Paste Brazing & Soldering Alloys

FUSION INCORPORATED

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Filler Metal • Fluxing Agent • Neutral Binder

The Fusion Paste Process

Paste Alloys

Custom blended to meet your requirements, each Fusion Paste Brazing or Soldering Alloy contains the following basic components:

- **Finely atomized filler metal,** alloyed to exacting standards for composition, melting range, and compatibility with base metals to be joined. Most Fusion alloys conform to industry standards while others are customized for improved properties.
- **Fluxing agent,** designed to remove and prevent reformation of surface oxides during heating. Type and amount are carefully matched to the individual application, ensuring consistent, dependable joints with minimal flux residue.
- **Paste-like binder,** which holds flux and filler metal in stable suspension while minimizing metal-flux interaction. Controlled formulation ensures consistent application and keeps paste alloy localized in the joint area.

Applicators

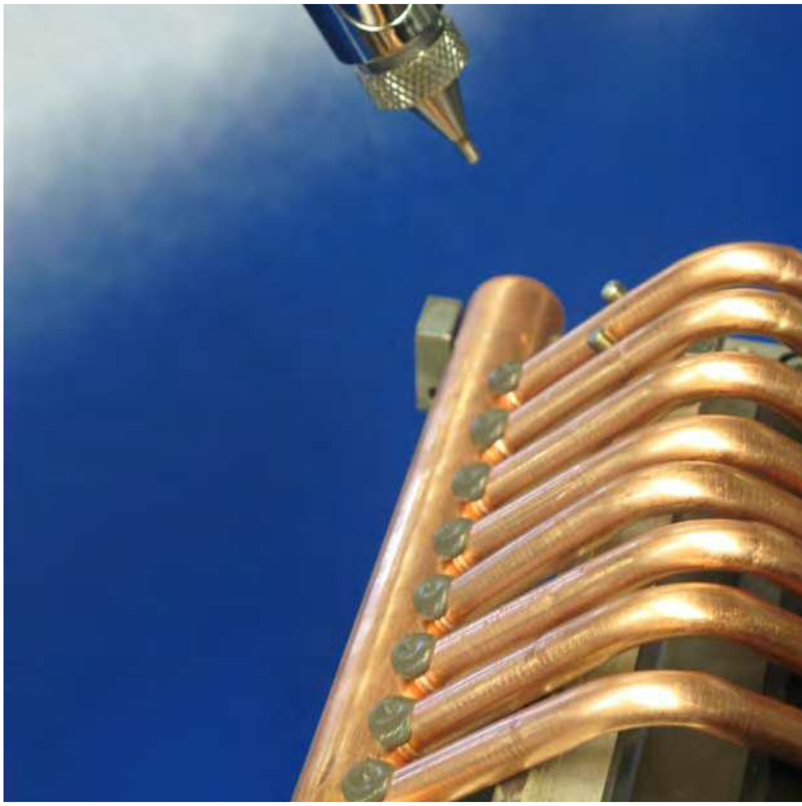
Unlike soldering or brazing alloys in other forms, Fusion Paste Alloys permit single- step application of filler metal and flux to the assembly. The paste alloy itself is stored in a pressurized reservoir, generally sized to meet production requirements for a full 8-hour shift. Fusion positive-displacement applicators may be used for hand-held, semi-automatic dispensing, or built into high-speed production equipment for fully automatic processing.

Heating

Heating may be accomplished by most conventional methods, including open flame, atmospheric or non-atmospheric furnace, infra-red, resistance or induction. At specified temperature, the flux is activated, cleaning the joint area of surface oxidation which promotes wetting and maximum bond reliability. The atomized filler metal then liquifies and flows onto the newly- cleaned area, cooling to form a structurally sound brazed or soldered joint.

Total Responsibility

Among the numerous benefits of the Fusion Paste Brazing and Soldering are elimination of pre-fluxing, more precise measurement of filler metal and flux, reduced costs via automation of manual steps, and more consistent joint quality through elimination of human error. In addition, Fusion's "Total Responsibility" approach ensures a coordinated effort in the manufacture of paste alloys, applicators, and equipment, plus expert system installation and service follow-up. *(Request Bulletin T-101 for information on Fusion Automatic Brazing & Soldering Machines.)*



Brazing & Soldering Basics with Fusion Paste Filler Metals

Joining Process & End-Use Service

Base metals, joint design, filler metals, and heating method can all impact key application properties ranging from joint strength to corrosion resistance. For this reason, the user must answer two questions...

1. What is the application end-use service requirements/conditions?
2. What is the optimum joining process?

Fusion Paste Filler Metals offer consistency and efficiency when properly selected and can help achieve the key project objectives.

Two applicator guns dispense 360° stripes of brazing paste to all joints of distributor assembly.

Joint Configuration

Joint designs can range from horizontal sandwich configurations to vertical tube to fittings. Fusion Pastes provide a unique solution since paste binder systems can be designed to optimize properties like adhesion and flow characteristics.

When brazing or soldering assemblies that require the filler metal to flow a considerable distance, a free-flowing flux/binder, and filler metal combination should be selected. Conversely, if the paste is applied to a joint with a narrow shoulder, a vertical surface, or larger gap, a restrictive flux/binder combination and/or sluggish filler metal may be required.

Since capillary flow and wetting are a combination of both the flux/binder and filler metal, Fusion Pastes come in different combinations to optimize these properties. For example, an adhesive binder can be paired with a free flowing alloy to stay in place on a vertical tube until the filler metal is molten, creating complete flow through the long tube joint interface.

Joint Clearance

Assembly tolerances are of prime importance when selecting a Fusion Paste. For most applications, joint clearances from .002” to .004” are optimum. A tight-fitting joint normally dictates the use of a free-flowing paste, while wider clearances require a more sluggish filler metal and/or restrictive flux/binder to minimize footprint and flow during heating. It should be noted that joint tolerances outside the optimum range may impair capillary attraction and impact joint integrity.

When brazing or soldering two dissimilar base metals, the rate of thermal expansion often becomes a critical factor as the base metal component with the higher expansion rate may cause an increase or decrease in joint clearances during heating and cooling. For this reason, assemblies composed of dissimilar base metals may require adjustment in tolerances or special fixtures to maintain desired clearances and minimize joint stress through the brazing process.

Base Metals & Oxides

It is important to consider the metallurgical compatibility of parent materials as well as their surface oxides. Base metal oxides vary in regard to rate of formation and tenacity. These surface oxides must be removed to enable wetting and create intermetallic bonding of the filler metal. A chemical flux is commonly used to remove surface oxidation and create a protective barrier, keeping the surface oxide-free during heating, when oxidation accelerates. Fusion pastes pair the appropriate flux required to remove the oxide in a select binder and alloy system.

For soldering, some metals such as aluminum, chrome, and zinc have very tenacious oxides. Oxide removal is typically marginal on these metals even with the use of highly corrosive, acid fluxes. To successfully solder such metals, plating the surface with easily soldered materials, such as tin or nickel, is sometimes desirable.

Brazing of metals with tenacious oxides (i.e. refractory metals and carbides) can usually be handled by an appropriate brazing flux, however, these oxides can also be removed in a controlled atmospheric or vacuum furnace using one of Fusion's Fluxless Binder Systems. *(see pages 16-17)*

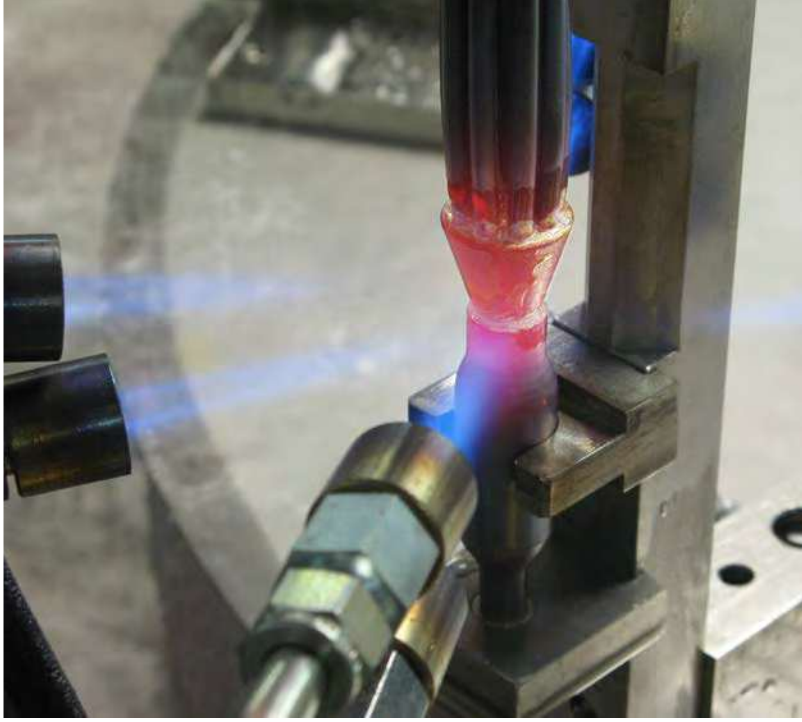
Fluxes: Types and Residues

Soldering fluxes activate at low temperatures and are classified by the corrosive properties of their post-soldering residue *(see pages 8-9)*. The three major solder flux categories are Non-corrosive, Intermediate, and Corrosive. Non-corrosive fluxes are typically inert, so they are selected for applications where residue removal is not possible.

Brazing fluxes *(see pages 14-15)* activate at higher temperatures and tend to be more aggressive than soldering fluxes. They work on more tenacious metallic oxides, however, their residues can interact in hot, humid environments so they generally require post braze removal.

Activation Temperatures & Heat Cycles

In both brazing and soldering, the flux generally activates below the liquidus temperature of the filler metal and remains active, providing a protective barrier throughout the metal joining process. If the flux is not activated prior to the filler metal reaching its liquidus temperature, there is risk that the oxides will not be removed, or that more tenacious oxides may build-up on the surface of the base and filler metals during the heating cycle. Either condition can prevent proper metal-to-metal bonding. The activation range is dependent on the chemical properties of the flux along with the joining process conditions (i.e. time and temperature). Slower heating rates often increase the risk of burning out the flux before the filler metal melts, while too fast a heating cycle might not allow enough time to properly remove base metal oxides.



Precision heat pattern distributes filler metal, resulting in void-free joints.

Filler Metals: Purpose and Interaction

Filler metals play an important role in both the structural integrity of the joint and ensuring chemical compatibility. Depending upon the application, a high degree of metallurgical interaction between base metal and filler metal may or may not be desirable. The degree of this metallurgical interaction at the grain boundaries is primarily a direct function of time and temperature at the filler metal liquidus state.

