the brazing filler metal from wetting and bonding to the surfaces. A coating of flux on the joint area, however, will shield the surfaces from the air, preventing oxide formation. And the flux will also dissolve and absorb any oxides that form during heating or that were not completely removed in the cleaning process.

How do you apply the flux to the joint? Any way you can, as long as you cover the surfaces completely. Since flux is conventionally made in a paste consistency, it's usually most convenient to brush it on. But as production quantities increase, it may be more efficient to apply the flux by dipping—or dispensing a pre-measured deposit of high viscosity dispensable flux from an applicator gun.

Why dispensable flux? Many companies find the repeatable deposit size improves joint consistency, and because typically less flux is used, the amount of residue entering the waste stream is also reduced.

When do you flux? Typically just before brazing, if possible. That way the flux has least chance to dry out and flake off, or get knocked off the parts in handling.

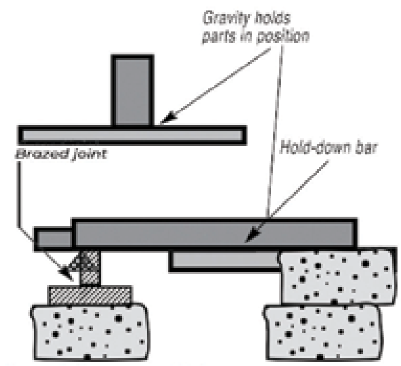
Which flux do you use? Choose the one formulated for the specific metals, temperatures and conditions of your brazing application. There are fluxes formulated for practically every need; for example—fluxes for brazing at very high temperatures (in the 2000°F/1093°C area), fluxes for metals with refractory oxides, fluxes for long heating cycles, and fluxes for dispensing by automated machines. Fortunately, your inventory problem is considerably simplified by the availability of general-purpose fluxes, such as Lucas Milhaupt's HANDY® Flux, which is suitable for most typical brazing jobs. (See page 54 for a chart of Lucas Milhaupt fluxes.) Our technical representatives can answer any questions you may have and assist you in your choice.

How much flux do you use? Enough to last throughout the entire heating cycle. Keep in mind that the larger and heavier the pieces brazed, the longer the heating cycle will take—so use more flux. (Lighter pieces, of course, heat up faster and so require less flux.)

As a general rule, don't skimp on the flux. It's your insurance against oxidation. Think of the flux as a sort of blotter. It absorbs oxides like a sponge absorbs water. An insufficient amount of flux will quickly become saturated and lose its effectiveness. A flux that absorbs less oxides not only insures a better joint than a totally saturated flux, but it is a lot easier to wash off after the brazed joint is completed.

Flux can also act as a temperature indicator, minimizing the chance of overheating the parts. Lucas Milhaupt's HANDY Flux, for example, becomes completely clear and active at 1100°F/593°C. At this temperature, it looks like water and reveals the bright metal surface underneath—telling you that the base metal is just about hot enough to melt the brazing filler metal.

We've said that fluxing is an essential step in the brazing operation. This is generally true, yet there are a few exceptions to the rule. You can join copper to copper without flux, by using a brazing filler metal specially formulated for the job, such as Lucas Milhaupt's SIL-FOS® or FOS-FLO®. (The phosphorus in these alloys acts as a fluxing agent on copper.)

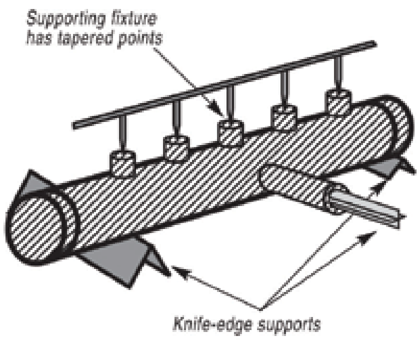


And you can often omit fluxing if you're going to braze the assembly in a controlled atmosphere. Generally, furnace brazing eliminates the need for flux in the brazing operation. Flux should never be used in a vacuum brazing application as it will become vaporized in the furnace and damage it over time.

HANDY® Flux as a temperature indicator.

Temperature	Appearance of Flux	Visual Example
212°F (100°C) A	Water boils off.	
600°F (315°C) B	Flux becomes white and slightly puffy, and starts to "work".	
800°F (425°C) C	Flux lies against surface and has a milky appearance.	
1100°F (593°C) D	Flux is completely clear and active, looks like water. Bright metal surface is visible underneath. At this point, test the temperature by touching brazing filler metal to base metal. If brazing filler metal melts, assembly is at proper temperature for brazing.	

In Controlled Atmosphere Brazing (CAB) with aluminum, a non-corrosive flux is often used to reduce oxides on the aluminum base metal surface, allowing the filler metal to flow more effectively. If the CAB furnace provides a sufficient environment for the brazing operation, flux should not be utilized, as it will damage the furnace over time. Sometimes if the controlled atmosphere doesn't have a sufficient dew point, you may find that a small amount of flux may improve the flow of the filler metal during brazing.



The atmosphere used within the furnace is carefully controlled primarily to prevent oxidation. There are two types of furnace atmospheres.

Controlled Atmospheres utilize inert gases such as nitrogen, argon, or helium to remove oxygen and protect the metal surfaces during the brazing process. Hydrogen can also be used to actively reduce the metallic oxides off the surface of the metal.

In a Vacuum Atmosphere the furnace chamber is evacuated of all residual gases, creating a vacuum that prevents oxidation and allows for the brazing of even the most highly reactive metals.

Step 4: Assembly for brazing.

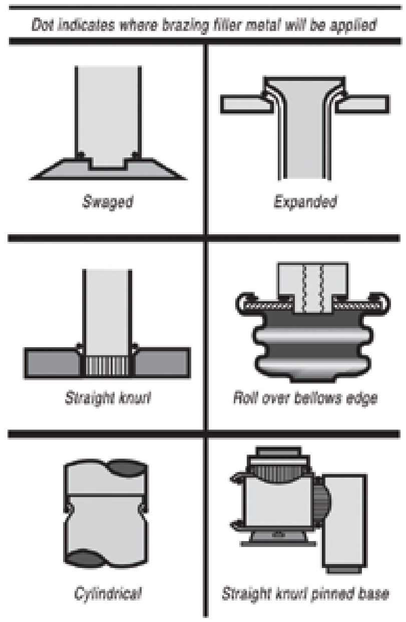
The parts of the assembly are cleaned and ready for brazing. Now you have to hold them in position for brazing. And you want to be sure they remain in correct alignment during the heating and cooling cycles, so that capillary action can do its job.

If the shape and weight of the parts permit, the simplest way to hold them together is by gravity, also referred to as self-fixturing.

Or you can give gravity a helping hand by adding additional weight.

If you have a number of assemblies to braze and their configuration is too complex for self-support or clamping, it may be a good idea to use a brazing support fixture.

In planning such a fixture, design it for the least possible mass, and the least contact with the parts of the assembly. (A cumbersome fixture that contacts the assembly broadly will conduct heat away from the joint area.) Use pin-point and knifeline-edge design to reduce contact to a minimum.



Try to use materials in your fixture that are poor heat conductors, such as stainless steel, Inconel, or ceramics. Since these are poor conductors, they draw the least heat away from the joint. Choose materials with compatible expansion rates so you won't get alterations in assembly alignment during the heating cycle.

However, if you're planning to braze hundreds of identical assemblies, then you should think in terms of designing the parts themselves for self-support during the brazing process.

At the initial planning stage, design mechanical devices that will accomplish this purpose, and that can be incorporated in the fabricating operation. Typical devices include crimping, interlocking seams, swaging, peening, riveting, pinning, dimpling, or knurling.

Sharp corners should be minimized in these mechanically held assemblies, as such corners can impede capillary action. Corners should be slightly rounded to aid the flow of filler metal.

The simplest mechanical holding device is the best, since its only function is to hold the parts together while the permanent joint is made by brazing.

When designing a fixture to be used in a furnace, it's important to avoid the use of any components that may become compromised at elevated temperatures, such as springs.

Step 5: Brazing the assembly.

The fifth step is heating to braze the joint. It involves heating the assembly to brazing temperature, and flowing the filler metal through the joint.

First, the heating process. As previously discussed, you apply heat broadly to the base metals. When brazing with a hand held torch, a variety of fuels are available such as natural gas, acetylene, propane, propylene, etc., combusted with either oxygen or air. (Most popular is still the oxy/acetylene mixture.)

All you have to keep in mind is that both metals in the assembly should be heated as uniformly as possible so they reach brazing temperature at the same time. When joining a heavy section to a thin

Advantages of furnace brazing.

Uniform Heating: The controlled and uniform heating provided by the furnace prevents localized overheating, which can distort or damage the base materials and weaken the joints. This is particularly beneficial when brazing complex assemblies with multiple joints.

Minimized Base Metal Damage: The slow and even heating provided by the furnace minimizes the risk of damaging the base materials. This is crucial for applications where maintaining the integrity of the base materials is essential.

Improved Joint Quality: The controlled atmosphere or vacuum environment prevents oxidation, resulting in cleaner and stronger joints. The absence of flux further reduces joint porosity and allows the clearance to be tighter, which improves the overall quality and strength of the joints.

Efficiency in Mass Production: Furnace brazing is highly efficient for mass production, as high-volume quantities can be brazed simultaneously. The controlled operation of the furnace allows for consistent and repeatable results, reducing variation and ensuring high-quality joints across all parts.

Enhanced Aesthetics: The environments in CAB reduces the amount of flux required, which may reduce or eliminate flux residue and voids in the joints. This not only improves the joint strength but also enhances the aesthetic appearance of the brazed assemblies.

section, the "splash-off" of the flame may be sufficient to heat the thin part. Keep the torch moving at all times and do not heat the braze area directly. When joining heavy sections, the flux may become transparent—which is at 1100°F (593°C)—before the full assembly is hot enough to receive the filler metal.

Some metals are good conductors—and consequently carry off heat faster into cooler areas. Others are poor conductors and tend to retain heat and overheat readily. The good conductors will need more heat than the poor conductors, simply because they dissipate the heat more rapidly.

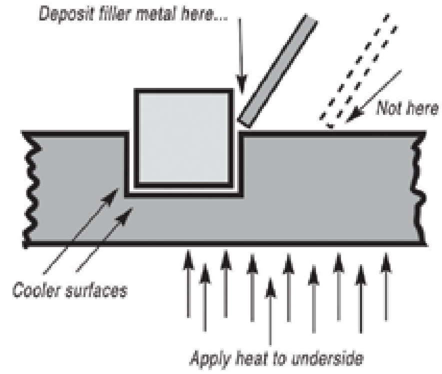
In all cases, your best insurance against uneven heating is to keep a watchful eye on the flux. If the flux changes in appearance uniformly, the parts are being heated evenly, regardless of the difference in their mass or conductivity.

You've heated the assembly to brazing temperature. Now you are ready to deposit the filler metal.

In manual brazing, all this involves is carefully holding the rod or wire against the joint area. The heated assembly will melt off a portion of the filler metal, which will instantly be drawn by capillary action throughout the entire joint area.

You may want to add some flux to the end of the filler metal rod—about 2" to 3" (51 mm to 76 mm)— to improve the flow. This can be accomplished by either brushing on or dipping the rod in flux. On larger parts requiring longer heating time, or where the flux has become saturated with much oxide, the addition of fresh flux on the filler metal will improve the flow and penetration of the filler metal into the joint area.

However, there is one small precaution to observe. Molten brazing filler metal tends to flow toward areas of higher temperature. In the heated assembly, the outer base metal surfaces may be slightly hotter than the interior joint surfaces. So, take care to deposit the filler metal immediately adjacent to the joint. If you deposit it away from the joint, it tends to plate over the hot surfaces rather than flow into the joint. In addition, it's best to heat the side of the assembly opposite the point where you're going to feed the filler metal. In the example above, you heat the underside of the larger plate, so that the heat draws the filler metal down fully into the joint. (Always remember—the filler metal tends to flow toward the source of heat.)



And if you're using preforms—slugs, washers, shims, or special shapes of filler metal—preplace them at the joint area *before* you heat the assembly.

With furnace brazing, the actual brazing step requires a bit more preparation. A furnace profile will need to be created and programmed. The filler metal will always be preplaced on the assembly as either a preform or paste. Once in the furnace, the alloy will melt and capillary as discussed previously, the primary difference being the use of a controlled atmosphere or vacuum instead of flux.

Step 6: Cleaning the brazed joint.

When it comes to furnace brazing, minimal post-braze cleaning is needed, as there is no flux used. As long as the parts were precleaned well and the atmosphere was sufficient, there will be little to no residue to remove post-braze.

With open air brazing, post-cleaning is always a requirement. And cleaning is usually a two-step operation. First—removal of the flux residues. Second—pickling to remove any oxide scale formed during the brazing process.

Flux removal is a simple, but essential operation. (Flux residues are chemically corrosive and, if not removed, could weaken certain joints.) Since most brazing fluxes are water soluble, the easiest way to remove them is to quench the assembly in hot water (120°F/50°C or hotter). Best bet is to immerse them while they're still hot, just making sure that the filler metal has solidified completely before quenching. The glass-like flux residues will usually crack and flake off. If they're a little stubborn, brush them lightly with a wire brush while the assembly is still in the hot water.

When quenching, use caution to ensure that the base materials of that assembly have similar expansion rates. When an assembly composed of multiple components with different rates of thermal expansion is submerged in water while still hot, one material will shrink more rapidly than the other, causing enough internal stress to compromise the braze joint. In situations where the base materials have different CTE values, slow cooling is advised.

You can use more elaborate methods of removing flux as well—an ultrasonic cleaning tank to speed the action of the hot water, or live steam.

The only time you run into trouble removing flux is when you haven't used enough of it to begin with, or you've overheated the parts during the brazing process. Then the flux becomes totally saturated with oxides, usually turning green or black. In this case, the flux has to be removed by a mild acid solution. A 25% hydrochloric acid bath (heated to 140-160°F/60-70°C) will usually dissolve the most stubborn flux residues. Simply agitate the brazed assembly in this solution for 30 seconds to 2 minutes. No need to brush. A word of caution, however—acid solutions are potent, so when quenching hot brazed assemblies in an acid bath, be sure to wear a face shield and gloves.

After you've gotten rid of the flux, use a pickling solution to remove any oxides that remain on areas that were unprotected by flux during the brazing process. The best pickle to use is generally the one recommended by the manufacturer of the brazing materials you're using.

Highly oxidizing pickling solutions, such as bright dips containing nitric acid, should be avoided if possible, as they attack the silver filler metal. If you do find it necessary to use them, keep the pickling time very short.

Once the flux and oxides are removed from the brazed assembly, further finishing operations are seldom needed. The assembly is ready for use, or for the application of an electroplated finish. In the few instances where you need an ultra-clean finish, you can get it by polishing the assembly with a fine emery cloth. If the assemblies are going to be stored for use at a later time, give them a light rust-resistant protective coating by adding a water soluble oil to the final rinse water.

Basic steps in brazing:

1. Ensure fit & clearance
2. Clean metal surfaces
3. Flux prior to brazing
4. Fixturing of parts
5. Brazing the assembly
6. Cleaning the new joint

Hidden treasure in your scrap.

There's one last thing you should take into account, as part of your cleaning and finishing operations—the possible salvage value of your brazing scrap.

Brazing filler metals may contain silver, often in fairly high proportions. So does the filler metal scrap. And that silver is reclaimable at a good price.

It's hard to believe that the amount of scrap you generate in your brazing operation is large enough to warrant salvaging. But consider this true story...

A Lucas Milhaupt brazing representative, inquiring about scrap salvage, was told by a plant superintendent, "We don't have any brazing scrap. We tack the rod stubs and coil ends together and use them up."

The representative, however, noticed some brazing filler metal drippings hanging from the fixtures of a conveyorized brazing operation. He took a couple of samples for lab analysis. Some weeks later he presented the superintendent with a bright disc of pure silver. The silver had been refined from those few "worthless" drippings.

From then on, those conveyor fixtures were cleaned regularly—and every bit of scrap accumulated for its silver value.

Conveyor fixture drippings are just one source of reclaimable silver. There are others. For example, suppose you're hand-cutting brazing filler metal strip to make custom-shaped shims for brazing carbide tool tips. The leftover scrap has just as high a silver content as the brazing shim itself.

Depending on the nature of your brazing operations, there's always the possibility that you're generating enough scrap to make accumulation of it over a period of time very worthwhile.

The fact is—the refining of brazing filler metal scrap can often substantially reduce the cost of brazing operations. Your Lucas Milhaupt representative can help you spot the "hidden treasure" in your operation and implement the best salvage procedures.

Balancing the picture.

We've discussed the six basic steps required in correct brazing procedures. And we've gone into a fair amount of detail in order to be as informative as possible.

To get a more balanced picture of the overall brazing process, it's important to note that in most day-to-day brazing work, these steps are accomplished very rapidly.

Take the cleaning process, for example.

Newly-fabricated metal parts may need no cleaning at all. When they do, a quick dip, dozens at a time, in a degreasing solution does the job.

Fluxing is usually no more than a fast dab of a brush or dipping ends of the parts in flux.

Heating can often be accomplished in seconds with an oxy-acetylene torch. And flowing the filler metal is virtually instantaneous, thanks to capillary action.

Finally, flux removal is generally no more than a hot water rinse, and oxide removal needs only a dip into an acid bath.

There are exceptions to the rule, of course, but in most cases a brazed joint is made fast—considerably faster than a linear welded joint. And, as we'll see later on, these economies in time and labor are multiplied many times over in high production automated brazing.

The pure speed of brazing represents one of its most significant advantages as a metal joining process.

Safety in brazing.

In brazing, there is always the possibility of dangerous fumes and gases rising from base metal coatings, zinc and cadmium-bearing filler metals, and from fluorides in fluxes. The following well-tested precautions should be followed to guard against any hazard from these fumes.

1. **Ventilate confined areas.** Use ventilating fans and exhaust hoods to carry all fumes and gases away from work, and air supplied respirators as required.
2. **Clean base metals thoroughly.** A surface contaminant of unknown composition on base metals may add to fume hazard and may cause a too-rapid breakdown of flux, leading to overheating and fuming.
3. **Use sufficient flux.** Flux protects base metals and filler metal during the heating cycle. Full flux coverage reduces fuming. Also, consult your Safety Data Sheet (SDS) regarding specific hazards associated with brazing flux.
4. **Heat metals broadly.** Heat the base metals broadly and uniformly. Intense localized heating uses up flux, increasing danger of fuming. Apply heat only to base metals, not to filler metal. (Direct flame on filler metal causes overheating and fuming.)
5. **Know your base metals.** A cadmium coating on a base metal will volatilize and produce toxic fumes during heating. Zinc coatings (galvanized) will also fume when heated. Learn to recognize these coatings. It is recommended that they be removed before parts are heated for brazing.
6. **Know your filler metals.** Be especially careful not to overheat assembly when using filler metals that contain cadmium. *Consult alloy Safety Data Sheet for maximum recommended brazing temperatures for your selected filler metals.* The filler metal carries a warning label. Be sure to look for it and follow the instructions carefully.

