ECSS-Q-ST-70-40C
8 April 2022

Space product assurance

Processing and quality assurance requirements for brazing of flight hardware

ECSS Secretariat
ESA-ESTEC
Requirements & Standards Section
Noordwijk, The Netherlands

Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering, product assurance and sustainability in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards. Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

This Standard has been prepared by the ECSS-Q-ST-70-40C Working Group, reviewed by the ECSS Executive Secretariat and approved by the ECSS Technical Authority.

Disclaimer

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1 Scope

This Standard specifies the processing and quality assurance requirements for brazing processes for space flight application. Brazing is understood as the joining and sealing of materials by means of a solidification of a liquid filler metal.

The term brazing in this standard is used as equivalent to soldering, in cases that the filler materials have liquidus temperatures below 450 °C.

Brazing and soldering are allied process to welding and this standard is supplementing the standard for welding ECSS-Q-ST-70-39.

This standard does not cover requirements for:

- Joining processes by adhesive bonding (ECSS-Q-ST-70-16),
- Soldering for electronic assembly purposes (ECSS-Q-ST-70-61),
- Soldering used in hybrid manufacturing (ESCC 2566000).

The standard covers but is not limited to the following brazing processes:

- Torch brazing,
- Furnace brazing,
- Dip Brazing and Salt-bath brazing,
- Induction Brazing.

This Standard does not detail the brazing definition phase and brazing pre-verification phase, including the derivation of design allowables.

This standard may be tailored for the specific characteristic and constraints of a space project in conformance with ECSS-S-ST-00.

2
Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

ECSS-S-ST-00-01	ECSS system – Glossary of terms
ECSS-E-ST-32-01	Space engineering – Fracture control
ECSS-E-ST-10-02	Space engineering – Verification
ECSS-M-ST-40	Space management – Configuration and information management
ECSS-Q-ST-10-09	Space product assurance – Nonconformance control system
ECSS-Q-ST-70	Space product assurance – Materials, mechanical parts and processes

3
Terms, definitions and abbreviated terms

3.1 Terms from other standards

a. For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply and in particular the following:

1. critical

b. For the purpose of this Standard, the terms and definitions from ECSS-E-ST-32-01 apply.

1. fail-safe

3.2 Terms specific to the present standard

3.2.1 alpha sample

sample brazed prior to the start of a production run, used to verify selected aspects of the quality of the brazing joint to be produced during production

3.2.2 beta sample

sample brazed at the end of a production run, used to verify selected aspects of the quality of the brazing joint to be produced during production

3.2.3 braze metal

see "**filler metal**"

3.2.4 brazer

person who performs brazing in a manual operation, guides the heating means, ensures the introduction of the brazing filler material and verifies the braze joint configuration specified by the design

3.2.5 brazing

joining and sealing of parent materials by means of a solidification of a liquid filler metal

NOTE Terms brazing and soldering are synonymous independent from the liquidus temperature or the filler material. For more details see clause 4.

3.2.6 brazing inspector

person with the responsibility and ability to judge the quality of brazed joints in relation to the specification

3.2.7 brazing operator

person who prepares the joint and sets up brazing equipment and thereby has direct influence on the brazed joint quality

3.2.8 brazing responsible

person who is nominated by the company to follow and organise brazing processes, establish the BPS, be responsible for training and realisation of acceptable brazing for production

3.2.9 design and engineering authority

organization that has the responsibility for the structural integrity and maintenance of flightworthiness of the hardware and compliance with all relevant documents related to brazing and soldering

3.2.10 filler metal

material required for soldered/brazed joints

NOTE The term "**braze metal"** is synonymous

3.2.11 flux

material which promotes wetting of the parent material by the filler metal

3.2.12 parent material

material being brazed and soldered

3.2.13 soldering

see "**brazing"**

NOTE Terms soldering and brazing are used synonymously in this standard. For more details see clause 4.

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms and symbols from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
BPS	brazing procedure specification
BVTP	brazing verification test plan
BVTR	brazing verification test report
CTE	coefficient of thermal expansion
ECSS	European Cooperation for Space Standardization
HAZ	heat affected zone
NCR	nonconformance report
NDT	non-destructive test
RfA	request for approval

3.4 Conventions

For the purpose of this Standard, the following conventions apply:

Convention	Meaning
qualification	In this ECSS-Q-ST-70-40 the term is synonymous with the term "verification" used in ECSS documentation.
qualification test plan (QTP)	used in common brazing documentation is synonymous with the term "Brazing verification test plan (BVTP)" from this ECSS-Q-ST-70-40
qualification test report (QTR)	used in common brazing documentation is synonymous with the term "Brazing verification test report (BVTR)" from this ECSS-Q-ST-70-40

3.5 Nomenclature

The following nomenclature applies throughout this document:

a. The word “shall” is used in this Standard to express requirements. All the requirements are expressed with the word “shall”.

b. The word “should” is used in this Standard to express recommendations. All the recommendations are expressed with the word “should”.

NOTE It is expected that, during tailoring, recommendations in this document are either converted into requirements or tailored out.

c. The words “may” and “need not” are used in this Standard to express positive and negative permissions, respectively. All the positive permissions are expressed with the word “may”. All the negative permissions are expressed with the words “need not”.

d. The word “can” is used in this Standard to express capabilities or possibilities, and therefore, if not accompanied by one of the previous words, it implies descriptive text.

NOTE In ECSS “may” and “can” have completely different meanings: “may” is normative (permission), and “can” is descriptive.

e. The present and past tenses are used in this Standard to express statements of fact, and therefore they imply descriptive text.

3.6 Schematic of brazed assembly

Figure 3-1 shows a typical joint made by brazing and soldering.

