ECSS-Q-ST-70-15C
1 May 2021

EUROPEAN COOPERATION FOR SPACE STANDARDIZATION

Space product assurance

Non-destructive testing

ECSS Secretariat
ESA-ESTEC
Requirements &and Standards Division
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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-70-15C Working Group, reviewed by the ECSS Executive Secretariat and approved by the ECSS Technical Authority.

Disclaimer

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Introduction

This standard specifies general requirements for flight parts. It also covers specific requirements for flight metallic components, structures and composite parts used for space missions. It does not explicitly cover all the flight parts, components, structures and techniques. Consequently, some techniques as acoustic emission, shearography, IR thermography or specific guided waves techniques are not addressed in detail and are to be agreed per NDT plan, in line with the general requirements of clauses 5 and 9 (and covered by Annexes).

Non-destructive testing (NDT) covers a wide range of processes used in quality control. The generic term NDT covers several sub processes such as Dye Penetrant testing (PT), Radiographic testing (RT), Magnetic particle testing (MT), Ultrasonic testing (UT) and Eddy current testing (ET). The processes are applied at the discretion of the design authority depending on the criticality of the part or component and inherent risk of the manufacturing process to create detrimental discontinuities. It is expected that every component used in spaceflight is subjected to some level of NDT in accordance with the present standard, which complements the ECSS-Q-ST-70-39 "Welding of metallic materials for flight hardware".

The lack of NDT control throughout the supply chain has been evident in all space projects across the Europe. As no standard was in place at that time this has resulted in inconsistency in the rationale and application for NDT selection. NDT is generally applied for quality control to ensure that components are free of unacceptable discontinuities. NDT is used in cases, in which the damage or destruction of the item under test is not desired. Examples for this are root cause analysis and quality control to ensure that components are free of discontinuities.

For some components the NDT methods used form the basis of the fracture and fatigue verification and thus the assurance of design margins. The level of NDT (testing level) is expected to be decided based on the manufacturing processes applied and the criticality of the part or component and the impact if that part fails in service.

1 Scope

This standard specifies NDT requirements for flight parts, components and structures used for space missions. It covers the NDT methods and stipulates the certification levels for personnel. The qualification of such processes are also specified for non-standard NDT techniques or where complex components are concerned. This standard also identifies the best practice across the large range of international and national standards. When international or national NDT standards are referenced within this document, alternative equivalent standards can be considered acceptable subject to customer approval.

Visual testing included in this standard is not intended to include incoming inspection of, for example, raw materials, damage during transport, storage and handling and parts procurement verification. Furthermore, the visual testing performed in the NDT (discontinuities, surface structure) does not cover the visual testing in the Cleanliness and Contamination standard.

The minimum requirements for NDT documentation are specified in the DRDs of the Annexes.

This standard does not cover the acceptance criteria of components, structures and parts submitted to this examination; it is expected that these criteria are identified on specific program application documentation.

This Standard does not apply to EEE components.

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-M-ST-40	Space management – Configuration and information management
ECSS-Q-ST-10	Space product assurance – Product assurance management
ECSS-Q-ST-10-09	Space product assurance – Nonconformance control system
ECSS-Q-ST-20	Space product assurance – Quality assurance
ECSS-Q-ST-70-39	Space product assurance -Welding of metallic materials for flight hardware
ECSS-E-ST-32	Space engineering – Structural general requirements
ECSS-E-ST-32-01	Space engineering – Fracture control
EN 4179:2017	Aerospace series – Qualification and approval of personnel for non-destructive testing
EN 12668-1:2010	Non-destructive testing – Characterization and verification of ultrasonic examination equipment – Part 1: Instruments
EN 12668-2:2010	Non-destructive testing – Characterization and verification of ultrasonic examination equipment – Part 2: Probes
EN 13068-3:2001	Non-destructive testing – Radioscopic testing – Part 3: general principles or radioscopic testing of metallic materials by x- and gamma rays
EN 1779:1999/A1:2003	Non-destructive testing – Leak testing – Criteria for method and technique selection
EN ISO 17637:2016	Non-destructive testing of welds – Visual testing of fusion-welded joints

