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Designation and processing of relevant parent and filler materials, fluxes/gases

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Presentation Agenda



- Parent Materials Used in Aerospace and Defence
- Effects of Brazing on Parent Materials
- Specific Considerations for Common Aerospace Materials
- Filler Materials for Aerospace and Defence Brazing
- Forms and Applications of Filler Materials
- Role and Types of Fluxes in Brazing
- Fluxes for Different Brazing Temperatures and Materials
- Atmospheres in Brazing Processes



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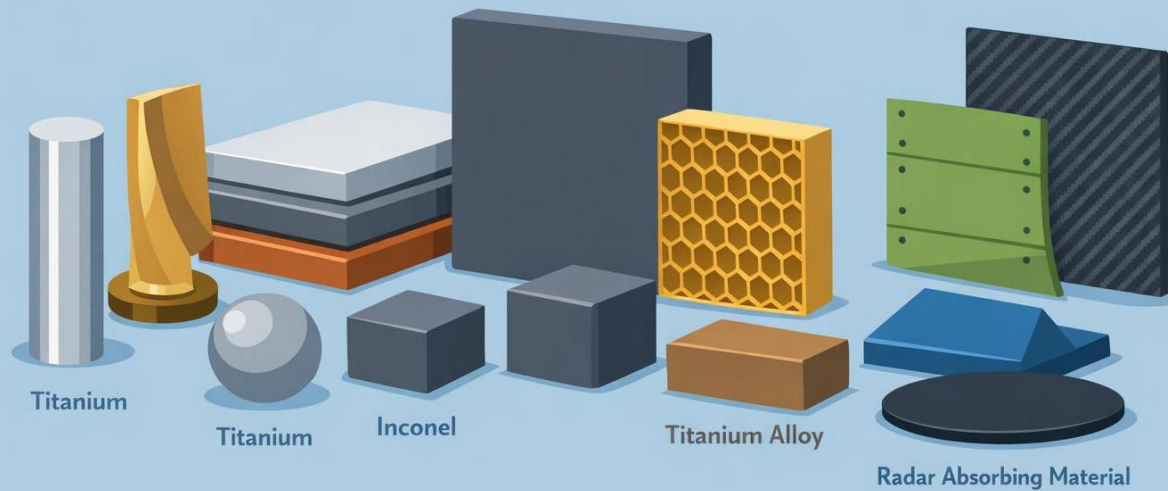
Parent Materials Used in Aerospace and Defence

General categories of parent materials



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Aerospace & Defense Materials



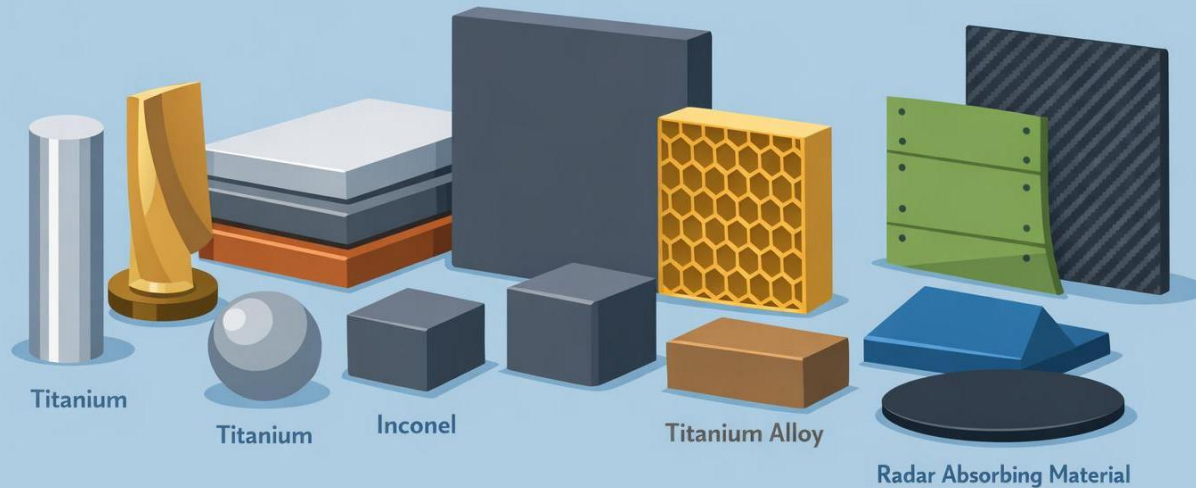
- **Aluminum and its Alloys:** Includes pure aluminum, aluminum-zinc alloys (less than 6% zinc), aluminum-manganese alloys (less than 2% manganese), aluminum-silicon alloys (less than 2% silicon), and aluminum-magnesium alloys (less than 2% magnesium).
- **Coated Materials:** Materials with electrodeposited or other types of surface coatings.
- **Cobalt and its Alloys:** Covers pure cobalt, hard facing alloys, and corrosion-resistant alloys.
- **Copper and its Alloys:** Includes unalloyed copper, phosphorus-bearing copper, silver-bearing copper, low alloyed copper alloys (such as beryllium-copper, chromium-copper), copper-zinc alloys (brasses), copper-tin alloys (tin-bronzes, phosphor-bronzes, some gunmetals), copper-tin-lead alloys (some gunmetals), copper-nickel-zinc alloys (nickel-silvers), copper-nickel alloys (cupronickel), copper-aluminum alloys (aluminum bronzes), and copper-manganese-aluminum alloys.