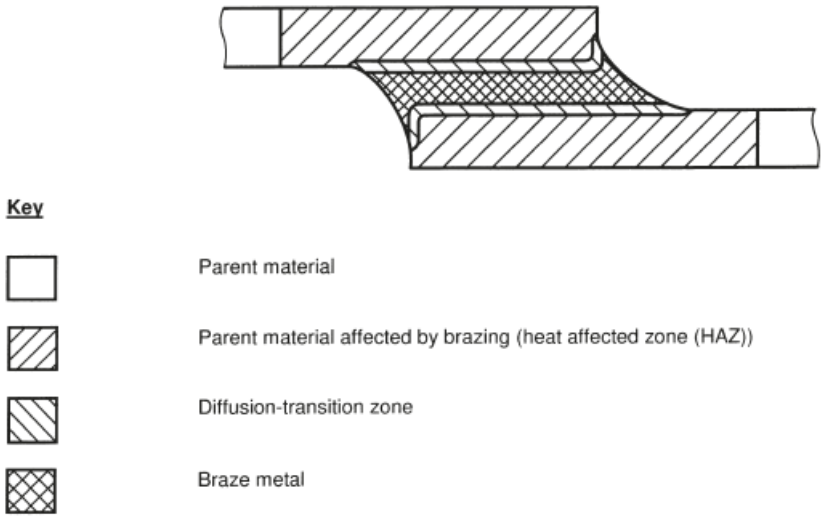


Figure 3-1: Schematic of a brazed and soldered joint (taken from EN ISO 18279:2004)

4
Principles

4.1 General

Brazing is the joining of two materials by the introduction of a liquid metal filler that on solidification holds the two materials together. The parent materials can react with the braze alloy but remain solid during the process. This differs from welding where the parent materials partially melt during the joining operation.

The process of brazing has been in use for several millennia, pictures of craftsmen carrying out brazing operations have been found in an Egyptian tomb from around 1475 BCE. This long history and development as an artisanal skill has resulted in a wide imprecise vocabulary with similar terms having different meanings in multiple languages. For example, by convention, English differentiates between brazing and soldering when the liquidus temperature of the filler is above or below 450°C respectively.

In this standard the term brazing is meant to cover also "soldering" processes with filler materials melting at temperatures lower than 450°C. When the term brazing is used, then this is meant equivalent to soldering in case that the filler materials have liquidus temperature below 450°C.

Not all languages make the same distinction. To add to the confusion the filler metal referred to as 'silver solder' is in fact a braze alloy and translations of terms such as 'soft brazing' and 'hard brazing' are also freely used in several languages.

The 450°C boundary in the past was convenient in that it allowed a differentiation between the:

a. Higher temperature process producing strong structural joints and,

b. Lower temperature processes used for sealing and joining plumbing joints and now electronic systems.

Although this boundary is still used it is less relevant in modern brazing systems where many lower temperature alloys, for example based on tin or indium, have provided good structural joints in space systems. Soldering for exclusively electronic applications has already been extensively covered by its own standards and will not be covered by this standard.

A significant advantage of brazing is that with the correct selection of process, flux system, braze alloy and joint design, reliable structural joints can be made between almost any combination of parent materials. Within the space industry we have successfully used brazing to make structural joints between metals, ceramics, glasses, ceramic matrix composites (CMCs) and reinforced plastics. Often a brazing process is selected when a joint between complex material combinations is required in difficult environments. As an example, outgassing of brazed systems can be very low simplifying cleanliness aspects.

This standard specifies the necessary requirements to perform brazing for space applications, and is comprised of the following clauses:

1. Brazing design,
2. Brazing and inspection personnel,
3. Equipment and facilities,
4. Brazing Procedure Specification (BPS),
5. Brazing inspection,
6. Joint acceptance criteria,
7. Brazing process verification,
8. Flight hardware production,
9. Quality assurance.

Figure 4-1 identifies the steps to be taken in order to produce a verified process which can then be used to produce flight hardware.