For this reason, the two most important factors in determining base metal/filler metal interaction are heating cycle time and filler metal melting temperatures. The more rapid the heating cycle, and the lower the melting temperature of the filler metal, typically leads to a milder interaction. Longer, higher temperatures tend to increase this interaction. The degree of this interaction affects the mechanical and physical properties of the base metals as well as the filler metal integrity, thus influencing corrosion resistance and strength among other attributes. As such, it is critical to select the proper filler metal for the application and optimize the brazing process.

Selection Guide: General Base Metal/Filler Metal

Filler Metal Family	Base Metal Family		
	Aluminum and Al Alloys	Copper and Cu Alloys	Carbon and Low Alloy Steels
Solder Fillers	*** ZnAl Solders (Fusion 720, 845, 892)** - Low temperature aluminum zinc alloys; ideal for rework and step processing aluminum *** Lead Free Solder (Fusion 441)** - Potential for joining dissimilar aluminum/copper base metals.	*** Lead Free Solders (430, 441, 500, 505)** *** Lead Bearing Solders (136, 165, 360, 365, 450, 455, 560)**	*** Lead Free Solders (430, 441, 500, 505)** *** Lead Bearing Solders (360, 365, 450, 455, 560)**
Silver Braze Fillers (Cadmium Containing)	NR	*** BAg-1 (Fusion 1000) and BAg-1a (Fusion 1050)** - free flowing, excellent for tight clearances	*** BAg-1 (Fusion 1000) and BAg-1a (Fusion 1050)** - free flowing, excellent for tight clearances
Silver Braze Fillers (Cadmium Free)	NR	*** BAg-7 (Fusion 1205)** - Cadmium free offset to BAg-1; tin improves wetting/flow and reduces stress cracking of nickel containing alloys and small carbides *** BAg-8 (Fusion 1400)** - Eutectic, good for furnace applications. Sluggish on steel and nickel alloys *** BAg-28 (Fusion 1202)** - General purpose, low silver content *** BAg-5 (Fusion 1250)** - Longer melt range for gap filling *** BAg-37 (Fusion 1265)** - Lower ductility, economical filler for use on copper base metals and some steels	*** BAg-18 (Fusion 1115)** - Similar to BAg-8; tin improves wetting for improved use on carbon and nickel based steels *** BAg-7 (Fusion 1205)** - Cadmium free offset to BAg-1; tin improves wetting/flow and reduces stress cracking of nickel containing alloys and small carbides *** BAg-28 (Fusion 1202)** - General purpose, low silver content *** BAg-5 (Fusion 1250)** - Longer melt range for gap filling *** BAg-37 (Fusion 1265)** - Lower ductility, yet economical filler for use on copper base metals and some steels
Copper Braze Filler Metal	NR	NR	*** BCu-1a (Fusion G1900F)** - Free flowing eutectic
Phos Copper/ Braze Fillers	NR	*** Proprietary (Fusion 1190)** - Near eutectic lowest melt temp. High silver for good electrical conductivity. *** BCuP-2 (Fusion 1300)** - Long melting range. High copper aids electrical conductivity *** BCuP-4 (Fusion 1306)** - Low temp, long melt range. *** Proprietary (Fusion 1310)** - Tin improves flow. Great all purpose alloy, self fluxing on copper *** BCuP-5 (Fusion 1315)** - Very sluggish alloy for large gaps or poor fit-up parts. *** Proprietary (Fusion 1320)** - Low temp, tight melt range	NR
Brass/ Bronze Braze Fillers	NR	*** Other brass alloy (Fusion 1650)** - Free flowing for smooth tight gap fillet. Close to AWS RBCuZnC *** Other brass alloy (Fusion 1565)** - Longer melt for gap filling. Good musical instrument color match. *** Other brass alloy (Fusion 1440)** - Lower melting temp brass, "low brass" with lower strength	*** Other brass alloy (Fusion 1650)** - Free flowing for smooth tight gap fillet. Close to AWS RBCuZnC *** Other brass alloy (Fusion 1565)** - Longer melt for gap filling. Good musical instrument color match. *** Other bronze alloy (Fusion1720)** - Good gap bridging properties with excellent resistance to interfacial corrosion, but manganese requires furnace with atmosphere dew point < -40.
Nickel Braze Fillers	NR	NR	*** BNi-1 (Fusion 4775) and BNi1a (Fusion 4776)** - Often used for nickel, chromium, or iron base metals; often used in highly stressed parts in corrosive environments. *** BNi-2 (Fusion 4777)** - General purpose nickel filler metal widely used in a variety of applications - contains Boron *** BNi-5 (Fusion 8100)** - Boron free with high silicon content, good for narrow deep joints. General purpose nickel filler metal
Aluminum Braze Fillers	*** BAlSi-2 (Fusion 1080)** - High melting point with long melt range. Good for step brazing applications; care during brazing due to liquidus temperature. *** BAlSi-4 (Fusion 1070)** - General purpose aluminum alloy with narrow melting range. No copper or zinc; good for post treatment processes. *** Other Aluminum alloys (Fusion 1040 and 1022)** - Lower melting temperatures aid with step brazing and aluminum safety.	NR	NR

Base Metal Family		
Stainless Steel	**Nickel and Ni Alloys**	**W, Mo, Carbides, and Refractory Metal Alloys**
*** Lead Free Solders (430, 500, 505)** *** Lead Bearing Solders (450, 455, 560)**	TS	NR
*** BAg-3 (Fusion 1200)** - Nickel containing improved corrosion resistance	*** BAg-3 (Fusion 1200)** - Nickel containing improved corrosion resistance	*** BAg-3 (Fusion 1200)** - Nickel containing improved corrosion resistance
*** BAg-18 (Fusion 1115)** - Similar to BAg-8; tin improves wetting for improved use on carbon and nickel based steels *** BAg-7 (Fusion 1205)** - Cadmium free offset to BAg-1; tin improves wetting/flow and reduces stress cracking of nickel containing alloys and small carbides *** BAg-24 (Fusion 1260)** - Nickel improves wetting on carbides and corrosion resistance of nickel containing alloys *** BAg-4 (Fusion 1240)** - Long melt, sluggish alloy for gap filling; nickel helps compatibility for carbides and stainless steels	*** BAg-18 (Fusion 1115)** - Similar to BAg-8; tin improves wetting for improved use on carbon and nickel based steels *** BAg-24 (Fusion 1260)** - Nickel improves wetting or carbides and corrosion resistance of nickel containing alloys *** BAg-4 (Fusion 1240)** - Long melt sluggish alloy for gap filling. Nickel helps compatibility of carbides and stainless steels	*** BAg-7 (Fusion 1205)** - Cadmium free offset to BAg-1; tin improves wetting/flow and reduces stress cracking of nickel containing alloys and small carbides *** BAg-24 (Fusion 1260)** - Nickel improves wetting on carbides and corrosion resistance of nickel containing alloys *** BAg-4 (Fusion 1240)** - Long melt, sluggish alloy for gap filling. Nickel helps compatibility for carbides and stainless steels
*** BCu-1A (Fusion G1900F)** - Free flowing eutectic	*** BCu-1A (Fusion G1900F)** - Free flowing eutectic	TS
NR	NR	NR
*** Other bronze alloy (Fusion 1720)** - Good gap bridging properties with excellent resistance to interfacial corrosion, but manganese requires furnace with atmosphere dew point < -40. Limited possibility to heat treat during brazing.	TS	TS
*** BNi-1 (Fusion 4775) and BNi-1a (Fusion 4776)** - Often used for nickel, chromium, or iron base metals. Ideal for highly stressed parts in corrosive environments. *** BNi-2 (Fusion 4777)** - General purpose nickel filler metal widely used in a variety of applications - contains Boron *** BNi-5 (Fusion 8100)** - Boron free with high silicon content. Good for narrow deep joints. *** BNi-6 (Fusion 1610)** - Low erosion properties make it a good option for thin walled components like heat exchangers *** BNi-7 (Fusion 1630)** - Strong oxidation and corrosion resistant joints. Free flowing material often used for honeycomb and thin-walled parts. *** BNi-15 (Fusion 1633)** - Lower melting temperature material ideal for thin walled and honeycomb structures.	*** BNi-1 (Fusion 4775) and BNi1a (Fusion 4776)** - Often used for nickel, chromium, or iron base metals. Ideal for highly stressed parts in corrosive environments. *** BNi-2 (Fusion 4777)** - General purpose nickel filler metal widely used in a variety of applications - contains Boron *** BNi-5 (Fusion 8100)** - Boron free with high silicon content is good for narrow deep joints. *** BNi-6 (Fusion 1610)** - Low erosion properties make it a good option for thin walled components like heat exchangers. *** BNi-7 (Fusion 1630)** - Strong oxidation and corrosion resistant joints. Free flowing material, often used for honeycomb and thin-walled parts. *** Other nickel alloy (Fusion 1633)** - Lower melting temperature material ideal for thin walled and honeycomb structures.	TS *** BNi-2 (Fusion 4777)** - Sometimes used in carbide applications.
NR	NR	NR

NR = Not typically recommended, yet may have some special applications.
TS = Contact Our Technical Services Team to discuss

Selection Guide: Solder Paste Fluxes

Non-Corrosive Fluxes

Fluxes are classified as "Non-Corrosive" when their post solder residue is deemed inert and won't impact the joint integrity if allowed to remain under normal use conditions. Non-corrosive fluxes are typically rosin-based, however, they may contain some mild organic acids or special additives to increase fluxing action and oxide removal. Many active constituents are designed to decompose at soldering temperatures, typically resulting in an inert flux residue which doesn't require removal. These fluxes are particularly useful in electrical applications, where their non-conductive, non-corrosive residue may be safely left on the assemblies. The most common non-corrosive solder flux systems are as follows:

GPR General purpose electronics flux/ binder with low flux activity. Average restrictive action (flow) which is typically driven more by alloy and process temperature. Residue is hard, slightly opaque, sticky, and non-conductive which doesn't need to be removed.

MBC Activated rosin system with good capillary flow. Restrictive action is driven more by alloy and process temperature. Currently the most cartridge stable of the Fusion non-corrosive systems. Softer, slightly sticky, non-conductive residue which doesn't need to be removed.

LPS Very restrictive, activated rosin system binder which localizes alloy flow (binder more influential than alloy). Excellent for applications requiring localized alloy deposits. Strongest fluxing power of the activated rosin systems which produces a slightly sticky, non-conductive residue which doesn't need to be removed.