EN ISO 3452-1:2013	Non-destructive testing — Penetrant testing — Part 1: General principles
EN ISO 3452-2:2013	Non-destructive testing – Penetrant testing – Part 2: Testing of penetrant materials
EN ISO 3452-3:2013	Non-destructive testing – Penetrant testing – Part 3: Reference test blocks
EN ISO 5579:2013	Non-destructive testing – Radiographic testing of metallic materials using film and X- or gamma rays – Basic rules
EN ISO 9712:2012	Non-destructive testing – Qualification and certification of NDT personnel
EN ISO 9934-1:2016	Non-destructive testing – Magnetic particle testing – Part 1: General principles
EN ISO 9934-2:2015	Non-destructive testing – Magnetic particle testing – Part 2: Detection media
EN ISO 9934-3:2015	Non-destructive testing – Magnetic particle testing – Part 3: Equipment
EN ISO 15548-1:2013	Non-destructive testing – Equipment for eddy current examination – Part 1: Instrument characteristics and verification
EN ISO 15548-2:2013	Non-destructive testing – Equipment for eddy current examination – Part 2: Probe characteristics and verification
EN ISO 15548-3:2008	Non-destructive testing – Equipment for eddy current examination – Part 3: System characteristics and verification
EN ISO 15549:2019	Non-destructive testing – Eddy current testing – General principles
EN ISO 15708-2:2019	Non-destructive testing – Radiation methods for computed tomography – Part 2: Principles, equipment and samples
EN ISO 15708-4:2019	Non-destructive testing – Radiation methods for computed tomography – Part 4: Qualification
EN ISO 16810:2014	Non-destructive testing – Ultrasonic testing – General principles
EN ISO 16811:2014	Non-destructive testing – Ultrasonic testing – Sensitivity and range setting
EN ISO 17635:2016	Non-destructive testing of welds – General rules for metallic materials
EN ISO 17636-1:2013	Non-destructive testing of welds – Radiographic testing – Part 1: X- and gamma-ray techniques with film
EN ISO 17636-2:2013	Non-destructive testing of welds – Radiographic testing – Part 2: X- and gamma-ray techniques with digital detectors

EN ISO 17640:2018	Non-destructive testing of welds – Ultrasonic testing – Techniques, testing levels and assessment
ASTM E 127:2019	Standard Practice for Fabrication and Control of Flat Bottomed Hole Ultrasonic Standard Reference Blocks
ASTM E 164:2019	Standard Practice for Contact Ultrasonic Testing of Weldments
ASTM E 426:2016	Standard Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys
ASTM B 594:2019	Standard Practice for Ultrasonic Inspection of Aluminium-Alloy Wrought Products
ASTM E 1254:2013(2018)	Standard guide for storage of radiographs and unexposed industrial radiographic films
ASTM E 1417/1417M-11:2016	Standard Practice for Liquid Penetrant Testing
ASTM E 1444/ E1444M:2016	Standard Practice for Magnetic Particle Testing
ASTM E 1734:2016	Standard Practice for Radioscopic Examination of Castings
ASTM E 1742/ E1742M:2018	Standard Practice for Radiographic Examination
ASTM E 1814:2014	Standard Practice for Computed Tomographic (CT) Examination of Castings
ASTM E 2375:2016	Standard Practice for Ultrasonic Testing of Wrought Products
ASTM E 2445/M2445M:2020	Standard Practice for Performance Evaluation and Long-Term Stability of Computed Radiography Systems
ASTM E 2698:2018-e1	Standard Practice for Radiological Examination Using Digital Detector Arrays
IR99: 1999	Ionizing Radiation Regulations 1999
NAS 410:2014	NAS Certification and Qualification of Non Destructive Test Personnel
SAE-ARP-4402:2013	Eddy Current Inspection of Open Fastener Holes in Aluminium Aircraft Structure
SAE-AS-4787:2013	Eddy Current Inspection of Circular Holes in Nonferrous Metallic Aircraft Engine Hardware
SAE-AMS-2154D:202020	Process for Inspection, ultrasonic, wrought metals
SAE-AMS-2647:2009	Fluorescent Penetrant Inspection Aircraft and Engine Component Maintenance
SAE-AMS-2644:2006	Inspection material penetrant
QPL-AMS-2644:2016	Inspection material, penetrant

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.

b. For the purposed of this Standards, the term and definition from ECSS-E-ST-32-01 apply:

1. safe life potential fracture critical item

NOTE This definition is equivalent to the definition of "damage tolerant fracture critical items" in NASA standards like NASA-STD-5019.

