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Visual Inspection Criteria and Avoidance of Imperfections on Brazed Joints

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CESOL

Agenda Overview



- Overview and Project Information
- Visual Examination of Brazed Joints
- Inspection Aids, Equipment, and Procedures
- Classification of Imperfections in Brazed Joints
- Acceptance Guidelines for Brazed Joints
- Common Causes and Avoidance of Imperfections
- Influence of Brazing Parameters on Joint Quality



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Visual Examination of Brazed Joints



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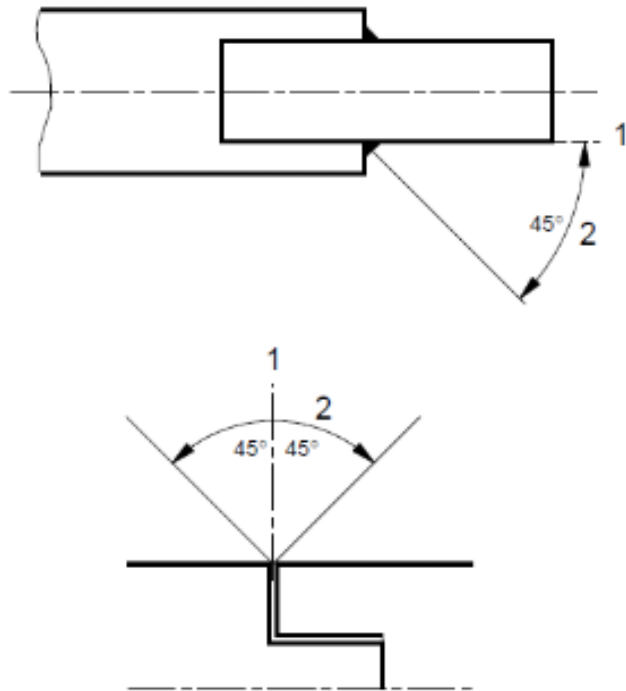
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General requirements and design considerations for inspection



Key
1 Axis
2 Viewing angle

Visual Inspection Fundamentals

Visual examination is a fundamental non-destructive testing method focusing on joint quality without dimensional measurements.

Design for Inspection Access

Design must ensure sufficient access to joints for effective visual inspection, enhancing examination reliability.

Joint Accessibility Criteria

Inspection requires determining which joints are viewable directly or with aids, ensuring proper evaluation angles.

Principle of Visual Examination

Detailed inspection of brazed joints and parent material using aided and unaided visual methods evaluates joint integrity.

Qualification and training of inspection personnel



Knowledge of Braze Process

Inspectors must understand the braze process and recognize common imperfections to ensure accurate inspections.

Vision Testing Standards

Inspectors' vision must be tested according to EN 473:1993 to meet inspection reliability standards.

Training on Specific Requirements

Personnel receive focused training on specific visual examination requirements to improve accuracy and consistency.

Training Records and Proficiency

Training records confirm compliance and include supervisor approval of inspectors' proficiency levels.

Specific requirements and pre-examination considerations



Pre-Examination Requirements

Determine the manufacturing stage and ensure surface preparation meets inspection needs for accurate visual examination.

Inspection Criteria and Scope

Define minimum imperfection size, inspection extent, and acceptance criteria for consistent evaluation of workpieces.

Documentation and Reporting

Provide written inspection procedures and clarify reporting requirements to ensure proper documentation of results.

Operator Preparation

Equip operators with all necessary information and procedures before examination to guarantee thorough inspection.



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Inspection Aids, Equipment, and Procedures



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Aids and equipment for effective visual inspection



Adequate Illumination

Proper lighting is essential for clear observation during visual inspections, enhancing visibility of all areas.

Low-Magnification Viewer

A bench-mounted wide-angle viewer with approx. 5x magnification allows hands-free inspection with integrated lighting.

Comparison Gauge and Loupe

Comparison gauges and 8x magnification loupes help measure and verify the size of imperfections accurately.