Intermediate Fluxes

Intermediate fluxes usually consist of mild organic salts. These constituents activate at soldering temperatures and are considerably stronger than non-corrosive flux additives, however, they often decompose quickly and can have relatively short activity periods. Residues after soldering are normally not harmful to the soldered joint, however, they should be removed whenever possible as moisture in the atmosphere may trigger reactions of the decomposed byproducts which could lead to corrosion. Common intermediate solder flux systems are as follows:

PA, PAN, PAD Family Very low activation temperature and often paired with the "fusible alloys" (i.e. Fusion 136). These fluxes have a short activation period but can wet some CRS and SS when paired with tin silvers, provided there is an optimized solder process. PA is the most restrictive system of this family and has good slump characteristics, allowing use on vertical or narrow-shoulder joints. PA residue tends to be more difficult to remove than both PAN and PAD.

WC Mild organic halide flux with good oxide removal power. Moderately restrictive solder footprint with good capillary flow and penetration. Often paired with mid to higher temperature solder alloys (not recommended for low temperature "fusible alloys"). Mild residue is primarily water soluble.

PMS & PWC Family Mild organic halide flux with excellent fluxing action. PWC has improved slump properties over PMS but both are very restrictive with good capillary flow. Ideal for copper and brass tube/fitting applications requiring good pull through, but less effective on stainless and some CRS. Post solder residues in this family are oilier and can be difficult to remove with plain water, so either hot water or detergent is recommended.

SUN Extremely mild organic acid flux. The binder system is specifically formulated to allow higher alloy loading which, in combination with the low flux activity, results in a residue that behaves closer to a non-corrosive system without the sticky rosin characteristics.

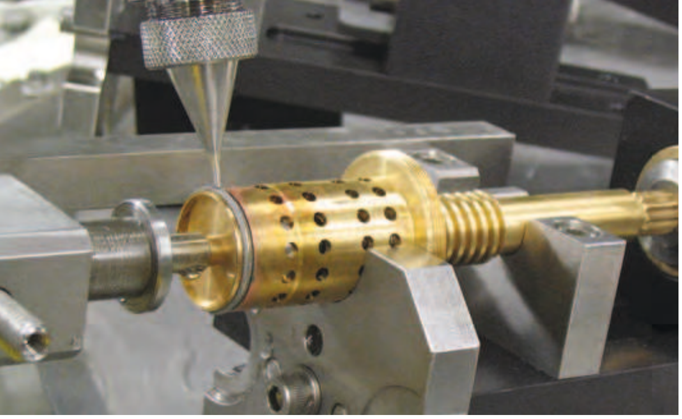
Corrosive Fluxes

Corrosive fluxes are primarily derived from inorganic acids and salts. They are highly active and tend to have a long flux life even at elevated temperatures, so they are often used for removing tenacious oxides (i.e. use on stainless base metals). The residues tend to form inorganic, metallic-oxide salt complexes which remain chemically active so they must be removed to prevent corrosion and maintain joint integrity. Removal can be challenging if not done immediately after soldering due to the metallic interaction between the inorganic residue complex and base metals. The following describe some of the more common corrosive flux systems:

SFC, FCC, 2JN, SMH Family Strong, inorganic flux with relatively long activation life, which work well in some oven applications and longer heat cycle processes. They range in binder viscosities and restrictive action (least restrictive SFC < 2JN < FCC < SMH most restrictive). Slower heat cycle is usually recommended to ensure proper off-gassing and minimize "jumping/popping" of the paste deposit.

PPP, SSX, SSE Family Extremely strong inorganic flux package, excellent for tenacious oxides. Due to flux strength and binder composition, pastes can contain high alloy loadings (pending application). These systems have moderate restrictive action with excellent capillary flow, but can tend to jump/pop under fast heat cycles if the process is not optimized.

WCC, WCE, WCS Family Very active, inorganic halide flux systems which are suitable for use on most steel, stainless steel, and plated surfaces. Based on the WC binder system, these systems offer good capillary flow with varying levels of restrictive action. Often used for fast heating cycles where off gassing and surface tension could impact deposit location during the solder process.



Solder Paste PWC-430-830 automatically applied to brass assembly.

Fusion Solder Flux/Binder Systems

Fusion System	Key Flux/Binder Properties				Base Metal Compatibility					Filler Metal Compatibility			
	Flux Activity Range (typical)	Restrictive Level	Residue	Residue Removal	Brass	Copper	Stainless	Cold Roll	Other	"Fusible" Low Temp (136-165 °F)	Tin Silvers	Tin Leads	Other (Sb, Cu)
Flux Class: Non-Corrosive													
GPR	300-525°F (149 - 273°C)	Fair Spread - alloy /process dependent	Non-Corrosive	Organic solvent / hydrocarbon solvent	Y	Y	N	N	LT	LT	Y	Y	Y
MBC	300-595°F (149 - 313°C)	Fair Spread - alloy /process dependent	Non-Corrosive	Organic solvent / hydrocarbon solvent	Y	Y	N	N	LT	LT	Y	Y	Y
LPS	300-525°F (149 - 273°C)	Very Restrictive	Non-Corrosive	Organic solvent / hydrocarbon solvent	Y	Y	N	N	LT	LT	Y	Y	Y
Flux Class: Intermediate													
WC	300-525° F (149 - 273°C)	Restrictive	Moderately Corrosive	Hot Water / Detergent	Y	Y	Y	Y	LT	N	Y	Y	Y
PWC / PMS Family	300-525°F (149 - 273°C)	Very Restrictive	Moderately Corrosive	Organic solvent / hydrocarbon solvent	Y	Y	LT	Y	LT	N	Y	Y	Y
PA / PAD / PAN Family	125-525°F (52 - 273°C)	Very Restrictive (PA) Moderately Restrictive (PAN/PAD)	Moderately Corrosive	Hot Water / Detergent	Y	Y	LT	LT	LT	Y	Y	Y	LT
SUN	300-525°F (149 - 273°C)	Moderately Restrictive	Low Corrosivity	Hot Water / Detergent	Y	Y	LT	LT	LT	LT	Y	Y	LT
Flux Class: Corrosive													
SFC, FCC, 2JN, SMH Family	300-600°F (149 - 316°C)	Moderately Restrictive (SFC, FCC, 2JN) Very Restrictive (SMH)	Very Corrosive	Detergent Water / mild acid	Y	Y	Y	Y	LT	N	Y	LT	Y
PPP, SSX, SSE Family	300-600°F (149 - 316°C)	Restrictive	Very Corrosive	Detergent Water / mild acid	Y	Y	Y	Y	LT	N	Y	LT	Y
WCC, WCE, WCS Family	300-600°F (149 - 316°C)	Moderately Restrictive	Moderate to Very Corrosive	Detergent Water / mild acid	Y	Y	Y	Y	LT	N	Y	Y	Y

** Extended heating times can cause fluxes to chemically change as well as impact the oxide layer of alloy*
*** Unusual service conditions may facilitate stress corrosion of certain brass parts.*

Y = Common use
N = Not typically recommended
LT = Lab testing required (Depends on base metal, filler metal, and solder process)

Selection Guide: Solder Paste Filler Metals

By definition *(see Glossary page 27)*, a soldering filler metal has a melting range generally below 840°F and always below that of the base metal to be joined. Solder filler metals are based on one of three main constituents (tin, zinc, and/or lead) and are typically broken into three main categories: Lead Containing Alloys, Lead Free Alloys, and Fusible Metals (Low Temperature Alloys). Fusion Solder Paste Alloys are designed to meet specific requirements in joint performance and melting range. The following summarizes key properties of the various solder categories and page 11 identifies Fusion's most common solder offerings.

Tin/Lead Alloys

Tin/lead filler metals are easy to work with and generally have good wetting and flow properties. They are typically "softer" and lower in shear strength. Higher lead content tends to increase the liquidus temperature and are not as free flowing as those alloys with higher tin content. They are good, general purpose solders which can be paired with non-corrosive, intermediate, and corrosive fluxes. However, the lead does have some environmental concerns in specific applications.

Lead-Free Alloys

Fusion lead free alloys are typically based on the Tin backbone and use various additives (i.e. silver, antimony, copper, bismuth) to increase strength and other physical properties. The most common alloys in this category are the Tin/Silver alloys which exhibit better strength and improved creep resistance over the standard tin/lead series. Although slightly higher in cost, they have good capillary flow and offer excellent electrical conductivity. The absence of lead, however, can impact surface energy and wetting angle so they are not as easy to use as tin/lead alloys. These alloys are suitable for use in food handling vessels where lead is prohibited. They also have wide applications, ranging from structural joining (e.g. tube to fitting) to electronics applications.

Fusible Alloys (Low Temperature Alloys)

Fusible Alloys use a combination of Cadmium, Indium, and Bismuth to decrease the melting temperatures for unique applications (e.g. fire suppression). Due to the special properties and low melting ranges, the integrity of the alloy can be susceptible to the soldering process (i.e. heating time, temperature, cooling rates).

Applicators dispense PAD-136-850 solder paste onto cover plates.

Flame heat melts fusible filler metal, bonding housing to cover plate.

Fusion Solder Paste Alloys										
	Fusion Number	Nominal Alloy Composition					Solidus Temperature		Liquidus Temperature	
		Sn	Pb	Bi	Ag	Other				
Lead Free Alloys	281	42	—	58	—	—	281°F	138°C	281°F	138°C
	425	91.8		4.8	3.4	—	410°F	210°C	425°F	219°C
	430	96.15	—	—	3.5	0.35 Sb*	430°F	221°C	430°F	221°C
	431	96.5	—	—	3.5	—	430°F	221°C	430°F	221°C
	441	99	—	—	—	1 Cu	440°F	228°C	440°F	228°C
	460	95	—	—	—	5 Sb	452°F	233°C	464°F	240°C
	500	100	—	—	—	—	449°F	231°C	449°F	231°C
	505	94.65	—	—	5	0.35 Sb*	430°F	221°C	473°F	245°C
Tin / Lead Alloys	360	60	40	—	—	0.35 Sb*	361°F	183°C	374°F	190°C
	361	62	36	—	2	0.35 Sb*	354°F	180°C	354°F	180°C
	365	63	37	—	—	0.35 Sb*	361°F	183°C	361°F	183°C
	450	50	50	—	—	0.35 Sb*	361°F	183°C	421°F	217°C
	455	40	60	—	—	0.35 Sb*	361°F	183°C	460°F	238°C
	560	5	93	—	2	—	530°F	277°C	568°F	297°C
	570	10	88	—	2	—	530°F	277°C	568°F	297°C

** ASTM B32 1970: Antimony added to minimize / prevent Tin Pest*

Fusion Brazing Paste Flux and Binder Systems OVERVIEW

The basis for Fusion's industry changing brazing pastes is a unique carrier binder which holds a finely atomized filler metal, and in some cases an oxide removing proprietary flux, in a stable suspension. These binders are specifically formulated to ensure optimum characteristics regardless of customer application methods and brazing processes. The binder systems can be broken into two main groups: fluxless binder carrier systems and fluxed binder carrier systems.

