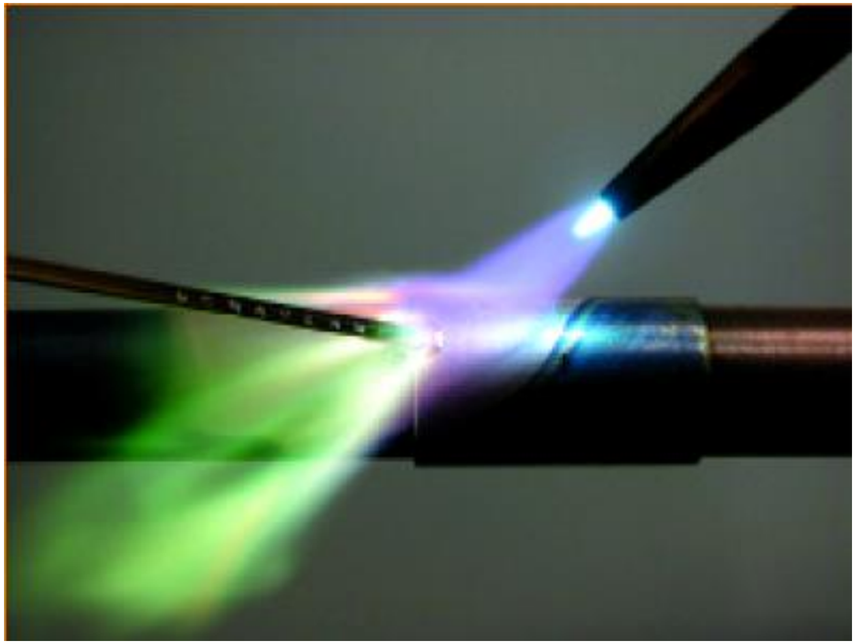
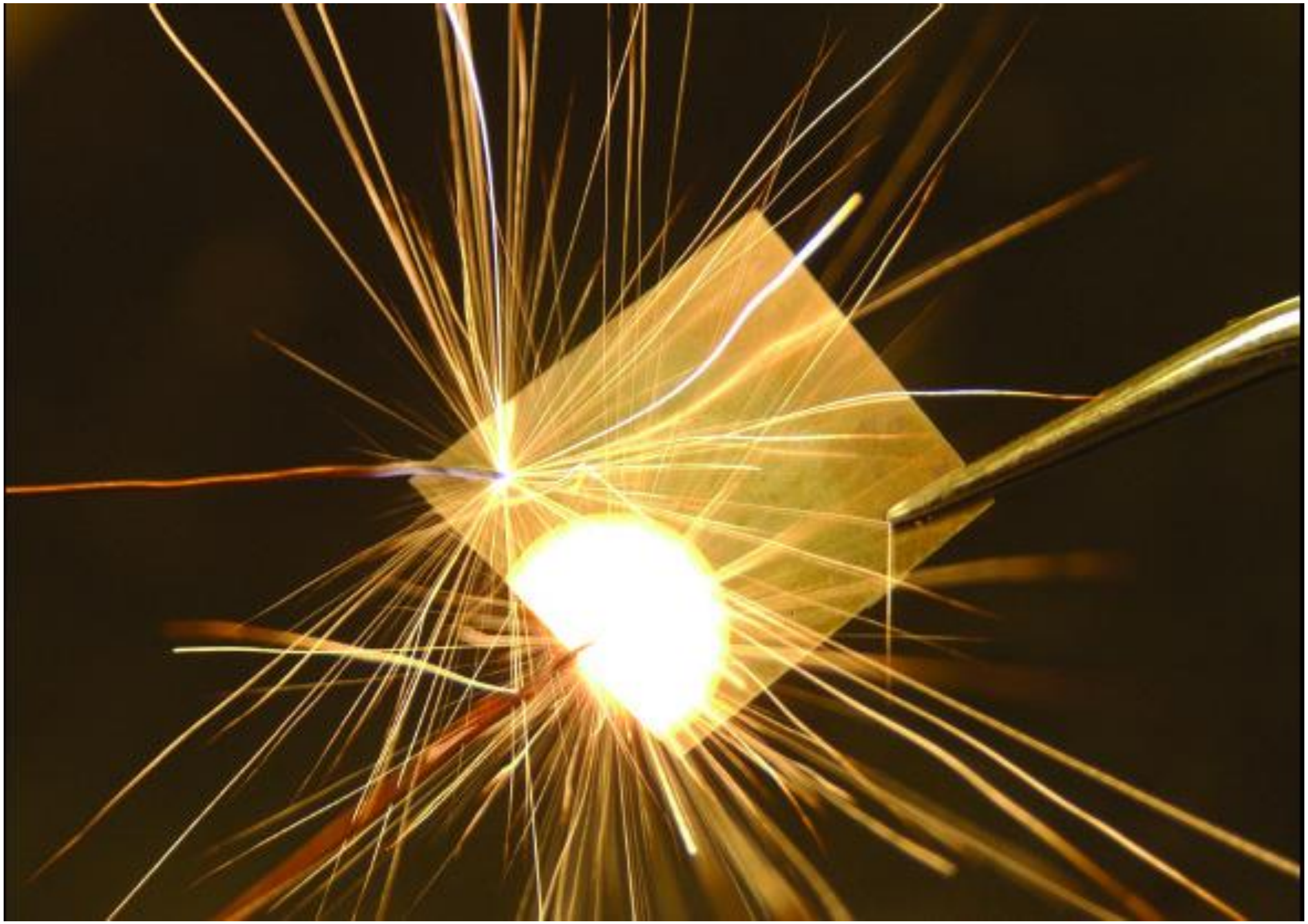
Brazing and Soldering