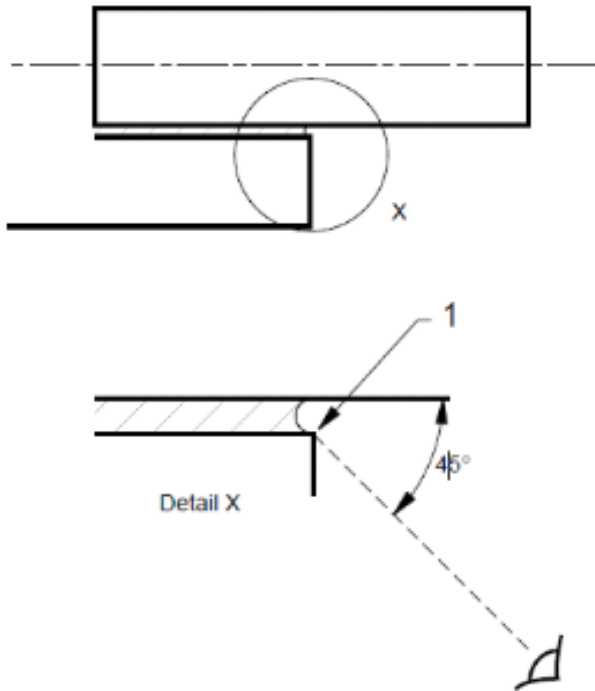
Mirrors and Localized Lighting

Small mirrors and fiber optic lightguides enable inspection of hidden or shadowed areas effectively.

Approved Marking Tools

Waterproof felt markers or specified marking tools ensure clear identification without damaging the workpiece.

Defining extent and documentation of inspection on workpieces



Key

1 Bottom of recess to be visible at 45 ° to the joint axis

Scope of Visual Inspection

Inspection procedures must define the scope clearly to ensure consistency across workpieces, especially for hard-to-access fillets.

Marking Inspection Sites

Inspection locations should be clearly indicated on assembly or separate drawings for clarity and reference during inspection.

Acceptance Criteria Documentation

Drawings must specify or reference acceptance criteria to guide evaluation and ensure standardized inspections.

Examination procedures and marking inspected joints



Magnification and Illumination

Use low-power magnifiers and fiber optic lights to reduce eye strain and improve visibility of joints during inspection.

Imperfection Size Gauge

Employ gauges to standardize minimum imperfection size detection, ensuring consistent inspection results among operators.

Workpiece Segregation

Separate inspected from uninspected and acceptable from unacceptable workpieces to prevent mix-ups during inspection.

Marking Inspected Joints

Mark joints with color-coded felt pens; green for acceptable and red for defective joints to visually indicate status.

Reporting and documentation of inspection results



Inspection Organization Details

The report must state the official name of the organization conducting the inspection.

Workplace and Batch Identification

Include the workplace name, drawing number, and a unique batch identification number in the report.

Extent and Acceptance Criteria

Document the inspection scope and acceptance criteria, referencing procedures or drawings as needed.

Inspection Results and Inspector Info

Record the number of components inspected, pass count, inspector's name, signature, and inspection date.



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Classification of Imperfections in Brazed Joints

Systematic categorization and examples of imperfections



Imperfection Groups

Imperfections in brazed joints are categorized into six groups: cracks, cavities, solid inclusions, bonding, shape/size, and miscellaneous.

Internal Imperfections

Internal imperfections occur inside brazed joints and include cracks, solid inclusions, gas entrapment, and lack of fusion.

External Imperfections

External imperfections appear on the brazed joint surface, such as underfill, surface porosity, discoloration, and spatter.