"Fluxless" Binder systems are primarily utilized in a variety of brazing furnace operations, however, they also can be tested in select flame or induction systems depending on the application. Some applications where a fluxless system may be implemented include: atmospheric furnace, vacuum furnace, open air when paired with a self-fluxing phos-copper alloy for use on copper/copper alloy base metals, flame when used with gas flux, or in a special induction machine containing an atmospheric chamber. Fusion offers a diverse portfolio of fluxless binder systems optimized for a variety of application methods (e.g. machine dispensing, dip/roll coat, stencil, squirt bottle) and "staged properties" (i.e. adhesion, slump, dry time). Another advantage of a fluxless system is that they can offer higher alloy loading than traditional fluxed paste systems helping to minimize residue in furnace applications. The adjacent table describes some of Fusion's fluxless binder systems.

The key ingredient in Fusion's "Fluxed" binder system is a proprietary flux. The role of the flux is to remove surface oxides, and prevent reoccurrence of filler and base metal oxidation, during open air brazing applications. Industry standards dictate the performance criteria and include general chemical family requirements which often impact activation temperatures and residues, however, the actual flux itself remains a proprietary formulation. The adjacent table *(Flux Selection Guide by Base Metal / Filler Metal)* provides an industry defined starting point for identifying the proper flux required to properly join base materials based on their composition and filler metal selected for the joint.

Flux Selection Guide by Base Metal/Filler Metal*					
Industry Classification**			General Description	Common Base Metals / Parent Materials	AWS Filler Metal Family
AWS A 5.31M	AMS	EN 1045			
FB3-A	3410	FH10	General purpose flux with strong oxide removal power and average life in open air brazing applications above 600°C. Often selected to pair with lower temperature filler metals.	Steel, low grade Stainless Steel (i.e. 304), copper, select nickel and nickel alloys	BAg
				Copper and copper alloys	BAg, BCuP
FB3-C	3411	FH20	General purpose silver brazing flux with extended life and higher temperature activity range for open air brazing. Often selected for brazing temperatures above 750°C	Steel, stainless steel, and cemented carbides	BAg
				Copper and copper alloys	BAg, BCuP
FB3-D	3417	FH21	Extremely high (activity) temperature flux, with extended life for long brazing cycle times, or sluggish alloys for open air brazing. Can often remain active at temperatures up to 1100°C	Steel, stainless steel, nickel, and nickel alloys	BAg, BNi, BAu, RBCuZn
				Copper and copper alloys	BAg, BCuP, BNi, BAu, RBCuZn
FB1-A	3412	FL10	Hygroscopic brazing flux common for torch and furnace brazing of aluminum and its brazeable alloys. Residue is typically corrosive and requires removal.	Aluminum and its brazeable alloys	BAlSi
		FL20	Non-Hygroscopic brazing flux common for torch and furnace brazing of aluminum and its brazeable alloys. Residues are generally non-corrosive and typically do not require removal.	Aluminum and its brazeable alloys	BAlSi

** The flux classifications, and their descriptions, provide a general overview of flux compatibility according to base and filler metal selection. Due to the wide range of chemistry and physical properties for both the filler and base metals, please contact your Fusion technical representative to identify the best solution to meet your needs.*
*** ISO/CD 18496 (Brazing – Fluxes for brazing – Classification and technical delivery conditions) is currently in draft form at time of this publication.*

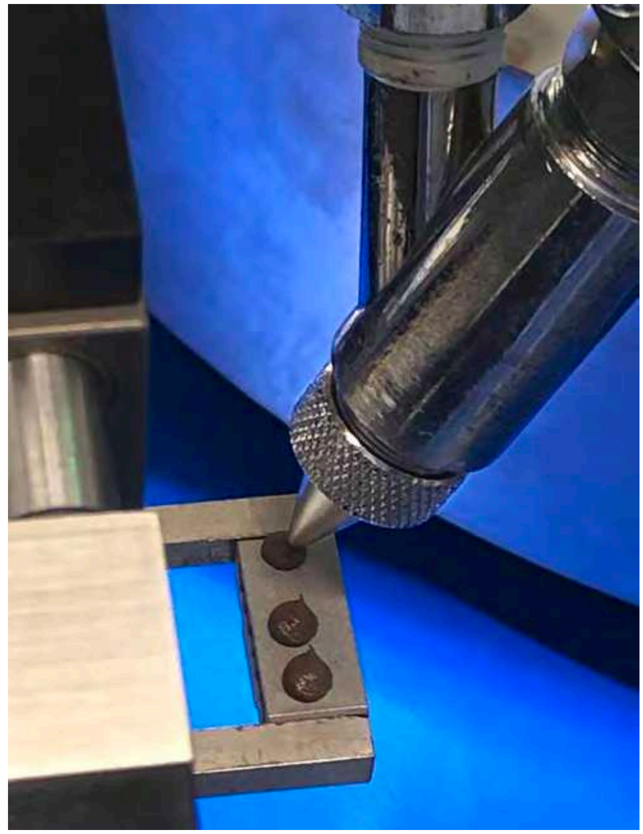
Fusion “Fluxed” binder systems incorporate a variety of proprietary fluxes as well as the brazing filler metal in suspension. These binder systems are optimized for Fusion’s automated dispensing systems, providing the benefit of improved application consistency. Although we offer a wide variety of fluxed binder systems, our technical team has the capability to make minor modifications to customize each system for a customer’s specific application requirement. As such, the physical properties of each binder system can vary to ensure optimum results for a variety of factors including joint design, filler metal composition/loading, part fixture orientation, brazing process, and temperature constraints. Since brazing fluxes are composed of chemically active, and often corrosive materials, their post braze residue should typically be removed to minimize corrosion issues and ensure joint integrity. The table on pages 14-15 discuss some of Fusion’s more common flux/binder systems.

Selection Guide: Brazing Paste Flux/Binders

Industry Class	Flux System	Description
Chemistry and properties similar to AWS FB3-A, AMS 3410, and EN 1045 FH10	STL	Very active, free-flowing flux, for use on both ferrous and non-ferrous base metals. Strong oxide removal capability enables use on many "hard- to-braze materials" like cadmium-oxide and nickel-chrome. Unique blend of flux constituents enable wide temperature activation window and long flux life.
	BHL	Lower flux content with oxide removal similar to STL. Binder has good adhesion to part, improved slump properties, and increased restrictiveness. Formulation permits higher alloy loading which makes it ideal for a wide range of applications ranging from tube to fitting, to electrical contact applications where alloy coverage and large fillets are preferred.
	LHK	Fluxing properties similar to STL. LHK is formulated to have a more restrictive flow than STL in molten state, while maintaining excellent joint penetration and capillary pull through. Ideal for pairing with a wide variety of BAg and BCuP alloys.
	MHK	Lower flux content with oxide removal similar to LHK. Binder has good adhesion to the part with some increased restrictiveness over LHK, resulting in a smaller post braze footprint. Pull through is generally not as good as LHK.
	LEE	Similar in both binder and flux constituents to WSK, LEE is ideal for fast heat cycles, including induction with slightly less smoke generation. It maintains minimal hot and cold slump characteristics with good capillary flow. The restrictive nature of binder helps minimize post braze footprint which makes it a good choice for post braze plating.
	SL5	SL5 has a similar binder backbone and adhesive properties to STL, however, in an effort to identify a more environmentally sustainable option for the brazing industry, Fusion SL5, free-flowing flux formulation is considered CMR-Free*. It maintains minimal hot and cold slump characteristics with good capillary flow.
Chemistry and properties similar to AWS FB3-C, AMS 3411, and EN 1045 FH20	STN	Very active, free-flowing flux, provides excellent wetting and alloy spread similar in nature to its FB3-A sister, STL. The STN binder formulation is optimized for higher process temperatures and longer heat cycles typically required for "hard- to-braze materials" as well as many carbide applications.
	STK	STK is a more restrictive silver brazing flux for use in prolonged heating cycles and when maximum activity at higher process temperatures are required. It is an excellent choice for stainless steels and carbides and is often chosen for use with suitable silver filler metals when brazing and heat-treating operations are combined.
	WSK	WSK is specially formulated for long term stability when packaged in cartridges and can handle higher loading levels of most alloys without impacting paste stability. WSK has minimal hot and cold slump characteristics with good capillary flow. The restrictive nature of the binder, along with possible higher alloy loading levels, help minimize post braze footprint which makes it a good selection for plating parts after brazing.
	2MJ	2MJ is the next generation DMX product specifically designed for higher alloy loading, cartridge stability, and maximum shelf life. It is extremely restrictive with very little capillary flow so it is best used when sandwiched inside a joint. It maintains good activation life through high temperatures and long cycle times making it a good choice for stainless steel and carbide tooling. Due to high alloy loading the residue is minimal but any residue is typically more challenging to remove than with STK or STN.
Chemistry and properties similar to AWS FB3-D, AMS 3417, and EN 1045 FH21	BMW	Very high temperature borate flux with good capillary flow and wetting characteristics. BMW has good adhesive properties to minimize cold and hot slump. Often paired with brass filler metals for use on steel, brass, and copper base metals when the joint requires a smooth fillet and good capillary flow (e.g. fishhooks and musical instruments). It can be used with some of the lower temperature nickel filler metals provided optimum process conditions (i.e. fast heat cycle like induction)
	BMO	More restrictive version of BMW with good adhesive properties and minimal cold and hot slump. BMO is often used with brass and bronze filler metals for carbide and steel applications (i.e. circular saw teeth) however, it can work with some higher temperature, longer melting range silver alloys.
	BMA	Most restrictive system, with excellent part adhesion, makes BMA a good choice for vertical joints where gravity assist is not favorable. The post braze residue is tougher and more resistant to thermal shock than the BMW or BMO systems.
	JAN	Similar to BMW in activation temperatures and physical properties, JAN is a higher fluxed system which enables even longer activation life. Ideal for more prolonged heating cycles when paired with more sluggish alloys.