General categories of parent materials



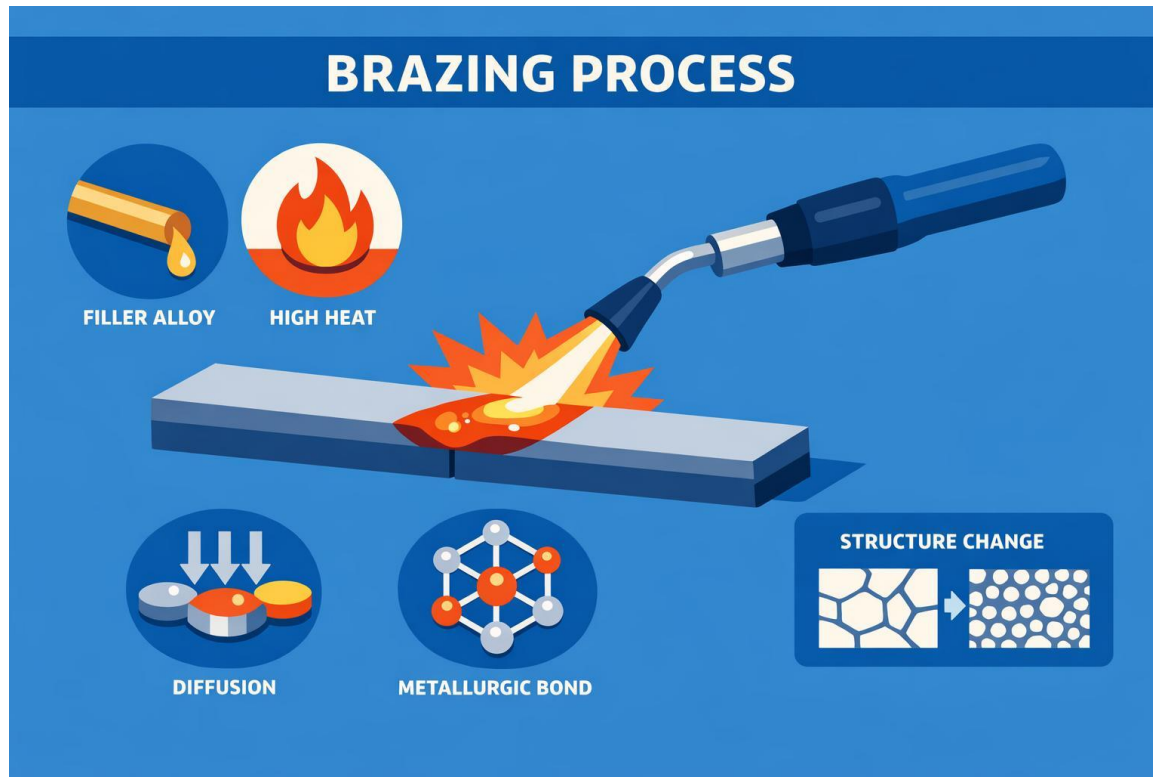
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Aerospace & Defense Materials



- **Ferrous Metals:** Includes cast iron, malleable iron, mild steel, carbon and low alloy steels, alloy steels, high speed and tool steels, stainless steels, and heat and corrosion-resistant steels.
- **Nickel and its Alloys:** Covers pure nickel, nickel-copper, nickel-iron, nickel-chromium-iron, and nickel-chromium alloys.
- **Precious Metals:** Includes gold, platinum, palladium, silver, and their alloys.
- **Refractory Metals and Alloys:** Covers titanium, zirconium, tantalum, niobium, and their respective alloys.
- **Tungsten and Molybdenum:** Includes tungsten, molybdenum, cemented carbides, silver-tungsten, and copper-tungsten composites.
- **Non-Metallic Materials:** Examples include ceramics, graphite, tungsten carbide, diamonds, cermets, glass, and sapphire.

Special considerations for brazing parent materials



Temperature Effects

High brazing temperatures can alter the mechanical properties of parent materials, affecting strength and durability.

Metallurgical Interactions

Brazing involves metallurgical reactions between filler and parent materials, influencing joint quality and performance.

Dissimilar Material Challenges

Brazing dissimilar materials requires special care to manage different thermal expansion and chemical properties.

Effects of the Brazing Process on Parent Material Properties



- Alloys strengthened by work hardening lose their strength during brazing, and this loss is permanent.
- Precipitation-hardenable alloys may be affected by brazing but can regain strength with proper heat treatment.
- Brazing can alter the corrosion resistance of parent materials.
- It is important to consult the parent material supplier for advice on changes caused by brazing.