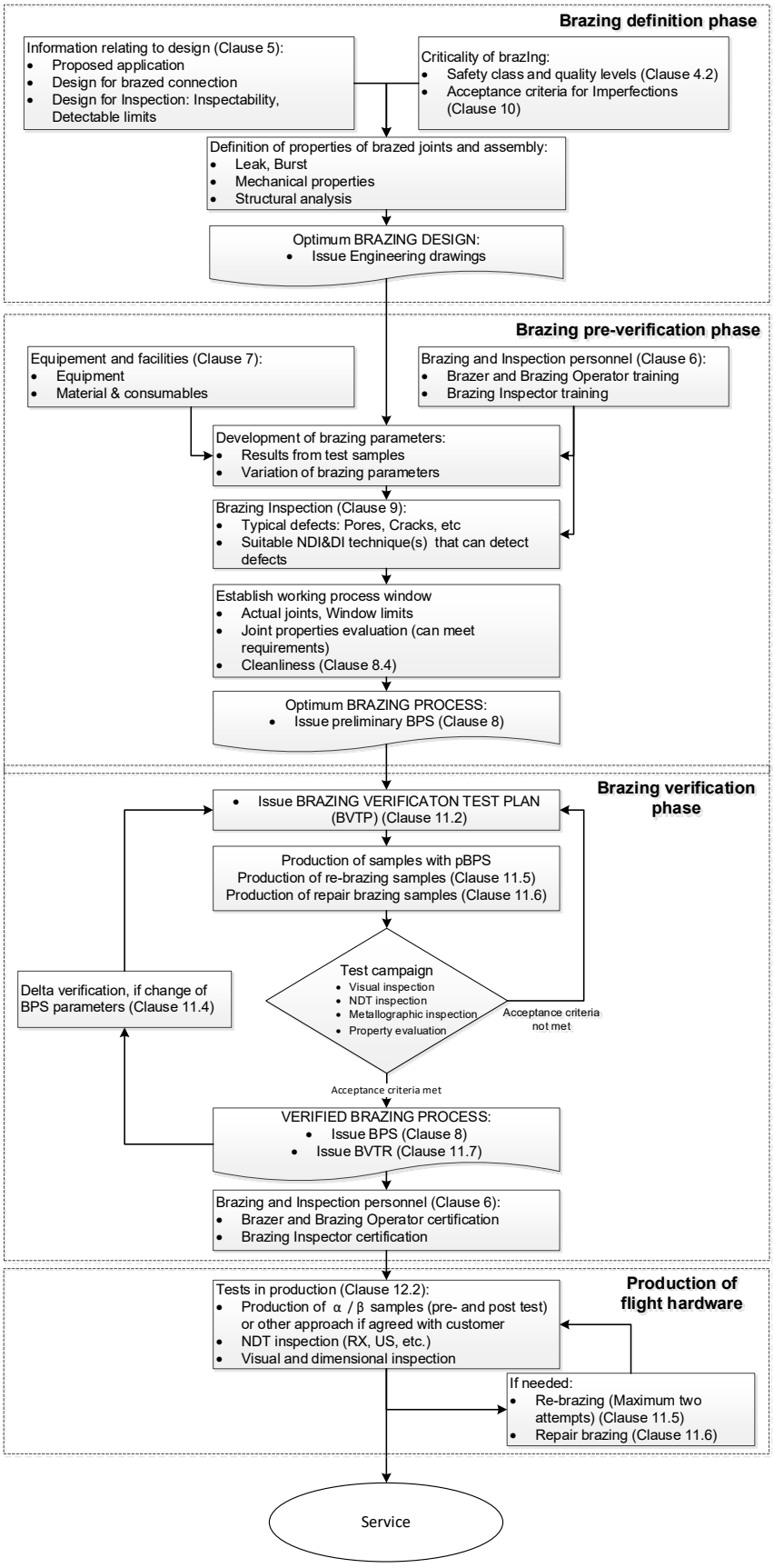


Figure 4-1: Steps for brazing process verification and flight hardware production

4.2 Classification of safety classes and quality levels

4.2.1 Overview

Brazed joints follow the same definition as welded joints for the classification related to safety classes depending on their function. Furthermore, the acceptance criteria for imperfections are by definition of three quality levels.

4.2.2 Safety classes

Class 1 joints are considered critical and structural. Failure of a Class 1 joint results in a loss of spacecraft, major components, loss of life, or loss of control of the spacecraft. Class 1 joints have the highest level of scrutiny in terms of acceptance, which is appropriate to the criticality of performance including internal and external brazing joint integrity verification.

Class 2 joints are non-critical but structural; their failure can reduce the efficiency of the system but not cause the loss of the spacecraft. Class 2 joints require brazing joint integrity verification (either external, internal, or both) appropriate for the intended application.

Class 3 joints are non-critical and non-structural and are contained so that failure does not affect other flight elements. These joints require minimal brazing joint integrity verification, the controls are mainly visual.

For all classes the design and engineering authority has the responsibility to declare a part structural or not.

4.2.3 Quality levels

In brazing joints it is inevitable that some defects and features can be present. The acceptability of such defects or features differ by their nature and size and are assigned for the purpose of quality inspection to three quality acceptance levels (A, B or C) according to the compliance with the component requirement.

Level A represents the more stringent requirements and Level C the least stringent requirements and B is in between A and C.

For the selection of the Quality levels see clause 10.4.

4.3 Tailoring of the brazing acceptance criteria

Verification of brazed products takes into account the requirements and acceptance criteria of this standard. If they turn out to be insufficient (or too strict), tailoring can be necessary in agreement with the customer.

5
Brazing Design

5.1 Design for brazed connections

ECSS-Q-ST-70-40_1500001

a. The engineering authority together with the brazing responsible shall select the brazing design.

ECSS-Q-ST-70-40_1500002

b. The engineering authority together with the brazing responsible shall specify the requirements relevant for brazing to ensure compliance with all system and mission requirements.

ECSS-Q-ST-70-40_1500003

c. Brazing Procedure Specification (BPS) specified in clause 8 shall be in compliance with all design requirements.

ECSS-Q-ST-70-40_1500004

d. The engineering authority together with the brazing responsible shall specify controls to demonstrate that brazing joints are satisfying the design requirements.

NOTE Directions for design of brazed components can be found in DIN 65169:2017. Brazed and high-temperature brazed components- directions for design.

5.2 Design for inspection

ECSS-Q-ST-70-40_1500005

a. Brazing joints classified as Class 1 and Class 2 shall be designed to be inspectable.

ECSS-Q-ST-70-40_1500006

b. Brazing joints shall be designed that excess of filler material is not affecting inspectability of sensitive areas.

ECSS-Q-ST-70-40_1500007

c. In case that Class 1 and Class 2 joints are not inspectable an alternative test shall be agreed with the customer.

6
Brazing and inspection personnel

6.1 Overview

The aim of this clause is to ensure that the brazers have the manual skills and brazing operators and inspectors have the technical knowledge demanded by the brazing operations.

6.2 Brazer and brazing operator training

ECSS-Q-ST-70-40_1500008

a. Brazers performing brazing processes requiring manual interaction shall be trained and certified.

ECSS-Q-ST-70-40_1500009

b. The training for manual brazers shall be performed with test pieces according to national and international standards or by an equivalent dedicated training plan established by brazing responsible.

NOTE Example of international standards: ISO 11745:2016.

ECSS-Q-ST-70-40_1500010

c. Brazing operators shall be trained to demonstrate compliance to the BPS specified in the clause 8 with specific brazing test piece representative for production part.

ECSS-Q-ST-70-40_1500011

d. The training of the brazers and brazing operator shall be traceable in a written document.

ECSS-Q-ST-70-40_1500012

e. After training, the brazer and brazing operator may operate for a maximum period of two years.