** SL5 does not contain any raw materials deemed to be a carcinogen, mutagen, or reproductive toxin according to global regulatory agencies at the time of this document printing. Due to the unique chemical requirements in this industry, and the ever-changing regulatory landscape, please contact Fusion's Technical Service Team should you have questions regarding the most up to date regulatory compliance status.*

Flux Range	Residue Type	Residue Removal
1000 - 1600°F (538 - 871°C)	Clear, corrosive. Must be removed.	Hot water/detergent or a chemical dip containing either an acid or alkaline cleaner. (i.e. Fusion Fuze-Clean FS)
1000 - 1600°F (538 - 871°C)	Clear, corrosive. Must be removed.	Hot water/detergent or a chemical dip containing either an acid or alkaline cleaner. (i.e. Fusion Fuze-Clean FS)
1000 - 1600°F (538 - 871°C)	Clear, corrosive. Must be removed.	Hot water/detergent or a chemical dip containing either an acid or alkaline cleaner. (i.e. Fusion Fuze-Clean FS)
1000 - 1600°F (538 - 871°C)	Clear, corrosive. Must be removed.	Hot water/detergent or a chemical dip containing either an acid or alkaline cleaner. (i.e. Fusion Fuze-Clean FS)
1000 - 1600°F (538 - 871°C)	Clear, corrosive. Must be removed.	Hot water/detergent or a chemical dip containing either an acid or alkaline cleaner. (i.e. Fusion Fuze-Clean FS)
1000 - 1500°F (538 - 871°C)	Clear, corrosive. Must be removed.	Hot water/detergent or a chemical dip containing either an acid or alkaline cleaner. (i.e. Fusion Fuze-Clean FS)
1000 - 1700°F (538 - 927°C)	Dark corrosive residue. Must be removed.	Hot water/detergent or a chemical dip containing an acid or alkaline cleaner. Ultrasonic or agitation preferred.
1000 - 1700°F (538 - 927°C)	Dark corrosive residue. Must be removed.	Hot water/detergent or a chemical dip containing an acid or alkaline cleaner. Ultrasonic or agitation preferred.
1000 - 1600°F (538 - 871°C)	Clear, corrosive. Must be removed.	Hot water/detergent or a chemical dip containing either an acid or alkaline cleaner. (i.e. Fusion Fuze-Clean FS)
1000 - 1700°F (538 - 927°C)	Harder dark, corrosive residue. Should be removed.	Hot water/detergent or a chemical dip containing an acid or alkaline cleaner. Ultrasonic or agitation preferred.
1400 - 2200°F (760 - 1205°C)	Extremely hard and dark residue. Should be removed.	Mechanical removal or heated chemical dip containing strong acids with agitation.
1400 - 2200°F (760 - 1205°C)	Extremely hard and dark residue. Should be removed.	Mechanical removal or heated chemical dip containing strong acids with agitation.
1400 - 2200°F (760 - 1205°C)	Extremely hard and dark residue. Should be removed.	Mechanical removal or heated chemical dip containing strong acids with agitation.
1400 - 2200°F (760 - 1205°C)	Extremely hard and dark residue. Should be removed.	Mechanical removal or heated chemical dip containing strong acids with agitation.



Scara robot moves mount beneath applicator to accept (3) deposits of STK-1260-650 brazing paste.

Induction coil brings silver brazing filler metal to 1305°F liquidus temperature.

Selection Guide: Brazing Paste Fluxless Binders

Binder System	Description
CAP CKG	CAP and CKG stay in place through heating cycle and are considered quick drying. CAP pastes tend to be less viscous and have higher dispensing flow rates than its thicker sister, CKG. CKG is extremely quick drying, often making it more ideal for vacuum applications. Both stay in place once applied.
CNG CNT	CNG and CNT have similarities to CAP and CKG above. They are quick drying and tend to stay in place through heating cycle. CNG pastes tend to be less viscous and have higher dispensing flow rates, whereas CNT is typically faster drying and often used more commonly in vacuum applications.
CCR BAZ GAL	This binder family has a wide range of viscosities and dispensing properties. CCR tends to have the most flow and is easily dispensed through squeeze bottles. GAL has the least flow, most body, and is most viscous.
EXO**	Unlike typical aqueous systems, EXO is specifically formulated for improved performance in Exothermic and Endothermic applications. It has little to no residue under those conditions, however, it is not recommended in High Hydrogen or Vacuum applications. This fast drying product is easily dispensed through both squeeze bottles and air applicators.
CBL CBC	Non-drying, neutral binder systems with great versatility. Very sticky and adhesive in nature, these materials are ideal for vertical joints requiring minimal flow and slump properties. They have versatility in a variety of atmospheric environments, and are less reliant on dew points than some other binders. Adhesive nature often results in an oily off-gas, so they are more heating profile dependent to minimize residue build-up on equipment.
PNP PLA	Formulated to have excellent chain scission during decomposition, PNP and PLA have extremely low residue in a variety of lower temperature furnace applications. They have the ability for high alloy loading and are an excellent choice for vacuum applications, however, their unique formulation leads to pronounced slump, so their use is not recommended for vertical or complex joint designs.
CP CFW	CP and CFW are optimized for lower temperature silver and phos-copper alloys. Like PNP and PLA, they have a good residue profiles in lower temperature furnace applications. CP can offer extremely high alloy loadings (i.e. 87-90%), however, it does have more pronounced slump, similar to PNP and PLA. Not recommended for vertical or complex joint designs. CFW is formulated to provide improved adhesion over CP. This limits CFW's loading closer to 80% alloy. Not as adhesive in nature as the CBL or CBC family of products.
CDW	CDW is a hybrid system with excellent versatility in all environmental atmospheres ranging from vacuum furnace to higher dew point exothermic atmospheres. Semi-drying on the part with excellent part adhesion similar to the CBL/CBC family with improved hot and cold slump throughout the staging and brazing cycle times. Has superior snap off / break similar to an aqueous system (i.e. less stringy than CBL/CBC family)
CTT	CTT is formulated to have minimal residue in all environmental atmospheres, ranging from vacuum furnace to higher dew point exothermic atmospheres. CTT is non-drying and an excellent choice for roll coat or stencil applications. Excellent part adhesion with little to no hot and cold slump throughout the staging and brazing cycle times. Unique chemistry typically permits higher alloy loading. Pastes have superior snap off / break similar to an aqueous system (i.e. less stringy than CBL/CBC family)

Alloy loading depends on the binder composition, filler metal, and application method. Irregular powders tend to have lower filler loading as do thicker binder systems.

	Common Filler Metal	Typical Filler Loading Levels[1]	Aqueous System[2]	Non-Aqueous System[3]	Specialty System[4]	Typical Furnace Conditions
	Coppers, Nickels, Silvers, Golds	75 - 87%	X			High Hydrogen or Vacuum Furnace applications with low dew points. Recommend for dew points < 0°F but certain alloys require < -30°F
	Coppers, Nickels, Silvers, Golds	75 - 88%	X			High Hydrogen or Vacuum Furnace applications with low dew points. Recommend for dew points < 20°F but certain alloys prefer < 0°F
	Coppers and Brass Fillers	75 - 78 %	X			High Hydrogen or Vacuum Furnace applications with low dew points. Recommend for dew points < 0°F but certain alloys require < -30°F
	Coppers	75%	X			Exothermic, Endothermic, and Rich Endothermic applications which tend to have higher dew points (between 0° - 60°F)
	Coppers, Phos-Coppers, Silvers, and Golds	75% with pure copper filler metals up to 85% with other filler metals		X		Exothermic, Endothermic, and Rich Endothermic, High Hydrogen furnace applications. Not typically recommended for Vacuum
	Silvers, Golds, Phos-Coppers	75 - 90%		X		Excellent in Vacuum applications for Silver and Gold fillers but can be used in all furnace conditions including higher dew points.
	Silvers, Phos-Coppers	80 - 90%		X		Recommended low dew, High Hydrogen furnace applications. Possible for Exothermic, Endothermic, and Vacuum applications, but will be filler metal dependent.
	Copper	75 - 78%			X	Versatile in all furnace applications: Exothermic, Endothermic, and Rich Endothermic, High Hydrogen furnace applications, and Vacuum furnaces.
	Coppers, Phos-Coppers, Nickels	80 - 93%			X	Versatile in all furnace applications: Exothermic, Endothermic, and Rich Endothermic, High Hydrogen furnace applications, and Vacuum furnaces.

[1] Filler loading depends on the binder composition, filler metal, and application method.

[2] Aqueous System refers to water soluble chemistries and generally means of, relating to, or resembling water. Quick drying and good for High Hydrogen / Vacuum applications but can introduce atmospheric moisture.

[3] Non-Aqueous System refers to non-water soluble chemistries. Less atmospheric dependent and typically non-drying for better shock resistance with long staging time, however, can lead to more pronounced slump.

[4] Specialty System refers to unique, proprietary formulations. Provide versatility of the non-aqueous systems with improved properties like dispensing flow of aqueous systems, improved slump resistance, and/or higher alloy loading.

*** Unique additives help EXO perform better than traditional aqueous systems in higher dew point furnaces.*

Selection Guide: Silver Brazing Filler Metals

By definition, a brazing filler metal has a liquidus temperature greater than 840°F, but lower than that of the base metal(s) being joined. Fusion paste brazing filler metals are classified based on their primary metal alloy composition. These filler metals can be paired with a Fusion flux containing or fluxless binder system depending on the brazing process. The most common categories of industrial use compositions include Silver Brazing Filler Metals, Copper/Copper Alloy Filler Metals, Nickel Filler Metals, Gold Filler Metals, and Aluminum Filler Metals. The following pages explain the primary applications and attributes for common Fusion industrial filler metals. The table on *pages 6-7, "General Base Metal / Filler Metal Selection Guide"*, provides a basic starting point for identifying an appropriate alloy to use with a specific component base metal. As with all brazing/soldering applications, the joint configuration, design requirements, and process conditions may impact the joint integrity and dictate specific filler metals. Please contact your Fusion Representative to help identify the proper product.

Scara robot moves lower carrier beneath applicator to accept exact pattern of 2MJ-1260-800 braze paste.

Silver Brazing Filler Metals (BAg)

Silver bearing pastes are among the most widely used structural filler metals. These may be used to braze most ferrous and non-ferrous base metals, excluding aluminum, titanium, and magnesium. They have become popular due to their free-flowing, ductile nature and relatively low melting range. All conventional heating methods may be used with the silver-bearing brazing pastes, however, the process conditions and part design can influence the alloy/flux/binder combination best suited for the project. In general, open air brazing (torch, induction, resistance) is easily accomplished using a proprietary Fusion flux binder system with all silver alloys. Silver brazing in atmospheric furnaces require extremely low dew points to obtain appropriate wetting. Zinc and tin containing silver alloys are often avoided in vacuum brazing due to volatilization of those constituents.

Induction coil brings silver brazing filler metal to 1305°F liquidus temperature.