Alloys with Tenacious Surface Oxides



- Alloys containing elements like aluminum and titanium often develop strong oxide films that complicate brazing.
- Surface preparation is critical when brazing these materials to ensure proper joint formation.
- Specialized fluxes may be needed to break down robust oxide layers.
- Protective atmospheres or pre-brazing plating can be employed to improve brazing outcomes.

Porous Metals



- Powder metallurgy parts with interconnected porosity (under 90% theoretical density) can draw in filler by capillary action during brazing.
- This absorption of filler material makes brazing these components challenging.
- Proper surface preparation ensures better joint quality and reduces filler loss.

Material Considerations



- **Aluminum and its alloys** are typically brazed using Al-Si based filler materials. Magnesium present in the parent material can react with silicon in the brazing alloy, forming intermetallic compounds at the interface. If the magnesium content exceeds 2%, the resulting compound may embrittle the joint.
- **Lead is used in copper alloys** to improve machinability but is insoluble in copper. Lead content above about 2% can interfere with brazing by forming unwettable dross at the interface or causing cracking. These effects can be reduced with adequate fluxing and uniform heating without imposed stress.
- **Free Machining Carbon Steels:** Lead and sulfur are added to carbon steels for machinability. Lead below 0.35% does not significantly affect brazeability or joint strength, but higher levels may reduce joint strength due to interaction with the filler
- **Cast Iron:** Spheroidal graphite (s.g.) cast irons can be brazed using silver filler materials. Flake graphite irons are more challenging due to flakes interfering with wetting, which can be addressed by special surface treatments or using silver brazing filler with nickel.

Material Considerations



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- Reactive and Refractory Metals and Their Alloys:
 - **Titanium, zirconium, niobium, and tantalum** alloys are generally not brazed; specialist advice and inert atmospheres (argon or vacuum) are required, and hydrogen atmospheres must be avoided
 - **Molybdenum and tungsten** can be brazed in **hydrogen or inert atmospheres**, though it is preferable to keep brazing temperatures below their recrystallization points to avoid embrittlement.
- **Metals Prone to Cracking During Brazing:** Cracking is often caused by stressing components while they are in contact with molten filler material, due to work hardening, jig restraint, or uneven heating. Cracks usually form at grain boundaries, a phenomenon known as **stress cracking** or liquid metal penetration.
- **Non-Metallic Materials:** Ceramics may be brazed by metallizing the surface prior to brazing or using reactive metal filler materials. For glass materials, special glass filler materials are available.



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Overview and storage of filler materials



Principal Filler Materials

The primary filler materials are specified in EN 1044 and categorized into several classes for aerospace use.

Alternative Materials Usage

Other commercially available filler materials can be used if approved by both manufacturer and user for suitability.

Storage and Handling

Filler materials must be stored and handled following manufacturer guidelines to maintain quality and performance.

Commonly used filler materials for parent material combinations

Parent materials	Al & Al alloys	Cu & Cu alloys	Carbon & low alloy steels Cast iron	Stainless steel	Ni & Ni alloys	Ti & Ti alloys	Refractory metals
Filler material classes in accordance with EN 1044							
Al & Al alloys	AL						
Cu & Cu alloys		AG AU CP NI CU3XX					
Carbon and low alloy steels Cast iron		AG CU3XX	AG CU CU3XX				
Stainless steel	AL	AG NI AU D	AG CU NI	AG AU CU NI			
Ni & Ni alloys		AG AU PD	AG CU NI	AG AU CU NI	AG AU CU NI PD		
Ti & Ti alloys	AL				AG	AG AL	
Refractory metals		AG PD AU					PD AU
NOTE Bold entries are those most commonly used.							

Suitability of filler material classes for brazing methods

Filler material class in accordance with EN 1044	Brazing method							Laser beam
	Flame	Induction	Resistance	Protective/ reducing atmosphere	Vacuum	Flux bath	Dip bath	
AL	S	S	U	S ^a	S ^b	S	U	S
AG	S	S	S	S ^c	AG401 ^e	U	S	S
CP	S	S	S	S	U	U	U	-
CU1XX and CU2XX	U	S	S	S	S	U	U	S
CU3XX	S	S	S	U	U	U	S	S
NI & CO	U	S	U	S	S	U	U	-
PD	U	S	U	S	S ^d	U	U	-
AU	U	S	U	S	S	U	U	-
Key S Suitable U Unsuitable ^a Only with flux. ^b Not all filler metals in the class are suitable . ^c With flux in some cases. ^d Not PD202. ^e AG401 is suitable for vacuum furnace brazing.								

Filler Material Categories

Different classes of filler materials are designed to match specific brazing requirements and metal substrates.

Common Brazing Methods

Popular brazing methods include torch brazing, furnace brazing, and induction brazing, each with unique process characteristics.

Material Suitability Factors

Suitability depends on temperature, joint design, material compatibility, and desired joint strength.



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Forms and Applications of Filler Materials

Available forms of brazing filler materials



Forms of filler materials

Brazing filler materials come in rod, wire, foil, preforms, powder, paste, and clad sheet forms.