ECSS-Q-ST-70-40_1500013

f. Validity of training may be extended indefinitely provided the two following conditions are met:

1. A record is maintained from the date of the initial training,
2. Brazer and brazing operator use the process at least once every six months from initial training.

6.3 Brazing inspector training

ECSS-Q-ST-70-40_1500014

a. Brazing inspectors shall be nominated by the company with involvement of quality assurance responsible.

ECSS-Q-ST-70-40_1500015

b. Brazing inspectors shall be trained for this standard and the specific BPS with the involvement of the brazing responsible.

7
Equipment and facilities

7.1 Equipment

ECSS-Q-ST-70-40_1500016

a. All equipment used for brazing shall be subject to testing, inspection and maintenance in accordance with the requirements of the equipment manufacturer and the process necessities.

ECSS-Q-ST-70-40_1500017

b. When there is no period for the inspection and maintenance defined, inspection and maintenance shall be performed at least every 12 months.

7.2 Materials and consumables

7.2.1 Filler material

ECSS-Q-ST-70-40_1500018

a. Filler metals shall be procured according to clause 5.6 of ECSS-Q-ST-70.

NOTE Filler materials are specified for example in EN ISO 17672:2016.

7.2.2 Flux

ECSS-Q-ST-70-40_1500019

a. Flux shall be procured according to clause 5.6 of ECSS-Q-ST-70.

NOTE Flux materials are specified for example in 1045:1997.

7.2.3 Tooling and fixtures

ECSS-Q-ST-70-40_1500020

a. Only the tooling and fixtures specified in the BPS in Annex A shall be used for the brazing operation.

NOTE Change of tooling can have impact on brazing joints. This can be e.g. because of different coefficients of thermal expansion impacting

directly the solder gap and capillary effects and thus brazing joint quality.

ECSS-Q-ST-70-40_1500021

b. Tooling and fixtures shall be checked for cleanliness to comply with requirements from the clause 8.4.

8
Brazing procedure specification (BPS)

8.1 General

ECSS-Q-ST-70-40_1500022

a. A Brazing Procedure specification shall be written in accordance with DRD in Annex A.

ECSS-Q-ST-70-40_1500023

b. A BPS specified in requirement 8.1a shall be established for each type of brazed joint in a space application.

ECSS-Q-ST-70-40_1500024

c. All brazing joints shall be in conformance with the BPS specified in the DRD in the Annex A.

8.2 Drawing

ECSS-Q-ST-70-40_1500025

a. Features for all brazing joints shall be specified either on the engineering drawing or in supporting documentation.

ECSS-Q-ST-70-40_1500026

b. The information related to the brazing on the drawing shall be in conformance with BPS from DRD in Annex A.

NOTE A template for a table of brazing details can be similar as shown for welding in DIN 65118:2010.

ECSS-Q-ST-70-40_1500027

c. The drawing shall contain the BPS-reference.

8.3 Process description

ECSS-Q-ST-70-40_1500028

a. The minimum of documentation for process description shall be in conformance with information required from DRD in Annex A.

8.4 Cleanliness aspects of Brazing

8.4.1 Overview

Brazing processes can be source of particular and molecular contamination.

8.4.2 Requirements

ECSS-Q-ST-70-40_1500029

a. To minimise the contribution to the contamination budget during brazing, the following requirements shall apply for operators and other personnel involved in the brazing process:

   1. When brazing is in a clean room: use only nitrile gloves,
   2. When brazing is outside a clean room: wear lint free clothing and lint free gloves for assembly and brazing of flight hardware,
   3. Ensure that tooling and fixtures are not a source of contamination to the brazed hardware,
   4. Remove corrosive residues from brazing process.

      NOTE To avoid cross-contamination it is good practice that the molecular and particular cleanliness of tooling and fixtures is at least same level as the brazed H/W. In addition, contaminants transfer mechanisms depending on the used process are considered, for example from outgassing and condensation during vacuum brazing.

ECSS-Q-ST-70-40_1500030

b. After brazing, the brazed parts shall be cleaned as specified in the BPS.

9
Brazing inspection

9.1 Non-destructive testing

ECSS-Q-ST-70-40_1500031

a. The selected NDT method shall be able to detect the compliance with the defined acceptance criteria.

ECSS-Q-ST-70-40_1500032

b. NDT method shall be selected from the following list:

1. Visual examination;
2. Ultrasonic examination;
3. Radiographic examination;
4. Leak testing;
5. Proof testing;
6. Thermography.

NOTE 1 For example use methods in accordance with ECSS-Q-ST-70-15 and EN12799:2000.

NOTE 2 Visual inspection of brazing joints is described in the DIN ISO 19828:2021.

ECSS-Q-ST-70-40_1500033

c. Any acceptance criteria for the NDT, not covered in clause 10.3, shall be agreed with the customer.

9.2 Destructive testing

ECSS-Q-ST-70-40_1500034

a. The selected destructive test-method shall be able to demonstrate the compliance with the acceptance criteria from clause 10.

ECSS-Q-ST-70-40_1500035

b. For destructive testing the test method shall be selected from the following list:

1. Shear test,
2. Tensile test,
3. Metallographic examination,
4. Hardness testing,

5. Peel testing,
6. Bend testing,
7. Burst test.

NOTE For example use methods in accordance with EN12797:2000.

10
Brazing acceptance criteria

10.1 General

ECSS-Q-ST-70-40_1500036

a. The baseline acceptance criteria for brazing joints shall be in conformance with the requirements of clause 10.3, except cases specified in the requirements 10.1b and 10.1c.

ECSS-Q-ST-70-40_1500037

b. In case the brazing acceptance criteria are different to that specified in the requirements of clause 10.3, an RfA shall be raised.

ECSS-Q-ST-70-40_1500038

c. For imperfections that are not covered by requirements specified in 10.2, the brazing acceptance criteria shall be agreed with the customer.