Cadmium Free Silver Brazing Alloys (BAg)									Specifications			
Fusion Number	Ag	Cu	Zn	Cd	Ni	Sn	Solidus Temperature	Liquidus Temperature	AWS A5.8: 2019	AMS	ISO 17672:2016	EN 1044:1999
1076	42	33	—	—	—	25	1040°F 560°C	1076°F 580°C	—	—	—	—
1115	60	30	—	—	—	10	1115°F 602°C	1325°F 718°C	BAg-18	4773	AG160	AG402
1202	40	30	28	—	—	2	1200°F 649°C	1310°F 710°C	BAg-28	—	AG140	AG105
1204	45	27	25	—	—	3	1195°F 646°C	1251°F 677°C	BAg-36	—	AG145	AG104
1205	56	22	17	—	—	5	1145°F 618°C	1205°F 652°C	BAg-7	4763	AG156	AG102
1206	60	26	14	—	—	—	1260°F 682°C	1325°F 718°C	—	—	—	—
1235	65	20	15	—	—	—	1240°F 671°C	1325°F 718°C	BAg-9	—	AG265	—
1238	38	31	28.8	—	—	2.2	1220°F 660°C	1292°F 700°C	—	—	—	—
1240	40	30	28	—	2	—	1240°F 671°C	1435°F 779°C	BAg-4	—	AG440	—
1246	45	25	30	—	—	—	1256°F 680°C	1292°F 700°C	—	—	—	—
1250	45	30	25	—	—	—	1225°F 663°C	1370°F 743°C	BAg-5	—	AG245	—
1255	55	21	22	—	—	2	1166°F 630°C	1220°F 660°C	—	—	AG155	—
1260	50	20	28	—	2	—	1220°F 660°C	1305°F 707°C	BAg-24	4788	AG450	—
1265	25	41	32	—	—	2	1270°F 688°C	1435°F 779°C	BAg-37	—	AG125	AG108
1400	72	28	—	—	—	—	1435°F 779°C	1435°F 779°C	BAg-8	—	AG272	AG401
4765	56	42	—	—	2	—	1420°F 771°C	1640°F 893°C	BAg-13a	4765	AG456	—
4772	54	40	5	—	1	—	1325°F 718°C	1575°F 857°C	BAg-13	4772	AG454	—
4774	63	28.5	—	—	2.5	6	1275°F 691°C	1475°F 802°C	BAg-21	4774	AG463	—

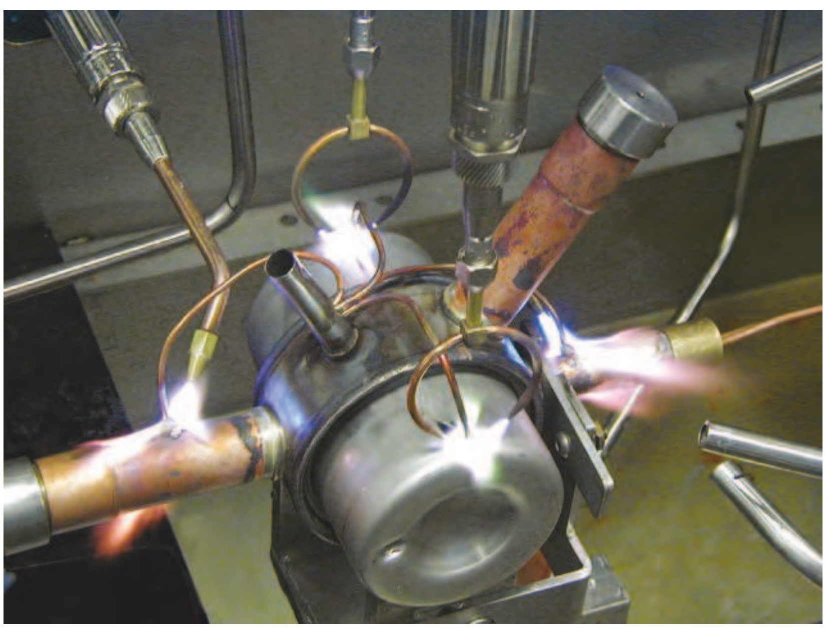
Cadmium Containing Silver Brazing Alloys (BAg)									Specifications			
Fusion Number	Ag	Cu	Zn	Cd	Ni	Sn	Solidus Temperature	Liquidus Temperature	AWS A5.8: 2019	AMS	ISO 17672:2016	EN 1044:1999
1000	45	15	16	24	—	—	1125°F 607°C	1145°F 618°C	BAg-1	4769	AG345	AG302
1050	50	15.5	16.5	18	—	—	1160°F 627°C	1175°F 635°C	BAg-1a	4770	AG350	AG301
1142	42	17	16	25	—	—	1130°F 610°C	1148°F 620°C	—	—	—	AG303
1200	50	15.5	15.5	16	3	—	1170°F 632°C	1270°F 688°C	BAg-3	4771	AG351	AG351

Selection Guide: Copper-Bearing Filler Metals

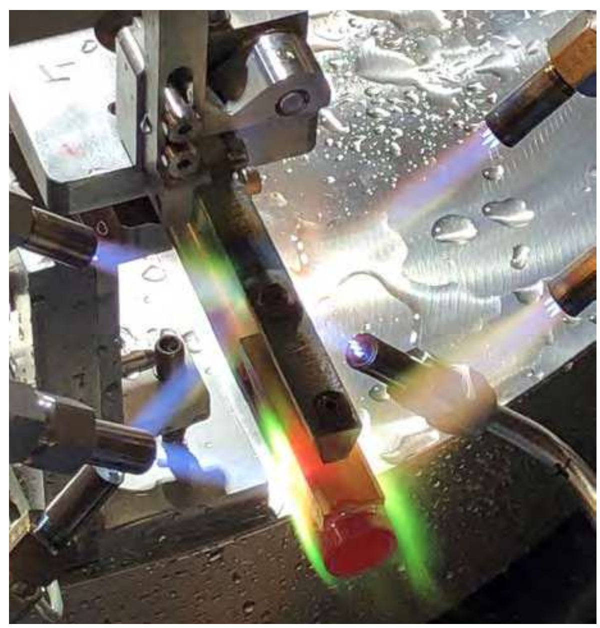
Fusion Copper (BCu), Phos-Copper (BCuP), Copper Zinc (Brass) and Copper Tin (Bronze) Filler Metals

Copper filler metals and their alloys are an economical option for many applications. Pure copper brazing alloys are extremely free-flowing and exhibit excellent strength properties. In fact, some pure copper joints approach the strength of the parent metals themselves. The addition of various oxides (copper oxide and iron oxides) can somewhat restrict the free-flowing nature of pure copper filler metals, while improving the ability to fill joint gaps. The high temperatures required for pure copper brazing often requires the use of a reducing atmosphere or vacuum, so these filler metals are commonly paired with a fluxless binder system for use on steel and stainless steel base metals. The table below outlines Fusion's common copper and copper-oxide filler metals.

Copper Brazing Alloys (BCu)								
Fusion Number	Cu	Cu2O	Fe2O3	Solidus Temperature	Liquidus Temperature	AWS A5.8: 2019	ISO 17672:2016	EN 1044:1999
G1900F	100	—	—	1981°F 1083°C	1981°F 1083°C	BCu-1a	CU 099	CU 103
GA1900F	95	5	—	1981°F 1083°C	1981°F 1083°C	—	—	—
GC1900F	90	10	—	1981°F 1083°C	1981°F 1083°C	—	—	—
GH1900F	98.5	—	1.5	1981°F 1083°C	1981°F 1083°C	—	—	—
GF1900F	95	—	5	1981°F 1083°C	1981°F 1083°C	—	—	—
GM1900F	90	7	3	1981°F 1083°C	1981°F 1083°C	—	—	—



Gas/Oxygen torches melt copper/phosphorus filler metal at 1256°F, sealing capillary tube joints.



Copper/brass assembly joined with LHK-1310-750, copper/ phosphorus brazing paste

Applicators dispense (93) deposits of EXO-G1900F-750 copper paste to torque converter

The addition of phosphorus to a copper-based alloy (known as Phos-Copper Alloys or designated as BCuP alloys) has been known to offer "self-fluxing" properties when used on copper base metals. These BCuP filler metals, however, should not be used on steel or nickel base metals due to the possibility of Phosphorus Embrittlement - a weakening condition created by base metal / filler metal interactions.

Phos/Copper Alloys (BCuP)									
Fusion Number	Cu	P	Ag	Other	Solidus Temperature	Liquidus Temperature	AWS A5.8: 2019	ISO 17672:2016	EN 1044:1999
1190	75	7.25	17.75	—	1190°F 643°C	1191°F 644°C	—	—	—
1300	92.75	7.25	—	—	1310°F 710°C	1460°F 793°C	BCuP-2	CuP 181	—
1306	86.75	7.25	6	—	1190°F 643°C	1325°F 718°C	BCuP-4	CuP 283	—
1310	86.25	6.75	—	7 Sn	1184°F 640°C	1256°F 680°C	—	—	—
1315	80	5	15	—	1190°F 643°C	1475°F 802°C	BCuP-5	CuP 284	CP 102
1318	94	6	—	—	1310°F 710°C*	1634°F 890°C*	—	—	—
1320	91.75	8.25	—	—	1310°F 710°C	1320°F 716°C	—	—	—
1325	69.45	5.35	25.2	—	1190°F 643°C*	1256°F 680°C*	—	—	—

** estimated solidus and liquidus temperature from phase diagrams*

When copper is combined with zinc (Brass) or tin (Bronze), the resulting alloys create an economical method for joining both ferrous and non-ferrous base metals at temperatures lower than pure copper braze joints. These brazing filler metals have wide application uses in industry, however, testing should be conducted on the finished part as the addition of zinc and tin may decrease the resistance to corrosion and increase the chance for stress corrosion cracking.

Other Copper Alloys (Brass and Bronze Alloys)										
Fusion Number	Cu	Mn	Ag	Zn	Other	Solidus Temperature	Liquidus Temperature	AWS A5.8: 2019	ISO 17672:2016	EN 1044:1999
1440	27.5	—	—	65	7.5 Sn	1385°F 751°C	1440°F 782°C	—	—	—
1565	53	—	9	38	—	1450°F 788°C	1565°F 851°C	—	—	—
1600	54	—	4.5	41.5	—	1410°F 766°C	1635°F 890°C	—	—	—
1650	55	.25	—	44.75	—	1610°F 877°C	1635°F 890°C	—	—	—
1664	60	—	—	39.7	0.3 Si	1607°F 875°C	1643°F 895°C	—	—	—
1681	48.5	—	—	41.3	10 Ni, 0.2 Si	1690°F 921°C	1715°F 935°C	—	—	—
1720	77.85	20	—	—	2.15 Ni	1688°F 920°C	1742°F 950°C	—	—	—