Comparison of soldering, brazing, and welding

Parameter	Process		
	Soldering	Brazing	Welding
Joint formed	Mechanical	Metallurgical	Metallurgical
Filler metal melt temperature, °C	<450	>450	>450
Base metal	Does not melt	Does not melt	. . .
Fluxes used to protect and to assist in wetting of base-metal surfaces	Required	Optional	Optional
Typical heat sources	Soldering iron; ultrasonics; resistance; oven	Furnace; chemical reaction; induction; torch; infared	Plasma; electron beam; tungsten and submerged arc; resistance; laser
Tendency to warp or burn	Atypical	Atypical	Potential distortion and warpage of base-metal likely
Residual stresses	. . .	. . .	Likely around weld area

- **Brazing** joins materials by heating them in the presence of a filler metal having a liquidus above 450°C but below the solidus of the base metals. Heating may be provided by a variety of processes. The filler metal distributes itself between the closely fitted surfaces of the joint by capillary action. Brazing differs from soldering, in that soldering filler metals have a liquidus below 450°C.
- Brazing does not include the process known as braze welding. Braze welding is a method of welding with a brazing filler metal. In braze welding, the filler metal is melted and deposited in grooves and fillets exactly at the points where it is to be used.

Capillary action is not a factor in distribution of the brazing filler metal. Indeed, limited base metal fusion may occur in braze welding.

Brazing must meet each of three criteria:

(1) The parts must be joined without melting the base metals.

(2) The filler metal must have a liquidus temperature above 450°C.

(3) The filler metal must wet the base metal surfaces and be drawn into or held in the joint by capillary action.

To achieve a good joint using any of the various brazing processes, the parts must be properly cleaned and must be protected by either flux or atmosphere during the heating process to prevent excessive oxidation. The parts must be designed to afford a capillary for the filler metal when properly aligned, and a heating process must be selected that will provide the proper brazing temperature and heat distribution.

Applications

The brazing process is used to join together various materials for numerous reasons. By using the proper joint design, the resulting braze can function better than the base metals being joined. In many instances it is desirable to join different materials to obtain the maximum benefit of both materials and have the most cost- or weight-effective joint. Applications of brazing cover the entire manufacturing arena from inexpensive toys to highest quality aircraft engines and aerospace vehicles. Brazing is used because it can produce results which are not always available with other joining processes.

Advantages of brazing to join components include:

(1) Economical for complex assemblies
(2) Simple way to join large joint areas
(3) Excellent stress and heat distribution
(4) Ability to preserve coatings and claddings
(5) Ability to join dissimilar materials
(6) Ability to join nonmetals to metals
(7) Ability to join widely different thicknesses
(8) Capability of joining precision parts
(9) Joints require little or no finishing
(10) Can do many parts at one time (batch processing)

Limitations of Brazing

A brazed joint is not a homologous body but rather is heterogeneous, composed of different phases with differing physical and chemical properties. In the simplest case, it consists of the base metal parts to be joined and the added filler metal. However, partial dissolution of the base metal, combined with diffusion processes, can change the composition and therefore the chemical and physical properties of the boundary zone formed at the interface between base metal and filler metal and often of the entire joint. Thus, in addition to the two different materials present in the simplest example given above, a complicated transitional or even completely different zone must be considered.

In determining the strength of such heterogeneous joints, the simplified concepts of elasticity and plasticity theory valid for a homogeneous metallic body where imposed stresses are uniformly transmitted from one surface or space element to the adjacent ones--no longer apply. In a brazed joint formed of several materials with different characteristics of deformation resistance and deformation speed, the stresses caused by externally applied loads are nonuniformly distributed.

Mechanics of Brazing

Brazing involves a limited dissolution or plastic deformation of the base metal. Brazing comprises a group of joining processes in which coalescence is produced by heating to a suitable temperature above 450 °C and by using a ferrous or nonferrous filler metal that must have a liquidus temperature above 450 °C and below the solidus temperature of the base metal. The filler metal is distributed between the closely fitted surfaces of the joint. Brazing is distinguished from soldering in that soldering employs a filler metal having a liquidus below 450 °C.

Brazing proceeds through four distinct steps

- The assembly or the region of the parts to be joined is heated to a temperature of at least 450 °c.
- The assembled parts and brazing filler metal reach a temperature high enough to melt the filler metal (foil, wire, paste, platings, etc.) but not the parts.
- The molten filler metal, held in the joint by surface tension, spreads into the joint and wets the base metal surfaces.
- The parts are cooled to solidity, or "freeze," the filler metal, which is held in the joint by capillary attraction and anchors the parts together by metallurgical reaction and atomic bonding.