For other safety considerations, see the American National Standard Z49.1, "Safety in Welding and Cutting", published by the American Welding Society (AWS),d 8669 NW 36th St., Doral, FL 33166

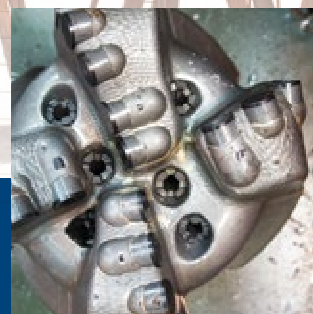
Section 2: Products to Meet Your Brazing Needs

Discover the cutting-edge brazing products designed to meet the diverse needs of modern industries.

Lucas Milhaupt strives to develop new products tailored to the many evolving brazing applications. This section highlights some of our newly launched products and outlines their benefits. The following pages illustrate a wide range of brazing materials that have been perfected by the material scientists and engineers at Lucas Milhaupt to deliver stronger, longer lasting joints for a variety of industries, such as microelectronics, downhole drilling, automotive, and other specialty applications.

Each of the products featured in this section were developed to solve common challenges in modern brazing and provide a number of benefits to the end user – from flux reduction and enhanced aesthetics to improved operational efficiency and throughput.

SILVACUT®



Increase the Life of Drill Bits with SILVACUT

Flux cored alloy developed specifically for improved bit performance in downhole drilling.

Superior Wetting

SILVACUT offers superb wetting on tungsten carbide, even on lower cobalt bearing grades, such as C2 (6% Co). By virtue of its optimized nickel and manganese content, SILVACUT flashes farther and yields a smaller contact angle than other common carbide brazing alloys, such as AWS BAg-24 and AWS BAg-7 as seen in Figure 1 and 2.

Improve Braze Joint Integrity

A highly fluid and aggressive flux in the core ensures fresh flux is applied just ahead of the filler metal to cut through tenacious oxides and displace flux inclusions producing higher integrity joints.

Why SILVACUT?

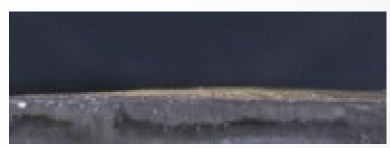
- Liquidus of 1274°F and superior rapid flow minimizes heat duration and overheating of the PCD (polycrystalline diamond, also referred to as PCD)
- No need to use extra heat to improve wetting and alloy flow
- Decrease lost cutter occurrence and increase drill head life

Product Name	Liquidus	
	°F	°C
SILVACUT	1274	690

Figure 1: Alloy Wetting on C2 Carbide

SILVACUT AWS BAg-24 AWS BAg-7

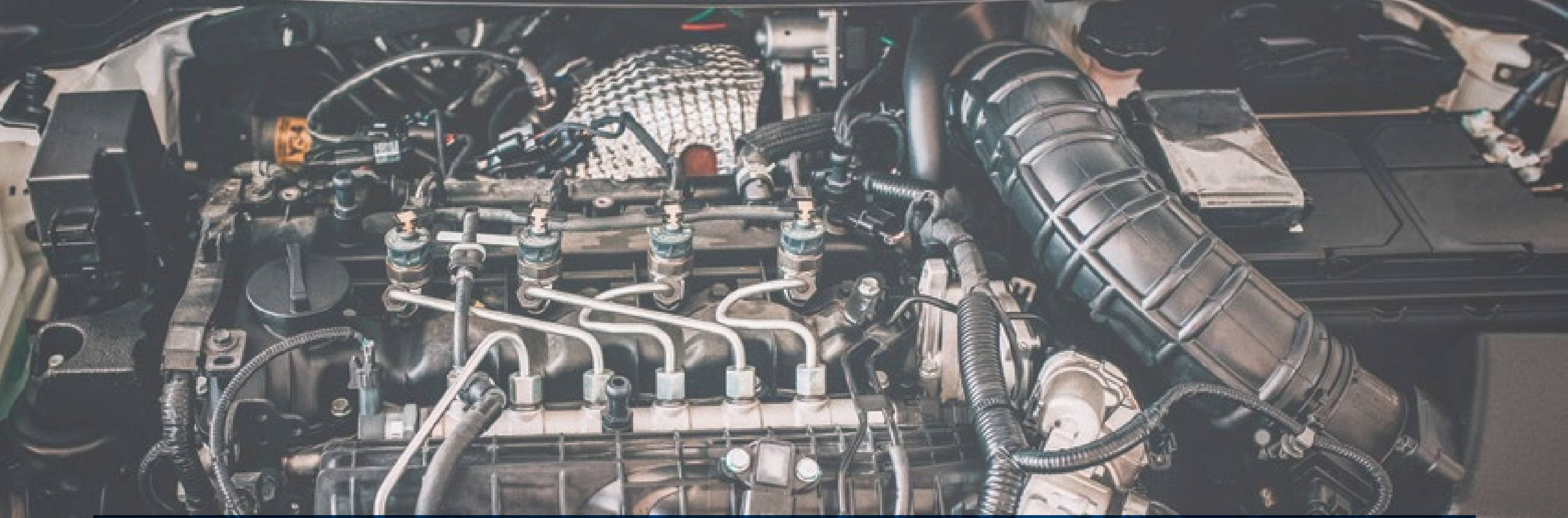
Figure 2: Alloy Contact Angle on C2 Carbide



SILVACUT

SILVALOY 505 (BAg-24)

SILVALOY 560 (BAg-7)



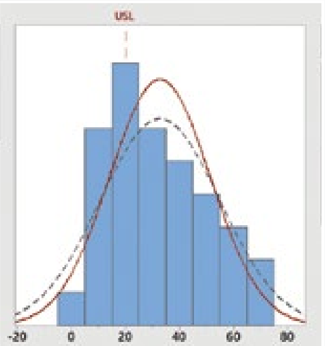
AL CC® ALUMINUM CORROSIVE CORED

The Automotive Industry's Aluminum Braze Solution

Corrosive flux cored wire developed specifically for easy-to-clean, visually appealing aluminum braze joints

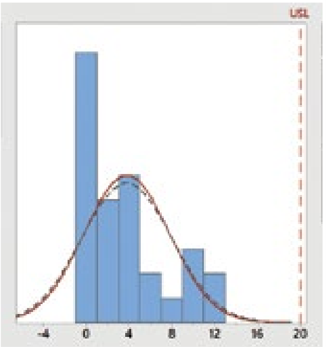
Clean Finish

AL CC offers a controlled amount of corrosive flux in a cutting-edge flux cored design which reduces overall flux consumption, reduces time spent applying separate paste flux, eliminates variability, and improves throughput.



Current State Industry

- Average Porosity: 33%
- Standard Deviation: 19%
- CpK: -0.3

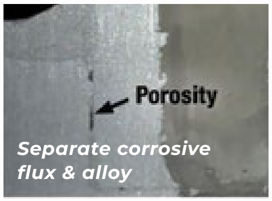


Corrosive Cored Results

- Average Porosity: 3.8%
- Standard Deviation: 4.0%
- CpK: 1.30

Leak Free Joints

Significantly lowers braze joint porosity and reduces the risk of leak paths, thereby increasing First Pass Yield (FPY).



Why AL CC?

- Minimizes potential for transfer of flux that can corrode equipment and facilities
- Flux cored design means less operator exposure to corrosive flux
- Visually appealing braze joints, significantly easier to clean compared to other aluminum fluxes in the industry
- Superior wetting on Mg bearing aluminum alloys (5000, 6000, and some 7000 series aluminum) due to its ability to more effectively remove tenacious surface oxides compared to standard non-corrosive fluxes
- Easy-to-use flux cored design
- Easily cleaned off with water and leaves behind a clean aluminum surface for an aesthetically pleasing braze joint while reducing costs associated with post-cleaning
- Controlled volume of flux eliminates flux staining on critical sealing surfaces

CONE CORED™

Improve First Pass Yield with CONE CORED

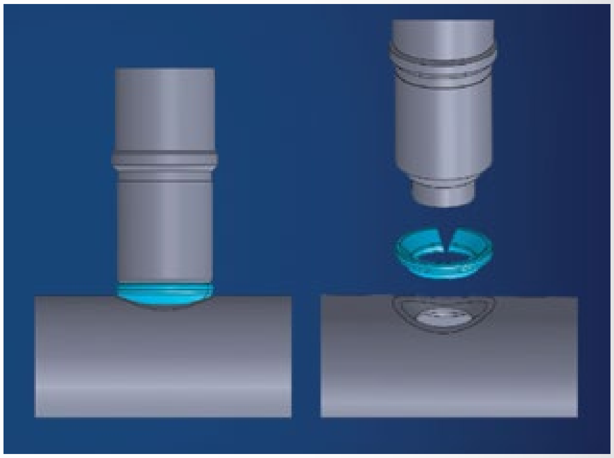
A washer designed specifically to braze tapered valve joints

Maximum Contact. Shorter Brazing Time.

CONE CORED offers a flux cored washer design with superior contact to existing preforms when brazing a Schrader valve or tapered joint. The increased contact with the CONE CORED design allows for more heat transfer which promotes a shortened braze cycle time.

Why CONE CORED?

- Flux is protected from the heat, ensuring activation at the appropriate time
- No additional flux is required for brazing
- Heat can be applied directly to the joint without risk of spill over due to improved preform fit
- Improved preform fit simplifies fixturing and assembly alignment
- Superior joint aesthetics reduce visual inspection time
- Consistent alloy to flux ratio improves process stability
- Better fit reduces the need to force the valve when seating a tapered joint



CONE CORED ring shown in Schrader valve application.

PREMABRAZE® 800 & 880

Achieve Precision Hermetic Seals for Mission-Critical Microelectronic Packaging

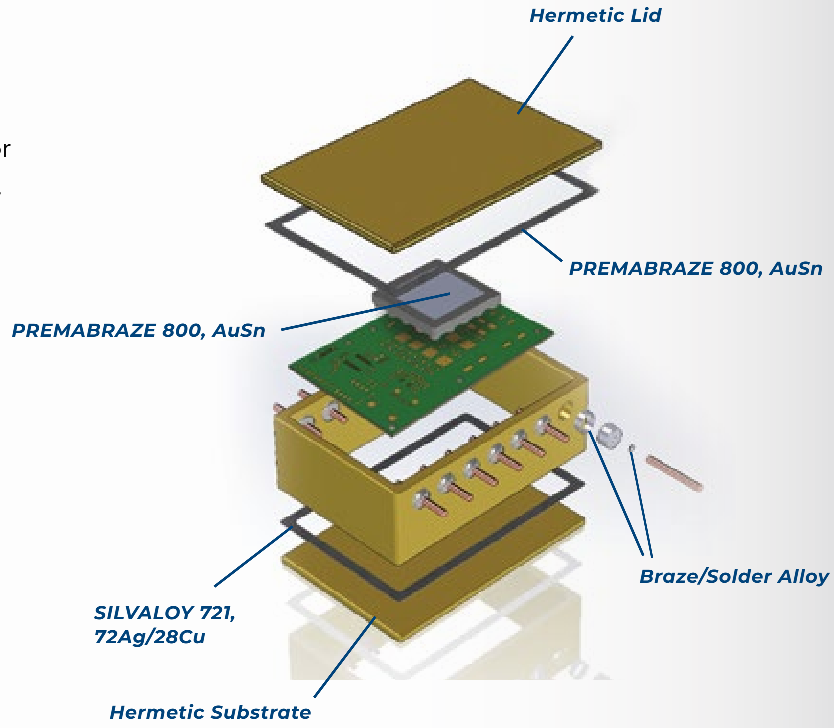
Our PREMABRAZE 800 and 880 alloys deliver high bond strength, exceptional corrosion and oxidation resistance, and good thermal and electrical transfer at the solder joint. These solder alloys make for an excellent choice for your high power and high reliability applications. Our silver based SILVALOY® 721 is often used in conjunction with AuSn and AuGe applications as it has high thermal and electrical conductivity, capillaries very well into joints, and holds up well in high stress applications and CTE mismatches.

Precision. Quality. Speed.

As miniaturization continues in microelectronics, thermal management is becoming increasingly important. More than ever, this drives the need for high-quality connections, especially in aerospace, automotive, defense, and medical industries. We supply premium gold-based solder alloys, ensuring robust and reliable connections for critical microelectronics applications.

Why PREMABRAZE 800 & 880?

- Highest tensile strength of any solder
- High melting point is compatible with subsequent reflow processes
- Superior thermal conductivity
- Resistance to corrosion
- Superior thermal fatigue resistance
- Excellent wetting properties
- Resistance to oxidation



ULTRACOAT®

All-in-One Alloy and Flux Solution for Strip Preforms

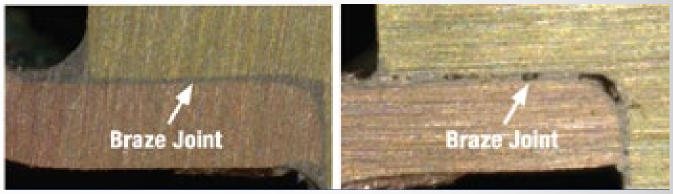
Take brazing optimization to the next level with ULTRACOAT. Our flux coated braze materials were designed to improve productivity, reduce cycle times, and eliminate variability.

Having issues with overconsumption, variability, and poor part quality?

Solve all these variables with one simple solution: ULTRACOAT. As the industry leader in solution driven support, Lucas Milhaupt introduced its ULTRACOAT product line—flux coated strip that eliminates the need for a separate flux application. By coating the strip with a precise amount of flux, operator variability is eliminated and First Pass Yield (FPY) increases. The amount of flux coated on the braze foil is calculated precisely for your application and helps ensure the proper amount of fluxing action for superior alloy wetting without increasing the amount of flux inclusions and porosity left inside the joint. By driving down porosity and improving alloy wetting, no joint strength is sacrificed, and, in many cases, joint strength is higher than joints that use manual flux and braze alloy.

Why ULTRACOAT?

- Available flux coatings for brazing carbide, stainless steel, steel, copper, brass, and aluminum
- Eliminate flux spend and associated management costs
- Improved FPY - Fixed volume of flux eliminates flux load variation common with separate paste flux application
- Minimize post braze flux removal costs
- Minimize operator exposure to flux
- Reduced flux void porosity common in over application of flux
- No spattering means a clean work area and reduced tooling maintenance



ULTRACOAT (left, no porosity) vs. separate flux and alloy (right, high porosity).

Section 3: Choices in Brazing Materials

Selecting your brazing materials.

Before choosing a filler metal, you must understand and evaluate the three basic characteristics of filler metals: physical properties, melting behavior and forms available. Let's look at each of these characteristics.

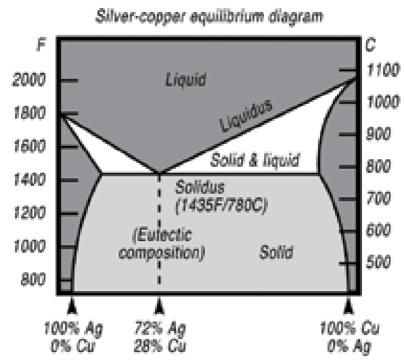
Physical properties and melting behavior.

The physical properties of a filler metal are based on metallurgical composition. (Brazing filler metals are invariably alloys, made of two or more "pure" metals.) This composition determines whether the filler metal is compatible with the metals being joined—capable of wetting them and flowing completely through the joint area without forming detrimental metallurgical compounds. Plus, special service or production requirements may call for special properties. For example, if you're brazing in a vacuum, you need a filler metal free of any volatile elements, such as cadmium or zinc. Some electronic components require filler metals of very high purity. And corrosion-resistant joints need filler metals that are both corrosion-resistant and compatible with the base metals being joined.

Melting behavior is also based on metallurgical composition. Since most filler metals are alloys, they usually do not melt the same as pure metals, which change from a solid to a liquid state at one temperature. However, there is an important exception to this statement. There is a class of alloys, termed "eutectics," that do melt in the same manner as pure metals.

An example of an eutectic composition is SILVALOY 721, a simple silver-copper alloy made of 72% silver and 28% copper. This filler metal melts completely at a single temperature—1435°F (780°C). In metallurgical terms, its melting point (solidus) and flow point (liquidus) are identical.

This melting behavior is shown on the following chart. Note that at the 72% silver, 28% copper composition, liquidus and solidus temperatures are the same. And, the alloys to the left or



right of this eutectic composition do not go directly from a solid to a liquid state, but pass through a "mushy" range where the alloy is both solid and liquid. This range is the difference between the "solidus" temperature, which is the highest temperature at which the alloy is completely solid (i.e., the point where melting starts when the alloy is heated) and the "liquidus" temperature, which is the lowest temperature at which the alloy is completely liquid (i.e., the point where solidifying starts as the alloy is cooled.)

Importance of "melting range".

Look at a couple of examples. If you are brazing an assembly with a narrow, closely controlled clearance, SILVALOY 560 filler metal works well. This cadmium-free alloy begins to melt at 1145°F/620°C and flows freely at 1205°F/650°C. Its melting range is 60° F/ 15°C. When brazing an assembly with wide clearances (greater than .005"), select a filler metal like the cadmium-free SILVALOY 380. As it starts to melt at 1200°F/650°C and becomes fully liquid at 1330°F/720°C, its flow characteristics are sluggish enough to fill wide gaps.

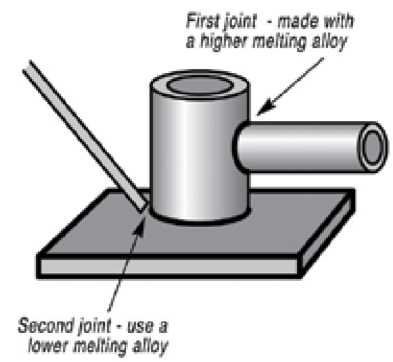
Consider the "liquidus temperature."

In all brazing applications, the "liquidus temperature" of the brazing filler metal is a critical factor. Since in brazing you never want—or need—to melt the base metals, you should select a filler metal whose liquidus temperature is lower than the solidus temperature of both of the base metals being joined.

There are several brazing situations in which the liquidus temperature factor calls for special consideration.

For example, when "step brazing" an assembly—that is, brazing in the vicinity of a previously brazed joint, you don't want the second brazing operation to disturb the first joint. The way to prevent this is to use more than one type of filler metal. Make the second joint with a filler metal lower in liquidus temperature than that used for the first joint. This way you are assured the first joint will not be re-melted when making the second.

Also consider liquidus temperature when brazing assemblies that must be heat treated. In these instances, you have two options. You can heat treat and then braze—in which case you should select a filler metal whose liquidus temperature is lower than the heat-treating temperature. This way the hardness properties won't be adversely affected by brazing. Or you can heat treat and braze simultaneously. In this case, the liquidus temperature of the filler metal should be closely equivalent to the heat treating temperatures.



Brazing temperature.

In most cases, the brazing temperature will be above the liquidus temperature of the filler metal and below the solidus temperature of the metal being joined. The actual brazing temperature will depend on factors such as the rate of heating, the type of filler metal flow required, the melt range of the filler metal and any elements in the filler metal that may inhibit flow.

In general, rapid heating and the use of eutectic compositions or alloys with small melt ranges will allow you to braze at a lower temperature. There are a few filler metals which will flow acceptably below their liquidus temperatures. These are the FOS-FLO® and SIL-FOS® filler metals.

Forms of filler metal.

Finally, in selecting a brazing filler metal, consider the forms in which it is available;

as coils or spools of wire, lengths of rod, strip, powder, paste, and preforms (including flux coated products).