3.2 Terms specific to the present standard

3.2.1 black light (UVA light)

near ultraviolet radiation used for exciting fluorescence

3.2.2 close visual testing

close proximity, intense visual examination of the internal and external surfaces of a structure, including structural details or locations, for indications of impact damage, flaws, and other surface defects

NOTE 1 The testing capability is evaluated by the surface deflection measurement (impact depth).

NOTE 2 Close visual testing is considered to detect reliably a deflection larger than the visual damage threshold (VDT).

3.2.3 Image Quality Indicator (IQI)

series of wires or series of plates-containing holes having different diameters

3.2.4 NDT method

disciplines of non-destructive testing within which different techniques exist

NOTE Example of the different techniques are: ultrasonic and radiography.

[Based on EN 4179:2017]

3.2.5 NDT instruction

written description of the precise steps to be followed in testing to an established standard, code, specification or NDT procedure

NOTE This standard specifies in all cases an NDT procedure.

3.2.6 NDT technique

specific way of utilizing an NDT method

NOTE For example, ultrasonic immersion technique.

[adapted from EN 4179:2017]

3.2.7 NDT procedure

written description of all essential parameters and precautions to be applied when non-destructively testing products in accordance with standard(s), code(s) or specification(s)

NOTE An NDT procedure can involve the application of more than one NDT method or technique.

3.2.8 responsible Level 3

a level 3 designated by the employer with the responsibility and authority to ensure that the requirements of this standard are met to act on behalf of the employer

[EN 4179:2017]

3.2.9 special fracture control NDT

NDT methods applied in the context of fracture control implementation on safe life items that are capable of detecting cracks or crack-like discontinuities smaller than those assumed detectable by standard fracture control NDT or do not conform to the requirements for standard fracture control NDT

[adapted from “Special NDI” definition of ECSS-E-ST-32-01C (2008)]

NOTE Special NDT methods are not limited to fluorescent penetrant, radiography, ultrasonic, eddy current, and magnetic particle.

3.2.10 standard fracture control NDT

NDT methods of metallic materials for which the required statistically based detection capability has been established.

[adapted from “Special NDT” definition of ECSS-E-ST-32-01]

NOTE Standard NDT methods addressed by this document are limited to fluorescent penetrant, radiography, ultrasonic, eddy current, and magnetic particle.

3.2.11 personnel qualification

skills, training, knowledge, examinations, experience and visual capability required for personnel to properly perform to a particular level

[adapted from EN 4179:2017]

3.2.12 personnel certification

written statement by an employer that an individual has met the applicable requirements

[adapted from EN 4179:2017]

NOTE In some standards employer is called certifying agency or body.

3.2.13 product family

combination of the following penetrant testing materials: penetrant, excess penetrant remover and developer

[adapted from EN ISO 3452-2:2013]

3.2.14 NDT procedure verification

process of certifying the efficacy of a testing process through a demonstration, on a representative structure, in a representative environment, and by representative testing personnel

[adapted from MIL-HDBK-6870B]

NOTE 1 Equipment, reference standards and written procedures are all examples of items that are included in the procedure verification process.

NOTE 2 The term "qualification" from the ECSS-Q-ST-70-15 is synonymous with the term "verification" used in ECSS documentation.

NOTE 3 Examples for processes to be certified are testing process and manufacturing process.