Application methods

Filler materials can be applied by spraying, coating, vacuum deposition, or blending from powders depending on the project needs.

Design phase considerations

It is essential to determine the intended form of brazing filler material during the design phase of the project for optimal results.

Selection and application of filler materials

Factors Influencing Filler Selection

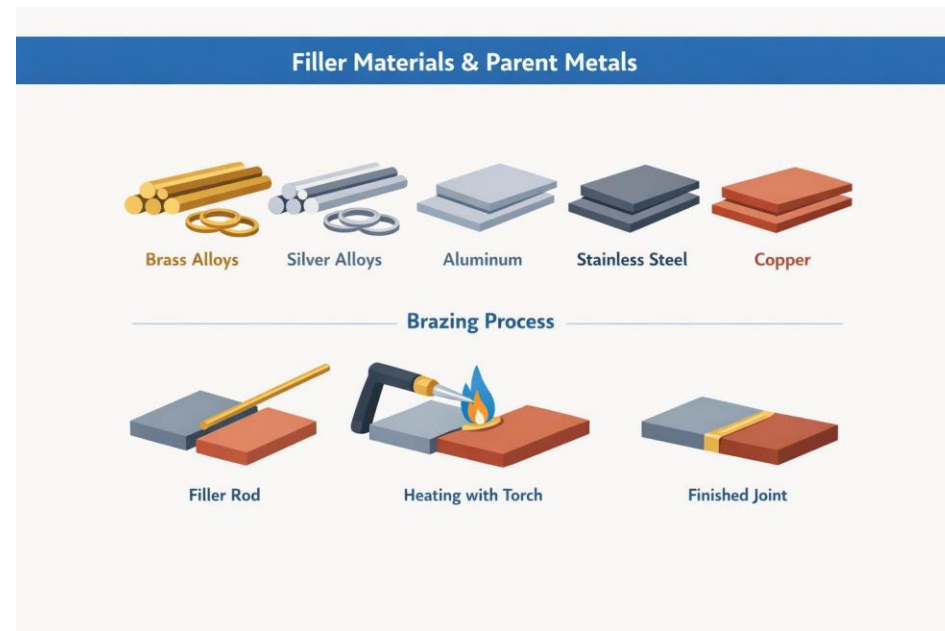
Choosing a filler material depends on the properties of the parent materials and specific application requirements.

Single vs Multiple Options

Some brazing cases allow only one suitable filler, while others may have several filler material options.

Suitability Within Material Classes

Not all filler materials within a class are appropriate for every brazing application, highlighting the need for correct matching.



Classes of filler materials and their uses



Class AL Filler Materials

Used mainly for joining pure aluminum and select aluminum alloys, ensuring strong aluminum bonds.

Class AG Silver Brazing

Widely used for brazing various metals except aluminum, magnesium, and refractory metals; vacuum grades available.

Class CP for Copper Alloys

Primarily for joining copper and alloys; self-fluxing on copper, requires flux or atmosphere for alloys.

Class CU and Ferrous Metals

Used for brazing copper, carbide, and ferrous metals, often with flux or protective atmosphere.

Class NI and CO for Stainless Steel

Specialized for joining stainless steel and corrosion-resistant alloys, used under vacuum or protective atmospheres.

Class PD and AU Versatility

Used in protective or vacuum settings for metallized ceramics and challenging metals including nickel alloys.