In maintenance brazing, single assembly brazing or short-run production, the manual torch, with wire or rod fed by hand, remains the most widely used method. Preforms and pastes are used frequently in production brazing.

Furnace brazing may use various filler metals depending on the base materials, atmosphere, and the desired joint properties. Commonly used filler metals include aluminum-silicon alloys for aluminum parts, specialized silver or gold-based alloys for critical hermetic applications, and nickel based alloys for high-temperature and high-strength applications. Vacuum brazing generally requires vacuum-grade filler metals, often denoted with a "V" or "VTG".

Evaluate your needs and select the form that provides the best results and most efficient use of material. The information at right should help you in your selection.

How much filler metal to use.

Once you've carefully determined the best filler metal for the job, you need to figure out how much filler metal is needed for the joint.

When brazing a single assembly, this is seldom a problem. You touch the brazing rod to the heated joint area, a portion of the rod melts and capillary action draws it through the joint. When you remove the rod from the joint, you can see the fine line of filler metal running all around the joint edge. No calculation is needed.

When in doubt during maintenance brazing or in short-run production, the rule of thumb is to use more rather than less filler metal. Joint soundness is your primary goal, so it's best to use a little extra filler metal to insure that soundness.

In high production brazing, however, particularly where you're pre-placing or automatically feeding the filler metal, unnecessary use of filler metal can be costly. Here you want to calculate the amount of filler metal as precisely as possible, so you make sound joints with minimum usage of materials. To accomplish this, calculate the volume of the joint (at the brazing temperature), adding 10-25% for fillet and shrinkage, and then supply the equivalent volume of filler metal.

Using the selection charts.

One final word on filler metal selection—manufacturers' selection charts can make your job easy. Make use of them and you won't have to be a graduate metallurgical engineer to pick the right filler metal for your brazing application. For example, the charts on pages 32-51 guides you to the right Lucas Milhaupt filler metal with little difficulty.

Let's look closer at this chart. Note that a relatively few "general purpose" alloys can cover over 90% of your brazing needs. And for specialized applications, you can readily determine the "special purpose" alloy best suited to the job. The chart also includes all the information you need on the melting range and metallurgical composition of each filler metal.

It's important to remember that every brazing and soldering application has requirements which may make one filler metal alloy and form more appropriate and cost effective than another. When you need assistance, let our technical experts evaluate your unique needs and give you a completely objective recommendation.

Selecting a filler metal form.

Filler metals for brazing applications are available in numerous forms.

Bulk Wire & Strip Coils or spools of wire, lengths of rod and filler metal strips work well in maintenance brazing, one-assembly-at-a-time brazing or short-run production where the wire or rod is fed by hand. These traditional forms of filler metal are available in stock sizes or, upon request, can be modified to custom widths and thicknesses to provide the best use of material. In automated production, rods and strips are typically not the best option.

Wire & Strip Preforms Filler metal preforms are manufactured by forming bulk wire and strip into special shapes. A variety of shapes can be produced, from simple to intricate, to best meet the needs of each application. There are many advantages to preforms. Because preforms permit alloy pre-placement, they are highly adaptable to automation. Automation increases overall production rate and allows the use of unskilled labor; both of which save time and money. Preforms also help minimize and standardize costs. Hand feeding filler metal may use up to 50% more alloy than actually necessary. Preforms are measured amounts of alloy ensuring the exact volume required is used every time. Aesthetically, preforms help improve a part's appearance. Preforms are designed to surround the joint providing a smooth look with only a thin line of alloy visible. Since the correct amount of alloy fills the joint area, this usually results in a reduction of rejected parts.

Flux Cored Forms HANDY ONE® products are flux cored braze alloy product solutions. The advantage of cored wire and ring preforms is that the final fluxing step is eliminated. The final cleaning step is easier as well with less contaminants going out with the rinsing water.

Flux Coated Forms ULTRACOAT® products are flux coated braze alloy solutions that are designed to improve productivity, reduce cycle times, and eliminate variability. ULTRACOAT comes in rods, wire preforms, strip coils, and strip preforms.

Powders Filler metal powders are produced in a range of particle sizes. Although the standard is -100 mesh (-150 microns), other sizes can be produced to meet specialized needs. Prior to brazing, most powders are turned into a paste form, however there are some applications where powder is used directly. The distinct advantage of a powder form is the wide spectrum of available alloys. A variety of alloys can be produced in powder form but because of their unique characteristics cannot be made into wrought form or preform parts.

Pastes Brazing paste is produced by combining one or more parts of a filler metal, flux and a binder component. It comes in a consistency of caulking compound and can be easily dispensed making it ideally suited for manual applications and cost-saving automation. Using dispensing equipment, the desired quantity of paste can be placed directly, in a variety of configurations, on the joint to be brazed. Paste, like powders, offers a much wider choice of alloys. Paste can also be tailored to meet special application needs by varying the ingredients. Finally, since flux may already be formulated into the product, the extra step to apply flux is eliminated.

Grains Alloy grain is similar to alloy powder, but grains are in the 2-7mm (0.078-0.275in) range, whereas powder is much finer. Spheres are available to customer specifications.

Copper & Copper Alloys: Brazing Materials Selection Chart

General Group	Principal Types	Nominal Composition – Percentages	Principal Uses
Coppers	Electrolytic Tough Pitch Phosphorus Deoxidized Oxygen Free, High Conductivity	Cu–99.90 min., O2 –.04 Cu–99.90 min., P–.02 Cu–99.92 min.	Electrical conductors, automotive radiators, plumbing, dairy and heat exchanger tubing, busbars and wave guides.
Red Brasses	Gilding Metal, Commercial Bronze, Jewelry Bronze, Red Brass	Zn–5 to 15, Cu–Balance	Jewelry, marine hardware, heat exchangers, grille work, fire extinguisher cases
Yellow Brasses	Low Brass, Cartridge Brass, Yellow Brass, Muntz Metal	Zn–20 to 40, Cu–Balance	Musical instruments, lamp fixtures, hinges, locks, plumbing accessories, flexible hose, radiator cores, bellows
Leaded Brasses	Leaded Commercial Bronze, Low Leaded Brass, Medium Leaded Brass, High Leaded Brass, Free Cutting Brass, Free Cutting Muntz Metal, Architectural Bronze	Zn–9.25 to 40, Pb–0.5 to 3, Cu–Balance	Screw machine parts, pump cylinders and liners, plumbing accessories, gears, wheels, pinions, forgings, extrusions
Tin Brasses	Admiralty, Naval Brass Manganese Bronze	Zn–28 to 39, Sn–0.75 to 1, Admiralty: As–.04 Fe–1.4, Mn–0.1 All: Cu–Balance	Condenser and heat exchanger tubes and plates, marine hardware, pump rods, shafts and valve stems
Phosphor Bronzes	Phosphor Bronze (A, C, D, E)	Sn–1.25 to 10, P–.01 to .50, Cu–Balance	Chemical hardware, Bourdon tubing, electrical contacts, flexible hose, pole line hardware
Silicon Bronzes	Silicon Bronze (A,B) Silicon Aluminum Bronze	Si–1.5 to 3, Cu–Balance Si–2.0, Al–7.25, Cu–Balance	Hydraulic tubing, marine hard- ware, chemical equipment
Aluminum Bronzes & Aluminum Brasses	Aluminum Bronze (5%, 8%) Aluminum Silicon Bronze Nickel Aluminum Bronze	Al–5 to 8, Cu–Balance Al–7, Si–2, Cu–Balance Al–9.5, Ni–5, Fe–2.5, Mn–1, Cu–Balance	High strength forgings, pole line hardware, marine fittings, heat exchanger tubing
Cupro-Nickels	Cupro-Nickel (10%, 30%)	Ni–10 to 30, Fe–0.4 to 1.3, Cu–Balance	Marine piping and heat exchangers
Nickel-Silvers	Nickel-Silver { 65-18, 55-18, 65-15, 65-12	Ni–10 to 18, Zn–17 to 25, Cu–Balance	Plated flatware and holloware, camera parts, optical goods, costume jewelry
Beryllium Copper	1 to 2% Beryllium Copper Cu–Balance	Be–1.9, Ni or Co–0.2	Springs, diaphragms, contact braze 560 and 720 spark resistant tools

This table is intended to cover only a few typical applications. Many specific cases exist other than those listed. We invite your inquiry on any brazing problems. Inquire for specific recommendations when brazing copper and copper alloys to dissimilar metals.

	Recommended Brazing Filler Metals*	Recommended Fluxes**	Recommended Atmospheres		Remarks
			Type	Maximum Dew Point	
	Cadmium-Free Alloys SIL-FOS & FOS-FLO Series SILVALOY 560, 380, 452 and 402 **Cadmium Alloys** EASY-FLO & EASY-FLO 45 and 35	None required with SIL-FOS, SIL-FOS 5 or FOS-FLO; HANDY Flux or HANDY Flux with EASY-FLO & SILVALOY alloys	Lean or Rich Exogas Reacted Endogas Dissociated Ammonia Vacuum	+20°F/–6.7°C +20°F/–6.7°C +20°F/–6.7°C	To avoid embrittlement, electrolytic tough pitch copper should not be brazed in hydrogen-containing atmospheres. HANDY Flux is beneficial for long furnace brazing cycles.
	Cadmium-Free Alloys SIL-FOS & FOS-FLO Series SILVALOY 300, 380 and 452 **Cadmium Alloys** EASY-FLO & EASY-FLO 45 and 35	HANDY Flux, or ULTRA FLUX	Purified, Lean Exogas Reacted Endogas Dissociated Ammonia	+10°F/–12°C +10°F/–12°C +20°F/–6.7°C	In furnace brazing, flux may be used with the atmosphere for good "wetting" by the brazing alloy.
	Cadmium-Free Alloys SIL-FOS & FOS-FLO Alloys SILVALOY 202, 300, 380 and 452 **Cadmium Alloys** EASY-FLO & EASY-FLO 45 and 35	HANDY Flux or ULTRA FLUX	Purified, Lean Exogas Reacted Endogas Dissociated Ammonia	–40°F/–40°C –20°F/–28.9°C +20°F/–6.7°C	In furnace brazing, flux may be used with the atmosphere for good "wetting" by the brazing alloy. The EASY-FLO alloys are preferred for furnace brazing to avoid dezincification of high zinc brasses.
	Cadmium-Free Alloys SILVALOY 560, 603 and 380 SIL-FOS Series **Cadmium Alloys** EASY-FLO & EASY-FLO 45 and 35; SILVALOY 560	HANDY Flux or ULTRA FLUX	Purified, Lean Exogas Reacted Endogas Dissociated Ammonia	–40°F/–40°C –20°F/–28.9°C +20°F/–6.7°C	In furnace brazing, flux may be used with the atmosphere for good "wetting" by the brazing alloy. Keep brazing cycles short to minimize lead pickup in the brazing alloy. Leaded brasses must be stress relieved before brazing to avoid intergranular cracking. Heat uniformly. The EASY-FLO alloys, SILVALOY 560 or SILVALOY 603 are preferred for furnace brazing to avoid dezincification of high zinc brasses. Furnace brazing of leaded brasses containing more than 5% lead is not recommended.
	Cadmium-Free Alloys SILVALOY 600, 202, 300, 380, 450 and 560 **Cadmium Alloys** EASY-FLO & EASY-FLO 45 and 35, 560 SIL-FOS Series	HANDY Flux or ULTRA FLUX	Purified, Lean Exogas Reacted Endogas Dissociated Ammonia	–40°F/–40°C –20°F/–28.9°C +20°F/–6.7°C	In furnace brazing, flux may be used with the atmosphere for good "wetting" by the brazing alloy. The EASY-FLO alloys are preferred for furnace brazing to avoid dezincification of high zinc brasses.
	Cadmium-Free Alloys SILVALOY 300, 380, 450 and 255 SIL-FOS Series **Cadmium Alloys** EASY-FLO & EASY-FLO 45 and 35	HANDY Flux or ULTRA FLUX	Lean or Rich Exogas Reacted Endogas Dissociated Ammonia Vacuum	+20°F/–6.7°C +20°F/–6.7°C +20°F/–6.7°C	The dew point and CO_2 content of the recommended atmospheres are not critical for phosphor bronzes, but flux may be required with the atmosphere for good "wetting" by the brazing alloy.
	Cadmium-Free Alloys SILVALOY 600 and 505 **Cadmium Alloys** EASY-FLO & EASY-FLO 45 and 35 EASY-FLO 3	HANDY Flux, ULTRA FLUX, or HANDY Flux Type A-1	Purified, Lean Exogas Dissociated Ammonia Vacuum	–40°F/–40°C –40°F/–40°C	In furnace brazing, flux may be used with the atmosphere for good "wetting" by the brazing alloy. Silicon bronzes must be stress relieved before brazing to avoid intergranular cracking and must be brazed below 1400°F (760°C) to avoid hot shortness. Use HANDY Flux Type A-1 with silicon bronzes containing aluminum.
	Cadmium-Free Alloys SILVALOY 505, 501 and 600 TRIMET 259 **Cadmium Alloys** EASY-FLO 3, TRIMET 258	HANDY Flux Type A-1	Purified, Lean Exogas Dissociated Ammonia Vacuum (Bronzes only)	–40°F/–40°C –40°F/–40°C	In furnace brazing, HANDY Flux Type A-1 should be used with the atmosphere for good "wetting" by the brazing alloy. Dry H_2 will not reduce aluminum or titanium oxides.
	Cadmium-Free Alloys SIL-FOS Series w/ 10% Ni or less SILVALOY 603 and 450 **Cadmium Alloys** EASY-FLO, EASY-FLO 45 and 35	HANDY Flux or ULTRA FLUX	Lean or Rich Exogas Reacted Endogas Dissociated Ammonia Vacuum	+20°F/–6.7°C +20°F/–6.7°C +20°F/–6.7°C	The dew point and CO_2 content of the recommended atmospheres are not critical for cupro-nickels but flux may be required with the atmosphere for good "wetting" by the brazing alloy. Cupro-nickels must be stress relieved before brazing to avoid intergranular cracking. Cupro-nickels containing more than 10% nickel should not be brazed with SIL-FOS or FOS-FLO type filler metals.
	Cadmium-Free Alloys SILVALOY 600, 202, 300, 380, 505 and 450 **Cadmium Alloys** EASY-FLO & EASY-FLO 45 and 35	HANDY Flux or ULTRA FLUX	Purified, Lean Exogas Reacted Endogas Dissociated Ammonia	–40°F/–40°C –20°F/–28.9°C +20°F/–6.7°C	In furnace brazing, flux may be used with the atmosphere for good "wetting" by the brazing alloy. Nickel-silvers must be stress relieved before brazing to avoid intergranular cracking. Heat uniformly.
	Cadmium-Free Alloys HANDY Flux Type A-1 For Be-Cu to Steel use SILVALOY 505 or TRIMET 259 **Cadmium Alloys** EASY-FLO 3, EASY-FLO 45 or TRIMET 258	HANDY Flux, ULTRA FLUX or Vacuum	Dissociated Ammonia	–40°F/–40°C	See Aluminum Bronzes. Flux is necessary to wet this material.

* Call our technical team for other possible alloy suggestions.
** For automated brazing, HANDY Flux Type D or DB may be used where flux is required.

Stainless Steel Alloys: Brazing Materials Selection Chart

General Group	AISI or Trade Designation	Nominal Composition – Percentages	Principal Uses	Recommended Brazing Filler Metals
Austenitic, Non-Hardenable†	302, 303, 304, 316	Mn–2.0 max. Si–1.0 max. Plus Grade: 302 / 303 / 304 / 316 Cr: 18.0 / 18.0 / 19.0 / 17.0 Ni: 9.0 / 9.0 / 10.0 / 12.0 Max. { Mo: - / 0.60 / - / 2.5 Max. { C: 0.15 / 0.15 / 0.08 / 0.08 Max. { P: 0.045 / 0.20 / 0.045 / 0.045 S: 0.030 / 0.15 min. (or Se) / 0.030 / 0.030	Chemical processing equipment, architectural trim	SILVALOY 505, EASY-FLO 3, SILVALOY 630
			Cooking utensils and hospital equipment	SILVALOY 403, SILVALOY 630, SILVALOY 505, SILVALOY 560
			Elevated temperatures (700°F/370°C max.)	SILVALOY 541, HI-TEMP 095, HI-TEMP 870
			Heat exchangers	LITHOBRAZE 925, LITHOBRAZE 720
			Vacuum tubes	PREMABRAZE 131, HI-TEMP 095, HI-TEMP 870
	321, 347	Cr–18.0 Ni–11.0 Mn–2.0 max. Si–1.0 max. (321 only) 5xC-Ti min. (347 only) 10xC-Cb+Ta min. C–.08 max. P–.045 max. S–.030 max. Fe–Bal.	High temperature service (800-1500°F / 415-815°C) or for max. corrosion resistance	PREMABRAZE 130
			Aircraft hydraulic tubing	SILVALOY 541
			Cryogenic apparatus	SILVALOY 505, EASY-FLO 3
Ferritic, Non-Hardenable	430	Cr–16.0 Mn–1.0 max. Si–1.0 max. C–.12 max. P–.040 max. S–0.30 max. Fe–Bal.	Decorative automotive trim and kitchen sinks	SILVALOY 630, SILVALOY 559
			Nitric acid tanks	Silver brazing not recommended
	446	Cr–25.0 Mn–1.5 max. Si–1.0 max. C–.20 max. P–.040 max. S–.030 max. N–.25 max. Fe–Bal.	Resistance to high temperature scaling	SILVALOY 541 (700°F/370°C max. joint service)
				PREMABRAZE 131 (1500°F/815°C max. joint service)
			Resistance to sulphur bearing gases or compounds	PREMABRAZE 131
Martensitic, Hardenable	403, 410	Cr–12.25 Mn–1.0 max. C–.15 max. (403 only) Si–0.5 max. (410 only) Si–1.0 max. P–.040 max. S–.030 max. Fe–Bal.	Steam turbine blades	SILVALOY 630, SILVALOY 403
			Jet engine compressor blades	SILVALOY 541
	440A	Cr–17.0 Mn–1.0 max. Si–1.0 max. C–.60 -.75 P–.040 max. S–.030 max. Mo–.75 max. Fe–Bal.	Cutlery and surgical tools	SILVALOY 630
Percipitation, Hardenable	17-7 PH, 15-7 PH Mo	Ni–7.0 Mn–1.0 max. Si–1.0 max. C–.09 max. (17-7 Ph only) Cr–17.0 (PH 15-7 Mo only) Cr–15.0, Mo–2.5 Al–1.1 Fe–Bal.	Aircraft and missile honeycomb panels	LITHOBRAZE 925
	17-4 PH	Cr–16.5 Mn–1.0 max. Si–1.0 max. C–.07 max. Cu–4.0 Ni–4.0 Cb+Ta–0.30 Fe–Bal.	Aircraft and missile components	LITHOBRAZE 720
				SILVALOY 505, EASY-FLO 3
				SILVALOY 541
	AM-350	Cr–16.65 Ni–4.50 Mo–2.85 Mn–.75 C–.09 Si–3.5 N–10 max. Fe–Bal.	Aircraft panels	LITHOBRAZE 925
			Aircraft hydraulic tubing	LITHOBRAZE 720

This table is intended to cover only a few typical applications. Many specific cases exist other than those listed. We invite your inquiry on any brazing problems. Inquire for specific recommendations when brazing copper and copper alloys to dissimilar metals.