3.3 Abbreviated terms and symbols

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

Abbreviation	**Meaning**
AMS	Aerospace Material Specification
ASTM	American Society for Testing and Materials
CR	computed radiography
CT	computed tomography
DDA	digital detector array
DRD	document requirements definition
DR	digital radiography

Abbreviation	Meaning
ET	eddy current testing
EEE	electrical, electronic and electromechanical
EN	European Standard
FMECA	failure modes, effects and criticality analysis
FSW	friction stir welding
MMC	metal matrix composites
MPCB	materials and processes control board
MT	magnetic particle testing
NAS	National Aerospace Specification
NCR	nonconformance report
NDT	non-destructive testing
NRB	nonconformance review board
PFCI	potential fracture control critical
POD	probability of detection
PSM	penetrant system monitoring
PT	penetrant testing
RFD	request for deviation
RT	radiographic testing
QQI	quantitative quality indicator
QMS	quality management system
TIG	tungsten inert gas welding
UT	ultrasonic testing
UTG	ultrasonic thickness gauge
UV	ultraviolet
VDT	visual damage threshold

3.4 Nomenclature

3.4.1 Formal verbs

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.

3.4.2 Conventions

The term "qualification" from the ECSS-Q-ST-70-15 is synonymous with the term "verification" used in ECSS documentation. This is not applicable to the qualification of personnel.

4
Principles

The NDT of materials is carried out in such a way that product integrity and surface texture remain within specifications. The NDT of parts is particularly important for products or components where failure or malfunction can have serious implications.

These include loss of mission hardware and for flight hardware.

If NDT methods are selected but not covered by the current version of this standard, then the generic processes defined in clause 5 and clause 9 are followed.

This is presented in the following Figure 4-1 which shows the steps taken and the choice of NDT method and technique.

NOTE Additional complementary material information can be found in Annex G.

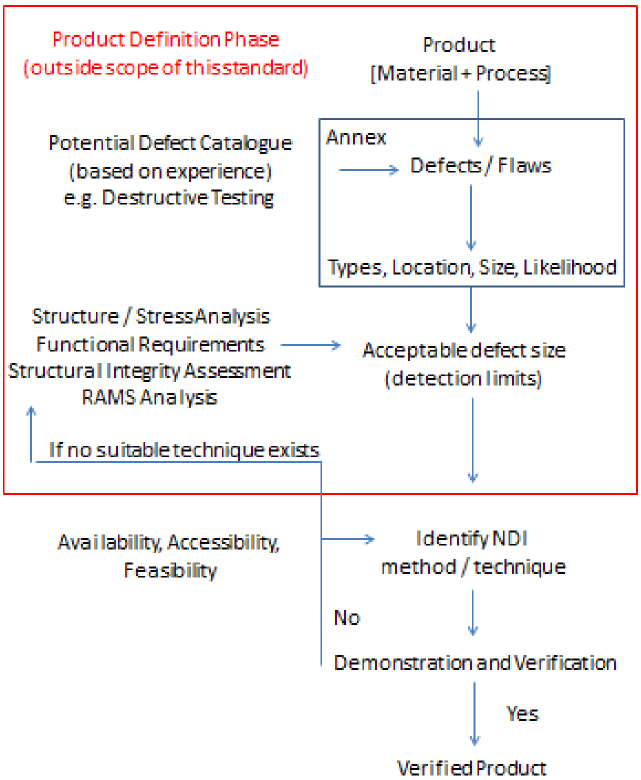


Figure 4-1: Flow chart showing steps to be taken for a part and choice of NDT method and technique

Examples for potential discontinuities are presented in Annex D.

ECSS-E-ST-32-01 requires many parts subjected to fracture control are subjected to NDT and proof testing to screen for internal and external cracks. Specific additional requirements are addressed in clause 9.

5 Generic requirements

5.1 General

ECSS-Q-ST-70-15_1470001

a. The supplier shall, for each part or assembly to be tested, establish and maintain documented NDT procedures in compliance with Annex C.

ECSS-Q-ST-70-15_1470002

b. NDT procedures shall be made available for review at customer request.

ECSS-Q-ST-70-15_1470003

c. The design definition authority shall specify NDT acceptance criteria.

NOTE It is assumed that accept and reject criteria reflect the possible need to ensure that cracks smaller than the targeted crack size are reported as "detected cracks" in line with ECSS-E-ST-32-01 clause 10.7 (for example > 50 % of the targeted crack size).

ECSS-Q-ST-70-15_1470004

d. The NDT procedure shall be written in accordance with the DRD in Annex C.

ECSS-Q-ST-70-15_1470005

e. All NDT procedures shall be verified to assure repeatable sensitivity needed for classification of the part.