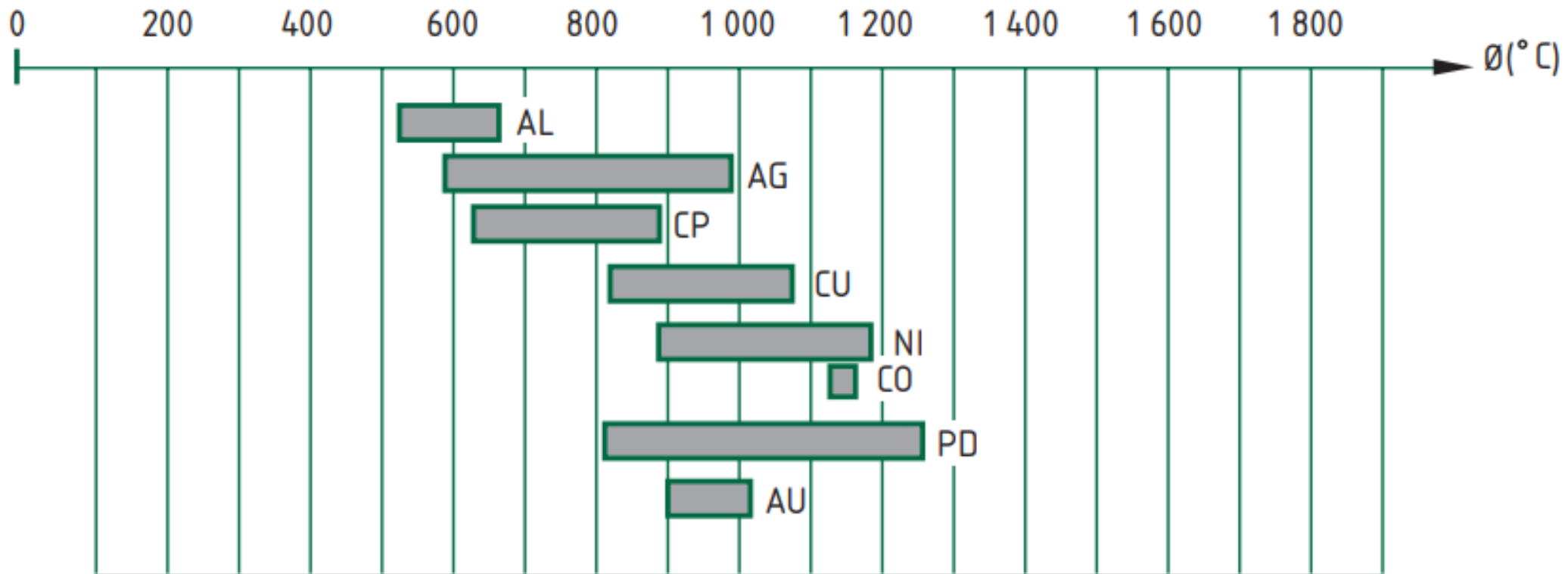
Filler Material Classes

EN 1044:1999 reference	Class	Composition
Table 2	AL	Aluminium brazing filler materials
Table 3	AG	Silver brazing filler materials
Table 4	CP	Copper-phosphorus brazing filler materials
Table 5	CU	Copper brazing filler materials
Table 6	NI	Nickel brazing filler materials
Table 6	CO	Cobalt brazing filler materials
Table 7	PD	Palladium bearing brazing filler materials
Table 8	AU	Gold bearing brazing filler materials
Table 1		Special 'vacuum application' versions of certain AG, PD and AU brazing filler materials

Filler Material Classes



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Role and Types of Fluxes in Brazing

Importance and forms of fluxes in brazing



Role of Fluxes in Brazing

Fluxes remove oxides and prevent oxidation during brazing, especially when performed in air.

Self-Fluxing Filler Materials

Self-fluxing copper-phosphorus fillers usually do not require additional flux for brazing.

Forms of Flux

Fluxes come in powders, pastes, gases, liquids, flux-coated or cored filler materials, offering application flexibility.

Flux in Protective Atmospheres

Fluxes are sometimes used even in brazing with protective atmospheres to ensure clean joints.

Standard practices and specifications for fluxes



Flux Application Practice

Flux is applied to components before heating to ensure proper joining during brazing.

Standardized Flux Importance

Using standardized fluxes guarantees consistent and reliable brazing results across applications.

EN 1045 Compliance

All fluxes must meet EN 1045 specifications to ensure quality and performance in brazing.

Flux removal: procedures and considerations



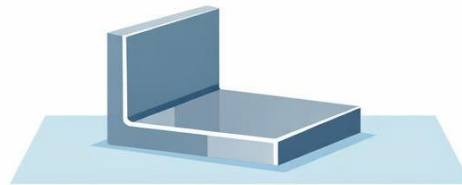
Brazing



Flux Removal



Water Quenching



Finished Part

Chemical Activity of Flux Residues

Some flux residues remain chemically active after brazing and can cause corrosion if not completely removed.

Factors Influencing Flux Removal

Effective flux removal depends on correct flux amount, avoiding overheating, and minimizing heating time.

Water Quenching Method

Quenching the assembly in water after solidification can ease flux removal if no damage occurs.

Proper Flux Disposal

All flux residues must be disposed of according to regulations to ensure safety and environmental protection.



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Fluxes for Different Brazing Temperatures and Materials



