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Copper Brazing Technology

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Abstract: Copper Brazing is a method used to join metal parts by melting a copper or copper-based filler metal, which flows into the small gap between the parts without melting the parts themselves. This process uses high heat and often takes place in special environments like vacuum chambers or gas-filled furnaces to prevent oxidation. It creates strong, leak-proof joints that work well under high stress and temperature. Copper brazing is commonly used in industries like HVAC, Automotive, and Refrigeration to make parts like heat exchangers and radiators. The technique offers strong bonds and works with many metals, but it requires precise control of temperature, part fit, and cleanliness. New improvements in heating and equipment have made copper brazing even more reliable and efficient for modern manufacturing.
Keywords: Dissimilar metal joining, Copper brazing, High temperature joining, Capillary action, Furnace brazing, Vacuum brazing, Induction brazing, Joint strength, Corrosion resistance.

I. INTRODUCTION

Copper brazing is a metal joining process that uses copper or copper-based filler metals to form strong, leak-proof joints without melting the base materials. The process operates at temperatures typically above 1083°C, relying on capillary action to draw the molten filler metal into narrow gaps between closely fitted metal surfaces. Unlike welding, which melts the base materials, brazing produces minimal distortion and can join dissimilar metals, making it highly versatile. Common filler materials include pure copper, copper-phosphorus, and copper-silver alloys, while typical base metals are copper, brass, steel, and stainless steel. The brazing process can be performed using several methods, including furnace brazing, vacuum brazing, induction brazing, and torch brazing—each suited to different applications based on production scale, joint design, and material compatibility. Control over various process parameters is essential to ensure quality and consistency in copper brazing. These parameters include brazing temperature, joint clearance, heating rate, atmosphere type (e.g., vacuum, hydrogen, nitrogen), and surface preparation. Proper joint design is critical, with ideal gap tolerances typically ranging from 0.025 to 0.125 mm to facilitate capillary flow of the filler metal. The advantages of copper brazing include excellent mechanical strength, good thermal and electrical conductivity, resistance to corrosion, and the ability to produce clean, aesthetically pleasing joints. However, limitations such as the need for precise temperature control, potential oxidation, and equipment costs must also be considered. Copper brazing finds wide application in industries such as HVAC, automotive, aerospace, and refrigeration, where durable and thermally efficient joints are required. Components like heat exchangers, radiators, and tubing systems benefit significantly from the strength and reliability of brazed joints. In recent years, advancements in automation, improved filler metal formulations, and the development of more efficient heating systems have enhanced the speed, precision, and environmental sustainability of copper brazing. As manufacturing demands evolve, copper brazing continues to play a vital role in producing high-performance, cost-effective assemblies across multiple engineering sectors.

II. COMPONENTS OF COPPER BRAZING

1) Base Metals - Metals to be joined (e.g., copper, brass, steel, stainless steel)
2) Filler Metal-Typically pure copper or copper-based alloys (e.g., copper-phosphorus, copper-silver)
3) Flux *(when required)* – 1. Chemical compound used to prevent oxidation and improve filler metal flow, 2. Not needed in vacuum or controlled-atmosphere brazing
4) Heat Source- Supplies the necessary brazing temperature

Types:

- Furnace (batch production)
- Induction heater (localized, fast)
- Torch (manual or repair work)
- Vacuum chamber (oxidation-free, high precision)
- Atmosphere
- Environment in which brazing takes place

- Options:
  - Air
  - Vacuum
  - Inert gas (e.g., argon, nitrogen)
  - Reducing gas (e.g., hydrogen)

5) Joint Design - Proper fit and gap (typically 0.025–0.125 mm) for capillary action. Smooth, clean surfaces for good adhesion
6) Temperature Control System- Ensures accurate heating to melt filler metal without affecting base metals
7) Cleaning and Surface Preparation-Removal of oxides, grease, and dirt for proper bonding

III. WORKING OF COPPER BRAZING

1) Preparation of Components
- The base metals are cleaned to remove oxides, oil, dirt, or other contaminants.
- Surfaces are aligned with a precise joint gap (typically 0.025–0.125 mm) to allow capillary action.