NOTE Active brazing can produce features looking like local melting. This is not an imperfection in the context of this brazing method.

10.2 Classification of Imperfections

ECSS-Q-ST-70-40_1500039

a. The imperfections in brazing joints shall be classified into groups as follows:

1. Group I: Cracks,
2. Group II: Cavities,
3. Group III: Solid inclusions,
4. Group IV: Bonding imperfections,
5. Group V: Shape and size imperfections,
6. Group VI: Miscellaneous imperfections.

NOTE The classification is derived from EN ISO 18279:2004.

10.3 Brazing Imperfections Acceptance Criteria

ECSS-Q-ST-70-40_1500040

a. The acceptance criteria for brazed joints, specified in Table 10-1, shall be applied.

ECSS-Q-ST-70-40_1500041

b. Limits specified in Table 10-1 shall be used in absence of other application specific definition agreed with the customer.

NOTE The evaluation of brazed joints in Table 10-1 is derived from the EN ISO 18279:2004 Table B.1 "Quality levels for brazed joints imperfections".

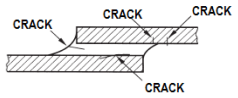
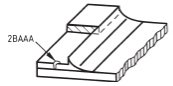
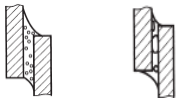
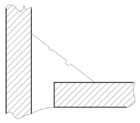
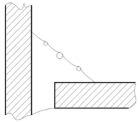
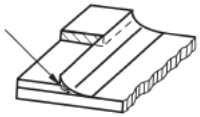
10.4 Selection of quality levels

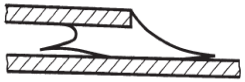
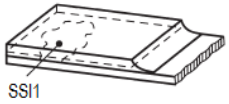
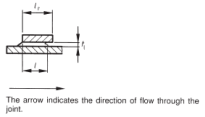
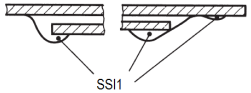
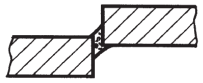
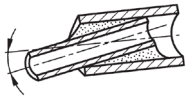
ECSS-Q-ST-70-40_1500042

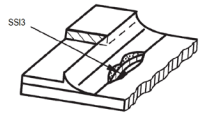
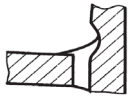
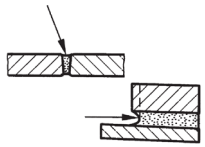
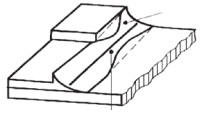
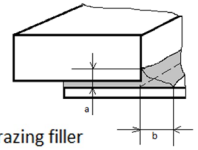
a. For the selection of the quality levels from Table 10-1 the following rule shall apply:

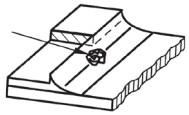
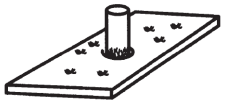
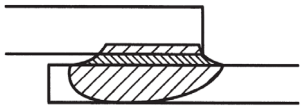
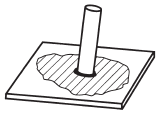
1. For Safety Class 1: Quality Level A,
2. For Safety Class 2: Quality Level B as a minimum,
3. For Safety Class 3: Quality Level C as a minimum.

Table 10-1: Classification of imperfections in Brazing joints (the classification of imperfections is derived from EN ISO 18279:2004)

Designation	Description	Remarks	Drawing	Limits for imperfections for quality levels		
				Level C	Level B	Level A
I **CR**acks						
CR1	Crack	Limited separation of the material, predominantly two dimensional extension. A crack may be longitudinal or transverse. It can lie on one or more of the following: in the braze metal at the interface and including the diffusion zone in the HAZ in the unaffected parent material		Permissible where component function is not adversely affected	Not permissible by inspection with x5 magnification	Not permissible by inspection with x10 magnification
II **CA**vities						
CA1	Cavities	Gas fillet cavity		Max of 40% of the projected area	Max of 30% of the projected area	Max of 20% of the projected area
		Pores		Note: to be considered together with inclusions of SI1. The accumulated area of voids (CA1) and inclusion (SI1) shall not exceed the specified percentage (no more than 20%, 30%, 40% respectively in total for projected area of CA1 + SI1)		
CA2	Surface pore	Gas pore breaking the surface		Permissible where component function is not adversely affected	Max of 20% of the projected area permissible where component function is not adversely affected	Not permissible
CA3	Surface bubble	Gas pore near the surface which results in swelling		Permissible where component function is not adversely affected	Permissible where component function is not adversely affected	Not permissible
III **S**olid **I**nclusions						
SI1	Solid inclusion	Inclusion of foreign metal or non-metallic particles in the braze metal		Max of 40% of the projected area	Max of 30% of the projected area	Max of 20% of the projected area

Designation	Description	Remarks	Drawing	Limits for imperfections for quality levels		
				Level C	Level B	Level A
IV **B**onding **I**mperfection						
BI1	Bonding Imperfection	No bonding or inaquate bonding between the braze metal and the parent material		Not permissible	Not permissible	Not permissible
BI2	Filling imperfection	Incomplete filling of the gap		60% or more of the projected area to be filled with braze metal	70% or more of the projected area to be filled with braze metal	80% or more of the projected area to be filled with braze metal
BI3	Incomplete penetration	The braze metal has failed to flow though the required length of the joint		Permissible where component function is not adversely affected and not breaking the surface Note: Acceptability depends on the design definition about the minimum requirement of brazed area.		Not permissible.
V **S**hape and **s**ize **i**mperfection						
SSI1	Excess braze metal	Braze metal has spilled over onto parent material solidifying as a bead or a thick layer		Permissible when inspectability is not affected and no lack of material is present in the joint area	Permissible when inspectability is not affected and no lack of material is present in the joint area	Permissible when inspectability is not affected and no lack of material is present in the joint area
SSI2	Linear misalignement	The components are parallel but offset		Permissible where component function is not adversely affected Note: The acceptance criteria for these imperfections are understood not to be from the brazing process but from the tolerances definded for the brazed assembly.		
	Angular misalignemet	The components form an angle deviating from the required value				
	Distortion	Unwanted change in the shape of the brazed assembly				