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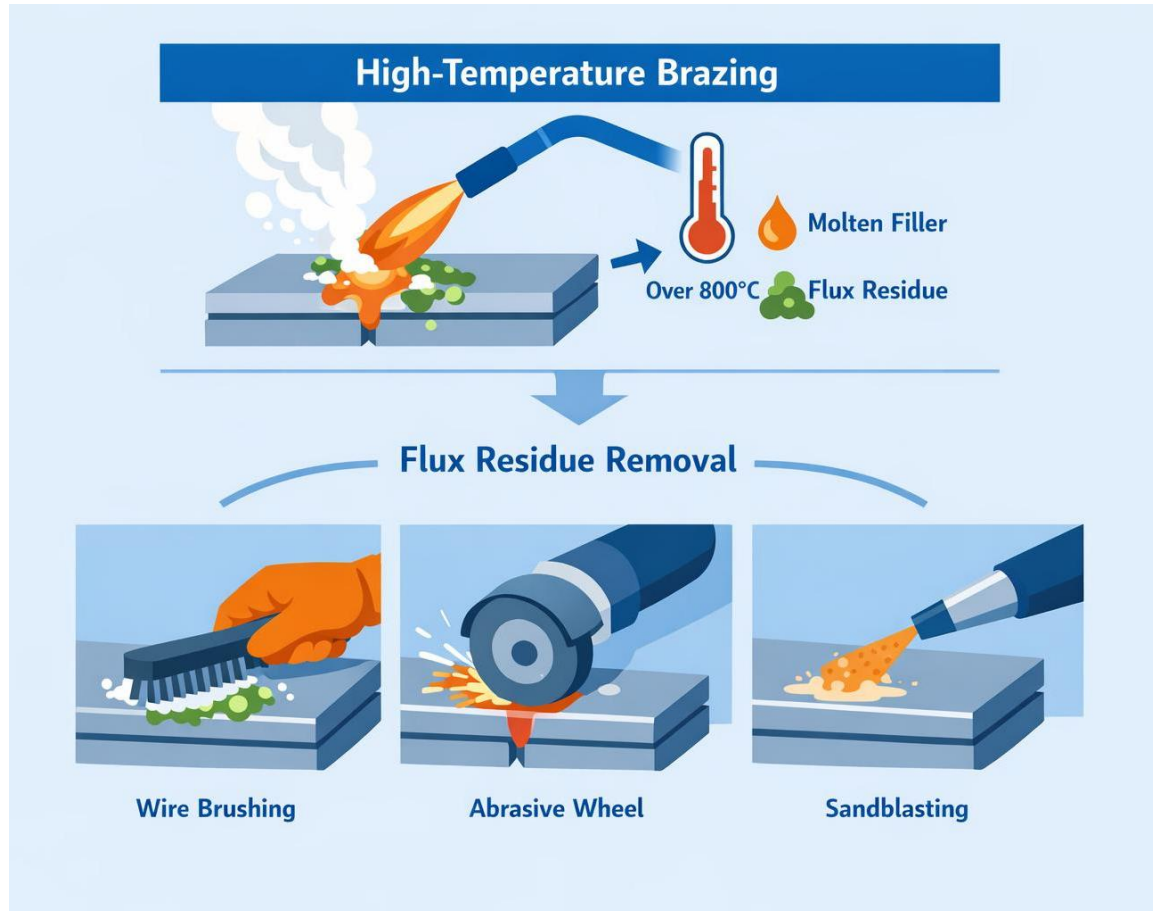
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High-temperature fluxes and their removal



High-temperature Flux Characteristics

Fluxes used at temperatures above 750°C create hard, glassy residues difficult to dissolve in water.

Mechanical Removal Methods

Hard flux residues require mechanical removal using abrasive techniques like grit or shot blasting.

Low-temperature fluxes and removal methods

INDUSTRIAL BRAZING PROCESS



BRAZING



FLUX APPLICATION



QUENCHING



PICKLING



BRUSHING

Low-Temperature Fluoroborate Fluxes

Fluoroborate fluxes are used for brazing below 750°C and produce water-soluble residues.

Water Washing Removal

Residues can be removed effectively by washing in hot or boiling water with agitation or ultrasonic vibration.

Chemical and Abrasive Techniques

Chemical descaling solutions and non-immersion methods like steam lancing or abrasives remove discoloration and residues.

Aluminum brazing fluxes: types and removal

ALUMINUM BRAZING PROCESS

CORROSIVE FLUX



FLUX RESIDUE



WASH WITH WATER



CLEAN WITH BRUSH

NON-CORROSIVE FLUX



FLUX RESIDUE



WIPE WITH CLOTH



LEAVE AS IS

Type FL10 Flux Characteristics

Type FL10 flux is highly corrosive and requires thorough removal after brazing to prevent damage.

Type FL20 Flux Characteristics

Type FL20 flux is generally non-corrosive, and residues can often be safely left on the aluminum surface.