	Recommended Fluxes*	Recommended Inert-type Furnace Atmospheres**	Remarks
	HANDY Flux, ULTRA FLUX HANDY Flux Type B-1 or Ultra Black Flux	Not necessary when flux is used. Dry hydrogen or vacuum without flux (SILVALOY 630 only)	The compatibility of the brazing alloy with the chemical environment must be checked. SILVALOY 630 provides a better color match than EASY-FLO 3. Brazing alloys containing cadmium should be avoided for food handling applications.
	HANDY Flux, ULTRA FLUX HANDY Flux Type B-1 or Ultra Black Flux	None or dry hydrogen, vacuum (Except with SILVALOY 541)	Flux sometimes used with atmosphere in furnace brazing.
	--	Argon or dry hydrogen, vacuum	The lithium content of these alloys imparts self-fluxing properties in a protective atmosphere.
	HANDY HI-TEMP Flux Boron Modified, or none	Not necessary when flux is used. Argon, vacuum or dry hydrogen without flux	For lower temperatures (700°F/370°C max.) and specific corrosion environments, LITHOBRAZE 925 and LITHOBRAZE 720 may be suitable.
	HANDY Flux Type B-1, Ultra Black Flux or HANDY Flux Type A-1	None or dry hydrogen --	Flux sometimes used with atmosphere in furnace brazing. **Note:** 347 is preferred over 321 for brazeability HANDY Flux Type A-1 actively fluxes the titanium oxides formed on Type 321 stainless steel.
	HANDY Flux, ULTRA FLUX or HANDY Flux Type B-1	Not necessary when flux is used. Dry hydrogen or vacuum without flux (SILVALOY 630 only)	SILVALOY 630 prevents interface corrosion.
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	HANDY Flux Type B-1 or Ultra Black Flux	None or dry hydrogen	Flux sometimes used with atmosphere in furnace brazing.
	HANDY HI-TEMP Flux Boron Modified, or none	None or dry hydrogen, vacuum	Flux required for brazing in air. Flux not required in atmosphere.
	HANDY Flux, ULTRA FLUX, HANDY Flux Type B-1 or Ultra Black Flux	None or dry hydrogen	SILVALOY 630 prevents interface corrosion. SILVALOY 403 resists interface corrosion. Flux sometimes used with atmosphere in furnace brazing.
	HANDY Flux, ULTRA FLUX, HANDY Flux Type B-1 or Ultra Black Flux	None or dry hydrogen, vacuum without flux	SILVALOY 630 prevents interface corrosion. Cadmium-free brazing alloys required for these uses.
	--	Argon	Not subject to interface corrosion. May require nickel plating prior to brazing.
	--	Argon	Not subject to interface corrosion.
	HANDY Flux, ULTRA FLUX, HANDY Flux Type B-1 or Ultra Black Flux	--	For parts not subjected to sustained high temperature service.
	HANDY Flux Type B-1 or Ultra Black Flux	None or dry hydrogen	For service up to 700°F (370°C).
	--	Argon	Filler metals not subject to interface corrosion.

* For automated brazing, HANDY Flux Type D or DB may be used where flux is required.
** Dry hydrogen should be –60°F/–50°C dew point or drier.
† EASY-FLO, EASY-FLO 45, SILVALOY 560 and EASY-FLO 35 may be used satisfactorily on any of the 300 series stainless steels provided the joint is protected from exposure to moist conditions or chlorides.

Silver Based Filler Metals

Alloy Type	Filler Metal Name	Typical Applications
Silver-Copper-Phosphorous Filler Metals	SIL-FOS 2	Low cost brazing filler metal suitable for joining copper alloys where critical impact or vibration stresses are not encountered in service.
	SIL-FOS 2M	Has ability to fill moderate gaps in poorly fitted joints. More ductile than FOS-FLO or SIL-FOS 2. Intended for use on copper tube headers and similar applications where a sleeve fit is not practical. Recommended joint clearance: .002” to .005” (.051 mm to .127 mm). Slow flow.
	SIL-FOS 5	Designed primarily for those applications where close fit-ups cannot be maintained. It has ability to fill gaps and form fillets.
	SIL-FOS 6	A very fluid filler metal for close fit-up work. Low melting range makes it ideal where temperature is a factor. Recommended joint clearance: .001” to .003” (.025 mm to .076 mm). Fast flow. Lowest melt and flow in the minimum silver class.
	SIL-FOS 15	For use where close fit-ups cannot be maintained and joint ductility is important. Recommended joint clearance: .002” to .005” (.051 mm to .127 mm). Slow flow.
	SIL-FOS 18	A ternary eutectic filler metal for joints where good fit-up can be maintained and low melting point is of prime importance. Clearance: .001” to .003” (.025 mm to .076 mm). Very fast flow.
	HANDY FLO 6	Recommended for use where close fit-up cannot be maintained. Has the ability to fill gaps and form fillets without affecting joint strength. Recommended joint clearance: .002” to .005” (.051 mm to .127 mm). Slow flow.
	SILVACAP	Recommended for use where close fit-up cannot be maintained. Has the ability to fill gaps and form fillets without affecting joint strength. Slow flow. Good on brass due to its lower melting point.
Copper-Phosphorous Filler Metals	FOS-FLO	An economical, very fluid medium temperature filler metal for use with copper, brass and bronze. Withstands moderate vibration. Recommended joint clearance: .001” to .003” (.025 mm to .076 mm). Fast flow.

NOTE: The SIL-FOS and FOS-FLO filler metals are for use with copper and copper alloy base metals. Do not use these materials to join ferrous materials as brittle phosphide compounds will be formed at the interface. The SIL-FOS and FOS-FLO filler metals have a unique characteristic called the “Flow Point”. The “Flow Point” is defined as the temperature at which the filler metal is fluid enough to capillary through a joint even though not completely liquid (i.e. above the liquidus temperature).

Alloy Type	Filler Metal Name	Typical Applications
Silver Filler Metals, Cadmium-Free	SILVALOY 071	Used when heat treatment follows brazing, as a lower melting alloy than copper, or in vacuum systems.
	SILVALOY 090	For copper base alloys such as in band instruments; or joint brazing/cyanide case hardening of steels.
	SILVALOY 202	For simultaneous brazing and heat treating of steels.
	SILVALOY 250	Low silver filler metal for joining ferrous and nonferrous alloys.
	SILVALOY 255	Economical filler metal for ferrous and nonferrous joints not requiring high ductility or impact strength.
	SILVALOY 299	Intermediate temperature brazing alloy for use on stainless steels, mild steels, cast and malleable irons and various nonferrous alloys. This alloy can be used in brazing tungsten carbide tools and inserts used in metal cutting, mining and wood working applications.
	SILVALOY 300	For steel and nonferrous alloys melting above 1450°F (790°C), nickel-silver knife handles, electrical equipment.
	SILVALOY 340	Often used in air conditioning and refrigeration which involve the joining of steels, copper, copper alloys, and nickel alloys.
	SILVALOY 351	Intermediate temperature filler metal for use with ferrous and nonferrous materials.
	SILVALOY 380	Free flowing, cadmium-free filler metal used with ferrous and nonferrous base metals.
	SILVALOY 401	For copper base alloys, mild steel, nickel and Monel, and where a narrow melt range is desired.
	SILVALOY 402	A free-flowing medium temperature filler metal for ferrous and nonferrous alloys.
	SILVALOY 403	For tungsten carbides, and stainless steel food handling equipment allowing no cadmium.
	SILVALOY 450	For ships’ piping, band instruments, aircraft engine oil coolers, brass lamps.

* Recommended heating methods: O = Open Air, C = Controlled Atmosphere, V = Vacuum Atmosphere

Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition				Joint Color as Brazed	Density (Toz/in^3)	Electrical Characteristics	
	F	C	F	C	F	C	Ag	Cu	P	Others			Conductivity % IACS	Resistivity Microhm-cm
OC	1190	643	1325	718	1500	816	2	91	7	0	Gray	4.21	5.5	31.5
OC	1190	643	1350	732	1550	843	2	91.5	6.5	0	Gray	4.26	7.5	22.9
OC	1190	643	1325	718	1500	816	5	89	6	0	Gray	4.29	9.6	18.1
OC	1190	643	1275	691	1450	788	6	86.75	7.25	0	Gray	4.14	7.9	21.9
OC	1190	643	1300	704	1500	816	15	80	5	0	Gray	4.45	9.9	17.4
OC	1190	643	1190	643	1300	704	17.6	76.05	6.35	0	Gray	4.27	5.9	29.4
OC	1190	643	1300	704	1500	816	6	88	6	0	Gray	4.26	8.8	19.7
O	1175	635	1250	677	1300	704	0	86.49	6.5	7 Sn, 0.01 Si	Gray	4.27	--	--
OC	1310	710	1460	793	1550	843	0	92.75	7.25	0	Gray	4.21	7.2	24.1

Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition					Joint Color as Brazed	Density (Toz/in^3)	Electrical Characteristics	
	F	C	F	C	F	C	Ag	Cu	Zn	Ni	Others			Conductivity % IACS	Resistivity Microhm-cm
OCV	1225	663	1805	985	2000	1093	7	85	0	0	8 Sn	Yellow	4.8	12.8	13.5
O	1410	766	1565	852	1665	907	9	53	38	0	0	Brass Yellow	4.49	20.5	8.43
O	1315	713	1500	816	1650	899	20	45	35	0	0	Brass Yellow	4.58	23.5	7.36
O	1250	677	1575	857	1665	907	25	52.5	22.5	0	0	Brass Yellow	4.71	24.4	7.06
O	1270	688	1435	779	1600	871	25	40	33	0	2 Sn	Light Yellow	4.62	19.4	9.0
O	1250	677	1450	788	1550	843	30	36	32	2	0	Light Yellow	4.54	--	--
O	1250	677	1410	766	1600	871	30	38	32	0	0	Light Yellow	4.66	24.4	6.85
O	1166	630	1346	730	1500	816	34	36	27.5	0	2.5 Sn	Pale Yellow	4.6	--	--
O	1265	685	1390	754	1600	871	35	32	33	0	0	Yellow	4.67	19.8	8.2
O	1200	649	1330	721	1500	816	38	32	28	0	2 Sn	Pale Yellow	4.77	18.0	9.5
O	1245	674	1340	727	1550	843	40	30	30	0	0	Yellow	4.72	20.8	8.3
O	1200	649	1310	710	1500	816	40	30	28	0	2 Sn	Pale Yellow	4.76	18.0	9.6
O	1220	660	1435	779	1600	871	40	30	28	2	0	Light Yellow	4.76	16.8	10.27
O	1225	663	1370	743	1550	843	45	30	25	0	0	Yellow White	4.8	19.0	9.08

This table is intended to cover only a few typical applications of the most frequently used brazing filler metals.
For special brazing applications, contact our Technical Services Department.

Alloy Type	Filler Metal Name	Typical Applications
Silver Filler Metals, Cadmium-Free	SILVALOY 452	Low temperature, free-flowing, Cadmium-free alloy.
	SILVALOY 495	For low-temperature brazing of tungsten carbides and stainless steels.
	SILVALOY 501	For steam turbine blading and heavily galvanized or tinned steel, aluminum brass tubing.
	SILVALOY 503 VTG ◊	For applications similar to SILVALOY 720 and 721 except where better gap filling is needed.
	SILVALOY 505	For 300 series stainless steel food handling equipment with close joint clearances.
	SILVALOY 541	Atmosphere furnace brazing for high temperature applications (up to 700°F/370°C), such as on jet engines.
	SILVALOY 550	Used for ferrous and non-ferrous alloys in joints requiring a low temperature, cadmium-free material, as in food handling equipment.
	SILVALOY 559	Same as SILVALOY 541, but used where zinc fumes in the furnace are not permissible.
	SILVALOY 560	For food handling equipment requiring a low melting, cadmium-free alloy.
	SILVALOY 580	A free flowing filler metal used in brazing tungsten carbide which is subsequently titanium nitrided.
	SILVALOY 600	For Monel and other nickel alloys, and in place of SILVALOY 650 on silverware.
	SILVALOY 603	For vacuum tube seals, brazing of ferrous and nonferrous alloys without flux, for brazing marine heat exchangers exposed to salt water at elevated temperatures (where zinc is objectionable).
	SILVALOY 604 VTG Gr1 & Gr2 ◊	For vacuum tube seals, brazing of ferrous and nonferrous alloys without flux, for brazing marine heat exchangers exposed to salt water at elevated temperatures (where zinc is objectionable). The VTG grade has low volatile impurities.
	SILVALOY 630	On 400 series stainless steels for corrosion resistance to salt spray, chlorine solutions, etc.
	SILVALOY 650	For silverware, iron and nickel alloys.
	SILVALOY 655	For brazing Invar, Kovar and similar alloys to copper in vacuum tubes; as jet engine rubbing seals.
	SILVALOY 697 VTG ◊	Generally used to braze copper, nickel, coppernickel alloys and stainless steel alloys in a vacuum environment without the necessity of plating of stainless steel substrates. Often used in brazing vacuum tube assemblies in a one step braze process.
	SILVALOY 700	For silverware, when subsequent joints are made with SILVALOY 650.
	SILVALOY 711 ◊	Can be used in all types of moderate temperature vacuum systems in particular brazing of the electronic vacuum tube assemblies.
	SILVALOY 716 VTG Gr2 ◊	Filler metal and high conductivity, similar to SILVALOY 720, but suitable for both ferrous and nonferrous alloys.
	SILVALOY 717 VTG Gr1 ◊	Filler metal and high conductivity, similar to SILVALOY 720, but suitable for both ferrous and nonferrous alloys.
	SILVALOY 720	For nonferrous electronic components requiring highest electrical and thermal conductivity.
	SILVALOY 721 VTG Gr1 ◊	For nonferrous electronic components requiring highest electrical and thermal conductivity. The VTG grade has low volatile impurities, good for use in moderate temperature vacuum systems.
	SILVALOY 750	On silverware for step brazing or enameling; for iron or nickel base alloys.
	SILVALOY 752	Generally used to join iron and nickel base material assemblies that come into contact with ammonia (NH3).
	SILVACUT	Used extensively for brazing tungsten carbide inserts to cutting tools and rock drills. It may be used for joining all types of stainless steels and carbon steels.
	Sterling Silver	Widely used in numerous electrical, electronic, and industrial applications such as contacts, fuse elements, lead wires, battery plated and ruptured discs.
	99.93/99.95 Commercial Grade Fine Silver ◊	Widely used in numerous electrical, electronic, and industrial applications such as contacts, fuse elements, lead wires, battery plated and ruptured discs.
	99.99 Commercial Grade Fine Silver ◊	Widely used in numerous electrical, electronic, and industrial applications such as contacts, fuse elements, lead wires, battery plated and ruptured discs.
	99.90 Commercial Grade Commercial Silver	Widely used in numerous electrical, electronic, and industrial applications such as contacts, fuse elements, lead wires, battery plated and ruptured discs.

◊ Available in vacuum grade.

* Recommended heating methods: O = Open Air, C = Controlled Atmosphere, V = Vacuum Atmosphere

Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition					Joint Color as Brazed	Density (Toz/in^3)	Electrical Characteristics	
	F	C	F	C	F	C	Ag	Cu	Zn	Ni	Others			Conductivity % IACS	Resistivity Microhm-cm
O	1195	646	1251	677	1500	816	45	27	25	0	3 Sn	Pale Yellow	4.85	18.0	9.6
O	1260	682	1290	699	1450	788	49	16	23	4.5	7.5 Mn	Yellow White	4.7	5.7	30.27
O	1270	688	1425	774	1600	871	50	34	16	0	0	Yellow White	4.92	25.5	6.76
CV	1435	779	1600	871	1800	982	50	50	0	0	0	Yellow White	5.08	78.0	2.2
O	1220	660	1305	707	1500	816	50	20	28	2	0	Yellow White	4.83	49.3	11.95
OC	1340	727	1575	857	1700	927	54	40	5	1	0	White	5.07	49.8	3.46
O	1166	630	1220	660	1400	760	55	21	22	0	2 Sn	White	4.81	8.3	20.8
CV	1420	771	1640	893	1800	982	56	42	0	2	0	White	5.14	51.2	3.37
O	1145	618	1205	652	1400	760	56	22	17	0	5 Sn	White	4.96	8.3	20.75
CV	1120	604	1345	729	1550	843	57.5	32.5	0	0	7 Sn, 3 Mn	White	5.17	25.3	6.81
O	1245	674	1325	718	1500	816	60	25	15	0	0	White	5.01	21.0	8.4
CV	1115	602	1325	718	1500	816	60	30	0	0	10 Sn	White	5.17	7.1	24.1
CV	1115	602	1325	718	1500	816	60	30	0	0	10 Sn	White	5.17	7.1	24.1
OCV	1275	691	1475	802	1700	927	63	28.5	0	2.5	6 Sn	White	5.19	12.8	13.4
O	1240	671	1325	718	1500	816	65	20	15	0	0	White	5.06	21.3	8.1
OCV	1385	752	1560	849	1700	927	65	28	0	2	5 Mn	White	5.2	12.8	13.4
CV	1435	779	1435	779	1650	899	69.7	28	0	0	2 Ge, 0.3 Co	Silver White	5.17	--	--
O	1275	691	1360	738	1550	843	70	20	10	0	0	White	5.15	26.7	6.45
OCV	1435	779	1465	796	1650	899	71.15	28.1	0	0.75	0	Silver White	5.26	--	3.4
OCV	1435	779	1465	796	1700	927	71.5	28	0	0.5	0	White	5.27	78.8	2.19
OCV	1435	779	1465	796	1700	927	71.5	28	0	0.5	0	White	5.27	78.8	2.19
OCV	1435	779	1435	779	1700	927	72	28	0	0	0	White	5.25	87.0	2.0
OCV	1435	779	1435	779	1700	927	72	28	0	0	0	White	5.25	87.0	2.0
O	1365	741	1450	788	1600	871	75	22	3	0	0	White	5.24	53.4	3.23
O	1300	704	1345	729	1610	877	75	0	25	0	0	White	4.95	--	--
O	Proprietary		1274	690	1500	816	Proprietary					Yellow White	Proprietary		
OCV	1450	788	1635	891	1735	946	92.8	7.2	0	0	0	Silver White	5.46	--	--
CV	1761	961	1761	961	--	--	99.93	0	0	0	0	Silver White	5.53	--	--
CV	1761	961	1761	961	--	--	99.99	0	0	0	0	Silver White	5.53	--	--
CV	1761	961	1761	961	--	--	99.9	0	0	0	0	Silver White	5.53	--	--

This table is intended to cover only a few typical applications of the most frequently used brazing filler metals.
For special brazing applications, contact our Technical Services Department.

Alloy Type	Filler Metal Name	Typical Applications
Silver Filler Metals, Cadmium-Free	LITHOBRAZE 720	For ferrous and nonferrous base alloys; especially thin sections of stainless steels.
	LITHOBRAZE 925	To join skins to honeycomb cores, particularly precipitation-hardening stainless steels.