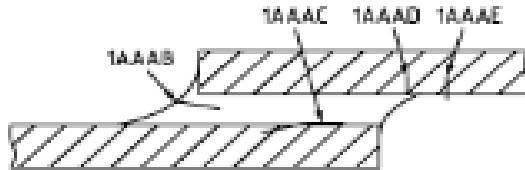
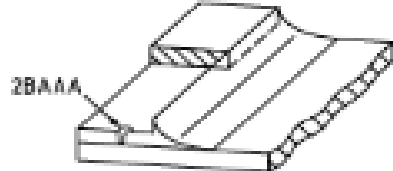
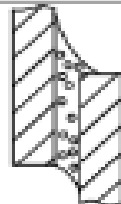
Inspection and Evaluation

Systematic classification helps inspectors consistently identify, document, and evaluate brazed joint imperfections.

Classification of imperfections



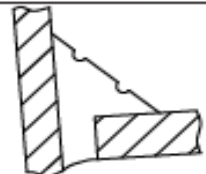
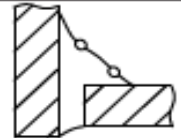
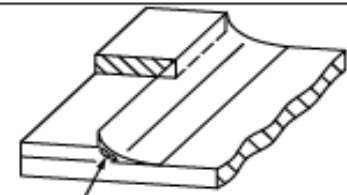
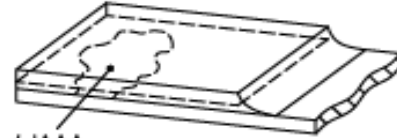
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Designation	Description	Remarks	Drawing
I Cracks			
1A ^a AAA	Crack	Limited separation of the material, predominantly two-dimensional extension. A crack can be longitudinal or transverse. It can lie in one or more of the following:	
1A ^a AAB		— in the base metal	
1A ^a AAC		— at the interface and including the diffusion zone	
1A ^a AAD		— in the HAZ	
1A ^a AAE		— in the unaffected parent material	
II Cavities			
2BAAA	Gas cavity	Gas-filled cavity	
2BGA.A	Gas pore	Spheroidal gas inclusion It can occur as:	
2BGGA		— uniformly distributed porosity	
2BGMA		— localized (clustered) porosity	
2BGHA		— linear porosity	
2L1AA	Large gas pocket	Large voids may be the width of the joint with elongated shape	
^a In the case of an intergranular crack, change this second symbol 'A' to the symbol 'F'. In the case of a transgranular crack, change this second symbol 'A' to the symbol 'H'.			
^b These imperfections often occur together.			

Classification of imperfections



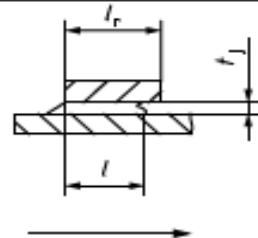
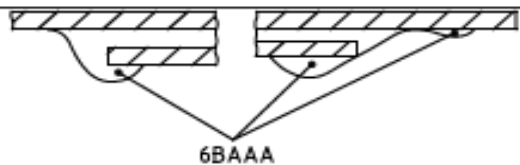
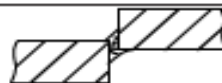
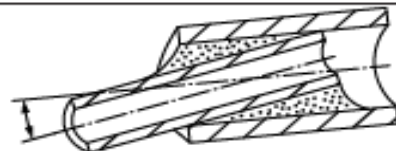
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Designation	Description	Remarks	Drawing
2BALF ^b	Surface pore	Gas pore breaking the surface	
2MGAF ^b	Surface bubble	Gas pore near the surface, which results in swelling	
III Solid inclusions			
3AAAA 3DAAA 3FAAA 3CAAA	Solid inclusion	Inclusion of foreign metal or non-metallic particles in the braze metal Could be possible to divide into: — oxide inclusion — metallic inclusion — flux inclusion	 3AAAA
IV Bonding imperfections			
4BAAA	Bonding imperfection	No bonding or inadequate bonding between the braze metal and the parent material	
4JAAA	Filling imperfection	Incomplete filling of the gap	 4JAAA
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Classification of imperfections