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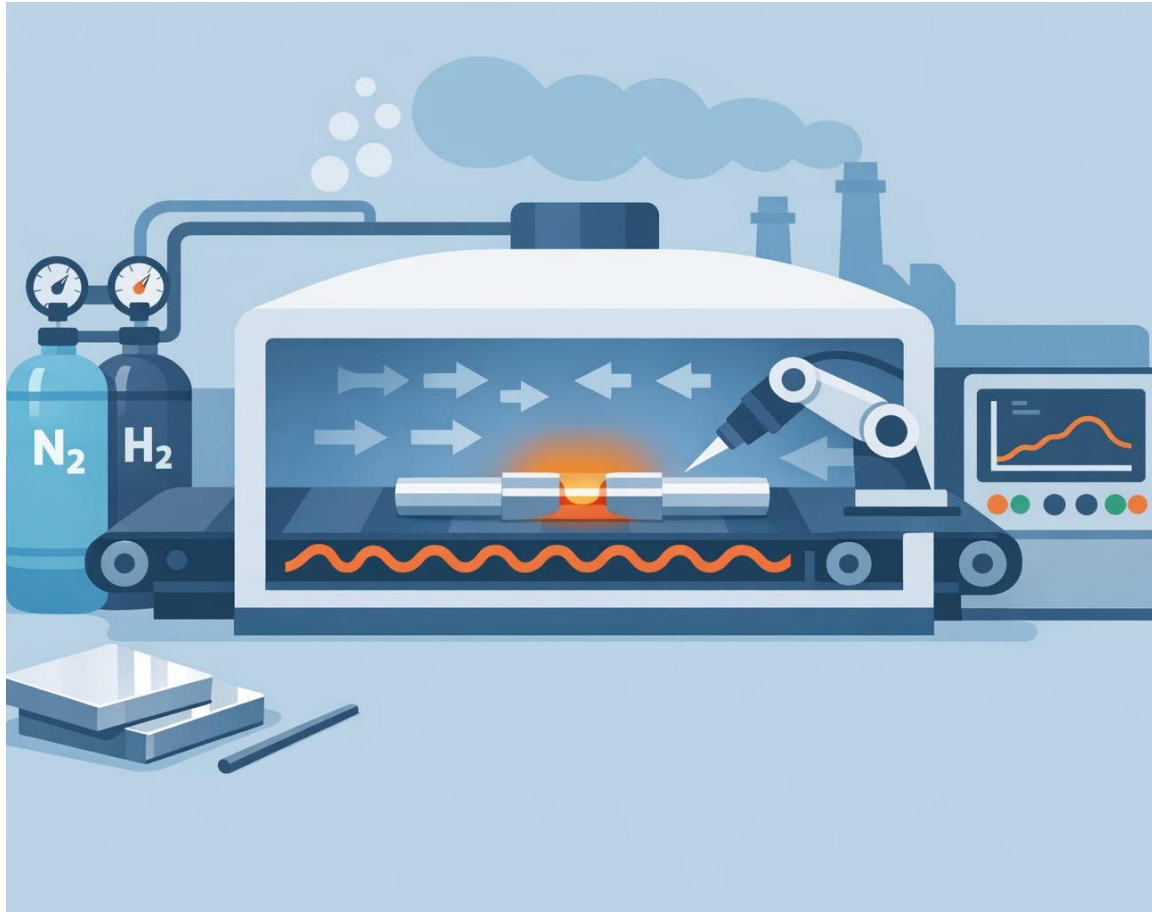


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Atmospheres in Brazing Processes

Protective atmospheres: functions and selection



Role of Protective Atmospheres

Protective atmospheres maintain cleanliness of parent and filler materials for effective brazing joints.