Alloy Type	Filler Metal Name	Typical Applications
Cadmium-Bearing Silver Filler Metals	EASY-FLO 053	A high temperature solder for medium strength joints above that of soft solders. Use TEC flux.
	EASY-FLO 056	A high temperature solder for medium strength joints above that of soft solders. Use TEC flux.
	EASY-FLO 25	Same as EASY-FLO 30, but used for most economical joints.
	EASY-FLO 30	Similar to EASY-FLO 35, but used for more economical joints.
	EASY-FLO 35	Similar to EASY-FLO 45, but used where joint clearances are large and fillets are desired.
	EASY-FLO 44	Low melting filler metal for brazing electrical contacts and molybdenum or copper-tungsten electrodes.
	EASY-FLO 45	Joining ferrous, nonferrous and dissimilar metals and alloys with close joint clearances.
	EASY-FLO 3	For 300 series stainless steels; for joining tungsten carbide, beryllium copper and aluminum bronze to steel.
	EASY-FLO	Same as EASY-FLO 45.

SAFETY NOTE: While Cadmium-Bearing Alloys have been extremely popular and versatile filler metals for decades, there are potential hazards associated with them due to their toxic nature. These alloys should only be used in well ventilated areas. We are prepared to assist you in the proper and safe use of these alloys. For additional information, contact our Technical Services Department.

Copper Filler Metals

These Copper filler metals have excellent corrosion resistance and high electrical and thermal conductivity. Lucas Milhaupt stocks many copper-based filler materials, including oxygen-bearing, oxygen-free, and specialty alloys in wire, strip, paste, and powder forms.

Alloy Type	Filler Metal Name	Typical Applications
Copper Filler Metals	CDA 101 ◊	For furnace brazing of steel, stainless steel and Ni-based alloys
	CDA 102	Used on ferrous, Ni-based and Cu-Ni alloys. Free flowing.
	CDA 110	Joining of ferrous, Ni-based and Cu-Ni alloys. Free flowing.
	CDA 510	Used on steels where brazing temperatures lower than that of pure copper are needed.
	CDA 521	Used on steels where brazing temperatures lower than that of pure copper are needed.
	CDA 655	Used on steels where brazing temperatures lower than that of pure copper are needed.
	CDA 680	Used on ferrous and copper materials where close fit up cannot be maintained and lower brazing temperature is required.
	CDA 681	Used on ferrous and copper materials where close fit up cannot be maintained and lower brazing temperature is required.

◊Available in vacuum grade.

* Recommended heating methods: O = Open Air, C = Controlled Atmosphere, V = Vacuum Atmosphere

Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition				Joint Color as Brazed	Density (Toz/in^3)	Electrical Characteristics	
	F	C	F	C	F	C	Ag	Cu	Li	Others			Conductivity % IACS	Resistivity Microhm-cm
C	1410	766	1410	766	1600	871	72	27.625	0.375	0	White	5.09	50.8	3.39
C	1400	760	1635	891	1800	1027	92.5	7.275	0.225	0	White	5.33	55.2	3.12

Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition					Joint Color as Brazed	Density (Toz/in^3)	Electrical Characteristics	
	F	C	F	C	F	C	Ag	Cu	Zn	Cd	Others			Conductivity % IACS	Resistivity Microhm-cm
O	640	338	740	393	840	449	5	0	0	95	0	Gray	4.6	22.0	7.9
O	480	249	600	316	700	371	5	0	16.6	78.4	0	Gray	4.44	20.6	8.4
O	1125	607	1375	746	1400	760	25	35	26.5	13.5	0	Light Yellow	4.71	29.7	5.7
O	1125	607	1310	710	1400	760	30	27	23	20	0	Light Yellow	4.79	31.0	5.5
O	1125	607	1295	702	1400	760	35	26	21	18	0	Light Yellow	4.84	28.6	6.02
O	1100	593	1370	743	1400	760	44	27	13	15	1 P	Light Yellow	4.86	13.8	12.5
O	1125	607	1145	618	1350	732	45	15	16	24	0	Light Yellow	4.96	27.6	6.06
O	1170	632	1270	688	1400	760	50	15.5	15.5	16	3 Ni	Light Yellow	5.02	18.0	9.58
O	1160	627	1175	635	1375	746	50	15.5	16.5	18	0	Light Yellow	4.98	23.9	7.0

Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition					Joint Color as Brazed	Density (Toz/in^3)	Electrical Characteristics	
	F	C	F	C	F	C	Cu	Zn	Sn	P	Others			Conductivity % IACS	Resistivity Microhm-cm
CV	1981	1083	1981	1083	2100	1149	99.99	0	0	0	0	Copper	4.71	101	1.71
CV	1981	1083	1981	1083	2100	1149	99.95	0	0	0	0	Copper	4.71	101	1.71
CV	1981	1083	1981	1083	2150	1177	99.90	0	0	0	0	Copper	4.71	101	1.71
CV	1750	954	1920	1049	2020	1104	94.81	0	5	0.19	0	Copper Yellow	4.59	15	11.5
CV	1620	882	1880	1027	1980	1082	91.81	0	8	0.19	0	Copper Yellow	4.59	13	13.3
CV	1780	971	1880	1027	1980	1082	95.8	0	0	0	3.3 Si, 0.9 Mn	Copper Yellow	4.49	7	--
O	1590	866	1620	882	1800	982	58	39.925	0.95	0	0.5 Ni, 0.255 Mn 0.25 Fe, 0.12 Si	Brass Yellow	4.26	24	7.18
O	1590	866	1630	888	1750	954	58	39.95	0.95	0	0.75 Fe, 0.255 Mn, 0.095 Si	Brass Yellow	4.26	24	7.18

This table is intended to cover only a few typical applications of the most frequently used brazing filler metals.
For special brazing applications, contact our Technical Services Department.

Gold & Palladium Based Filler Metals

Gold and palladium based filler metals are used to join steels, stainless steels, nickel based alloys and other materials, where ductility and resistance to oxidation or corrosion is necessary. Gold and palladium filler metals readily wet most base metals, including the super alloys, and are especially good for brazing thin sections due to their low interaction with the base metal. Most gold and palladium based brazing filler metals are rated for continuous service up to 800°F (425°C). Those containing nickel may be used at higher temperatures.

Alloy Type	Filler Metal Name	Typical Applications
Gold and/or Palladium Filler Metals	PREMABRAZE 025 ◊	Typical applications include brazing of electron tubes, vacuum tubes, and wave guides in electronics industry.
	PREMABRAZE 030 ◊	Low cost, low vapor pressure alloy that offers good wetting characteristics on ferrous and nonferrous alloys such as steels, stainless steels, copper and copper alloys, nickel, and nickel alloys.
	PREMABRAZE 051 ◊	Narrow melting range. Good for step-brazing.
	PREMABRAZE 110 ◊	Typical applications include brazing of electron tubes, vacuum tubes, and wave guides in electronics industry.
	PREMABRAZE 127 ◊	Low penetration of the base metal - well suited for brazing of thin sections, such as thin-wall tubing or electronic vacuum devices.
	PREMABRAZE 131 ◊	Low penetration of the base metal - well suited for brazing of thin sections, such as thin-wall tubing or electronic vacuum devices. Also used for applications such as jet engines and some nuclear power applications.
	PREMABRAZE 140 ◊	Typical applications include brazing of electron tubes, vacuum tubes, radar devices, wave guides in the electronics industry, and other aerospace applications.
	PREMABRAZE 178	Typical application include electronic valve construction, vacuum tube construction in electronics industry, and in aircraft engine components in the aerospace industry.
	PREMABRAZE 179	Low penetration of the base metal - well suited for brazing of thin sections, such as thin-wall tubing or electronic vacuum devices. Also used in brazing of aircraft engine components.
	PREMABRAZE 180 ◊	Low penetration of the base metal - well suited for brazing of thin sections, such as thin-wall tubing or electronic vacuum devices. Also used for applications such as jet engines and some nuclear power applications.
	PREMABRAZE 265 ◊	Low vapor pressure - suitable for use in all vacuum applications such as electronics valve construction and vacuum tube construction in electronics industry.
	PREMABRAZE 285	Used in the electrical contacts industry where improved electrical properties and low contact resistance are required.
	PREMABRAZE 286	Used in the electrical contacts industry where improved electrical properties and low contact resistance are required.
	PREMABRAZE 300	Typical uses for this alloy include brazing of assemblies requiring high oxidation resistance and high strength at elevated temperatures.
	PREMABRAZE 399 ◊	Typical applications include brazing of electron tubes, vacuum tubes, and wave guides in electronics industry.
	PREMABRAZE 402 ◊	Typical applications include brazing of electron tubes, vacuum tubes, radar devices, and wave guides in the electronics industry.
	PREMABRAZE 407 ◊	Typical applications include brazing of electron tubes, vacuum tubes, radar devices, and wave guides in the electronics industry.
	PREMABRAZE 408 ◊	Due to its low and narrow plastic range, this alloy is a preferred choice in step brazing operations.
	PREMABRAZE 409 ◊	Low penetration of the base metal - well suited for brazing of thin sections, such as thin-wall tubing or electronic vacuum devices.
	PREMABRAZE 500 ◊	Typical uses for this alloy include brazing of assemblies requiring high oxidation resistance,and high strength at elevated temperatures.
	PREMABRAZE 520 ◊	Low penetration of the base metal - well suited for brazing of thin sections, such as thin-wall tubing or electronic vacuum devices. Also used in x-ray applications.

◊ Available in vacuum grade.

* Recommended heating methods: O = Open Air, C = Controlled Atmosphere, V = Vacuum Atmosphere

Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition						Joint Color as Brazed	Density (Toz/in^3)	Electrical Characteristics	
	F	C	F	C	F	C	Au	Pd	Ag	Cu	Ni	Others			Conductivity % IACS	Resistivity Microhm-cm
CV	1900	1038	1940	1060	2040	1116	25	0	0	75	0	0	Red Brass	5.44	--	--
CV	1620	882	1790	977	1900	1038	0	0	0	88	0	12 Ge	Silver White	4.35	--	--
CV	1625	885	1643	895	1743	951	75	0	5	20	0	0	Gold Red	7.99	13.2	13.1
CV	1945	1063	1972	1078	2045	1118	10	0	0	90	0	0	Red Brass	4.98	40.5	--
CV	1814	990	1850	1010	1950	1066	35	0	0	62	3	0	Red Gray	5.8	13.5	12.8
CV	1740	949	1740	949	1840	1004	82	0	0	0	18	0	Nickel Gray	8.41	5.85	29.3
CV	1796	980	1832	1000	1932	1056	40	0	0	60	0	0	Red Brass	6.0	20.3	8.5
CV	1510	821	1750	954	1850	1010	0	36	0	0	50	10.5 Cr, 2.875 B, 0.625 Si	Silver White	4.57	--	--
CV	2260	1238	2260	1238	2385	1307	0	60	0	0	40	0	White Gray	5.55	9.37	18.4
CV	2245	1229	2255	1235	2385	1307	0	65	0	0	0	35 Co	White Gray	5.64	7.87	22.0
CV	1562	850	1652	900	1752	956	0	15	65	20	0	0	Silver White	5.44	22.0	7.8
CV	1435	779	1555	846	1671	911	0	0	85	15	0	0	Silver White	5.41	--	--
CV	1760	960	2615	1435	2715	1491	0	0	86	0	14	0	Silver White	5.27	--	--
CV	2075	1135	2130	1166	2250	1232	30	34	0	0	36	0	Silver	6.25	--	--
CV	1815	991	1860	1016	1960	1071	37.5	0	0	62.5	0	0	Red Brass	5.9	20.3	8.5
CV	1751	955	1778	970	1868	1020	50	0	0	50	0	0	Red Brass	6.44	7.87	23.7
CV	1814	990	1850	1010	1950	1066	35	0	0	65	0	0	Red Brass	5.8	20.0	8.62
CV	1535	835	1553	845	1653	901	60	0	20	20	0	0	Gold Red	7.27	13.2	13.1
CV	1670	910	1697	925	1797	981	81.5	0	0	16.5	2	0	Gold Gray	8.38	9.2	18.7
CV	2016	1102	2050	1121	2150	1177	50	25	0	0	25	0	Red Brass	6.9	4.6	37.5
CV	1607	875	1652	900	1778	970	0	20	52	28	0	0	Silver White	5.39	--	--

This table is intended to cover only a few typical applications of the most frequently used brazing filler metals.
For special brazing applications, contact our Technical Services Department.

Gold & Palladium Based Filler Metals (Continued)

Alloy Type	Filler Metal Name	Typical Applications
Gold and/or Palladium Filler Metals	PREMABRAZE 540 ◊	Low penetration of the substrates - often recommended in brazing of thin wall assemblies i.e. electron vacuum devices, honeycomb structures, and heat exchangers. Also used in brazing of compressor stator assemblies in the aerospace industry.
	PREMABRAZE 550 ◊	Suitable for use in all vacuum applications such as electronic valve construction, and vacuum tube construction in electronics industry. Also used in orthodontic applications.
	PREMABRAZE 580 ◊	Suitable for use in all vacuum applications such as electronic valve construction, and vacuum tube construction in electronics industry. Also used in fuel line assemblies and aero-engine components.
	PREMABRAZE 616 ◊	Low vapor pressure - formulated to meet the need for a composition free from volatile constituents, particularly in the brazing of vacuum tubes.
	PREMABRAZE 631 ◊	Typical applications include all types of moderate temperature vacuum systems, in particular in electronic vacuum tube assembly.
	PREMABRAZE 680 ◊	Suitable for use in all vacuum applications such as electronic valve construction, and vacuum tube construction in electronics industry.
	PREMABRAZE 700 ◊	Typical applications include brazing of electron tubes, vacuum tubes, wave guides in electronics industry. Also used in brazing of fuel line assemblies and aero-engine components.
	PREMABRAZE 800	Typical applications include soldering of electronic components requiring low vapor pressure filler metal.
	PREMABRAZE 820	Typical applications include dissimilar metallic interface joining requiring ductility and corrosion resistance. Can be used to join Ti to Ti and Ti to stainless steel.
	PREMABRAZE 880	Typical applications include soldering of electronic components requiring low vapor pressure filler metal.
	PREMABRAZE 901 ◊	Commonly used in brazing of cathode components.
	99.90 Commercial Pure Gold	Widely used in numerous electrical, electronic, and industrial applications, such as waveguides assemblies, transistor units and circuit boards. Gold has been readily used in coating and spattering applications in numerous electrical and industrial applications. Commercial grade fine gold has been extensively used in dental and jewelry applications as well.
	99.95 Commercial Pure Gold ◊	Widely used in numerous electrical, electronic, and industrial applications, such as waveguides assemblies, transistor units and circuit boards. Gold has been readily used in coating and spattering applications in numerous electrical and industrial applications. Commercial grade fine gold has been extensively used in dental and jewelry applications as well.
	99.99 Commercial Pure Gold ◊	Widely used in numerous electrical, electronic, and industrial applications, such as waveguides assemblies, transistors units and circuit boards. Gold has been readily used in coating and spattering applications in numerous electrical and industrial applications. Commercial grade fine gold has been extensively used in dental and jewelry applications as well.
	99.0 Commercial Pure Palladium	Widely used in electrical, electronic, and industrial applications. Used for contact materials used in electrical switches and relays assemblies. Shows favorable corrosion resistant properties in presence of hydrofluoric, phosphoric and acetic acids.
	99.95 Commercial Pure Palladium ◊	Widely used in electrical, electronic, and industrial applications. Used for contact materials used in electrical switches and relays assemblies. Shows favorable corrosion resistant properties in presence of hydrofluoric, phosphoric and acetic acids.
	99.95 Commercial Pure Platinum ◊	Widely used in numerous electrical, electronic, and industrial applications. Typically platinum is used in manufacturing of temperature measuring devices i.e. thermocouples. Platinum has been used in dental, jewelry, and medical applications.

◊ Available in vacuum grade.

* Recommended heating methods: O = Open Air, C = Controlled Atmosphere, V = Vacuum Atmosphere

Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition						Joint Color as Brazed	Density (Toz/in^3)	Electrical Characteristics	
	F	C	F	C	F	C	Au	Pd	Ag	Cu	Ni	Others			Conductivity % IACS	Resistivity Microhm-cm
CV	1652	900	1740	949	1840	1004	0	25	54	21	0	0	Silver White	5.5	15.0	11.5
CV	1520	827	1600	871	1800	982	0	10	55	30	5	0	Silver White	5.27	--	--
CV	1515	824	1565	852	1665	907	0	10	58	32	0	0	Silver White	5.3	37.0	4.7
CV	1155	624	1305	707	1450	788	0	0	61.5	24	0	14.5 In	Silver White	5.0	16.0	10.7
CV	1265	685	1346	730	1446	786	0	0	63	27	0	10 In	Silver White	5.07	19.2	8.97
CV	1485	807	1490	810	1650	899	0	5	68	27	0	0	Silver White	5.31	48.3	3.57
CV	1845	1007	1915	1046	2050	1121	70	8	0	0	22	0	Gold Gray	7.79	8.5	20.3
CV	536	280	536	280	644	340	80	0	0	0	0	20 Sn	Gold Silver	7.66	8.3	20.8
CV	1530	832	1615	880	1815	990	0	9	82	0	0	9 Ga	Silver Gray	5.4	--	--
CV	673	356	673	356	773	412	88	0	0	0	0	12 Ge	Gold	7.74	9.2	18.7
CV	1835	1002	1950	1066	2050	1121	0	10	90	0	0	0	Silver White	5.6	25.0	7.0
CV	1947	1064	1947	1064	2047	1119	99.9	0	0	0	0	0	Gold	10.18	73.4	23.4
CV	1947	1064	1947	1064	2047	1119	99.95	0	0	0	0	0	Gold	10.18	73.4	23.4
CV	1947	1064	1947	1064	2047	1119	99	0	0	0	0	0	Gold	10.18	73.4	23.4
CV	2826	1552	2826	1552	2926	1608	0	99	0	0	0	0	White	6.33	16.0	10.9
CV	2826	1552	2826	1552	2926	1608	0	99.95	0	0	0	0	White	6.33	16.0	10.9
CV	3216	1769	3216	1769	3316	1824	0	0	0	0	0	99.95 Pt	Silver Gray	11.3	--	--

This table is intended to cover only a few typical applications of the most frequently used brazing filler metals.
For special brazing applications, contact our Technical Services Department.

Soldering Filler Metals

Solders are low melting filler metals that are used to join a wide variety of materials. Solders melt below 840°F (450°C), and so can only be used for low temperature applications. The process is generally performed using a torch, induction, or using furnace, wave or ultrasonic methods. Soldering generally requires a flux. Fluxes for soldering range from being noncorrosive to being very corrosive. Flux selection is based on the materials to be soldered and the melting temperature of the base metal.

Solder selection is dependent upon the base metals, corrosion resistance required, service temperature, and required strength and creep properties.

These are just some of the more common solders that Lucas Milhaupt offers.

Call our customer service department for information on other alloys available.