Designation	Description	Remarks	Drawing	Limits for imperfections for quality levels		
				Level C	Level B	Level A
SSI3	Localized melting (or melt through)	Through going hole in the brazed jointor next to it		Not permissible	Not permissible	Not permissible
SSI4	Fused parent material surface	Fused surface of the brazed assembly in the region of the joint		Permissible where component function is not adversely affected	Not permissible	Not permissible
SSI5	Erosion by filler metal	Erosive damage to the surface ofthe brazed assembly		Nominal material thickness not to be reduced by more than 20%	Nominal material thickness not to be reduced by more than 15%	Nominal material thickness not to be reduced by more than 10%
SSI6	Recessed braze material (recessed fillet)	The surface of the braze material in the brazed joint is below the required dimension The surface of the braze metal has sunk below the surface of the parent material		Permissible where component function is not adversely affected	Permissible where component function is not adversely affected	Permissible where component function is not adversely affected
SSI7	Rough surface	Irregular solidification, liquation, etc.		Permissible	Permissible	Permissible where component function is not adversely affected.
SSI8	Irregular fillet	Imperfection is only by appearance in cases when no minimum fillet size is required and specified. The variability of fillet is identified as cosmetic without impact on component function		Permissible	Permissible	Permissible
SSI9	Insufficient fillet	Fillet below specified size has formed		Permissible where component function is not adversely affected	Permissible where component function is not adversely affected	Permissible where component function is not adversely affected

Designation	Description	Remarks	Drawing	Limits for imperfections for quality levels		
				Level C	Level B	Level A
VI **M**iscellaneous **I**mperfection Imperfection that cannot be classified into groups I to V of this table)						
MI1	Flux seepage	Emergence of flux residues at surface pores		Permissible where component function is not adversely affected Note: assessment of function includes that contamination from flux residues will not have detrimental effects from corrosion and cross-contamination	Permissible where component function is not adversely affected Note: permissable only when the pore is assessed to be acceptable (Imperfection CA2). Assessment of function includes that contamination from flux residues will not have detrimental effects from corrosion and cross-contamination	Not permissible
MI2	Spatter	Drops of braze metal adhering to the surfaceof the brazed assembly		Permissible where component function is not adversely affected	Permissible where component function is not adversely affected	Permissible where component function is not adversely affected. Must be be confirmed that the spattered material is removed or adheres firmely and has not initiated surface defects.
MI3	Discoloration oxidation	Oxidation/flux action/deposition of volatilized filler metal or parent material on the surface		Permissible where component function is not adversely affected	Permissible where component function is not adversely affected	Permissible where component function is not adversely affected.
MI4	Excessive alloy of parent and filler materials	Associated with excess of heat, time and/or filler materials		Permissible where component function is not adversely affected	Permissible where component function is not adversely affected	Permissible where component function is not adversely affected
MI5	Flux residue	Flux that has not been removed		Permissible where component function is not adversely affected	Permissible where component function is not adversely affected	Not permissible
MI6	etch marking	Reaction with flux on the parent material surface		Permissible where component function is not adversely affected	Permissible where component function is not adversely affected	Permissible where component function is not adversely affected

11
Brazing process verification

11.1 General

For the Brazing Procedure verification the preliminary BPS is used to produce test samples which are then tested to demonstrate compliance with the mission requirements. It is important to recognize that the form and size of the test pieces in brazing has impact on the service properties which are seldom observed in welding. Welded specimen beyond a certain minimum size have similar properties and for that reason welding procedures can be verified more general for range of different joints. Specific consideration is required when dissimilar materials with significantly different CTEs are brazed. The thermo-elastic stress from CTE-mismatch can prevent successful brazing depending on the assembly.

In some cases it is possible to use standard test pieces to demonstrate all joint properties relevant for the application. Tests on standardized test specimen aim to produce standardized and comparable results of the brazing joint.

To consider the size- and shape dependent properties in brazing, the verification of a brazing process needs taking into account also the application specific requirements related to on-ground storage, launch loads, environmental conditions. For that reason standard tests and test specimen are not sufficient but specific tests and test sample definition is needed for brazing process verification.

11.2 Brazing Verification Test Plan

ECSS-Q-ST-70-40_1500044

a. A Brazing Verification Test Plan (BVTP) shall be issued for brazing procedure verifications according to the DRD in Annex B.

ECSS-Q-ST-70-40_1500045

b. The test sequence shall be selected with consideration of the reliability under application loads and mission environmental condition.

ECSS-Q-ST-70-40_1500046

c. In case that there are no specific brazing joint tests defined, standard tests with standard test specimen shall be planned.

NOTE A test matrix of standard test can be found in Table 11-1.

ECSS-Q-ST-70-40_1500047

d. In case of specific requirements from the application, specific test shall be planned to verify compliance.

NOTE Examples of specific tests are Leak Test, Pressure Test, Noise and Vibration Test, Creep, Fatigue, Corrosion.

ECSS-Q-ST-70-40_1500048

e. In case that the brazed assembly is under thermo-elastic stress, specimen representative for the brazed assembly shall be defined.

ECSS-Q-ST-70-40_1500049

f. Test specimen from the requirement 11.2e shall be submitted to thermal cycling in the test sequence.

ECSS-Q-ST-70-40_1500050

g. Pass-Fail criteria of the verification test sequence shall be specified in the Test Plan.