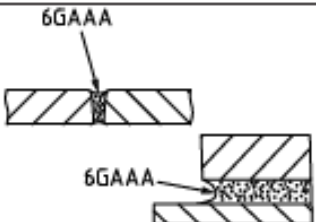
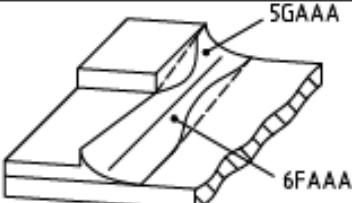
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Designation	Description	Remarks	Drawing
4CAAA	Incomplete penetration	The braze metal has failed to flow through the required length of the joint	 The arrow indicates the direction of flow through the joint
V Shape and size imperfections			
6BAAA	Excess braze metal	Braze metal has spilled over onto parent material solidifying as a bead or a thick layer	 6BAAA
5AAAA	Imperfect shape	Departure from the prescribed shape of the brazed joint	
5EIAA	Linear misalignment (linear offset)	The components are parallel but offset	
5EJAA	Angular misalignment	The components form an angle deviating from the required value.	
5BAAA	Distortion	Unwanted change in the shape of the brazed assembly	
^a In the case of an intergranular crack, change this second symbol 'A' to the symbol 'F'. In the case of a transgranular crack, change this second symbol 'A' to the symbol 'H'. ^b These imperfections often occur together.			

Classification of imperfections



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Designation	Description	Remarks	Drawing
5FABA	Localized melting (or melt-through)	Through-going hole in the brazed joint or next to it	
7NABD	Fused parent material surface	Fused surface of the brazed assembly in the region of the joint	
7OABP	Erosion by filler metal	Erosive damage to the surface of the brazed assembly	
6GAAA	Recessed braze metal (recessed fillet)	The surface of the filler metal in the brazed joint is below the level of the joint opening The surface of the braze metal has sunk below the surface of the parent material	
5HAAA	Rough surface	Irregular solidification, liquation, etc.	
6FAAA	Insufficient or excessive fillet	Fillet out of specified size has formed	
5GAAA	Irregular fillet	Appearance of fillet variable	

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Acceptance Guidelines for Brazed Joints

Guidelines for flux, imperfection size, and fillet continuity



Flux and Residue Removal

Specify required flux and residue removal level to enable thorough brazed joint inspections.

Minimum Imperfection Size

Imperfections smaller than 0.5 mm should be ignored; larger assemblies may require extra testing.

Fillet Continuity Criteria

Clearly define acceptance for complete or incomplete fillets with precise gap size and count limits.

Criteria for recessed fillets, excess filler, surface erosion, and cosmetic appearance



Recessed Fillets Criteria

Recessed fillets result from brazing gaps or insufficient filler; acceptance requires defined criteria for depth.

Managing Excess Filler Metal

Assembly drawings must indicate areas where filler metal must not encroach to guide stop-off agent application.

Surface Erosion Documentation

Surface erosion by filler metal, especially in aluminum brazing, should be recorded with sketches or photos.

Cosmetic Appearance Standards

Cosmetic requirements for braze fillets affect inspection and costs, needing permanent records of quality.



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Common Causes and Avoidance of Imperfections



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Overview of common causes and importance of prevention



Significance of Brazing

Brazing is essential for manufacturing strong, leak-proof joints used in various industries.

Common Imperfections

Imperfections during brazing can weaken joints and reduce performance if not properly managed.

Importance of Prevention

Recognizing causes and preventing imperfections ensures consistent, high-quality brazed connections.

Inadequate surface preparation and its prevention



Causes of Imperfect Joints

Residual oxides, oils, and dirt on base metals prevent proper filler metal adhesion, weakening brazed joints.

Importance of Cleaning

Thorough cleaning and degreasing of surfaces ensure better wetting and stronger brazed joints.

Oxide Removal Methods

Using chemical or mechanical methods to remove oxides improves bonding and joint durability.