Alloy Type	Filler Metal Name	Typical Applications
Soldering Filler Metals	SILVABRITE △	Eutectic alloy. Wets copper, brass, steel, stainless steel.
	SILVABRITE 100 △	This alloy is considered to be a high strength solder.
	SILVABRITE S △	High strength solder. Provides satisfactory color match for stainless steel assemblies.
	SILVABRITE 6 △	High strength solder. Provides satisfactory color match for stainless steel assemblies.
	SILVABRITE 973 △	This alloy is considered to be a high strength solder.
	EASY-FLO 053	A high temperature solder for medium strength joints above that of soft solders. Use TEC flux.
	EASY-FLO 056	A high temperature solder for medium strength joints above that of soft solders. Use TEC flux.
	95 Sn / 5 Sb △	For Cu to Cu. Good creep strength. Not for brass.
	PREMABRAZE 800 △	Low ductility alloy. Typical applications include soldering of electronic components requiring low vapor pressure filler metal.
	PREMABRAZE 880	Typical applications include soldering of electronic components requiring low vapor pressure filler metal.
	62 Sn / 36 Pb / 2 Ag △	Silver-Tin-Lead solders are widely used when soldering silver-coated surfaces. Commonly used in joining of electronic components.
	63 Sn / 37 Pb △	Widely used in electronics for both manual and automatic soft soldering applications and in general purpose applications where fast alloy flow is desired.
	60 Sn / 40 Pb △	Used in applications involving soldering of copper and copper alloys and/or ferrous base alloys. This alloy should not be used in soldering of potable water systems due to its high lead content.
	50 Sn / 50 Pb △	Used in applications involving soldering of copper and copper alloys and/or ferrous base alloys. This alloy offers satisfactory corrosion resistance properties. This alloy should not be used in soldering of potable water systems due to its high lead content.
	40 Sn / 60 Pb △	Used in applications involving soldering of copper and copper alloys and/or ferrous base alloys. This alloy offers satisfactory corrosion resistance properties. This alloy should not be used in soldering of potable water systems due to its high lead content.
	97.5 Pb / 1.5 Ag / 1 Sn △	Used to solder copper and/or ferrous base alloys. Offers satisfactory corrosion resistance properties. Should not be used in soldering of potable water systems due to its high lead content. Good corrosion resistance in humid atmospheres.
	97.5 Pb / 2.5 Ag △	Used in applications involving soldering of copper and copper alloys and/or ferrous base alloys. This alloy offers satisfactory corrosion resistance properties. This alloy should not be used in soldering of potable water systems due to its high lead content. Eutectic alloy–a homogenous alloy.
	99.95 Pure Tin △	Widely used in production of low temperature soft solders. Used in coating applications as it shows improved corrosion resistance when exposed to water and/or air environment. Due to its low toxicity, tin is used in joining and lining of water carrying systems.
	SAC 305 △	Lead-free solder alloy commonly used in electronic applications.
	SAC 387 △	Lead-free solder alloy commonly used in electronic applications.
	SAC 405 △	Lead-free solder alloy commonly used in electronic applications.
	SAC 0307 △	Lead-free solder alloy commonly used in electronic applications.

△Applies to J Standard.

Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition					Joint Color as Brazed	Density (Toz/in^3)	Electrical Characteristics	
	F	C	F	C	F	C	Ag	Sn	Pb	Cu	Others			Conductivity % IACS	Resistivity Microhm-cm
OC	430	221	430	221	530	277	3.6	96.4	0	0	0	White	3.89	14.0	--
OC	440	227	660	349	760	404	0.5	95.5	0	4	0	White	3.88	12.0	--
OC	430	221	473	245	573	301	4.6	95.4	0	0	0	White	3.91	12.6	--
OC	430	221	536	280	636	336	5.6	94.4	0	0	0	White	3.92	--	--
OC	440	227	572	300	672	356	0	96.5	0	3.5	0	White	3.88	--	--
O	640	338	740	393	840	449	5	0	0	0	95 Cd	Gray	4.6	22.0	7.9
O	480	249	600	316	700	371	5	0	0	0	16.6 Zn, 78.4 Cd	Gray	4.44	20.6	8.4
O	450	232	464	240	564	296	0	95	0	0	5 Sb	White	3.84	--	--
CV	536	280	536	280	644	340	0	0	0	0	80 Au, 20 Sn	Gold Silver	7.66	8.3	20.8
CV	673	356	673	356	773	412	0	0	0	0	88 Au, 12 Ge	Gold	7.74	9.2	18.7
O	354	179	372	189	472	244	2	62	36	0	0	White	4.45	--	--
O	361	183	361	183	461	238	0	63	37	0	0	White	4.43	15.0	--
O	361	183	375	191	475	246	0	60	40	0	0	White	4.43	11.5	--
O	361	183	421	216	521	272	0	50	50	0	0	White	4.68	10.9	15.8
O	361	183	460	238	560	293	0	40	60	0	0	White	4.89	10.1	17.07
O	588	309	588	309	688	364	1.5	1	97.5	0	0	Silver White	5.95	--	--
O	580	304	580	304	680	360	2.5	0	97.5	0	0	Silver White	5.96	8.8	19.5
OCV	449	232	449	232	549	287	0	99.95	0	0	0	Silver White	3.79	14.0	11.0
OCV	423	217	426	219	526	274	3	96.5	0	0.5	0	White	3.88	--	--
OCV	423	217	423	217	523	273	3.8	95.5	0	0.7	0	White	3.92	--	--
OCV	423	217	437	225	537	281	4	95.5	0	0.5	0	White	3.89	--	--
OCV	423	217	441	227	541	283	0.3	99	0	0.7	0	White	3.86	--	--

This table is intended to cover only a few typical applications of the most frequently used brazing filler metals.
For special brazing applications, contact our Technical Services Department.

Nickel Filler Metals

Nickel based filler metals are used to braze ferrous and nonferrous high temperature base metals. These braze filler metals are generally used for their strength, high temperature properties and resistance to corrosion. Some filler metals can be used up to 1800°F (980°C) for continuous service and 2000°F (1903°C) for short time service. Nickel based filler metals melt in the range of 1630 to 2200°F (890 to 1205°C), but can be used at the higher temperature due to diffusion of the melting point depressant elements from the filler metal into the base metal.

Joints made with nickel based filler metals tend to be more brittle than joints made with other filler metals. Care must be taken when using nickel filler metals containing boron on thin sections due to the erosive nature of the molten filler metal and the ability of this material to alloy with the base metal. Time and temperature must be monitored very carefully to prevent the molten filler metal from perforating the base metal.

Alloy Type	Filler Metal Name	Typical Applications
Nickel Filler Metals	HI-TEMP 095	High strength filler metal for joining carbides, steels and heat resistant alloys.
	HI-TEMP 548	Tough, moderate strength, low melting improved nickel silver filler metal for carbides, tool steels, stainless steels and nickel alloys.
	HI-TEMP 675	Designed for intermediate temperature brazing of carbides, cast irons, steel, stainless steels and nickel base heat-resistant alloys.
	HI-TEMP 720	Recommended for parts subjected to light stresses at elevated temperatures. Good corrosion and flow characteristics.
	HI-TEMP 773†	Primarily used to join tungsten carbide to steel. Brazing may be combined with heat treatment of the steel tool bits.
	HI-TEMP 801	Typically used in applications such as cobalt based jet engine component repair or where low erosion on honeycomb structures is desired.
	HI-TEMP 820	Widely used low melting filler metal for furnace brazing aircraft parts, medical devices and other food handling components. Good flow generous fillets, low base metal penetration are characteristics of this filler metal.
	HI-TEMP 850	Typically, this alloy is used for joining super alloys, corrosion and heat resistant steels, and alloys requiring good joint strength at high temperatures while maintaining good corrosion and oxidation resistant characteristics. Typical applications would include structural members in jet engines, turbines, thin-walled heat exchangers, and automotive components.
	HI-TEMP 851	Typically, this alloy is used for joining super alloys, corrosion and heat resistant steels, and alloys requiring good joint strength at high temperatures while maintaining good corrosion and oxidation resistant characteristics. Typical applications would include structural members in jet engines, turbines, thin-walled heat exchangers, and automotive components.
	HI-TEMP 870	Used for tungsten carbide to steel joints or stainless steels, requiring optimum high temperature shear strength, toughness and corrosion resistance. Brazing is often done in conjunction with heat treatment of the steel.
	HI-TEMP 910	Flows freely and less sensitive to atmosphere dryness than the other filler metals. Better for tight/longer joints.
	HI-TEMP 930	For stainless steels & Ni & Co base alloys with thin sections – Jet engine parts and chemical equipment. More sluggish and is better for wide gap applications.
	HI-TEMP 932	For stainless steels & Ni & Co base alloys with thin sections– Jet engine parts and Chemical Equipment. For uses that demand high temp properties and good corrosion resistance at low processing temperatures.
	HI-TEMP 933	Often used for brazing honeycomb structures, thin-walled tube assemblies, and for nuclear applications where boron can't be used. The addition of chromium gives it better high temperature and corrosion properties than HI-TEMP 932.
	HI-TEMP 951	Typically, this alloy is used to braze thin walled heat exchangers and automotive components, specifically EGR coolers.
	99.0 Commercial Pure Nickel	General uses include food handling equipment, structures that call for good corrosion resistance, and electrical contacts. Because of its magnetic and mechanical properties, Nickel 200 also sees usage in devices that require magnetic actuated parts.

† Same as CDA 773

* Recommended heating methods: O = Open Air, C = Controlled Atmosphere, V = Vacuum Atmosphere

Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition					Joint Color as Brazed	Density (Toz/in^3)	Electrical Characteristics	
	F	C	F	C	F	C	Ni	Cu	Cr	Si	Others			Conductivity % IACS	Resistivity Microhm-cm
OCV	1615	879	1700	927	2000	1093	9.5	52.5	0	0	38 Mn	Red Gray	4.04	14.7	11.7
O	1615	879	1685	918	1900	1038	6	55	0	0.15	34.85 Zn, 4 Mn	Light Yellow	4.4	10.6	16.2
CV	1697	925	1751	955	1900	1038	9	67.5	0	0	23.5 Mn	Iron Gray	4.49	--	--
CV	1780	971	1900	1038	2200	1204	73.125	0	14	4.5	4.5 Fe, 3.125 B, 0.75 C	Iron Gray	3.73	--	--
O	1690	921	1715	935	1800	982	10	48	0	0.145	41.545 Zn, 0.25 P, 0.05 Pb, 0.01 Al	Light Yellow	4.26	--	--
CV	2050	1121	2100	1149	2250	1232	17	0	19	8	0.8 B, 50.8 Co, 4 W, 0.4 C	Iron Gray	3.65	--	--
CV	1780	971	1830	999	2150	1177	82.375	0	7	4.5	3.125 B, 3 Fe	Iron Gray	3.79	--	--
CV	1975	1079	2075	1135	2200	1204	70.875	0	19	10.125	0	Iron Gray	3.3	--	--
CV	1950	1066	2100	1149	2200	1204	72.8	0	18	7.25	1.25 B, 0.5 Fe, 0.1 Co, 0.1 C	Iron Gray	3.3	--	--
CV	1760	960	1885	1029	2000	1093	0	87	0	0	10 Mn, 3 Co	Light Copper	4.62	14.5	11.9
CV	1800	982	1900	1038	2150	1177	92.375	0	0	4.5	3.125 B	Iron Gray	3.86	--	--
CV	1800	982	1950	1066	2150	1177	94.65	0	0	3.5	1.85 B	Iron Gray	4.08	--	--
CV	1610	877	1610	877	2000	1093	89	0	0	0	11 P	Iron Gray	3.28	--	--
CV	1630	888	1630	888	2000	1093	75.9	0	14	0	10.1 P	Iron Gray	3.28	--	--
CV	1778	970	1886	1030	2200	1204	60	0	30	4	6 P	Iron Gray	--	--	--
CV	2642	1450	2642	1450	--	--	100	0	0	0	0	Silver White	4.68	--	9.5

This table is intended to cover only a few typical applications of the most frequently used brazing filler metals.
For special brazing applications, contact our Technical Services Department.

Carbide Tool Tips: Brazing Materials Selection Chart

General Group	Recommended Brazing Filler Metals	
	Small Carbides (0.5 sq. in., 12.7 mm² or less)	Large Carbides* (Greater than 0.5 sq. in., 12.7 mm²)
Tungsten Carbide (WC) with cobalt binders	EASY-FLO 3 SILVACUT SILVALOY 403 SILVALOY 495 SILVALOY 505 SILVALOY 580 HI-TEMP 095 HI-TEMP 548	SILVACUT CLAD TRIMET 245 TRIMET 258 TRIMET 259
WC with moderate additions of Titanium Carbide (TiC), Tantalum Carbide (TaC) or Niobium (Columbium) Carbide (NbC), with cobalt binder	EASY-FLO 3 SILVACUT SILVALOY 252 SILVALOY 403 SILVALOY 495 SILVALOY 505 SILVALOY 580 HI-TEMP 080 HI-TEMP 095 HI-TEMP 548	SILVACUT CLAD TRIMET 245 TRIMET 258 TRIMET 259
WC with high percentage additions of TiC, TaC, or NbC, and cobalt or nickel binder	SILVACUT SILVALOY 495 SILVALOY 580 HI-TEMP 080 HI-TEMP 095	SILVACUT CLAD TRIMET 245
Complex carbides including chromium and molybdenum with nickel and/or cobalt or steel binders	SILVACUT SILVALOY 495 SILVALOY 580 HI-TEMP 080 HI-TEMP 095	SILVACUT CLAD TRIMET 245

NOTE: TRIMETs are also useful for brazing aluminum bronze/steel, preventing the diffusion of aluminum to the steel interface. They are effective for joining sintered powder parts and wire mesh assemblies where wicking is objectionable and restricted flow is desired.

*Alloy to be preplaced.

TRIMET® Filler Metals

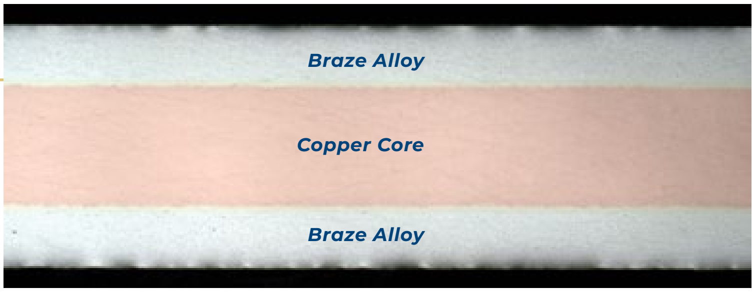
TRIMET material consists of two layers of braze filler metal clad onto a core of copper. TRIMETs are used for brazing carbides to ease the stresses that arise due to differences in thermal expansion between the carbide and the base metal when cooling from the brazing temperature. TRIMET materials are available in various filler metal compositions and different ratios of filler metals to copper. TRIMET selection is dependent upon base metals, service temperature, and carbide size. Brazing of small carbides (1⁄2 inch square (12.7 mm) or less) may not require the use of a TRIMET, but its use on larger pieces has proven very beneficial in preventing cracking and warpage of the carbide.

Alloy Type	Filler Metal Name	Typical Applications
TRIMET Clad Filler Metals	TRIMET 245	Useful for brazing large carbide tool inserts with braze surface areas in excess of 0.5 cubic in (322.58 cubic mm) or linear dimension over 0.75 in (19 mm).
	TRIMET 258	Useful for brazing large carbide tool inserts with braze surface areas in excess of 0.5 cubic in (322.58 cubic mm) or linear dimension over 0.75 in (19 mm).
	TRIMET 259	Useful for brazing large carbide tool inserts with braze surface areas in excess of 0.5 cubic in (322.58 cubic mm) or linear dimension over 0.75 in (19 mm).
	SILVACUT CLAD	Useful for brazing large carbide tool inserts with braze surface areas in excess of 0.5 cubic in (322.58 cubic mm) or linear dimension over 0.75 in (19 mm).

* Recommended heating methods: O = Open Air, C = Controlled Atmosphere, V = Vacuum Atmosphere

Recommended Fluxes	Remarks
Black Flux ULTRA FLUX ULTRA FLUX CHILL 6040 HANDY Flux HANDY Flux Type B-1 HANDY HI-TEMP Flux Boron Modified	The presence of nickel and manganese in the filler metals improves wettability. SILVALOY 403 is a sluggish alloy with long melting ranges. It produces relatively thick joints which helps to relieve residual stresses in the joint. When brazing carbides that are subsequently titanium nitrides use a filler metal that does not contain cadmium or zinc, such as SILVALOY 580.
Black Flux ULTRA FLUX ULTRA FLUX CHILL 6040 HANDY Flux Type B-1 HANDY HI-TEMP Flux Boron Modified	

The image to right is a cross section of Lucas Milhaupt's TRIMET material. A ductile copper core is sandwiched between two pieces of filler metal to help absorb thermal shock from base material combinations with large thermal expansion differences.



	Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition					Copper Core	Joint Color as Brazed	Density (Toz/in^3)	Electrical Characteristics	
		F	C	F	C	F	C	Ag	Cu	Zn	Ni	Others				Conductivity % IACS	Resistivity Microhm-cm
	O	1260	682	1290	699	1450	788	49	16	23	4.5	7.5 Mn	99.90	Yellow White	4.7	5.7	30.27
	O	1170	632	1270	688	1400	760	50	15.5	15.5	3	16 Cd	99.90	Light Yellow	5.02	18.0	9.58
	O	1220	660	1305	707	1500	816	50	20	28	2	0	99.90	Yellow White	4.83	49.3	11.95
	O	Proprietary		1274	690	1500	816	Proprietary					99.90	Yellow White	Proprietary		

This table is intended to cover only a few typical applications of the most frequently used brazing filler metals.
For special brazing applications, contact our Technical Services Department.

Brazing Ceramic Materials

Normally, the brazing of ceramics is a difficult matter since standard brazing alloys will not wet ceramic materials directly. Two brazing options exist for joining ceramics to metals or ceramic to ceramic.

One method involves coating the ceramic with molybdenum/manganese or some other type of metallizing procedure. Once this is done, the coated ceramic can be brazed with standard filler metal.

Unfortunately this metallizing process is very complicated and expensive to perform.

The second option involves a direct brazing process using an active metal. This process is suitably called "active metal brazing." In active metal brazing, the filler metal used contains active metal additions that wet certain ceramic materials. With this process, ceramics can be directly brazed.

Active metal products will join many types of ceramics and other hard to wet materials like carbide, diamond, sapphire, alumina, zirconia, silicon nitride, silicon carbide, titanium nitride, titanium and beryllium. These materials may be joined to themselves or to common substances such as stainless steel, copper, tool steel, kovar, etc.

In the direct brazing process, the brazing should be done in a vacuum, 1 x 10-4 Torr

Alloy Type	Filler Metal Name	Typical Applications
Active Alloys‡	Active 241	Typical applications include brazing of vacuum tubes, wave guides in electrical and electronic industry and PCD, CBN tungsten backed substrates in industrial tool applications.
	Active 270	Typical applications include brazing of vacuum tubes, wave guides in electrical and electronic industry and PCD, CBN tungsten backed substrates in industrial tool applications.
	Active 273	Typical applications include brazing of vacuum tubes, wave guides in electrical and electronic industry and PCD, CBN tungsten backed substrates in industrial tool applications, graphite, and diamonds.
	Tiger Ink	This proprietary product eliminates the need for molybdenum/manganese metallizing or other pre-metallizing treatments typically required in the joining of technical ceramics.

‡Addtional Active Alloys available in blended form.

* Recommended heating methods: O = Open Air, C = Controlled Atmosphere, V = Vacuum Atmosphere

minimum, or in an inert gas atmosphere using argon or helium.

Active metal products are available from Lucas Milhaupt in two forms; paste and strip.