Selection Guide: Nickel Brazing Filler Metals

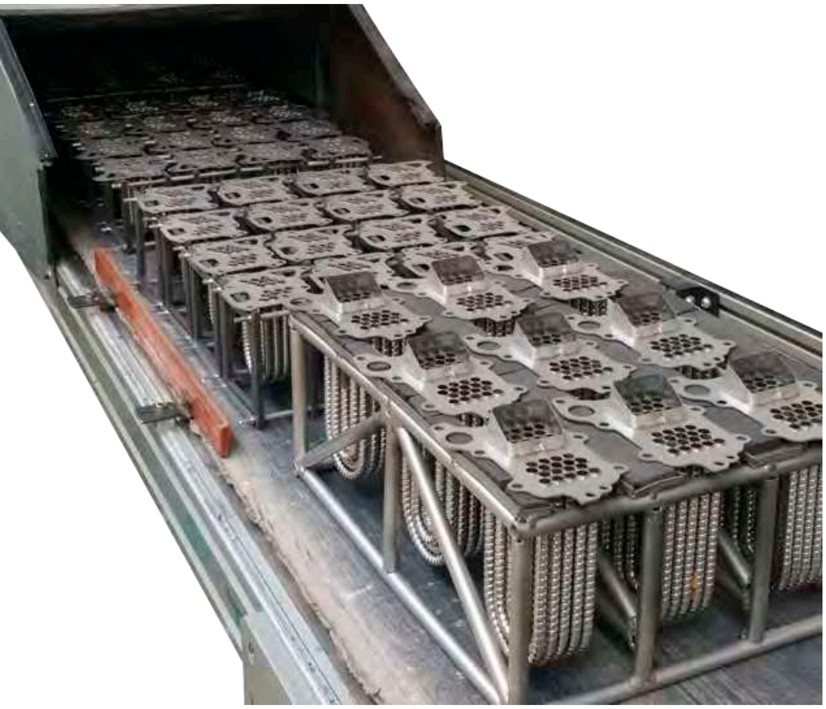
Fusion Nickel-Bearing Filler Metals (BNi)

Nickel brazing filler metals provide a variety of benefits including excellent strength and corrosion resistance both at elevated temperatures and in other harsh environments. Depending on the specific composition, nickel-bearing alloys can be resistant to service temperatures up to 1800 °F (980°C) and provide improved resistance to oxidation and corrosion for a variety of base metals, both ferrous and non-ferrous in nature. Although the best results are obtained by vacuum brazing or other furnace type, alternate heating methods can be used with the addition of an appropriate flux. Process application is critical when selecting the appropriate nickel filler metal. Boron containing filler metals are sensitive to nitrogen containing atmospheres as the boron has a strong affinity for nitrogen and can create a compound which inhibits braze flow (i.e. boron nitride). These boron containing filler materials should therefore be run in either vacuum, pure dry hydrogen, or argon furnace with a dew point of -60F or better for best results. The non-boron containing nickel filler metals, such as BNi-5, BNi-6 & BNi-7, can produce acceptable results in a nitrogen containing atmosphere assuming the atmosphere quality is good (-60F dew point). Nickel-bearing filler metals are most commonly used to braze stainless steel (300 and 400 Series), nickel, and cobalt-based alloys, however, they can be used on a variety of both ferrous and non-ferrous parent materials. The table below outlines some of the most common nickel filler metals offered by Fusion.

Robot-controlled, pneumatic dispenser applies multiple deposits of CNG-1630F-87X nickel braze paste to EGR assembly

Nickel Brazing Alloys (BNi)

Fusion Number	Ni	Cr	Fe	Si	B	P	Other	Solidus Temperature	Liquidus Temperature	AWS A5.8: 2019	AMS	ISO 17672:2016	EN 1044:1999
1610	89	—	—	—	—	11	—	1610°F 877°C	1610°F 877°C	BNi-6	—	Ni 700	NI 106
1630	75.9	14	—	—	—	10.1	—	1630°F 888°C	1630°F 888°C	BNi-7	—	Ni 710	NI 107
1633	60.5	29.5	—	4	—	6	—	1778°F 970°C	1886°F 1030°C	BNi-15	—	—	—
1635	65	25	—	—	—	10	—	1620°F 880°C	1740°F 950°C	BNi-12	4783	Ni 720	NI 112
4775	73.15	14	4.5	4.5	3.1	—	0.75	1790°F 977°C	1900°F 1038°C	BNi-1	—	—	—
4776	73.9	14	4.5	4.5	3.1	—	—	1790°F 977°C	1970°F 1077°C	BNi-1a	4776	Ni 610	NI 1a1
4777	82.4	7	3	4.5	3.1	—	—	1780°F 971°C	1830°F 999°C	BNi-2	4777	Ni 620	NI 102
4778	92.4	—	—	4.5	3.1	—	—	1800°F 982°C	1900°F 1038°C	BNi-3	4778	Ni 630	NI 103
8100	70.87	19	—	10.13		—	—	1975°F 1079°C	2075°F 1135°C	BNi-5	4782	Ni 650	NI 105



Continuous brazing furnace flows the nickel filler metal, sealing the tube joints

Selection Guide: Industrial Gold-Bearing Filler Metals (BAu)

Gold based filler metals are often used in industrial applications which require high resistance to corrosion and oxidation. Gold is relatively inert and tends not to react with a wide variety of chemical substances, including many parent metals. This low rate of interaction with various base metals make gold alloys an excellent choice for joining relatively thin assemblies used in harsh environments. Fusion's industrial gold solder and braze filler metals are identified below in the table below.

In addition to industrial applications, both gold and silver filler metals are used in jewelry applications. In addition to the Karat Law requirements, color matching and melting temperatures are the most critical attributes for such jewelry applications, so formula compositions are proprietary. Fusion offers a wide range of Gold and Silver alloys for jewelry applications so please contact your Fusion representative should you require assistance.

Industrial Gold-Bearing Alloys*									
Fusion Number	Au	Ni	Sn	Description	Solidus Temperature	Liquidus Temperature	AWS A5.8: 2019	ISO 17672:2016	EN 1044:1999
536	80	—	20	Industrial solder for specialty aerospace applications	536°F 280°C	536°F 280°C	—	—	—
1742	82	18	—	Industrial braze for high temperature nickel and iron based alloys	1740°F 949°C	1740°F 949°C	BAu-4	Au 827	AU 105

** Contact Fusion Sales or Technical Service Team for details on our jewelry product offerings*

Selection Guide: Aluminum Flux/Binders

Brazing Aluminum with the Fusion Process

Aluminum is a popular base metal because it is light weight, strong, and relatively chemically inert. For these reasons, Aluminum is used in everything from automobiles to airplanes and each year millions of aluminum parts are joined by brazing and soldering. Common filler metals for aluminum metal joining are primarily based on aluminum and often close to the base metal melting temperatures, so control of heat is a critical process parameter. The table on page 25 outlines popular Fusion aluminum filler metals.

Aluminum joining processes include traditional methods, from flame heating to furnace application. All aluminum joining methods (except vacuum furnace) utilize a flux to remove the tenacious aluminum oxides on the base metals. Fusion has developed a series of proprietary fluxed binder systems which efficiently remove the oxide layers of most aluminum base metals and facilitate a strong joint interface. There are two primary fluxed systems for joining aluminum. First is a non-corrosive system which contains a chloride-free flux. This system leaves an inert post braze residue which does not have any detrimental effect under normal service conditions and does not require removal. The second family is known as a water washable system. Fusion's water washable system results in a highly soluble post braze residue, however, this residue must be removed after brazing. In general, 90% or more of the residue is often removed by immersing the hot part in water. For a more thorough cleaning, Fusion recommends immersing the finished part in a 15% nitric acid/85% water solution under agitation for 30 seconds at room temperature followed by (2) hot water rinses and a final cold water rinse. The table below describes Fusion's aluminum flux/binder systems in more detail.

Linear robot guides applicator to dispense multiple deposits of GNC-1070-401 aluminum brazing paste to header joints.

Flux System	Description	AWS A 5.31M	AMS
ASN	Low activation temperature aluminum flux for use with Zinc Aluminum solder filler metals (Fusion 720, 845, and 892). Popular for use in torch or furnace rework applications. Also recommended for small, thin walled aluminum assemblies, heat exchangers, and condenser "piccolo" joints when low temperature, fast activating soldering is required. It produces a hard, white residue which is non-corrosive under most service environments.	–	–
KNC	Fast activation, general purpose aluminum brazing flux, suitable for a wide range of brazing filler metals. Due to the lower activation temperatures, KNC is often paired with lower temperature aluminum brazing filler metals such as 1022 and 1040. It removes tenacious aluminum oxides, making it ideal for a variety of aluminum base metals including 6061, 6262, 6063, and 3003. Can be used in both torch and furnace applications.	FB1-B[3]	–
GNC	Strong general purpose aluminum brazing flux with a wide temperature activation range. GNC has potent flux removal power, making it ideal for a wide range of aluminum base metals, including some 5000 series and other magnesium-containing alloys[1]. Activates at slightly higher temperatures than KNC which makes it ideal for both furnace and torch applications using Fusion's 1070 and 1080 alloys.	FB1-B[3]	–
NDA	NDA is a lower activating temperature general purpose flux with a wide activity range. Often paired with the lower temperature aluminum brazing alloys (Fusion 1022 and 1040) however, it can be used with the 1070 alloy provided the process is optimized. Typically used for torch brazing and produces a water washable residue, which much be removed.	FB1-A[2]	3412[4]
NPA	Strong general purpose aluminum brazing flux with a wide temperature activation range. NPA has potent flux removal power, ideal for most aluminum base metals including some 5000 series and other magnesium-containing alloys[1]. Activates at slightly higher temperatures than NDA which makes it ideal for pairing with Fusion 1070 and 1080 alloys. NPA is typically used in torch brazing and produces a water washable residue which much be removed.	FB1-A[2]	3412[4]

[1] Due to the tenacious oxide layers of new aluminum alloys, testing may be required to ensure suitability.
[2] Similar to FB1-A in activation temperature and chemistry, in paste form.

Selection Guide: Aluminum Filler Metals (BAlSi)

Fusion Number	Al	Zn	Si	Cu	Description	Solidus Temp	Liquidus Temp	AWS A5.8: 2019	AMS	Aluminum Association	ISO 17672:2016	EN 1044:1999
720	5	95	–	–	Low temp aluminum solder ideal for rework and joining dissimilar base metals - only available in non-corrosive binder system.	710°F 382°C	710°F 382°C	–	–	–	–	–
845	15	85	–	–	Low temp aluminum solder for rework and joining dissimilar base metals - only available in non-corrosive binder system.	718°F 380°C	845°F 452°C	–	–	–	–	–
892	20	80	–	–	Low temp aluminum solder ideal for rework and joining dissimilar base metals - only available in non-corrosive binder system.	756°F 402°C	892°F 478°C	–	–	–	–	–
1022	50	45	5	–	Low temp aluminum brazing alloy for step brazing. Exercise caution when treating post braze parts due to possible leaching of zinc.	896°F 480°C	1022°F 550°C	–	–	–	–	–
1040	76	10	10	4	Low temp aluminum brazing alloy for step brazing processes. Exercise caution when treating post braze parts due to possible leaching of zinc.	960°F 516°C	1040°F 560°C	–	–	4245	–	–
1070	88	–	12	–	General purpose aluminum brazing alloy common for most brazing applications including heat exchangers.	1070°F 577°C	1080°F 582°C	BAlSi-4	4185	4047	Al 112	AL 104
1080	92.5	–	7.5	–	Higher melting temp aluminum alloy commonly used for the initial braze joint in step brazing applications.	1070°F 577°C	1142°F 617°C	BAlSi-2	–	4343	Al 107	AL 102

Note: Caution should be excercised when using filler metals containing zinc, if the finished component will undergo a post solder/braze treatment process, as zinc may leach out under certain conditions.