Table 11-1: Test Matrix for standard test

Type of test	**Sample Number**				
Inspection	1	2	3	4	5
Visual Inspection	X	X	X	X	X
Radiographic Testing	X	X	X	X	X
Metallography and Hardness	X				X
Mechanical Tests (Shear / Bend / Tensile / Peel / Burst)		X	X	X	

11.3 Completion of verification

ECSS-Q-ST-70-40_1500051

a. The samples shall be marked and serialised.

ECSS-Q-ST-70-40_1500052

b. In the case when at least one measurement on one sample is non-compliant with the requirements of clause 11, the verification shall be rejected.

11.4 Delta verification

ECSS-Q-ST-70-40_1500053

a. In case one or more parameters in an approved BPS are changed outside the allowed range, a delta verification shall be performed.

ECSS-Q-ST-70-40_1500054

b. The decision to perform a delta verification or a complete verification shall be under the responsibility of the brazing responsible.

ECSS-Q-ST-70-40_1500055

c. Every change in the existing brazing configuration shall be agreed with the customer to specify if a re-verification or delta verification is necessary.

11.5 Re-brazing, in-process correction

ECSS-Q-ST-70-40_1500056

a. After the brazing operation has been completed, visual examination shall be performed by the brazing operator and the brazing inspector.

ECSS-Q-ST-70-40_1500057

b. Re-brazing shall be verified using the same method as for verification.

ECSS-Q-ST-70-40_1500058

c. Two additional brazing shall be produced in the brazing verification phase for re-brazing.

ECSS-Q-ST-70-40_1500059

d. In case defects are observed, then a maximum of two attempts may be made for in-process correction.

ECSS-Q-ST-70-40_1500060

e. The use of in-process correction shall be documented in the inspection report and shop traveller.

ECSS-Q-ST-70-40_1500061

f. In case the two re-brazing attempts cannot result in the required level of in process correction, the following shall be performed:

1. A NCR is raised in conformance with requirements from clause 5 of ECSS-Q-ST-10-09.
2. Repair brazing is performed in accordance with the requirements from clause 11.6.

11.6 Repair-brazing

ECSS-Q-ST-70-40_1500062

a. Repair-brazing shall only performed following the raising of an NCR in conformance with requirements from clause 5 of ECSS-Q-ST-10-09.

NOTE Reason for repair can be for example that 2 re-brazing attempts have not been successful, the use of wrong filler metal or flux, or when a re-braze extends outside the original brazing zone.

ECSS-Q-ST-70-40_1500063

b. Repair-brazing shall be performed using a BPS which is approved for brazing repair.

ECSS-Q-ST-70-40_1500064

c. Re-inspection of all repaired brazing areas shall be performed using the same methods and requirements as the original brazing.

ECSS-Q-ST-70-40_1500065

d. For multiple repair-brazing, it shall be demonstrated that design strength requirements are met in any given area.

11.7 Documentation

ECSS-Q-ST-70-40_1500066

a. For the verification of the brazing process, the following documents shall be issued:

1. Brazing Verification Test Plan (BVTP) in conformance with the DRD from Annex B.
2. Brazing Verification Test Report (BVTR) in conformance with Test Report DRD from Annex C of ECSS-E-ST-10-02.
3. Brazing Procedure Specification (BPS) in conformance with the DRD from Annex A for every dimension and material combination.

ECSS-Q-ST-70-40_1500067

b. Tailoring of the BVTP for other tests shall be agreed with the supplier and customer.

ECSS-Q-ST-70-40_1500068

c. Documents specified in the requirements from 11.7a.1 to 11.7a.3 and 11.7b shall be controlled in conformance with ECSS-M-ST-40.

12
Flight hardware production

12.1 Documentation

ECSS-Q-ST-70-40_1500069

a. Prior to the start of manufacturing the following documents shall be made available:

   1. BVTR,
   2. Complete set of drawings,
   3. BPS from DRD of Annex A.

ECSS-Q-ST-70-40_1500070

b. Any brazing performed on flight hardware shall be in conformance with the approved BPS.

ECSS-Q-ST-70-40_1500071

c. Any brazing performed on flight hardware shall be performed under configuration control.

12.2 Requirements for flight hardware brazing

12.2.1 General

ECSS-Q-ST-70-40_1500072

a. The preparation of a shop traveller shall be completed.

ECSS-Q-ST-70-40_1500073

b. Only approved BPS shall be used for the brazing of flight hardware.

ECSS-Q-ST-70-40_1500074

c. During brazing of flight hardware, the cleanliness requirements of clause 8.4 shall apply.

12.2.2 Extent of testing to support flight hardware production

ECSS-Q-ST-70-40_1500075

a. Prior to flight hardware production, application of Alpha and Beta samples or alternative brazing control technique in compliance with the Table 12-1 shall be agreed with the customer.

ECSS-Q-ST-70-40_1500076

b. Techniques specified in the requirement 12.2.2a shall be:

1. Demonstrated during verification, and
2. Results approved by the customer.

ECSS-Q-ST-70-40_1500077

Table 12-1: Tests to be performed on parts performed during production of flight hardware

Safety Class	Visual and Dimensional Inspection	Radiographic or Ultrasonic Inspection**
Class 1	100 %	100 %
Class 2	100 %	*
Class 3	100 %	*
*NOTE: NDT inspection for Class 2 and Class3 brazing joints as appropriate for intended use **NOTE: Alternative NDT from clause 9.1 can be defined when appropriate for the application		

13 Quality assurance

13.1 Maintenance of BPS

ECSS-Q-ST-70-40_1500078

a. All changes to the BPS from DRD from Annex A shall be controlled in conformance with the ECSS-M-ST-40.

ECSS-Q-ST-70-40_1500079

b. As a result of modifications to the brazing process specified in the requirement 13.1a, the BPS from DRD from Annex A shall be updated.