Paste form can be dispensed or silk screened on the parts to be brazed. This offers the advantage of conformance to any configuration. Wrought form products must be processed to the correct size.

	Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition				Joint Color as Brazed	Density (Toz/in^3)
		F	C	F	C	F	C	Ag	Cu	Ti	Others		
	CV	1148	620	1328	720	1580	860	60	24	2	14 In	Gray	4.9
	CV	1435	779	1472	800	1700	927	70	28	2	0	Gray	5.15
	CV	1435	779	1481	805	1742	950	70.5	26.5	3	0	Gray	5.09
	CV	Unique alternative solution to active filler metals in joining non-metallic materials. Compatible with various alloys.											

This table is intended to cover only a few typical applications of the most frequently used brazing filler metals. For special brazing applications, contact our Technical Services Department.

Aluminum Filler Metals

Aluminum filler metals are used to braze aluminum base metals using various methods, the most common being salt dip bath, vacuum, and flux (either torch or furnace). Aluminum brazing requires tighter process parameters than most brazing processes because of the close relationship between the melting point of the braze filler metal and the base metal.

Cleanliness is very important when brazing aluminum base metals. All oil, scale or heavy oxides from extrusion or rolling process must be removed prior to brazing. (Note: It is impossible to remove all oxides from aluminum due to its natural affinity to oxidize upon exposure to air.)

Filler metals for brazing aluminum are available in wire, powder and paste, foil and as clad sheet. Not all filler metals are available in all forms. Some may be very difficult to locate in small quantities domestically, if at all. Aluminum filler metals are also sometimes used to braze titanium alloys.

Alloy Type	Filler Metal Name	Typical Applications
Aluminum Filler Metals	AL 713	A general purpose brazing filler metal to join aluminum and aluminum alloys. The corrosion resistance of AL 713 is satisfactory but somewhat lower than that of AL 718 alloy.
	AL 714	A general purpose brazing filler metal to join aluminum and aluminum alloys, generally when a more sluggish alloy is needed to bridge wide gaps.
	AL 718	A general purpose brazing filler metal to join aluminum and aluminum alloys. Most fluid of the aluminum filler metals.
	AL 802	A general purpose, free flowing soft soldering filler metal for joining of all solderable grades of aluminum and aluminum alloys when using open air heating methods.
	AL 822	A general purpose aluminum brazing filler metal for joining of all brazeable grades of aluminum and aluminum alloys when using open air heating methods. Common filler metal for joining copper to aluminum and repair work on aluminum.

Flux Cored Filler Metals

Flux cored materials can be used to simplify and improve most metal joining operations because they eliminate a separate fluxing operation, and reduce the brazing cycle time. In addition, our tests indicate that joints made with flux cored materials are higher quality and significantly stronger due to a consistent flux application and the subsequent reduction in flux inclusions (or voids) at the interface.

We offer a variety of flux cored materials for most general purpose brazing applications. We also offer several flux options so we can tailor a product to your application, heating method, and joint configuration.

Aluminum wire and rings are also available with a variety of fluxes including corrosive and non-corrosive formulations.

Alloy Type	Filler Metal Name	Heating Methods*	Solidus		Liquidus	
			F	C	F	C
Flux Cored Filler Metals	HANDY ONE 299	O	1250	677	1450	788
	HANDY ONE 300	O	1250	677	1410	766
	HANDY ONE 380	O	1200	649	1330	721
	HANDY ONE 505	O	1220	660	1305	707
	HANDY ONE 560	O	1145	618	1205	652
	HANDY ONE SILVACUT	O	Proprietary		1274	690
	AL CORROSIVE CORED	O	1070	577	1080	582
	AL CONE CORED	O	1070	577	1080	582
	HANDY ONE AL 718	O	1070	577	1080	582
	HANDY ONE AL 802	O	710	377	725	385
	HANDY ONE AL 822	O	800	427	900	482

* Recommended heating methods: O = Open Air, C = Controlled Atmosphere, V = Vacuum Atmosphere

	Heating Methods*	Solidus		Liquidus		Max. Recommended Brazing Temps		Nominal Composition				Joint Color as Brazed	Density (Toz/in^3)
		F	C	F	C	F	C	Al	Si	Zn	Others		
	OCV	1070	577	1142	617	1150	621	92.5	7.5	0	0	Grayish White	1.41
	OCV	1070	577	1110	599	1120	604	90	10	0	0	Grayish White	1.47
	OCV	1070	577	1080	582	1120	604	88	12	0	0	Grayish White	1.4
	O	710	377	725	385	755	402	2	0	98	0	Grayish White	3.63
	O	800	427	900	482	1000	538	22	78	0	0	Grayish White	2.77

Flux Coated Filler Metals

Flux coated braze materials were designed to improve productivity, reduce cycle times, and eliminate variability.

In cases where two flat surfaces are to be brazed, many customers turn to braze alloy in the form of strip. Strip is ideal for covering large surface areas or for sitting flush between two components where wire would cause the parts to sit unevenly. This makes strip the ideal preform solution for use between two components, such as a carbide blank and a steel body.

Strip preforms can be designed in various geometries, such as shim or washer preforms - a great solution for when two parts require intimate contact during the braze cycle.

While alloy form and selection are critical aspects of a braze joint, flux is also an integral part in torch and induction brazing. To promote strong joints, a proper amount of flux is required and, in most cases, when left to manual application flux is either under- or over-applied.

When flux is underapplied, the flux present will saturate quickly during heating, and oxide build up will prevent the braze alloy from flowing and bonding effectively along both substrates. When flux is overapplied, the alloy cannot effectively flush the flux out of the joint resulting in flux inclusions and voids, which lead to lower joint strength. ***See page 25 to learn more about ULTRACOAT.***

Alloy Type	Filler Metal Name	Heating Methods*	Solidus		Liquidus	
			F	C	F	C
Flux Coated Filler Metals	ULTRACOAT 505	O	1220	660	1305	707
	ULTRACOAT 560	O	1145	618	1205	652
	ULTRACOAT SILVACUT	O	Proprietary		1274	690
	ULTRACOAT TRIMET 259	O	1220	660	1305	707
	ULTRACOAT HI-TEMP 548	O	1615	879	1685	918
	ULTRACOAT AL 718	O	1070	577	1080	582

This table is intended to cover only a few typical applications of the most frequently used brazing filler metals.
For special brazing applications, contact our Technical Services Department.

Filler Metals Based on Standard Specifications

Alloy Type	Filler Metal Name	American Welding Society (AWS) Classification A5.8/A5.8M	Society of Automotive Engineers (SAE) AMS	International Organization Standardization (ISO) 17672**	Federal Specification QQ-B-654
Silver-Copper-Phosphorous Filler Metals	SIL-FOS 2	BCuP-6	--	CuP 280	--
	SIL-FOS 5	BCuP-3	--	CuP 281	--
	SIL-FOS 6	BCuP-4	--	CuP 283	--
	SIL-FOS 15	BCuP-5	--	CuP 284	BCuP-5
	SIL-FOS 18	BCuP-8	--	BCuP-8	--
Copper-Phosphorous Filler Metals	Fos Flo	BCuP-2	--	CuP 181	--
Cadmium-Bearing Silver Filler Metals	EASY-FLO 25	BAg-27	--	--	--
	EASY-FLO 30	BAg-2a	--	--	--
	EASY-FLO 35	BAg-2	4768	Ag 335	--
	EASY-FLO 45	BAg-1	4769	Ag 345	GR VII
	EASY-FLO 3	BAg-3	4771	Ag 351	GR V
	EASY-FLO	BAg-1a	4770	Ag 350	GR IV
Silver Filler Metals	SILVALOY 255	BAg-37	--	Ag 125	--
	SILVALOY 300	BAg-20	--	--	BAg-20
	SILVALOY 340	--	--	Ag 134	--
	SILVALOY 351	BAg-35	--	Ag 235	--
	SILVALOY 380	BAg-34	4761	Ag 138	--
	SILVALOY 401	--	4762	--	--
	SILVALOY 402	BAg-28	--	Ag 140	--
	SILVALOY 403	BAg-4	--	Ag 440	BAg-4
	SILVALOY 450	BAg-5	--	Ag 245	BAg-5
	SILVALOY 452	BAg-36	--	--	--
	SILVALOY 495	BAg-22	--	Ag 449	BAg-22
	SILVALOY 501	BAg-6	--	Ag 250	--
	SILVALOY 503 VTG	BVAg-6b Grade 2	--	--	--
	SILVALOY 505	BAg-24	4788	Ag 450	--
	SILVALOY 541	BAg-13	4772	Ag 454	--
	SILVALOY 550	--	--	Ag 155	--
	SILVALOY 559	BAg-13a	4765	--	BAg-13a
	SILVALOY 560	BAg-7	4763	Ag 156	BAg-7
	SILVALOY 603	BAg-18	4773	Ag 160	--
	SILVALOY 604 VTG Gr1 & Gr2	BAg-18 Grade 1 & Grade 2	4773	--	BAg-18
	SILVALOY 630	BAg-21	4774	Ag 463	--
	SILVALOY 650	BAg-9	--	Ag 265	BAg-9
	SILVALOY 700	BAg-10	--	Ag 10	BAg-10
	SILVALOY 716 VTG Gr2	BVAg-8b Grade 2	--	--	--
	SILVALOY 717 VTG Gr1	BVAg-8b Grade 1	--	--	--
	SILVALOY 720	Bag-8	--	--	--
	SILVALOY 721 VTG Gr1	BVAg-8 Grade 1	--	--	--
	LITHOBRAZE 720	BAg-8a	--	--	BAg-8a
	LITHOBRAZE 925	BAg-19	4767	--	--

**Available upon request.

Filler Metals Based on Standard Specifications (Continued)

Alloy Type	Filler Metal Name	American Welding Society (AWS) Classification A5.8/A5.8M	Society of Automotive Engineers (SAE) AMS	International Organization Standardization (ISO) 17672**	Federal Specification QQ-B-654
Copper Filler Metals	CDA 101	BVCu-1x	--	--	--
	CDA 102	BCu-3	4501 (Sheet - Chemistry Only) 4701 (Wire - Chemistry Only)	--	--
	CDA 110	BCu-1b	4500 (Chemistry Only)	Cu 110	--
	CDA 680	RBCuZn-B	--	--	--
	CDA 681	RBCuZn-C	--	Cu 681	--
Gold and/or Palladium Filler Metals	PREMABRAZE 127	BAu-3, BVAu-3 Grade 1 and 2 (Chemistry Only)	--	Au 351	--
	PREMABRAZE 131	BVAu-4 Grade 1	4787	Au 827a	--
	PREMABRAZE 180	BVPd-1 Grade 1 and 2	--	Pd 657a	--
	PREMABRAZE 300	BAu-5	4785	Au 300	--
	PREMABRAZE 399	BAu-1	--	Au 375a	--
	PREMABRAZE 402	BVAu-10 Grade 1 and 2	--	Au 503	--
	PREMABRAZE 407	BVAu-9 Grade 1 and 2	--	Au 354	--
	PREMABRAZE 500	BVAu-7 Grade 1 and 2	4784	Au 507	--
	PREMABRAZE 540	BVAg-32 Grade 1 and 2	--	--	--
	PREMABRAZE 580	BVAg-31 Grade 1 and 2	--	Pd 387a	--
	PREMABRAZE 616	BVAg-29 Grade 1	--	Ag 261	--
	PREMABRAZE 680	BVAg-30 Grade 1 and 2	--	--	--
	PREMABRAZE 700	BAu-6	4786	Au 700	--
Nickel Filler Metals	HI-TEMP 095	--	4764	--	--
	HI-TEMP 720	BNi-1	4775	Ni 600	--
	HI-TEMP 773	RBCuZn-D	--	--	--
	HI-TEMP 801	BCo-1	--	Co 900	--
	HI-TEMP 820	BNi-2	4777	Ni 620	--
	HI-TEMP 850	BNi-5	4782	Ni 650	--
	HI-TEMP 851	BNi-5a	--	--	--
	HI-TEMP 910	BNi-3	4778	Ni 630	--
	HI-TEMP 930	BNi-4	4779	Ni 631	--
	HI-TEMP 932	BNi-6	--	Ni 700	--
	HI-TEMP 933	BNi-7	--	Ni 710	--
TRIMET Clad Filler Metals	TRIMET 245	BAg-22	--	--	--
	TRIMET 258	BAg-3	--	--	--
	TRIMET 259	BAg-24	--	--	--
Aluminum Filler Metals	AL 713	BAlSi-2	--	--	--
	AL 714	BAlSi-5	--	Al 110	--
	AL 718	BAlSi-4	4185	Al 112	--
HANDY ONE Filler Metals	SILVALOY 300	BAg-20	--	--	BAg-20
	SILVALOY 380	BAg-34	4761	Ag 138	--
	SILVALOY 505	BAg-24	4788	Ag 450	--
	SILVALOY 560	BAg-7	4763	Ag 156	BAg-7
	AL CORROSIVE CORED	BAlSi-4	4185	Al 112	--
	AL CONE CORED	BAlSi-4	4185	Al 112	--
	AL 718	BAlSi-4	4185	Al 112	--
ULTRACOAT Filler Metals	SILVALOY 505	BAg-24	4788	Ag 450	--
	SILVALOY 560	BAg-7	4763	Ag 156	BAg-7
	TRIMET 259	BAg-24	--	--	--
	AL 718	BAlSi-4	4185	Al 112	--

**Available upon request.

Brazing Fluxes

A flux for every brazing need.

Flux is critical to the brazing and soldering process because it minimizes the oxidation that may form on both the brazing filler metal and the materials being joined. Numerous formulations of flux are available for virtually all metal joining operations.

The majority of common brazing applications are readily met by HANDY Flux, the general purpose flux that has remained an industry standard for over 70 years. It is a powerful general purpose flux that protects your parts up to 1600°F (871°C).

For low temperature brazing, ULTRA FLUX is a creamy and smooth composition that provides excellent adhesion to parts. Its consistent blend will not spatter or run during a rapid heating cycle. ULTRA FLUX offers excellent fluxing action and oxide removal and will not crystallize under normal conditions.

We also offer fluxes for virtually every specialized application, including formulations for high and low temperature applications, furnace and induction brazing, as well as those for automatic flux dispensers.

For more information on any of these fluxes, or a recommendation on which flux to use, contact our Technical Services Department.

Brazing and Soldering Fluxes Listing & Descriptions*

Name of Flux & Form	Application	Description	Availability*
HANDY Flux / HANDY Flux SLS *Paste*	All purpose, low temperature flux for use in brazing both ferrous and nonferrous metals and alloys.	HANDY Flux is an active fluoride/borate-type flux which begins to melt and dissolve oxides at 600°F (320°C). Fully molten at 1100°F (600°C), it provides excellent protection of parts up to 1600°F (870°C). Cleanup should be with hot water.	7oz, 1lb, 5lb, 30lb
ULTRA FLUX *Paste*	General purpose, low temperature brazing flux which provides excellent adhesion and creamy smooth consistency. For brazing ferrous and nonferrous alloys.	Same as HANDY Flux. ULTRA FLUX dissolves the oxides that form on copper brass, nickel, monel, steel and stainless steel during heating. Will not crystallize.	7oz, 1lb, 5lb, 30lb
HANDY Flux Type D *Slurry*	For automatic dispensing as controlled dabs or sprays.	This flux has the same combination of salts as HANDY Flux, with additives to provide a lower (pourable) viscosity.	10lb
HANDY Liquid Flux *Liquid*	For brazing in furnaces with poor atmospheres or joining jewelry parts above 1160°F (625°C).	Used where only a limited fluxing ability is desired.	1pt, 1Qt, 1Ga
HANDY Flux Dry 6040 *Powder*	Primarily used as a general purpose brazing flux in brazing applications involving brazing of steel, stainless steel, copper, copper alloys, nickel, and nickel alloys. It is recommended for use with filler metals that flow between 1100°F (593°C) - 1600°F (871°C).	HANDY Flux Dry 6040 is an active fluoride/borate-type flux in the powder form, which has been specially formulated to give excellent oxidation protection of parts up to 1600°F (871°C).	10lb
ULTRA FLUX CHILL *Paste*	Recommended for use with braze filler metals that flow between 1100°F - 1500°F (600°C - 815°C). This product is recommended for carbide applications such as drill bits, to assist in cleaning braze flux as well as a chilling agent post-braze.	ULTRA FLUX CHILL is a high fluidity general purpose fluxing system. When used with appropriate silver bearing braze filler metal, ULTRA FLUX CHILL will provide sufficient fluxing action to join most ferrous and nonferrous metals providing high strength and hermetically sealed joints.	10lb, 25lb
HANDY Flux Type B-1 / HANDY Flux SLSB *Paste*	For brazing high chromium stainless steels, tungsten and chromium carbides, and molybdenum alloys.	Particularly useful in applications where a larger amount of refractory oxides may form, use HANDY Flux Type B-1 (boron modified). Its temperature range is 1100° to 1700°F (600°-925°C). It is valuable where local overheating may occur, as in fast induction heating.	7oz, 1lb, 5lb, 30lb
HANDY Flux B-1 Dry *Powder*	Recommended with braze filler metals that flow between 1100° to 1700°F (593° – 927°C)	HANDY Flux B-1 Dry is an active fluoride/borate-type flux in powder form, which has been specially formulated to provide excellent protection of parts up to 1700°F (927°C).	10lb, 25lb, 45lb
Ultra Black Flux *Paste*	Same as HANDY Flux B-1. Ideally suited for induction heating where localized over-heating, or longer heating cycles may occur.	Same as HANDY Flux B-1. Ideally suited where refractory oxides may form (chromium tungsten, etc.). Better brushability and excellent adhesion –will not spatter.	7oz, 1lb, 5lb, 30lb

NOTE: For information on proper fluxing procedures, see page 16.

*To learn more about availability, contact Lucas Milhaupt Customer Service.

Brazing and Soldering Fluxes Listing & Descriptions* (Continued)

Name of Flux & Form	Application	Description	Availability*
HANDY Flux Type A-1 *Paste*	For brazing aluminum bronze and other alloys containing small amounts of aluminum and/or titanium.	Type A-1 will readily flux the difficult, refractory oxides that form on these alloys and permits brazing them both to ferrous and nonferrous alloys. It is not recommended for use with aluminum- or titanium-base alloys. Active range: 1100° - 1600°F (600°-870°C).	1lb
HANDY Flux HI-TEMP *Paste*	Used where brazing temperatures go into the 1600° - 2000°F (870°-1100°C) range or for considerable lengths of time above 1450°F.	This high temperature flux contains still less flouride than Type LT. It is often used with brazing alloys melting above 1600°F (870°C)– and provides the adherence and fluxing action a general purpose flux cannot give at these temperatures.	1lb, 30lb
HANDY Flux HI-TEMP Boron Modified *Paste*	For high temperature Ag, Cu, Ni brazing in the range of 1600° to 2200°F (870°-1200°C), involving longer time or base metals with refractory oxides.	Particularly useful where refractory oxides are formed on the metals being joined. This added capability results from addition of a small amount of finely powdered boron to the flux.	1lb, 30lb
SILVABRITE Soldering Flux *Paste*	Recommended for use with solder filler metals that flow between 350°F - 500°F (177°C - 260°C). This product is recommended for use with the SILVABRITE alloys which includes silver-tin, silver-tin-copper, or tin-antimony combinations.	SILVABRITE Paste Solder Flux is a zinc chloride containing flux developed for soldering of steel, copper, brass, nickel and plated base metals. This paste is recommended for use in most soldering applications including torch and furnace.	4oz, 1lb
HANDY Flux Type TEC *Liquid*	For metal joining at temperatures in the 500° - 800°F (260°-425°C) range.	This widely used liquid flux provides excellent performance in soldering applications.	1pt, 1Qt, 1Ga
CX60 *Paste*	Designed for use with aluminum brazing filler metals for joining of 1000, 3000, 6000 and some 5000 and 7000 series aluminum alloys in an open air brazing processes.	CX-60 is a non-corrosive flux slurry that consists of an exclusive combination of fluorides and a binder system. This product is non-corrosive and the flux residue does not need to be removed from the assembly following the brazing operation.	Contact Lucas Milhaupt Customer Service for Availability

NOTE: For information on proper fluxing procedures, see page 16.