2) Filler Metal Selection and Placement
- A suitable copper or copper-based filler metal is selected based on the base materials and application.
- The filler may be placed as a preform, wire, paste, or ring near or inside the joint area.

3) Flux Application *(if required)*
- Flux is applied to prevent oxidation and aid filler flow.
- In vacuum or protective atmospheres, flux is usually not needed.

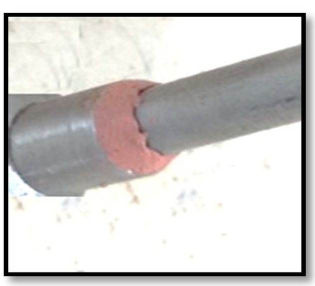
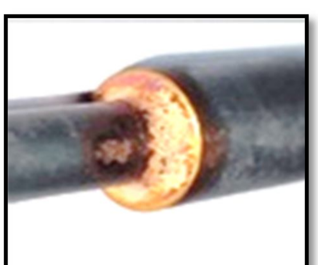
4) Heating
- The assembly is heated using a torch, furnace, induction coil, or vacuum chamber.
- Temperature is raised above the melting point of the filler metal up to 1100ºC but below that of the base metals.

5) Melting and Capillary Flow
- The filler metal melts and is drawn into the joint by capillary action, filling the gap between the base metals.

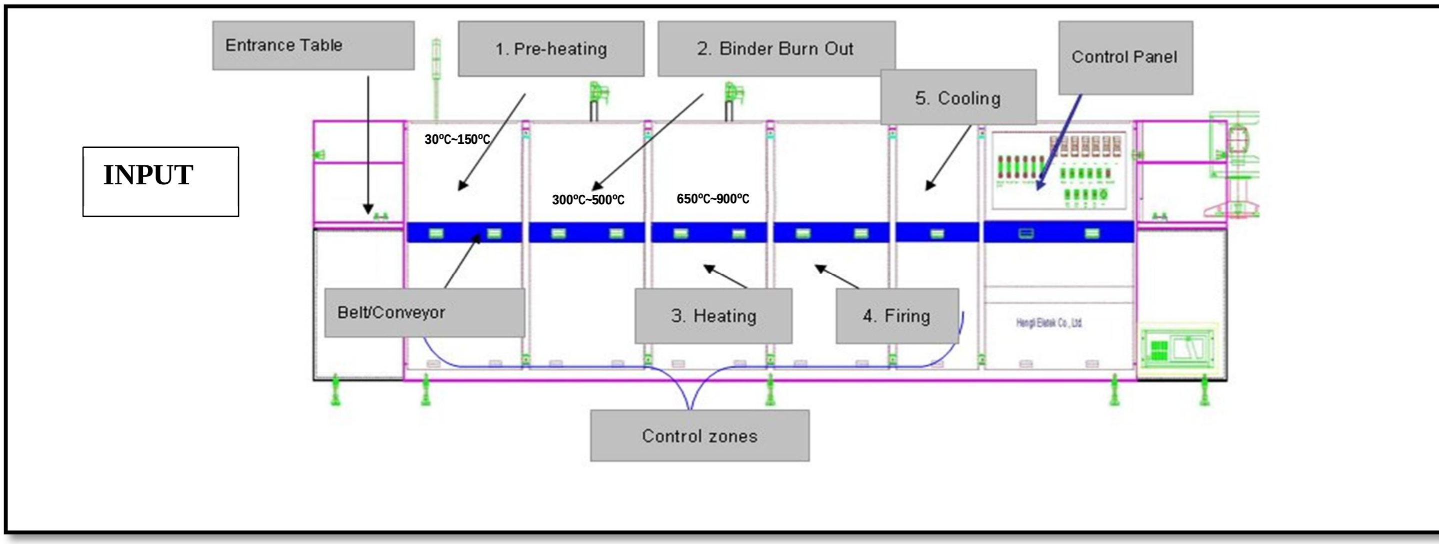
6) Cooling and Solidification
- The heat source is removed, and the assembly is allowed to cool.
- The molten filler solidifies, forming a strong, sealed joint.

7) Post-Braze Cleaning *(if flux was used)*
- Residual flux is removed to prevent corrosion.
- Inspection may be performed to check joint quality (e.g., leak testing, visual inspection).