EN 1045	Flux Range	Residue Type	Residue Removal
–	745°F - 1030°F (396°C - 554°C)	Non-corrosive residue, hard, white difficult to remove residue	Mechanical removal or strong pickling
FL20[4]	1040°F - 1140°F (560°C - 615°C)	Non-corrosive residue, hard, white difficult to remove residue	Mechanical removal or strong pickling
FL20[4]	1040°F - 1140°F (560°C - 615°C)	Non-corrosive residue, hard, white difficult to remove residue	Mechanical removal or strong pickling
FL10[4]	1040°F - 1140°F (560°C - 615°C)	Corrosive white residue, must be removed	Hot water/detergent wash or chemical pickling dip containing an acid or alkaline cleaner. Recommended cleaning in 15% nitric acid / 85% water solution followed by two hot water rinses.
FL10[4]	1040°F - 1140°F (560°C - 615°C)	Corrosive white residue, must be removed.	Hot water/detergent wash or chemical pickling dip containing either an acid or alkaline cleaner. Recommended cleaning in 15% nitric acid / 85% water solution followed by two hot water rinses.

[3] Similar to FB1-B in activation temperature and chemistry, in paste form. Produces a hard, white residue which is typically non-corrosive under most service conditions.
[4] Similar in activation temperature, flux life, and chemistry developed in paste form.

Two stations of flame heat bring the aluminum filler metal to its 1080°F liquidus temperature.

Cleaning Brazed or Soldered Joints

Cleanliness of a brazed or soldered joint, both before and after the joining process, is critical to ensure the integrity of the finished joint. Fusion offers select chemical products for precleaning and postcleaning of base metals. Fusion's common cleaning products are supplied in either powders or liquids and are generally safer than most conventional pickling bath chemical agents.

Chemical Cleaning products include detergents, solvents, or pickling/etching materials. Detergents and solvents typically remove organic materials such as cutting oils and dirt, whereas pickling/etching materials can remove a thin layer of the base metal which might contain oxides or inorganic materials bonded to the main substrate. There are several key factors which should be considered in the chemical cleaning process: Time, Temperature, Concentration, and Surface Contact (i.e. agitation). Chemical cleaning should always be followed by thorough rinsing. Care should be used to minimize carryover of the cleaning media and contaminants in the rinse tanks.

Mechanical/Physical Removal processes use brushing, grinding or blasting with an abrasive agent to remove surface contaminants, and heavy oxides deposits. When using mechanical means to preclean the materials, care must be taken to ensure that the abrasive and fine dust created is not left to contaminate the joint area prior to metal joining.

PRECLEANING / SURFACE PREPARATION

Although a proper flux will remove light surface oxidation during the metal joining process, foreign matter such as grease, oils, paint, cutting fluids, etc. should be cleaned away. If not removed, such materials may inhibit grain penetration into the base metal along with proper capillary flow into the joint region. Detergent cleaners or some mild solvents can often remove dirt and oil surface contamination, whereas thick oxide layers and inorganic contaminants can be removed using mild acidic (or basic) cleaning baths. After precleaning, it is imperative to remove the cleaning media using a thorough rinsing and drying process. It is suggested that brazing or soldering be performed shortly after any precleaning operation to prevent reoxidation of the base metals.

Fusion offers cleaners for refractory oxides, surface rust, flux residues, and heat scale. The most popular products are Fuzeclean S and Fuzeclean FS.

POSTCLEANING (FLUX RESIDUES)

A significant benefit of the Fusion Paste Process is that the type and amount of flux is carefully controlled, yielding minimal flux residues. Nonetheless, flux residues of a corrosive nature must be removed to prevent damage to the joint over an extended period.

Rosin Type Flux Residues are generally non-corrosive and may be left on the part without damage to the joint area. If residue removal is desired, it may be removed using organic solvents, alcohols, chlorinated hydrocarbon solvents, or combinations of solvent families.

Activated Rosin Fluxes Some rosin activators will cause corrosion under unusually hot or humid conditions. Most may be removed using organic solvents, alcohols or chlorinated hydrocarbon solvents, or combinations of solvent families.

Oily or Greasy Flux Residues These are generally binder residues and can be removed by organic solvents and some surfactant detergents.

Carbon Residues These are generally binder residues and can be removed by surfactant detergents.

Intermediate and Corrosive Solder Fluxes (Halides) These fluxes leave a fused residue which absorbs airborne moisture, causing a slow chemical reaction at the joint. Removal is required to protect the joint integrity. Removing these residues shortly after the soldering process can sometimes be accomplished in hot detergent water. Residues have an affinity for the base metal as they dry, so use of hot water containing dilute hydrochloric acid, or some other type of acidic type cleaner (i.e. Fuzeclean FS), followed by hot water rinse may be required especially if cleaning is done in a batch process.

Low-Temperature Brazing Fluxes (Silver Braze Fluxes) These residues may be removed with hot water along with detergents, alkaline cleaners, or acid cleaners. The most effective method is largely dependent on the base metals involved and, like corrosive solder fluxes, can be impacted by the time lapse between the brazing and post cleaning process. Use of a general purpose product such as Fuzeclean FS is a good starting point for most base metals.

High-Temperature Brazing Fluxes (Borates) These hard, glass-like deposits are insoluble in many cleaners. They may crack off under thermal shock by quenching the hot assembly in water immediately after brazing, however, caution should be used to ensure the thermal expansion/contraction doesn't stress the joint area. A solution of dilute hydrochloric acid, or other acidic cleaner (i.e. Fuzeclean FS), may also help remove this glass like residue, however, mechanical removal is most effective with these residues.

Aluminum Brazing Fluxes (Water Washable) Generally about 90% of such residues may be removed by immersing the hot part in water. For more thorough cleaning, immerse parts in a 15% nitric acid/85% water solution, under agitation for 30 seconds at room temperature, followed by two hot water (60-70°C) rinses at 20 seconds each, then a final cold water rinse. Parts are generally considered "flux free" when flux levels on the joint surface are below 10-50 ppm using a flux detection kit.

Aluminum Brazing Fluxes (Non-Corrosive) These residues are generally non-hygroscopic and often don't require removal in most service conditions, however, removal may be required if service conditions are harsh (continuous high temperature and humid environments). Removal is most often through mechanical means, however, strong acid or base etching solutions can also create a path under the residue to help lift and remove it (i.e. Fuzeclean S).

Glossary

As Applied to Fusion Paste Brazing & Soldering

Atmosphere A controlled brazing or soldering environment achieved by excluding oxygen and replacing it with one or a mixture of other gases. In production, this technique will minimize or eliminate the need for flux, as the atmosphere itself, combined with heat, acts to reduce existing surface oxides. Most often associated with furnace brazing.

Base Metal (Also, Parent Metal) The alloy or pure metal which is to be joined via soldering or brazing.

Binder A blending agent which, when added to paste brazing or soldering alloys, keeps the atomized filler metal and flux in stable suspension, prevents interaction of the two, and maintains extended shelf life.

Brazing A joining process whereby a non-ferrous filler metal is heated to melting temperature (above 840°F) and distributed between two or more closefitting parts by capillary attraction. At its liquidus temperature, the molten filler metal interacts with a thin layer of the base metal, cooling to form an exceptionally strong joint due to grain structure interaction.

Capillary Attraction A natural force of adhesion governed by the relative attraction of liquid molecules for each other and for those of two adjoining solids. As applied to soldering or brazing, the process by which liquid flux and filler metal are transported along the length of a close-fitting joint.

Dew Point A reference method of determining the amount of water vapor (and resultant oxygen) in a controlled atmosphere brazing operation. The Dew Point is that temperature at which water vapor of a given concentration will begin to condense, or become liquid.

Eutectic A specific alloy composition (two or more metals) that melts at a single temperature and not over a range (i.e., Solidus and Liquidus temperatures are the same).

Filler Metal An alloy or pure metal which, when heated, liquifies to flow into the space between two close-fitting parts, creating a brazed or soldered joint.

Fillet A clearly-defined bead of solder or brazing alloy which forms on and around the completed joint.

Fitup The joint clearance between two base metals to be soldered or brazed. Although requirements vary by technique and type of joint, optimum range for paste brazing and soldering is generally .002 to .004 inch.

Flux A material which, when heated, serves to remove and exclude surface oxides from the base metal. Brazing fluxes are generally of a highly corrosive nature. Solder fluxes may be classified into one of the following groups:

- **Non-corrosive** A rosin or mildly active organic acid used in wetting clean surfaces and producing a residue which is neither electrically conductive nor corrosive to the finished joint. Although such fluxes are active at elevated temperatures, they are inert at ambient temperature.
- **Intermediate** Generally, a mild organic acid which activates upon heating to achieve considerable stronger fluxing action than non-corrosive types. Relatively inert residue should be removed to ensure joint reliability.
- **Corrosive** Generally composed of strong organic or inorganic acids which promote high-speed cleaning of metals with strong surface oxides. Corrosive residue should be removed to prevent damage to the joint.

Liquidus The lowest temperature at which a particular metal or metal alloy will remain in a completely molten state. Generally considered the melting point of a particular filler metal.

Oxidation (Also, Surface Oxides) A chemical reaction promoted by oxygen and moisture in the air, wherein clean metal surfaces are covered with a metal oxide film which prevents proper wetting with soldering or brazing filler metal. Since oxidation accelerates during heating, the metal must not only be cleaned initially, but protected from oxidation during the joining process.

Penetration (Also “Pull Through”) The distance filler metal moves into the area to be joined.

Restrictive The ability to minimize paste flow/spread beyond the initial footprint, while still promoting full wetting, capillary flow, and intermetallic bonding.

Slump The relative tendency of a paste alloy to sag or flow away from a sloping or vertical joint. Largely a function of paste rheology, this may occur while the assembly is cold, or during heating – before the paste alloy has reached melting temperature.

Soldering A joining process whereby a non-ferrous filler metal is heated to melting temperature (below 840°F and below that of the base metal) and distributed between two or more close-fitting parts by capillary attraction. Upon cooling, the filler metal adheres tightly to the base metal of either part, achieving coalescence.

Solidus The highest temperature at which a particular metal or metal alloy will remain completely solid.

Wettability (Also, Wetting Action) The ability of a specific flux and/or filler metal to flow onto a clean metal surface, unrestricted by oxidation or other impurities at the point of contact.

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