Brazing Versus Other Welding Processes

The mere fact that brazing does not involve any substantial melting of the base metals offers several advantages over other welding processes. It is generally possible to maintain closer assembly tolerances and to produce a cosmetically neater joint without costly secondary operations. Even more important, however, is that brazing makes it possible to join dissimilar metals (or metals to ceramics) that, because of metallurgical incompatibilities, cannot be joined by traditional fusion welding processes. If the base metals do not have to be melted to be joined, it does not matter that they have widely different melting points. Therefore, steel can be brazed to copper as easily as to steel.

Brazing also generally produces less thermally induced distortion, or warping, than fusion welding. An entire part can be brought up to the same brazing temperature, thereby preventing the kind of localized heating that causes distortion in welding.

- Finally, and perhaps most important to the manufacturing engineer, brazing readily lends itself to mass production techniques. It is relatively easy to automate, because the application of heat does not have to be localized, as in fusion welding, and the application of filler metal is less critical. In fact, given the proper clearance conditions and heat, a brazed joint tends to "make itself" and is not dependent on operator skill, as are most fusion welding processes.

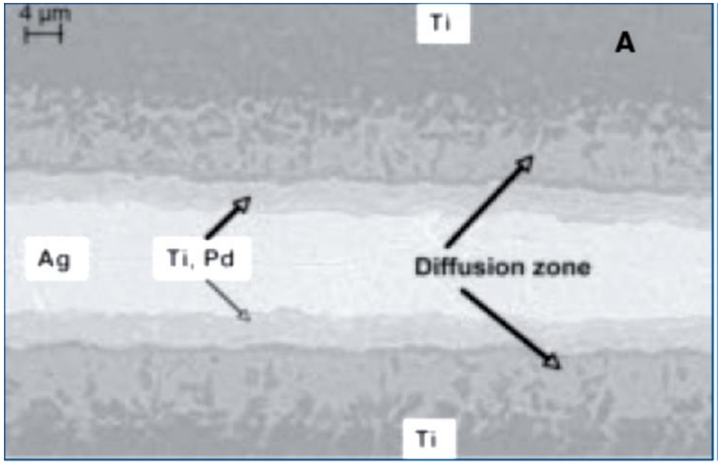
- Automation is also simplified by the fact that there are many means of applying heat to the joint, including torches, furnaces, induction coils, electrical resistance, and dipping. Several joints in one assembly often can be produced in one multiple-braze operation during one heating cycle, further enhancing production automation.
- As noted in Table 1, essentially no melting of the base metal occurs in brazing; however, the temperatures involved can affect the properties of the metals being joined.

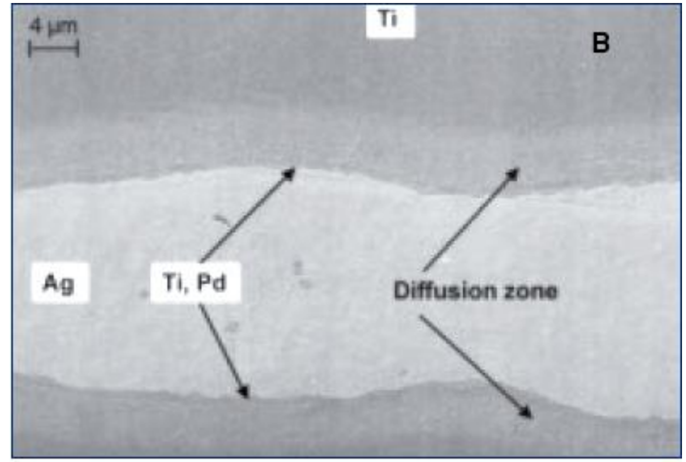
- Mechanical properties obtained by heat treatment may be altered by the heat of brazing. On the other hand, materials in the annealed condition are usually not altered by brazing.
- As with other welding processes, brazing produces a heat-affected zone (HAZ) with a strongly altered microstructure due to intensive mutual mass transfer between base metal and filler metal. The width of this zone varies with the heating process used. In torch and induction brazing, for example, only a localized zone is heated; in france and dip brazing, the entire part is subjected to the brazing temperature. As a rule, the HAZ produced during brazing is wider and less sharply defined than those resulting from other fusion-related processes.

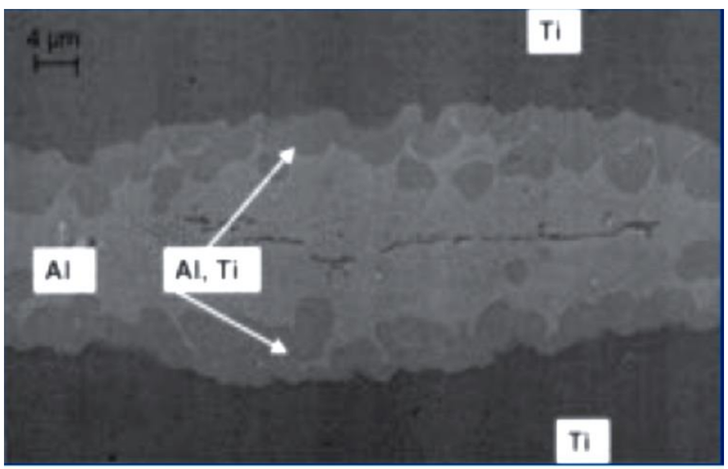
Several elements of the brazing process must be understood in order to produce satisfactory brazed joints:

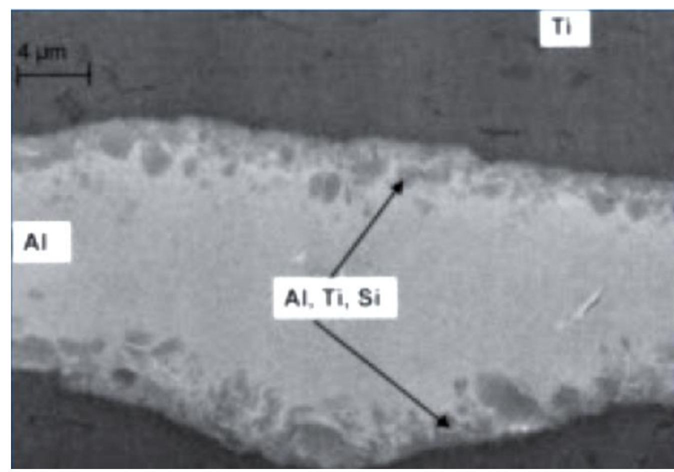
- Filler metal flow
- Base metal characteristics
- Filler metal characteristics
- Surface preparation
- Joint design and clearance
- Temperature and time
- Rate and source of heating

Different Zone in Brazed joints









Solutions to Typical Brazing Problems

PROBLEM	**NO FLOW, NO WETTING**	
	CAUSES:	
	Braze filler	Different lot or wrong one
	Low temp	Poor technique, thermocouple/controller error
	Time	Too short
	Dirty parts	Not cleaned properly
	Poor atmosphere	Too little flux, wrong flux, bad gas or vacuum
	No Ni-plate	Allowing oxidation of base metal
	Gap too large	poor fit up control

PROBLEM	**EXCESS FLOW or WETTING**	**Causes Hole Plugging, Brazing Wrong Joints**
	CAUSES:	
	Temperature too high	Poor technique, furnace error
	Time	Too long
	Too much filler metal	Poor technique, different gap size
	Braze filler	Different lot or wrong one
	No stop off used	

PROBLEM	**EROSION**	**BRAZE FILLER METAL EATS AWAY PARENT METAL**
	CAUSES:	
	Temperature too high	Poor technique, furnace error
	Time at temperature too long	Poor technique, controller error
	Excessive braze filler metal	poor technique, change in gap, parts in different attitude
	Cold worked parts	Highly susceptible
	change in part manufacturer	Not stress relieved
	Braze filler metals are too high above liquidus or high concentration of melting point depressants.	

Soldering

- Like brazing and other joining processes, soldering involves several fields of science, including mechanics, chemistry, and metallurgy. Soldering is a simple operation, consisting of the relative placement of the parts to be joined, wetting the surfaces with molten solder, and allowing the solder to cool until it has solidified.
- Soldering in the field of electronics is in many respects different from soldering in other branches of industry. Although the physical principles of all soldering (and brazing) processes are the same, the features specific to their use in electronics are so numerous that it is possible to speak of soldering in electronics as a separate subject.

Soldering Process Parameters

The parameters that affect wetting and spreading phenomena include:

- Temperature
- Time
- Vapor pressure
- Metallurgical and chemical nature of the surfaces
- Geometry of the solid

Relative solderability of selected metals and alloys

Easy to solder	Less easy to solder
➢ Platinum	➢ Lead
➢ Gold	➢ Nickel plate
➢ Copper	➢ Brass
➢ Silver	➢ Bronze
➢ Cadmium plate	➢ Rhodium
➢ Tin	➢ Beryllium copper
➢ Solder plate	
Difficult to solder	**Very difficult to solder**
➢ Glavanized iron	➢ Chromium
➢ Tin-nickel	➢ Nickel-chromium
➢ Nickel-iron	➢ Nickel-copper
➢ Mild steel	➢ Stainless steel
Most difficult to solder	**Not Solderable**
➢ Aluminum	➢ Beryllium
➢ Aluminum bronze	➢ Titanium

Soldering Versus Other Joining Technologies

Soldering has several clear advantages over competitive joining techniques, such as welding or bonding with conductive adhesives:

- The solder joint forms itself by the nature of the flow, wetting, and subsequent crystallization process, even when the heat and the solder are not directed precisely to the places to be soldered. Because solder does not adhere to insulating materials, it often can be applied in excess quantities, in contrast to conductive adhesives. The soldering temperature is relatively low, so there is no need for the heat to be applied locally as in welding.
- Soldering allows considerable freedom in the dimensioning of joints, so that it is possible to obtain good results even if a variety of components are used on the same product.

- The soldered connections can be disconnected if necessary, thus facilitating repair.
- The equipment for both manual soldering and machine soldering is relatively simple.
- The soldering process can be easily automated, offering the possibility of in-line arrangements of soldering machines with other equipment.