NOTE For example, changes to the jigs, parameter changes.

ECSS-Q-ST-70-40_1500080

c. Modifications to brazing parameters which fall outside the BPS shall lead to the issue of a new brazing configuration.

ECSS-Q-ST-70-40_1500081

d. In case of an issue of a new brazing configuration specified in the requirement 13.1c the existing brazing configuration shall become obsolete.

13.2 Quality control

13.2.1 Documentation of brazing parameters

ECSS-Q-ST-70-40_1500082

a. The data generated during mechanised brazing shall be recorded.

ECSS-Q-ST-70-40_1500083

b. All mechanised brazing data shall be available for review.

13.2.2 Anomalies and nonconformances occurring during the brazing process

ECSS-Q-ST-70-40_1500084

a. In case of anomalies occurring during the brazing process, leading to the brazing activities to be stopped in a controlled manner, the brazing operators shall inform the brazing responsible.

NOTE An unexpected change in one or more process parameters can be considered as anomalies.

ECSS-Q-ST-70-40_1500085

b. For Safety Classes 1 and 2, all anomalies identified in compliance with the requirement 13.2.2a shall be classified as major, and a major NCR in conformance with clause 5 of ECSS-Q-ST-10-09 be raised.

ECSS-Q-ST-70-40_1500086

c. For Safety Class 3, depending on the anomaly identified from the requirement 13.2.2a being minor or major, an NCR shall be raised as minor or major in conformance with clause 5 of ECSS-Q-ST-10-09 accordingly.

ECSS-Q-ST-70-40_1500087

d. Malfunctions of the brazing equipment shall be documented in the maintenance book.

ECSS-Q-ST-70-40_1500088

e. Malfunctions of the brazing equipment shall be reported to the brazing responsible.

ECSS-Q-ST-70-40_1500089

f. A NCR shall be raised in case a flight part is affected by the equipment malfunction.

ECSS-Q-ST-70-40_1500090

g. All the major and minor anomalies shall be recorded and made available for the customer to review upon request.

13.2.3 Inspection and test methods

ECSS-Q-ST-70-40_1500091

a. Inspection shall be performed on brazing joints to demonstrate compliance with the requirements from the clauses 9.1 and 9.2.

ECSS-Q-ST-70-40_1500092

b. Any nonconformance shall be recorded in compliance with clause 5 of ECSS-Q-ST-10-09 and made available to the customer.

Annex A (normative) Brazing Procedure Specification (BPS) - DRD

A.1 DRD identification

A.1.1 Requirement identification and source document

This DRD is called from ECSS-Q-ST-70-40, requirement 8.1a.

A.1.2 Purpose and objective

The purpose of the Brazing Procedure Specification is to ensure that all relevant information relating to the brazing process is documented in sufficient detail such that this information can be subsequently used to reproduce the brazing joint.

A.2 Expected response

A.2.1 Scope and content

<1> General

ECSS-Q-ST-70-40_1500093

a. The BPS shall include the date, issue and revision number.

ECSS-Q-ST-70-40_1500094

b. The BPS shall contain the following information:

1. Brazing process steps,
2. Brazing process parameters,
3. Parent material,
4. Filler and Flux,
5. Joint type,
6. Cleaning procedure,
7. Mechanical or thermal treatment before and after brazing,
8. Quality level for imperfections acceptance criteria,
9. Inspection steps.

<2> Manufacturer

ECSS-Q-ST-70-40_1500095

a. The BPS shall define the manufacturer as follows:

   1. Identification of the lower tier supplier who performs the brazing,
   2. Reference to the BVTR or other applicable documents.

<3> Equipment

ECSS-Q-ST-70-40_1500096

a. The BPS shall include the identification of the equipment, model and serial number, used to perform the brazing.

<4> Tooling and fixtures

ECSS-Q-ST-70-40_1500097

a. The BPS shall specify the tooling and fixtures used to perform the brazing.

<5> Non-destructive inspection

ECSS-Q-ST-70-40_1500098

a. The BPS shall specify all non-destructive inspection techniques.

A.2.2 Special remarks

None.

Annex B (normative) Brazing Verification Test Plan (BVTP) - DRD

B.1 DRD identification

This DRD is called from the ECSS-Q-ST-70-40, requirement 11.7a.1.

B.1.1 Purpose and scope

The purpose of the brazing verification test plan (BVTP) is to ensure that all relevant information relating to the test plan is documented in sufficient detail such that this information can be subsequently used to produce the required results.

B.2 Expected response

B.2.1 Scope and content

<1> General

ECSS-Q-ST-70-40_1500099

a. The BVTP shall include the date, issue and revision number.

ECSS-Q-ST-70-40_1500100

b. The BVTP shall include the following information:

1. Brazing process,
2. Parent material combination,
3. Filler material and Flux,
4. Joint type,
5. Cleaning procedure,
6. Types of test for the brazing verification,
7. Number and type of samples to be tested,
8. Criteria of acceptance of a brazing joints.

B.2.2 Special remarks

None.

Bibliography

ECSS-S-ST-00	ECSS system – Description, implementation and general requirements
ECSS-Q-ST-70-15	Space product assurance – Non-destructive testing
DIN 65118:2010	Welding in Aerospace – Indication in design documents and general design requirements
DIN 65169:2017	Aerospace – Brazed and high-temperature brazed components – Directions for design
DIN EN 1045:1997	Fluxes for brazing – Classification and technical delivery conditions
DIN ISO 19828:2021	Welding for aerospace applications – Visual inspection of welds
EN 12797:2000	Destructive tests on brazed joints
EN 12799:2000	Non-destructive examination of brazed joints
EN ISO 17672:2016	Brazing – Filler metals
EN ISO 18279:2004	Imperfections in brazed joints
ISO 11745:2016	Brazing for aerospace applications – Qualification test for brazer and brazing operators – Brazing of metallic components