NOTE This can include capability demonstration in accordance with clause 5.5.

ECSS-Q-ST-70-15_1470006

f. The NDT plan shall be prepared in accordance with Annex A, prior to performing NDT.

ECSS-Q-ST-70-15_1470007

g. The NDT plan prepared by the supplier responsible for the NDT, shall be submitted to the customer for approval.

ECSS-Q-ST-70-15_1470008

h. The areas of the part identified in the design definition file shall be tested.

ECSS-Q-ST-70-15_1470009

i. NDT shall be performed by certified NDT inspectors in accordance with requirements from clause 5.7 of the present standard and requirements from clause 5.1.2 of ECSS-Q-ST-20.

ECSS-Q-ST-70-15_1470010

j. All Work instructions, which in general are specific to a part number, shall be prepared by a NDT Level 2 inspector as a minimum and approved by a Level 3, both of whom are certified in the corresponding method in compliance with requirements from clause 5.7.

NOTE Definition of Level is given in the EN 4179 clause 5 (Qualification and Certification Levels).

ECSS-Q-ST-70-15_1470011

k. The Work Instruction shall as a minimum include:

1. Identification of parts
2. Applicable documentation
3. Sketch of the part, indicating testing zones
4. Preparation operations of the parts, prior to testing
5. Inspection equipment or systems, accessories and ancillary materials
6. Inspection method to be used
7. Parameters of testing equipment or systems
8. Calibration procedure
9. Inspection procedure
10. Reference standard
11. Scanning parameters for the applicable techniques:
    (a) Speed;
    (b) Index;
    (c) Positioning of the part in the testing area.
12. Evaluation criteria
13. NDT Acceptance criteria
14. Control data for a procedure:

(a) Unique Number;

(b) Issue;

(c) Preparation date;

(d) Record of revisions and dates;

(e) Author and qualification;

(f) Authorization and qualification;

(g) Date.

NOTE 1 to item 5.1k.7: the examples of parameters of testing equipment or systems are frequency and kV.

NOTE 2 to item 5.1k.9: reference can be made to the general procedures established in the specifications.

ECSS-Q-ST-70-15_1470012

l. Generic Instruction may be used when considered applicable by the responsible Level 3 within the method.

ECSS-Q-ST-70-15_1470013

m. All parts subject to an NDT examination shall be recorded for traceability in a logbook raised and controlled by the organisation performing the NDT.

ECSS-Q-ST-70-15_1470014

n. All NDT plans shall be subject to agreement between customer and supplier, at the latest during MPCB, in accordance with ECSS-Q-ST-70 in consultation with responsible Level 3.

ECSS-Q-ST-70-15_1470015

o. Supplier shall raise NCRs about any discontinuities detected during NDT testing not meeting the customer specifications.

ECSS-Q-ST-70-15_1470016

p. For any deviations from the customer requirements an RFD shall be raised in conformance with ECSS-M-ST-40.

NOTE In case of cracks see requirement 5.2c.

ECSS-Q-ST-70-15_1470017

q. The processing of the NCR shall be in compliance with requirements from ECSS-Q-ST-10-09.

NOTE This can lead to new testing or to re-testing of parts after identification of discontinuities to be performed by using the same NDT plan and procedure, and to the need of customer agreement.

ECSS-Q-ST-70-15_1470018

r. If NDT methods are selected that are not covered by this standard, then the generic process specified in clause 5 and clause 9 shall be followed.

ECSS-Q-ST-70-15_1470019

s. In the case of conflicting requirements, Clause 8 shall take precedence over Clause 6.

ECSS-Q-ST-70-15_1470020

t. In the case of conflicting requirements, ECSS-Q-ST-70-39 shall take precedence over Clause 6 requirements.

5.2 Discontinuities and cracks

ECSS-Q-ST-70-15_1470021

a. Any discontinuities outside of the acceptance limits shall be subject to the NCR process.

ECSS-Q-ST-70-15_1470022

b. For the discontinuities identified in 5.2a, the responsible Level 3 in the method shall assess the need to raise an NCR in conformance with the DRD in Annex A from ECSS-Q-ST-10-09.