Mass soldering by wave, drag, or dip machines has been the preferred method for making high-quality, reliable connections for many decades. Despite the appearance of new connecting systems, it still retains this position. Correctly controlled, soldering is one of the least expensive methods for fabricating electrical connections. Incorrectly controlled, it can be one of the most costly processes--not because of the initial cost, but because of the many far-reaching effects of poor workmanship.

Solder Metals

The solder metal business has changed dramatically, having moved from merely producing wire to producing bulk, perform, and paste in order to meet the needs of soldering techniques. Solder can be applied in several ways

- A mixture of solder powder and flux, known as **solder paste**, can be applied to the joints by screening, stenciling, or using one of the machines that applies dots of the paste by a simple pneumatic system. This method is especially useful where surface-mounted components are to be soldered and cannot be passed through the solder wave.
- Parts can be pertained, that is, coated with a layer of solder by fluxing and dipping into a bath of the molten metal.
- Solder can be obtained in the shape of rings, washers, or tubes, which are placed on or adjacent to the parts to be joined. These solder performs can be obtained with or without a flux coating.

Quality Control

Once a joint is made, its quality must be assessed through inspection. Advanced technology has produced some electronic assembly designs that are impossible to inspect visually, and an entire group of automated inspection tools has thus evolved. These tools include radiography, infrared signature, and two- or three-dimensional vision systems. Most of these are aided with very sophisticated computer software. The role of inspection, which historically was to locate those joints that needed rework, is changing along with the technology. Inspection is now used as a process-control audit to locate those portions of the process that need improvement or should returned to a position within the control limits. Therefore, the emphasis has shifted from merely shipping an acceptable product to manufacturing it correctly the first time.

Relative solderability of selected metals and alloys as a function of flux type used

Base Metal, Alloy or Applied Finish	Flux Type				Soldering not recommended
	Rosin	Organic	Inorganic	Special flux and solder	
Aluminum	. . .	. . .	. . .	X	. . .
Aluminum-Bronze	. . .	. . .	. . .	X	. . .
Beryllium	. . .	. . .	. . .	. . .	X
Beryllium-Copper	X	X	X	. . .	. . .
Brass	X	X	X	. . .	. . .
Cadmium	X	X	X	. . .	. . .
Cast Iron	. . .	. . .	. . .	X	. . .
Chromium	. . .	. . .	. . .	. . .	X
Copper	X	X	X	. . .	. . .
Copper-Chromium	. . .	. . .	X	. . .	. . .
Copper-Nickel	X	X	X	. . .	. . .
Copper-Silicon	. . .	. . .	X	. . .	. . .
Gold	X	X	X	. . .	. . .
Inconel	. . .	. . .	. . .	X	. . .
Lead	X	X	X	. . .	. . .
Magnesium	. . .	. . .	. . .	. . .	X

Base Metal, Alloy or Applied Finish	Flux Type				Soldering not recommended
	Rosin	Organic	Inorganic	Special flux and solder	
Manganese-Bronze	. . .	. . .	. . .	. . .	X
Monel	. . .	X	X	. . .	. . .
Nickel	. . .	X	X	. . .	. . .
Nickel-Iron	. . .	X	X	. . .	. . .
Nichrome	. . .	. . .	. . .	X	. . .
Palladium	X	X	X	. . .	. . .
Platinum	X	X	X	. . .	. . .
Rhodium	. . .	. . .	X	. . .	. . .
Silver	X	X	X	. . .	. . .
Stainless Steel	. . .	X	X	. . .	. . .
Steel	. . .	. . .	X	. . .	. . .
Tin	X	X	X	. . .	. . .
Tin-Bronze	X	X	X	. . .	. . .
Tin-Lead	X	X	X	. . .	. . .
Tin-Nickel	. . .	X	X	. . .	. . .
Tin-Zinc	X	X	X	. . .	. . .
Titanium	. . .	. . .	. . .	. . .	X
Zinc	. . .	X	X	. . .	. . .
Zinc Die Castings	. . .	. . .	. . .	. . .	X