Incorrect joint clearance and its effects

Brazed Joint Clearances



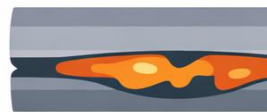
PROPER CLEARANCE

Good Filler Flow



TOO TIGHT

Poor Flow



TOO WIDE

Filler Void

Impact of Wide Joint Clearance

Wide joint gaps reduce capillary action, causing insufficient filler metal flow and resulting in weak, porous joints.

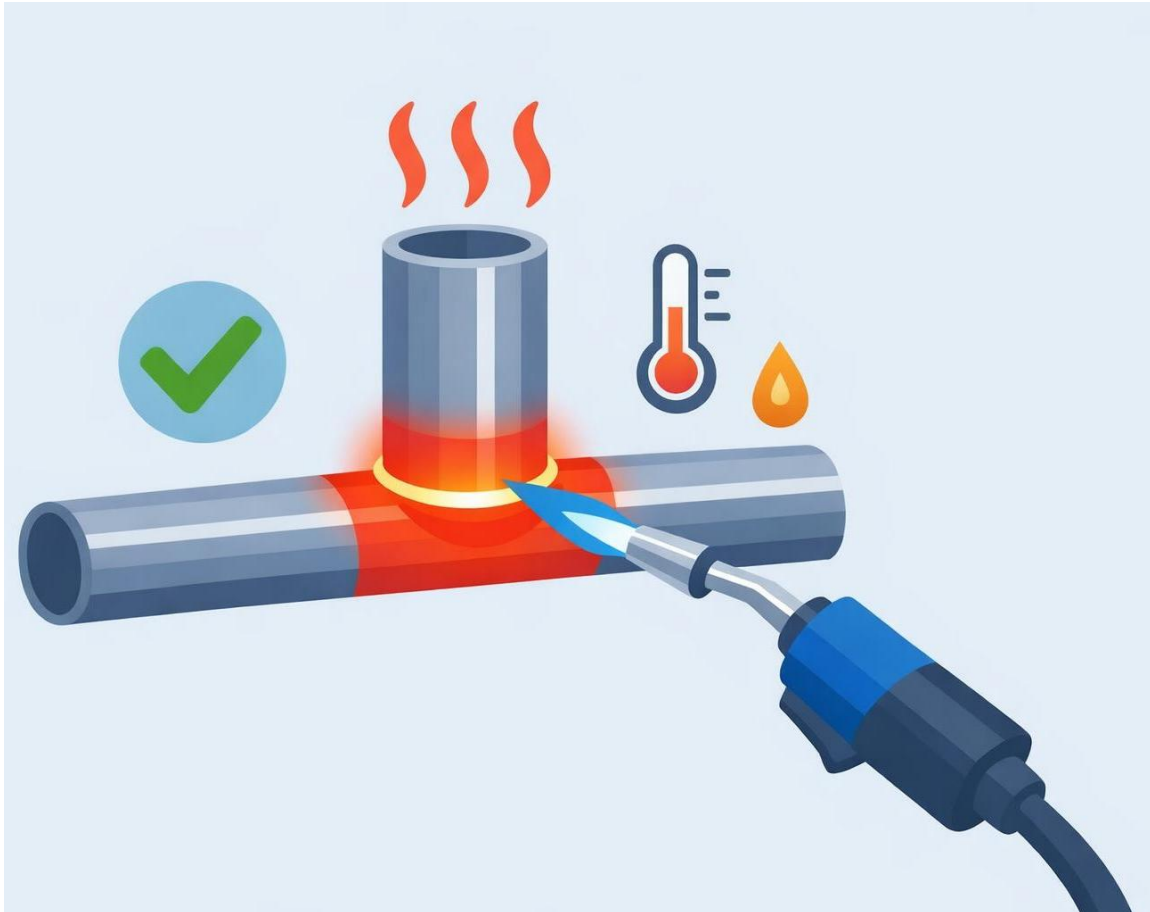
Impact of Narrow Joint Clearance

Narrow joint gaps restrict filler metal flow, leading to incomplete bonding and reduced joint strength.

Recommended Joint Clearance Range

Maintaining joint clearance between 0.05 and 0.15 mm ensures optimal filler metal flow and strong, durable joints.