8) Input - Output

Following Sketch is Shown How Copper Brazing Done at Conveyor Belt Furnace



To estimate how much filler metal (copper alloy) you need for a brazed joint, you can calculate the **volume of the gap** that needs filling.

9) Formula

Volume=Length of joint×Gap width×Height (thickness)

- Length of joint (L) = length of the brazed area (in mm or inches)
- Gap width (G) = the space between the parts (typically 0.05 - 0.2 mm)
- Height (H) = thickness of the joint area or the cross-sectional height of the joint

Example:

- Joint length = 100 mm
- Gap width = 0.1 mm
- Height/thickness = 2 mm

Volume=100×0.1×2=20 mm3

we can convert this volume to mass using the density of the filler metal:

10) Mass of Filler Metal Required

Mass=Volume×Density

900°C~1100°C 800°C~200°C

OUTPUT

Density of copper (approx.) = 8.96 g/cm³ = 8.96 × 10^-3 g/mm³

From the example:

Mass=20 mm3×8.96×10−3 g/mm3=0.1792 g

So, we would need about **0.18 grams** of copper filler metal for that joint.

11) Heat Required for Brazing

To calculate the heat energy needed to raise the temperature of the parts to the brazing temperature, use:

$Q = m \times c \times \Delta T$

- Q = heat energy (Joules)
- m = mass of the part (kg)
- c = specific heat capacity (J/kg°C) — for copper approx. 385 J/kg°C
- ΔT = temperature change (°C)

 General Brazing Temperature Range: Above 450°C (as per brazing definition) and usually between 900°C – 1100°C depending on filler alloy.

 Copper–Phosphorus Filler Alloys (BCuP series): 850°C – 1080°C

 Silver–Copper Alloys (BAg series): 600°C – 800°

V. ADVANTAGES OF COPPER BRAZING

1) Strong Joints – Produces durable and leak-proof joints.
2) Dissimilar Metals – Can join copper to other metals like Mild Steel, 300 &400 series of Stainless Steel and Carbon Steel and High Alloy Steel.
3) Low Distortion – Base metal does not melt, so less warping compared to welding.
4) Corrosion Resistance – Excellent resistance, especially in plumbing and HVAC systems.
5) Good Electrical & Thermal Conductivity – Ideal for electrical connectors and heat exchangers.
6) Economical – Uses less heat and filler metal compared to welding.
7) Versatile Heating Methods – Can be done using torch, furnace, or induction.
8) Smooth Finish – Produces clean joints requiring little or no finishing.
9) Automation Friendly – Suitable for large-scale production in industries.

VI. LIMITATIONS

1) Not suitable for very high-temperature applications.
2) Joint strength depends on surface preparation.
3) Requires precise temperature control.

VII. CONCLUSIONS

1) Copper brazing is a reliable, cost-effective technology that continues to be a vital process across various industries.
2) Its ability to produce strong, leak-proof, and durable joints has made it indispensable for applications ranging from HVAC systems to automotive manufacturing.
3) As brazing technology continues to evolve, its applications will expand, leading to improved efficiency, reliability, and sustainability in manufacturing processes.

VIII. ACKNOWLEDGEMENT

I sincerely acknowledge and express my gratitude to all those who have supported and guided me in gaining knowledge and practical experience in Copper Brazing.

I extend my special thanks to my mentors and supervisors for providing me with valuable instructions, technical guidance, and constant encouragement throughout the process. Their expertise has helped me understand the fundamentals of brazing, safety precautions, material handling, and quality standards.

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BIOGRAPHY

I am Roshan Gonnade, Basically, I Belongs to Bhandara District of Maharashtra. Now I am working with private company as an Engineer-Quality at Chh. Sambhaji Nagar, Maharashtra India.

With a keen interest in manufacturing processes, brazing technology, and quality control. I have studied the working of copper brazing furnaces, focusing on their design, temperature zones, advantages, and applications in industry.

Through this paper presentation, my aim is to highlight the importance of COPPER BRAZING TECHNOLOGY, its role in modern manufacturing, and the operational aspects that make it an efficient and reliable joining process.