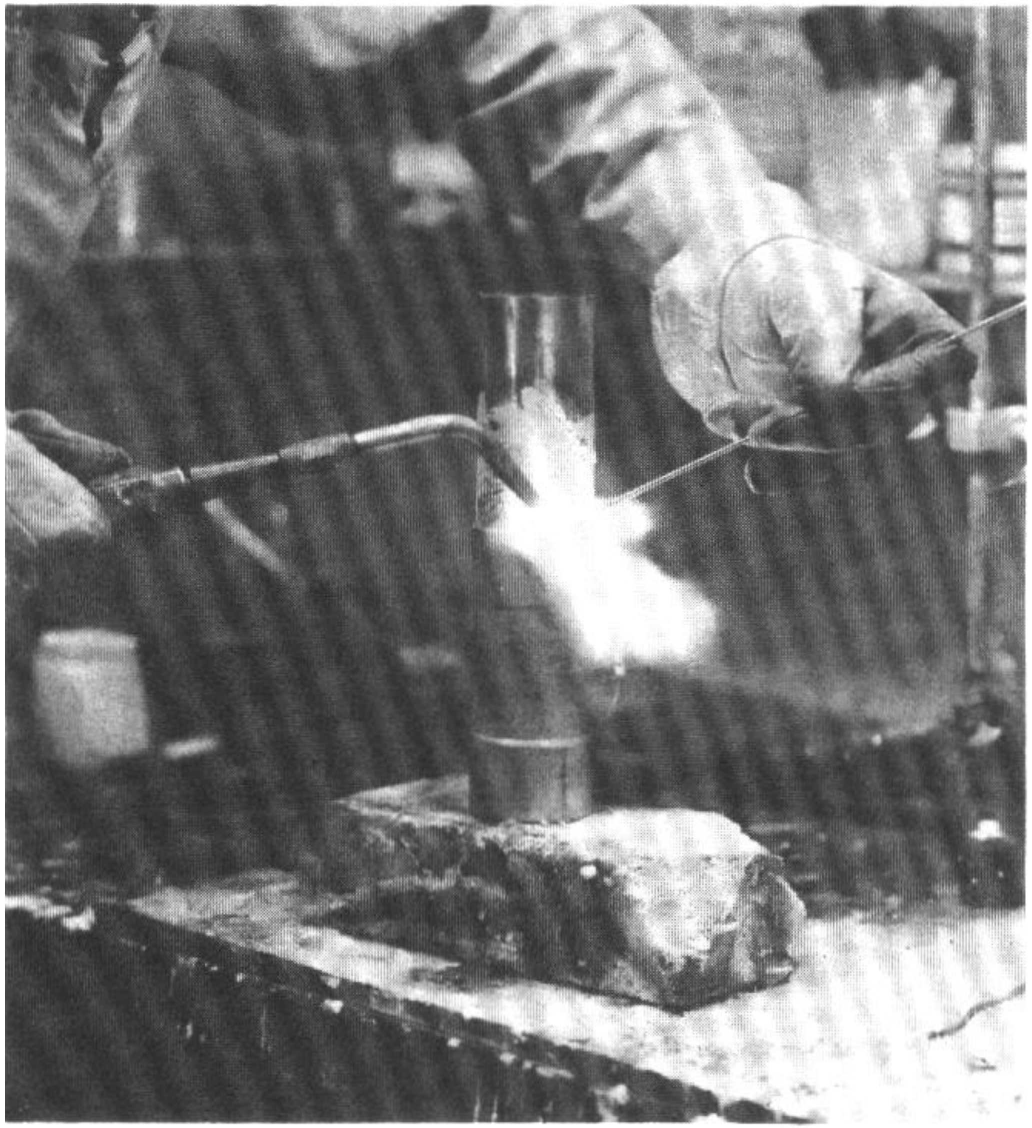


Figure 12.1–Manual Torch Brazing

Classification of Brazing Fluxes with Brazing or Braze Welding Filler Metals

Classification*	Form	Filler Metal Type	Activity Temperature Range °F	Activity Temperature Range °C
FB1-A	Powder	BA1Si	1080-1140	580-615
FB1-B	Powder	BA1Si	1040-1140	560-615
FB1-C	Powder	BA1Si	1000-1140	540-615
FB2-A	Powder	BMg	900-1150	480-620
FB3-A	Paste	BAg and BCuP	1050-1600	565-870
FB3-C	Paste	BAg and BCuP	1050-1700	565-925
FB3-D	Paste	BAg, BCu, BNi, BAu and RBCuZn	1400-2200	760-1205
FB3-E	Liquid	BAg and BCup	1050-1600	565-870
FB3F	Powder	BAg and BCuP	1200-1600	650-870
FB3G	Slurry	BAg and BCuP	1050-1600	565-870
FB3-H	Slurry	BAg	1050-1700	565-925
FB3-I	Slurry	BAg, BCu, BNi, BAu and RBCuZn	1400-2200	760-1205
FB3-J	Powder	BAg, BCu, BNi, BAu and RBCuZn	1400-2200	760-1205
FB3-K	Liquid	BAg and RBCuZn	1400-2200	760-1205
FB4-A	Paste	BAg and BCuP	1100-1600	595-870

* Flux 3B shown in the Brazing Manual, 3rd Edition, 1976 has been discontinued. Type 3B has been divided into types FB3C and FB3D.

Note: The selection of a flux designation for a specific type of work may be based on the form, the filler metal type, and the description above, but the information here is generally not adequate for flux selection. Refer to the latest issue of the Brazing Manual for further assistance.