Improper heating and its impact on joint quality



Uneven Heating Effects

Uneven heating causes localized overheating and oxidation, leading to weak joints and imperfections.

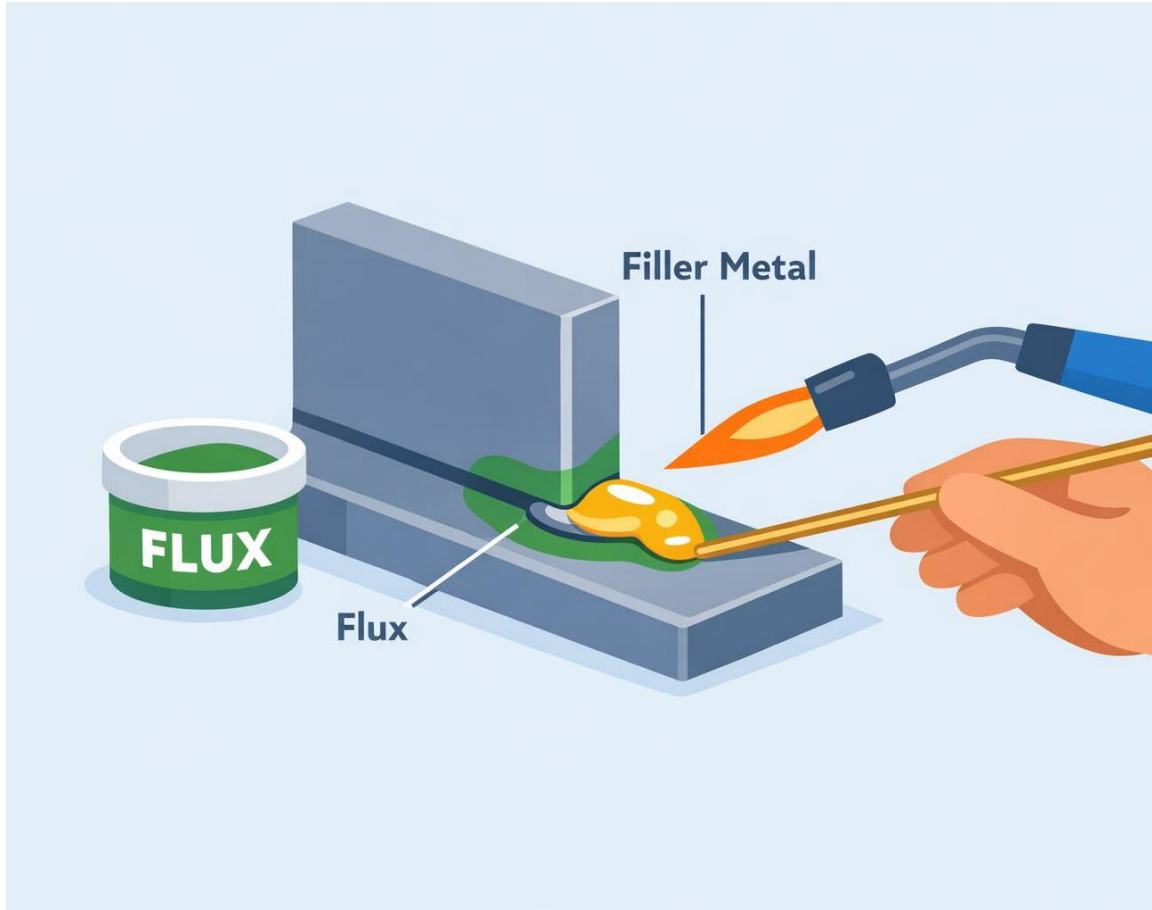
Incomplete Melting Risks

Insufficient heat prevents filler metal from melting properly, reducing bonding and joint strength.

Importance of Uniform Heating

Applying heat evenly ensures thorough melting and consistent joint formation for reliable performance.