*To learn more about availability, contact Lucas Milhaupt Customer Service.

Brazing Fluxes Based on Standard Specifications

AWS Brazing Flux Classification	Fed. Spec. O-F-499d (2/6/85)	Society of Automotive Engineers AMS	Lucas Milhaupt Brazing Flux Corresponding to Standard Specifications
FB3A	-	3410	HANDY Flux / HANDY Flux SLS
FB3A	Type B	3410	ULTRA FLUX
FB3G	-	-	HANDY Flux Type D
FB3E	-	-	HANDY Liquid Flux
-	-	-	HANDY Flux Dry
-	-	-	ULTRA FLUX CHILL
FB3C †	-	3411	HANDY Flux Type B-1 / HANDY Flux SLSB
FB3F	-	-	HANDY Flux B-1 Dry
FB3C †	-	3411	Ultra Black Flux
FB4A	-	-	HANDY Flux Type A-1
FB3D †	-	3417	HANDY Flux HI-TEMP
FB3D †	-	3417	HANDY Flux HI-TEMP Boron Modified

† AWS FB3C and FB3D were formerly type 3B.

Brazing Alloys in Powder Form

The atomization process is conducted in an inert gas atmosphere. As a result, the brazing alloy powders are exceptionally clean and free of oxides and impurities.

Most Lucas Milhaupt brazing alloys can be supplied in atomized forms. Control of particle size is extremely close. The powders are supplied in all standard mesh sizes, and may also be furnished, with the same close controls, to size limitations specified by the customer. Filed powders, produced in coarse-sized particles, are also available.

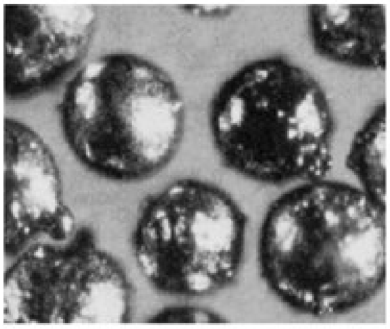
A range of atomization options enables us to meet wide variations in customer requirements—rapidly and economically, providing you the highest quality brazing alloy powders.

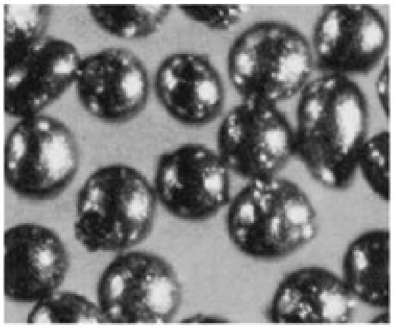
Particle Size Comparison Chart

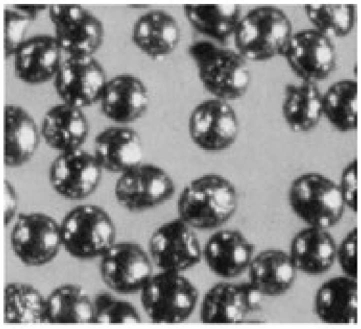
Measurements				Sieve (Screen)	
Millimeters (mm)	Microns (μ)	Inches (in)	Mils	U.S. Std. Sieve Designation*	Tyler Std. Sieve
0.0254	25.4	0.00100	1.00	-	-
0.0318	31.8	0.000125	1.25	-	-
0.0381	38.1	0.00150	1.50	38 μm (No. 400)	400 mesh
0.0445	44.5	0.00175	1.75	45 μm (No. 325)	325 mesh
0.0508	50.8	0.00200	2.00	-	-
0.0533	53.3	0.00210	2.10	53 μm (No. 270)	270 mesh
0.0635	63.5	0.00250	2.50	63 μm (No. 230)	250 mesh
0.0737	73.7	0.00290	2.90	75 μm (No. 200)	200 mesh
0.0762	76.2	0.00300	3.00	-	-
0.0889	88.9	0.00350	3.50	90 μm (No. 170)	170 mesh
0.1016	101.6	0.00400	4.0	-	-
0.1050	105.0	0.00413	4.13	106 μm (No. 140)	150 mesh
0.1250	125.0	0.00492	4.92	125 μm (No. 120)	115 mesh
0.1490	149.0	0.00587	5.87	150 μm (No. 100)	100 mesh
0.1770	177.0	0.00697	6.97	180 μm (No. 80)	80 mesh
0.2500	250.0	0.00984	9.84	250 μm (No. 60)	60 mesh
0.4200	420.0	0.01654	16.54	425 μm (No. 40)	35 mesh
0.8410	841.0	0.03311	33.11	850 μm (No. 20)	20 mesh
1.000	1000.0	0.03937	39.37	1 mm (No. 18)	16 mesh

*In accordance with ASTM E11, "Wire-Cloth Sieves for Testing Purposes"

Shown below are photographs of Lucas Milhaupt's SIL-FOS 5 powder in three standard mesh sizes. Photographs are all enlarged 100 times. Note the consistency of particle size and shape in all three sizes.







Brazing & Soldering Pastes: Materials Selection Chart

Paste products consist of an atomized filler metal powder, a flux (when necessary) and a binder to hold the components together in suspension. Pastes, like preforms, are advantageous because with the correct dispensing equipment, tight control can be exerted on material usage. This can reduce your unit costs and yield consistent high quality joints. And because pastes are essentially formless in nature, one paste product could be suitable for a wide variety of joint configurations.

Additional advantages of pastes include the ability to control so many of the performance characteristics. For example, the viscosity or thickness of the paste can be modified for your particular dispensing requirements. Another characteristic that can be adjusted is the size of the filler metal powder, and we offer a range of particle sizes to provide the best balance between cost and performance. Paste can also be formulated to behave differently during the heating cycle. This is referred to as the "slump" or restrictiveness of the product.

Because we offer so many different options, it is recommended that a Lucas Milhaupt Application Engineer is involved in the selection of the paste. Discussion on the specifics of your operation enables us to recommend the most suitable paste formulation.

Lucas Milhaupt offers a number of flux-binder systems for most brazing and soldering applications including those below.

Binder System	Active Range for Flux	Application & Uses
HANDY FLO 100 Series	1100˚F – 1650˚F 550˚C – 900˚C	General purpose flux binder systems for use with most common brazing alloys in torch, induction and resistance brazing operations.
HANDY FLO 200 Series	1500˚F – 2200˚F 800˚C – 1200˚C	Designed for higher temperature brazing applications in the 1500˚ - 2200˚F range. For use in torch, induction, resistance brazing operations.
HANDY FLO 300 Series	Flux Free	Exceptionally clean-burning system for controlled atmosphere and vacuum brazing operations. For use with High Purity or VTG brazing alloys.
HANDY FLO 400 Series	Flux Free	High temperature furnace binder system for brazing in exothermic, dissociated ammonia, and vacuum. Typically used with Ni, Cu, and bronze brazing alloys.
HANDY FLO 600 Series	1100˚F – 1650˚F 550˚C – 900˚C	The HANDY FLO 600 series is a clean-burning, furnace brazing binder system for use with the CuproBraze® alloys for joining copper and brass radiators.
HANDY FLO 700 Series	930˚F – 1100˚F 500˚C – 600˚C	Flux binder series for use with aluminum brazing alloys in open-air (torch, induction) operations. Available in both corrosive and non-corrosive formulations.
HANDY FLO 800 Series	300˚F –600˚F 150˚C – 315˚C	Low temperature, flux binder systems for soldering applications under 450˚C / 840˚F. For use in open-air applications including torch, induction, resistance, infrared, and oven. Easy clean up with a water rinse.

NOTE: These flux binder systems are blended with an appropriate filler metal powder to form a completed paste product. For additional information or assistance in selecting the right combination of flux binder and filler metal, please contact our Technical Services Department at 414-769-6000 or via email at LM_TechService@lucasmilhaupt.com.

CuproBraze® is a registered trademark of the International Copper Association, Ltd.

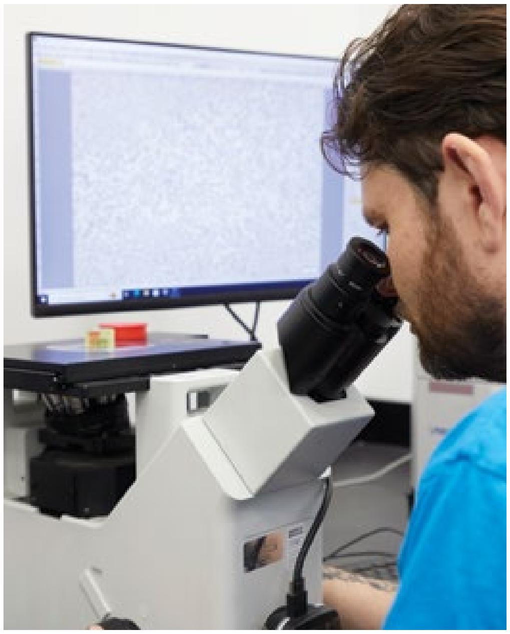
Section 4: The Lucas Milhaupt Advantage

The Center of Excellence

The Center of Excellence (COE) at Lucas Milhaupt is a state-of-the-art innovation hub equipped with advanced equipment and expert staff dedicated to researching, developing, and testing cutting-edge material joining solutions. This collaborative environment allows customers to work closely with Lucas Milhaupt engineers on their brazing challenges, ensuring the highest quality and efficiency in their operations.

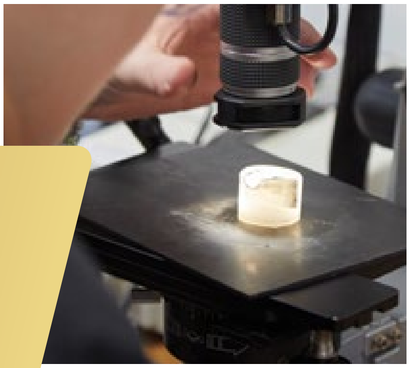
Brazing Lab

Our in-house Brazing Lab is used for product development and testing as well as customer trials and evaluations. We utilize automated oscillating and robotic controlled torch stations as well as a manual torch bench to mimic flame brazing operations. We also have air, controlled atmosphere, and vacuum capable equipment readily available to replicate and develop furnace and induction processes.



Metallurgical Lab

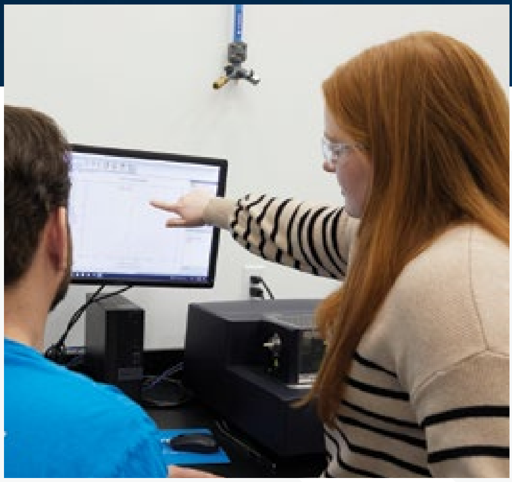
We have an advanced analysis lab with a wide range of capabilities used to investigate material properties, determine route cause to failure, and conduct process validation. This lab is designed to accommodate both industrial and research testing, under the supervision of our experts, and offers a wide selection of analytical instruments that cover thermal examination, microscopic investigation, compositional characterization, size and surface analysis of particles, and mechanical testing.

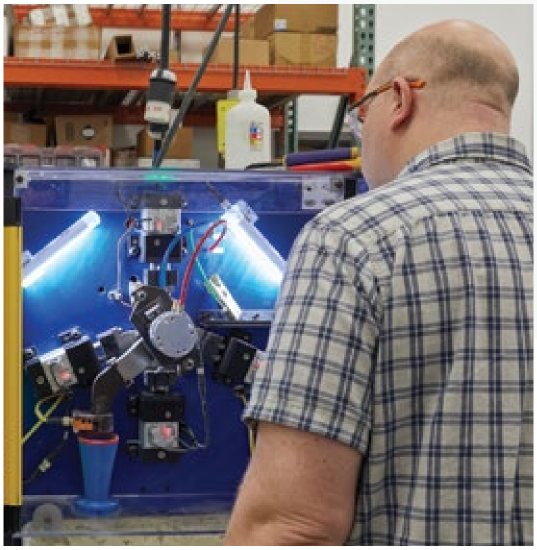


Next-Generation Joining Solutions Start Here

Contact Lucas Milhaupt to get started on your next project and bring your innovations to market quickly.

The Center of Excellence provides a space for internal validation, product testing, process replication, and analysis of customer samples, fostering innovation and collaboration in brazing technology.





Manufacturing Simulation

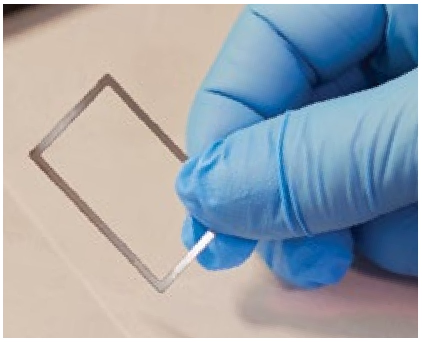
Within our COE Lab we have an entire braze alloy development center including metal casting, heat treatment, rolling, drawing, and stamping capabilities. This area is used to imitate our production floor to improve our processes as well as quickly create prototypes and materials used for development and testing.

Chem Lab

The chemical lab is a designated space to conduct both analytical and developmental work specifically for our formulated products. We conduct validation testing as well as support our customers through testing various fluxes, pastes, and powders both through processing and brazing end use.

Capabilities

At Lucas Milhaupt, we ensure efficient and reliable brazing solutions through complete in-house production. From casting to final cutting, our vertically integrated, USA-based facilities control every step, guaranteeing high-quality results. Explore our capabilities designed to meet your brazing needs with precision and consistency.



Lucas Milhaupt is the most diversified vertically integrated brazing alloy producer in the U.S.

Casting

All specialty alloys are cast in-house, which allows Lucas Milhaupt full control over the raw materials used in our brazing alloys.

Atomization

The powder for our braze pastes is atomized in-house using our four state of the art atomizers, allowing us full control over particle morphology, size, and distribution.

Flux Coating / Coring

We produce our flux cored and coated braze alloys in-house, which guarantees that you get the perfect amount of the highest quality flux every time.

Wire Fabrication

Our expertise in drawing brazing alloys allows us to produce precision wires, rods, rings, and slugs that deliver the right amount of alloy exactly where needed.

Strip Fabrication

We expertly roll brazing filler metals into spools or coils, then fabricate custom strip preforms or micropreforms through stamping or laser cutting for precise geometries.

Laser Cutting

Laser cutting of preforms ensures fast, repeatable parts every time, even with very thin and geometrically complex parts.

Vertical Integration

Everything from the initial casting of the material to the final rolling and cutting of preforms is done in-house. There are no subcontracted services to slow down the process.

USA-Based

All material production takes place in either our Warwick, RI or Cudahy, WI facilities.

Quality Assurance

As an AS9100 and ISO 9001 supplier, we deliver consistent, high-quality braze and solder products. Our quality assurance team ensures that every order meets precise customer specifications.

Technical Support Services

Lucas Milhaupt is not only a leading supplier of brazing and soldering products and services but also your complete source for technical information and assistance. Our team of chemists, metallurgists, and engineers is ready to provide expert technical support.

Our technical support staff helps customers solve their biggest brazing and soldering challenges.

Customer Assistance

Our technical support staff helps customers solve their brazing and soldering challenges by recommending appropriate alloys and offering various alternatives. This is achieved through test brazing of customer components, examination of previously brazed assemblies, and feasibility studies to explore options and their benefits.

Brazing Audits

A Lucas Milhaupt brazing audit involves a thorough examination of a customer's entire material joining operation by our technical service team, focusing on expressed customer pains and the Six Fundamentals of Brazing. After the audit, a detailed report is provided, offering recommendations to improve overall operating efficiencies and costs.

Training Seminars

Customers can benefit from two different Lucas Milhaupt seminars tailored to their specific metal-joining needs:

Fundamentals of Brazing/Design Course
Regional Braze School

This two-and-a-half-day seminar is designed to combine the basics and design aspects of brazing, providing comprehensive training and real-world experience for students at all levels.

- Combines elements from the Fundamentals of Brazing and Brazing and Soldering by Design courses.
- Evaluates and solves actual problem assemblies brought by students.
- Aims to increase brazing/soldering efficiency, reduce costs, and eliminate rejects.
- Tailored sections and discussions to meet specific customer requirements.
- Held nationwide by Lucas Milhaupt's Technical Services Group.

Road Show

We bring the seminar to you with this tailored training session performed right in your plant. The "Road Show" adapts our fundamentals course to meet specific needs and requirements, providing on-site training and support for your brazing and soldering processes.

Analytical Lab

Our Production Analytical Lab performs comprehensive chemical analyses on all cast materials. Using advanced techniques like X-ray fluorescence (XRF) and ICP-OES, we ensure precise measurement of alloy elements and impurities, guaranteeing the quality of every filler metal.

JOIN with the Best™

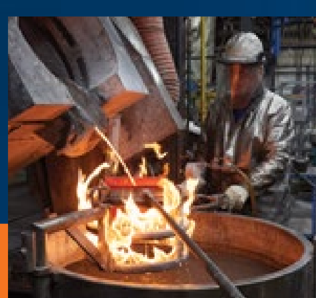
Notes

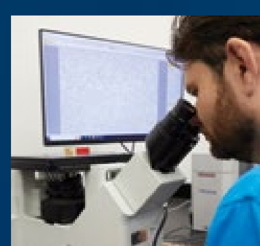
LucasMilhaupt®
A STEEL PARTNERS COMPANY
Join with the Best™

JOIN with the Best™

For more than 80 years, Lucas Milhaupt engineers have helped OEMs design stronger, longer lasting joints. Our brazing experts help manufacturing teams improve their brazing processes and bring innovations to market quickly.

Cudahy, WI, USA	Tel: +1 (414) 769-6000	ISO 9001-2015, ISO 14001-2015, & AS9100D Certified
Warwick, RI, USA	Tel: +1 (401) 739-9550	ISO 9001-2015 Certified
Ribérac, France	Tel: +33 (0) 5 53 92 5300	ISO 9001-2015, ISO 14001-2015, IATF-16949 Certified
Suzhou, China	Tel: +86 (512) 62 89 1510	ISO 9001-2015 Certified





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