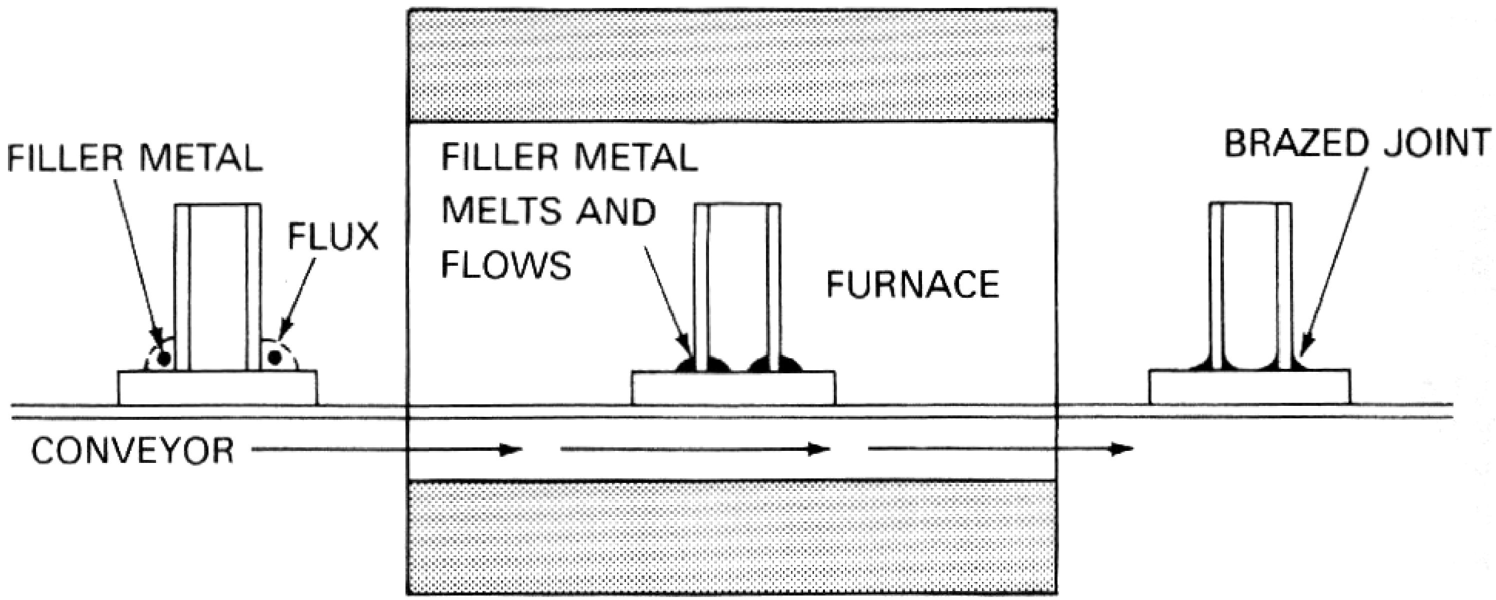


Figure 12.2–Illustration of Furnace Brazing Operation

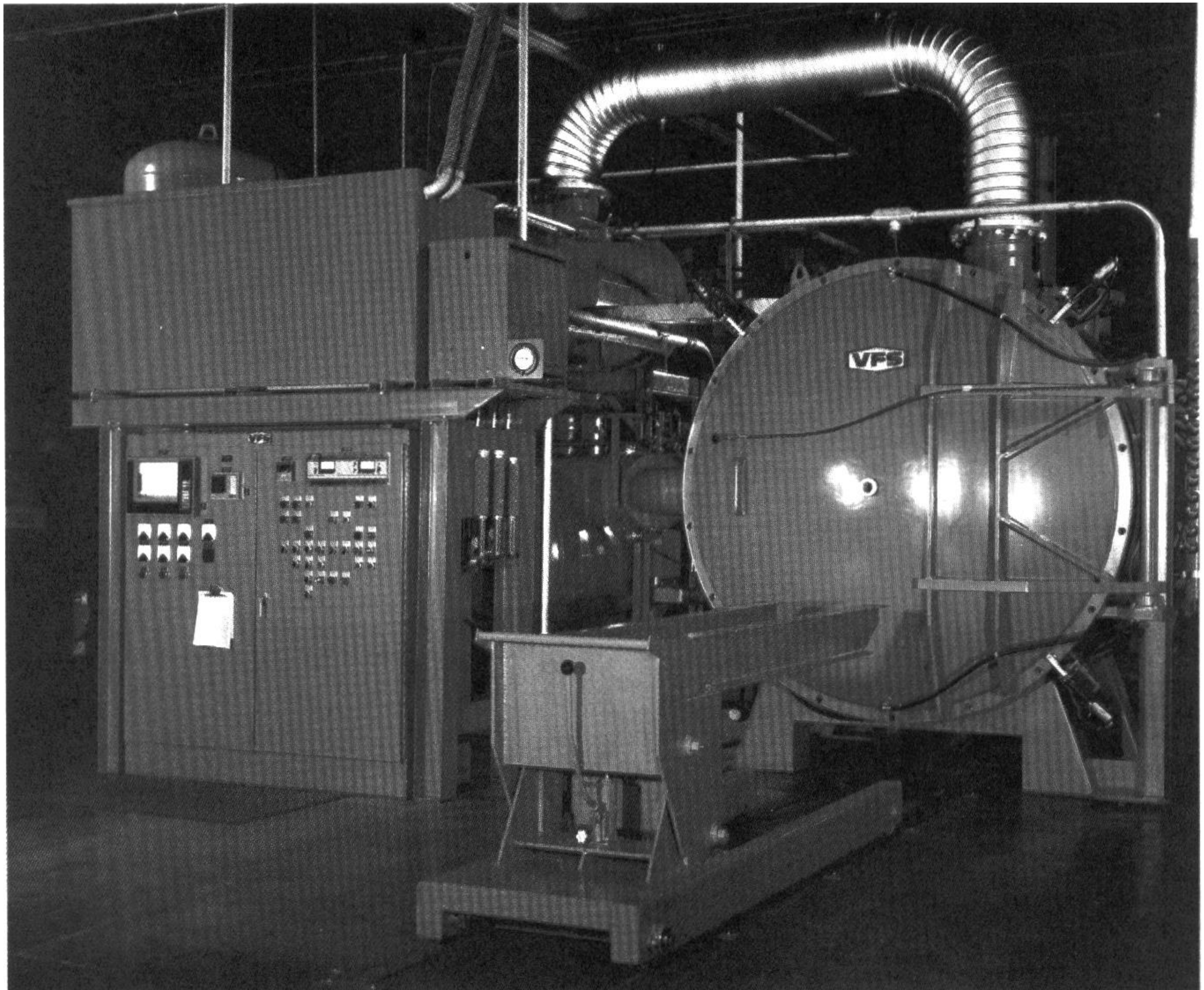


Figure 12.3–A High Temperature, High Vacuum Brazing Furnace with Control Panel and Charging Dolly

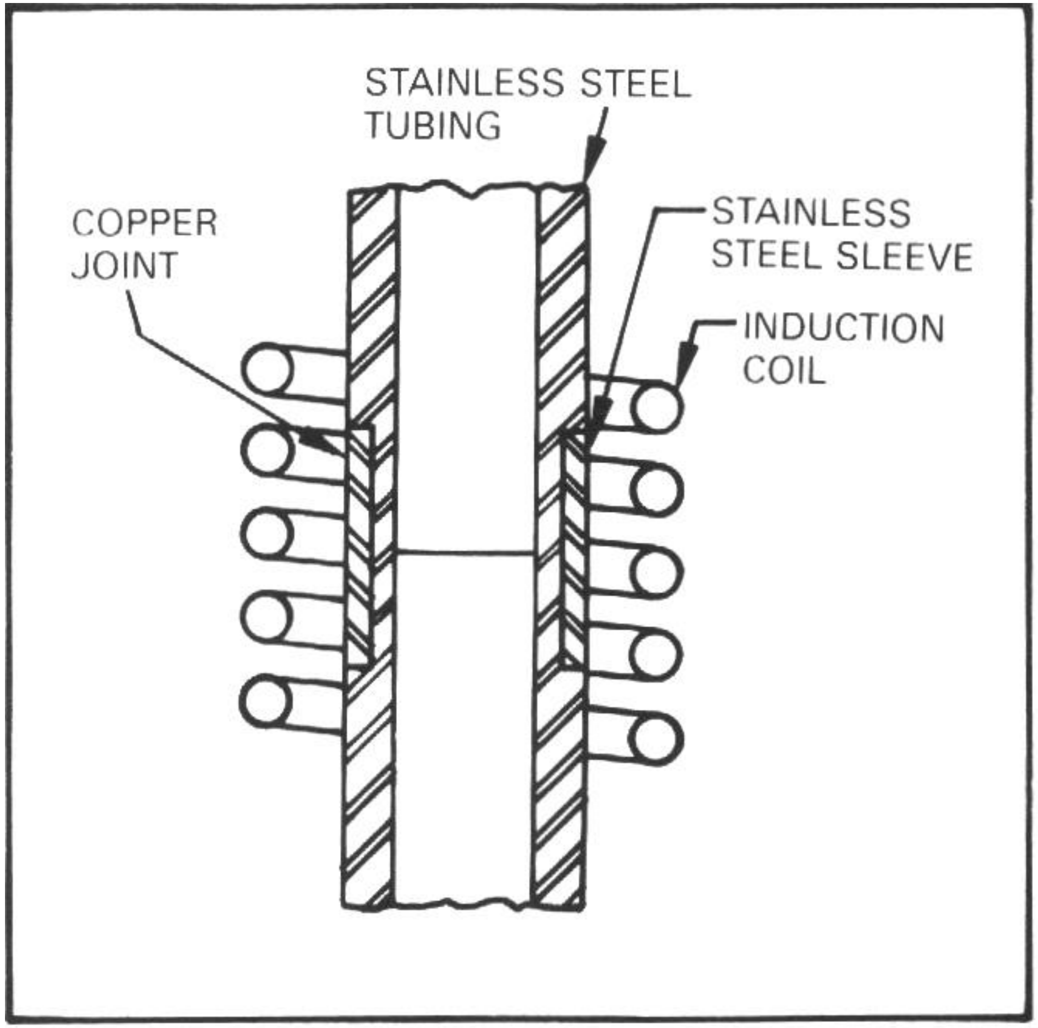


Figure 12.4–Joint in Stainless Steel Tubing Induction Brazed in a Controlled Atmosphere. Note Placement of Joint in Induction Coil.

Figure 12.6–Example of Vacuum Induction Brazing. A Tungsten Carbide Wear Pad is Being Brazing to A Titanium Compressor Blade