ECSS-Q-ST-70-15_1470023

c. All detected cracks, regardless of size, constitute ground for rejection and shall lead to a Major NCR as specified in ECSS-Q-ST-10-09.

NOTE The NRB decision is likely to lead to a rejection unless the customer agrees otherwise.

5.3 NDT drawing callouts

ECSS-Q-ST-70-15_1470024

a. NDT testing specifications for all parts to be tested shall be identified or referred to in all drawings.

ECSS-Q-ST-70-15_1470025

b. The drawings shall identify or refer to each testing requirement by zone when different zones require different NDT testing requirements and acceptance criteria.

ECSS-Q-ST-70-15_1470026

c. The drawings shall be updated when NDT testing requirements are updated.

5.4 NDT process and configuration control

ECSS-Q-ST-70-15_1470027

a. A written NDT procedure, in conformance with DRD from Annex C, shall be developed for each part to be tested, and approved by the responsible Level 3 of the appropriate NDT method.

ECSS-Q-ST-70-15_1470028

b. Configuration control shall be performed in compliance with ECSS-M-ST-40 for the following:

1. Personnel qualification and certification
2. NDT specification
3. NDT standards
4. Part specific NDT procedures

NOTE It is important that the meaning of NDT procedure, instruction, and specification is clarified between customer and supplier.

ECSS-Q-ST-70-15_1470029

c. All certification records, NDT reports, and associated paperwork shall be in accordance with requirements from ECSS-M-ST-40 clause 5.3.7 and ECSS-Q-ST-10 clause 5.2.6.

5.5 NDT procedure capability demonstration

ECSS-Q-ST-70-15_1470030

a. Supplier shall demonstrate NDT capability in accordance with clause 9.1.3.

ECSS-Q-ST-70-15_1470031

b. Capability demonstration test not covered by clause 9.1.3 shall be agreed between customer and supplier.

ECSS-Q-ST-70-15_1470032

c. The test specimens shall be representative of the features of the part to be tested, which affect the testing method.

NOTE 1 NDT procedures can be verified on parts or on test pieces simulating the actual part and which provide the essential features of the part with regard to the important application variables which can affect sensitivity of detection and confidence level. These aspects can differ significantly between different NDT methods.

NOTE 2 Examples are similarity based on wetting behaviour for penetrant testing and microstructure features for eddy current and ultrasonic testing.

ECSS-Q-ST-70-15_1470033

d. POD demonstration by "hit and miss" method needs not be performed for:

1. Guided manual testing

2. Manual testing of local area or volume with reference to the applied procedure and equipment, if coverage of the complete area or volume can be guaranteed.

NOTE The inspection procedure is approved by the customer according to 9.2.2.2h or 5.5b.

ECSS-Q-ST-70-15_1470034

e. For detected discontinuities the accuracy of the sizing method shall be demonstrated.

NOTE The concept of POD does not apply to already detected discontinuities. POD evaluation example is given in Annex F.

5.6 Organizational guidelines and documentation requirement

ECSS-Q-ST-70-15_1470035

a. The NDT organization shall be specified in the suppliers QMS.

NOTE Examples for the definition of this organization are provided in EN 4179:2017 and NAS 410:2014. Further guidelines are presented in NASA-STD-5009:2019 Appendix B.

5.7 NDT personnel qualification and certification

ECSS-Q-ST-70-15_1470036

a. For penetrant, magnetic particle, eddy current, ultrasonic, radiographic, thermographic and shearographic testing, personnel for non-destructive inspections shall be certified in accordance with EN 4179:2017 or NAS 410:2014.

ECSS-Q-ST-70-15_1470037

b. For NDT methods not explicitly covered by EN 4179:2017 or NAS 410:2014, each organisation shall write a procedure detailing the Qualification and approval of personnel for non-destructive testing.

NOTE Clause 6.4 of EN 4179:2017 is called “Emerging NDT methods”.

ECSS-Q-ST-70-15_1470038

c. The procedure document of 5.7b shall meet the minimum requirements of clause 6.4 of EN 4179:2017 or NAS 410:2014, commonly known as the Written Practice.