Filler metal selection and flux issues



Filler Metal Compatibility

Choosing compatible filler metal ensures joint strength and resistance to brittleness and corrosion.

Consequences of Poor Selection

Unsuitable filler metals cause brittle joints and increase corrosion risk, reducing durability.

Flux Application Issues

Incorrect or contaminated flux leads to oxidation and poor filler metal wetting, weakening joints.

Ensuring Effective Flux Use

Using correct, fresh flux applied evenly ensures strong, durable brazed joints.

Environmental contamination and preventive measures



Impact of Contaminants

Moisture, dust, and airborne contaminants cause porosity and inclusions, weakening the brazed joint's integrity.

Effect on Filler Metal Flow

Contaminants disrupt filler metal flow and wetting, leading to weak spots and incomplete bonding in the joint.

Preventive Clean Environment

Maintaining a clean, controlled environment and protecting components from contaminants ensures strong, durable brazed joints.

Key preventive actions for high-quality brazed joints



Surface Preparation

Thoroughly clean and prepare surfaces to ensure strong brazed joints and prevent contamination.

Joint Design and Clearance

Maintain proper joint design and clearance to allow effective filler flow and strong bonding.

Heat Application

Apply heat evenly and control temperature to ensure uniform brazing without damage.

Correct Materials and Environment

Use correct filler metals and fluxes in a clean environment to achieve quality brazed joints.



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Influence of Brazing Parameters on Joint Quality

Overview of critical brazing parameters



Importance of Brazing Parameters

Brazing parameters strongly influence the quality, strength, and reliability of the brazed joint.

Impact of Parameter Variations

Minor variations in parameters can cause imperfections or joint failures under operational conditions.

Key Brazing Parameters

Temperature, time, filler metal, and cleanliness are key parameters that affect brazing results.

Temperature and heating rate



Optimal Brazing Temperature

Selecting the right temperature melts filler metal without damaging the base materials or causing oxidation.

Effects of Improper Temperature

Too low temperature causes weak joints; too high leads to oxidation, grain growth, and distortion.

Heating Rate Importance

Controlled and uniform heating prevents thermal shock and uneven temperature distribution in the joint.

Risks of Incorrect Heating Rate

Rapid heating causes thermal shock; slow heating increases oxidation and flux degradation.

Joint clearance and atmosphere



Importance of Joint Clearance

Proper clearance between parts ensures effective capillary action and filler metal flow for strong joints.

Effects of Incorrect Clearance

Too wide clearance weakens joints due to poor capillary action; too narrow restricts filler metal flow.

Role of Atmosphere in Brazing

Protective atmospheres prevent oxidation and promote clean, strong bonds during brazing.

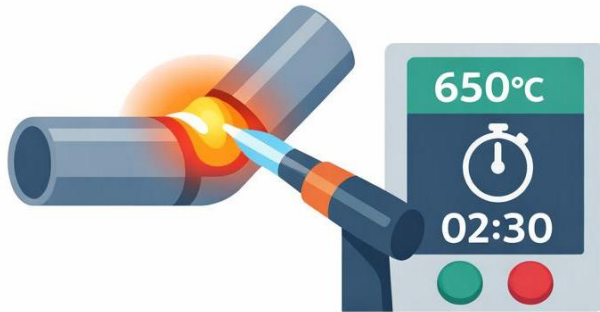
Oxidation and Flux Use

Oxidizing atmospheres cause oxide formation; flux and controlled atmospheres help maintain joint cleanliness.

Flux application and time at brazing temperature



Flux Application



Brazing Process

Proper flux application

Correct flux type and even application prevent oxidation and ensure good filler metal flow during brazing.

Effects of insufficient flux

Insufficient flux leads to oxide formation and poor filler flow, reducing joint quality.

Optimal brazing time

Maintaining proper time at brazing temperature ensures complete filler flow and strong bonding without damage.

Risks of excessive time

Excessive brazing time causes grain growth, metal erosion, and flux breakdown, harming joint quality.