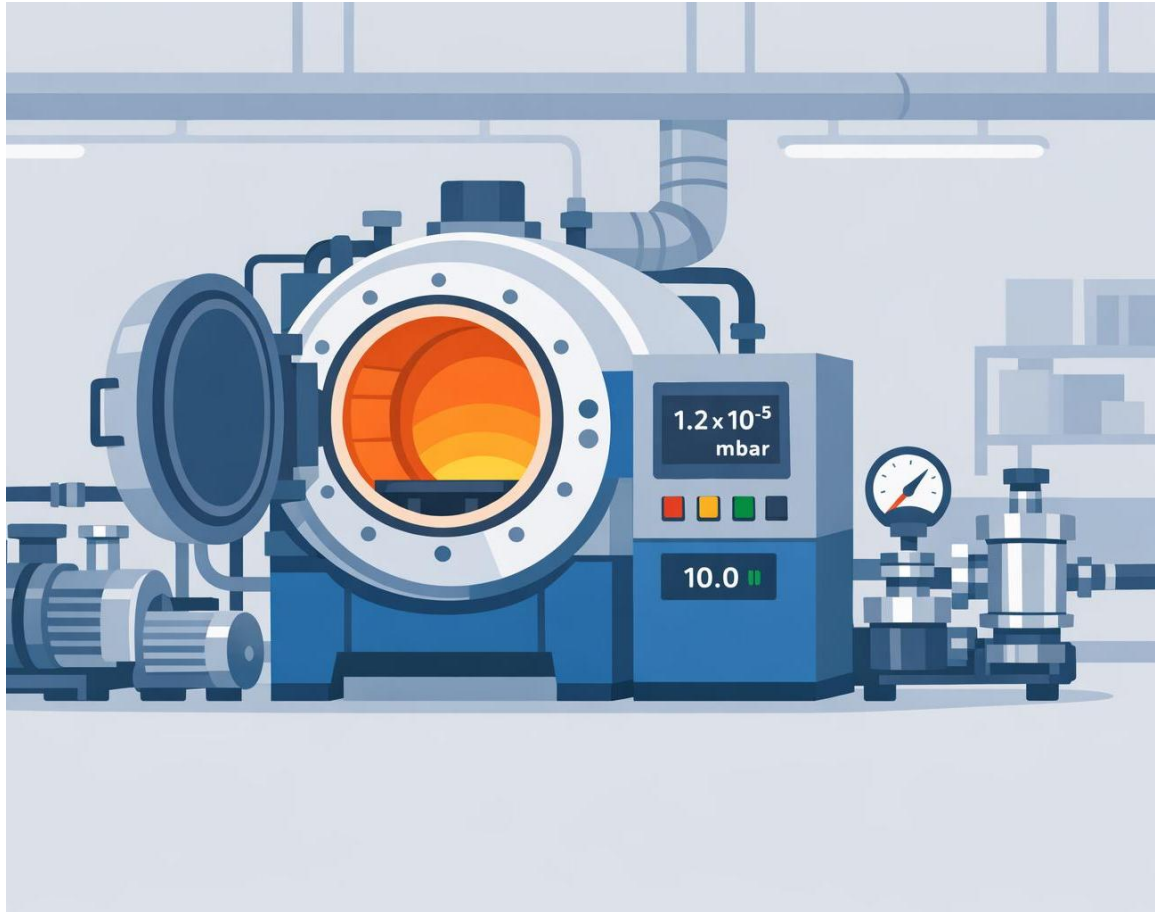
Atmosphere Selection Criteria

Choice of atmosphere depends on parent and filler material properties, using active or inert gases.

Interconnected Variables

Atmospheric purity, cycle time, and temperature are linked and affect brazing success.

Vacuum atmospheres: equipment and standards



Vacuum Pump Systems

Mechanical and oil diffusion pumps work together to quickly evacuate furnace air for brazing processes.

Outgassing Management

Automatic interlock of pumps and vacuum instruments controls pressure changes and maintains atmosphere quality.

High Vacuum Standards

Achieving vacuum better than 10^{-3} mbar ensures extremely low gas impurities for effective brazing.

Examples of protective atmospheres

No.	Source	Typical dew point of incoming gas °C	Approximate composition				Applications	
			H ₂ %	N ₂ %	CO %	CO ₂ %	Filler material class	Parent materials
1	Combusted fuel gas ^a (low hydrogen)	Up to +30	1 to 5	87	1 to 5	11 to 12	AG ² , CP, CU3XX ^a	Cu and some Cu alloys. Low and medium carbon steels
2	Combusted fuel gas ^a (decarburizing)	Up to +30	14 to 15	70 to 71	9 to 10	5 to 6	AG ² , CP, CU1XX, CU2XX, CU3XX ^a	Cu and some Cu alloys, low and medium C steel, Ni, Ni-Cu alloy
3	Combusted fuel gas ^a , dried	-40	15 to 16	73 to 75	10 to 11	-	AG ² , CP, CU1XX, CU2XX, CU3XX ^a	Cu and some Cu alloys, carbon steels, Ni-Cu alloy, Ni, Ni-Fe alloys
4	Combusted fuel gas ^a , dried (carburizing)	-40	38 to 40	41 to 45	17 to 19	-	AG ² , CP, CU1XX, CU3XX ^a	Cu and some Cu alloys, carbon steels, Ni-Cu alloy, Ni
5	Dissociated ammonia ^b (cracked ammonia)	-54	75	25	-	-	AG, CP, CU1XX, CU2XX, CU3XX, NI108, NI107	Cu and some Cu alloys, carbon steels, Ni-Cu alloy, Ni and Ni alloys, alloys containing Cr ^b
6	Cylinder hydrogen	Down to -80	100	d	-	-	AG, CP, CU1XX, CU2XX, CU3XX, NI107	Cu and some Cu alloys, low and medium carbon steels, Ni and Ni alloys and alloys of Co, Cr and cemented carbides ^b
7	Inert gas ^c , e.g. argon, nitrogen ^c	Below -80	-	-	-	-	CP, CU1XX, CU2XX, NI	Cu and some Cu alloys, carbon steels, Ni and Ni alloys ^d , alloys containing Cr

^a Flux additionally required when filler materials containing volatile elements are used.

^b Flux required in addition to atmosphere when appreciable quantities of aluminium, titanium, silicon or beryllium are present.

^c It is essential that nitrogen is not used with refractory metals or aluminium or when the filler material contains boron or silicon.

^d The combusted fuel gas (low hydrogen or decarburizing) may be referred to as exothermic. It may also be available as synthetic gas.

^e The combustible fuel gas (carburizing) may be referred to as endothermic. It may also be available as synthetic gas.

^f It may also be available as synthetic gas.

^g Certain filler materials in EN 1044:1999 Tables 7 and 8, can be brazed in protective atmospheres 5 and 7

Definition of Protective Atmospheres

Protective atmospheres are controlled gas environments used to prevent oxidation and degradation of materials.

Common Gas Compositions

Typical protective atmospheres include inert gases like nitrogen, carbon dioxide, and argon to reduce reactivity.

Applications of Protective Atmospheres

Used in food packaging, metal processing, and pharmaceutical industries to extend shelf life and quality.

Conclusion: Critical Insights for Effective Brazing in Aerospace and Defence



Parent and Filler Materials

Selecting compatible parent and filler materials is essential for strong brazed joints in aerospace applications.

Flux Selection

Proper flux choice prevents oxidation and ensures clean, reliable brazing results.

Protective Atmospheres

Using protective atmospheres during brazing avoids contamination and enhances joint integrity.

Performance and Longevity

Mastering brazing factors improves joint strength, performance, and longevity in defence and aerospace fields.