NOTE The procedure document is reviewed and approved by the responsible Level 3 of the organisation and finally authorised by a senior member of the organisation for example, Quality Manager or Director.

ECSS-Q-ST-70-15_1470039

d. Other standards may be accepted on a case by case basis, if agreed between the customer and supplier.

NOTE Examples of commonly applied standards are: EN ISO 9712:2012 that covers leak testing and visual testing not covered by EN 4179:2017 and NAS 410:2014. For critical applications additional requirements can apply in order to ensure that e.g. training and experience are in line with EN 4179 and NAS 410.

ECSS-Q-ST-70-15_1470040

e. Inspection personal shall be qualified in accordance with EN ISO 9712:2012 and documented within the company written practice, in compliance with 5.7c.

6
NDT methods

6.1 Visual testing

6.1.1 Overview

6.1.1.1 General process for visual testing

Visual testing contains the detection and appraisal of surface attributes by use of the human eye. In difference to any other NDT method that provide indications to be interpreted, visual testing provides quality indications like material discontinuities, dimensional deviations and surface quality levels that can be tested directly.

To judge about the level of quality deviation it can be necessary to use auxiliary equipment like magnifiers, microscopes, mirrors, endoscopes or borescopes. The reporting criteria of the indications are specified by the individual test procedure and depend on the kind of test object, application and criticality rating.

6.1.1.2 Visual testing process variations

The visual testing can be performed as direct or indirect testing:

a. All techniques that do not interrupt the glance of the human eye to the testing surface are direct visual testing techniques. For example: visual testing by use of a magnifier or a microscope.

b. All techniques that interrupt the glance of the human eye to the testing surface are indirect visual testing techniques. For example: visual testing by use of a camera endoscope or a mirror.

6.1.2 General visual testing requirements

ECSS-Q-ST-70-15_1470041

a. Visual testing of welds shall be performed in accordance with EN ISO 17637:2016.

ECSS-Q-ST-70-15_1470042

b. Any deviations from EN ISO 17637:2016 called in 6.1.2a shall be agreed with the customer.

NOTE This is likely to apply to additional viewing conditions needed for items other than welds.

ECSS-Q-ST-70-15_1470043

c. Additional viewing conditions shall be agreed with the customer, with the exception of welds.

ECSS-Q-ST-70-15_1470044

d. The testing object shall be accessible in that way, that the surface can be tested within a distance of 600 mm and with a viewing angle $\geq 30°$.

ECSS-Q-ST-70-15_1470045

e. A written instruction shall be prepared and approved by the responsible Level 3 within the method.

NOTE During visual testing special attention is given to optimization of the viewing and lighting conditions.

6.1.3 Visual testing equipment

6.1.3.1 Overview

Typical pieces of equipment in use for the visual testing are:

- Magnifiers
- Microscopes
- Endoscopes
- Lenses
- Mirrors
- Vernier callipers
- Scales
- Gauges
- Photometer
- Illuminations sources
- Comparison catalogues.

6.1.3.2 Requirements for visual testing equipment

ECSS-Q-ST-70-15_1470046

a. Electrical equipment shall be serviced and calibrated at least once a year, within a period agreed with the customer.

ECSS-Q-ST-70-15_1470047

b. All electrical and mechanical measurement instruments shall be calibrated at least once a year.

ECSS-Q-ST-70-15_1470048

c. All devices shall be listed and controlled in the user's measurement instruments calibration list.

ECSS-Q-ST-70-15_1470049

d. Comparison catalogues should be controlled within the company documentation management system.

6.1.4 Visual testing application

ECSS-Q-ST-70-15_1470050

a. Visual testing sequence as a minimum shall include the following:

   1. An overview of the part to be tested:

      (a) Check that the available documentation includes testing specification, drawings.

      (b) Check of the test designation

   2. Check of testing conditions,

   3. Check of testing sensitivity,

   4. Check of surface indications against specification,

   5. Appraisal of found indications against the acceptance criteria,

   6. Classification of indications.

ECSS-Q-ST-70-15_1470051

b. The acceptance criteria of visual testing shall be agreed between customer and supplier.

6.1.5 Visual testing documentation

ECSS-Q-ST-70-15_1470052

a. The visual testing documentation shall be in compliance with NDT report from the DRD from Annex B.

6.1.6 Visual testing process control

ECSS-Q-ST-70-15_1470053

a. The visual testing techniques shall include a trial testing by use of a test body, unless agreed with the customer.

ECSS-Q-ST-70-15_1470054

b. The test sample of requirement 6.1.6a shall be representative of the testing object with respect to reflection behaviour, surface texture, accessibility and contrast conditions.

ECSS-Q-ST-70-15_1470055

c. The test sample may be replaced by an original test object or an approved reference system, subject to customer approval.

NOTE Special test cards are in use to demonstrate the performance of endoscopes and borescopes.

6.1.7 Visual testing process limitations and peculiarities

ECSS-Q-ST-70-15_1470056

a. In the case of critical applications the visual testing should be combined with additional NDT processes to verify inspections results.

NOTE 1 Misinterpretation can result from peculiarities as for example grain boundaries at the surface which can be misinterpreted as cracks.

NOTE 2 Examples of additional NDT processes for metallic parts are dye penetrant, eddy current or magnetic particle testing.

ECSS-Q-ST-70-15_1470057

b. The magnification of the visual testing should be chosen based on the size and characteristics and criticality of the object to be tested, features to be detected and subsequently specified in the relevant testing procedure or work instruction.

ECSS-Q-ST-70-15_1470058

c. For small and smooth welds a magnification larger than five times shall be used.

6.2 Leak testing

6.2.1 Overview

6.2.1.1 General process for leak testing

Leak testing applies mainly to pressurized structures to justify that pressure loss over time does not lead to a critical hazard especially for components containing hazardous fluids or gases.

Furthermore leak testing can be used to localize a leak or measuring the leak rate or both.

Typical leak tested components are:

a. Pressure vessels and pressurized structures including:
   1. Sealing
   2. Welds
b. Valves and regulators
c. Tubing
d. Diaphragms

The major characteristics of leak testing are:

a. Tracer gas and concentration
b. Differential pressure
c. Temperature
d. Leak rate

6.2.1.2 Leak testing process variations

Leak testing can be performed globally (integral) or locally.

The most efficient method of leak testing is global testing performed in a vacuum chamber. This however applies only to parts with limited size.

Welds of large propellant tanks are mainly leak tested locally with a sniffer. Usually, gaseous helium is mixed to nitrogen or air during proof testing and leak testing is then performed under reduced inner pressure.

Global leak rate then applies to the complete component, whereas local leak rates apply to the location under testing.

Examples of acceptance limits leak test rates are provided in Table 6-1.

Table 6-1: Examples of acceptance limits leak test rates

Component	Leak test	GHe leak rate acceptance limit
Composite overwrapped pressure vessel (COPV)	Vacuum chamber (global)	1×10^{-6} scc/s
Propellant tank	Vacuum chamber (global)	1×10^{-6} scc/s
Large aluminium propellant tank welds (20 % GHe)	Sniffer (local)	1×10^{-3} to 1×10^{-5} scc/s
Gas control panels	Vacuum jacket (global)	1×10^{-7} scc/s
1 scc/s ≙ 1,013 mbar × l/s ≙ 0,1 Pa × m³/s		

6.2.2 General leak test requirements

ECSS-Q-ST-70-15_1470059

a. Leak test shall be performed according to EN 1779:1999/A1:2003.

ECSS-Q-ST-70-15_1470060

b. A written instruction for the leak test shall be prepared and approved by the responsible Level 3.

ECSS-Q-ST-70-15_1470061

c. Inspection personal shall be qualified in accordance with the company written practice or EN ISO 9712:2012.

6.2.3 Process application

6.2.3.1 Leak test procedure

ECSS-Q-ST-70-15_1470062

a. A leak test procedure shall be established and include:

1. Description of components to be tested
2. Description and reference of all customer requirements
3. General references
4. Internal instructions
5. Type of leak rate testing
6. Required leak rates
7. Applicable and justified tools and devices

8. Definition of test parameters
9. Calibration and check procedures
10. Measurement of ambient gas concentration
11. Test procedure
12. Documentation
13. Control of testing, measuring and test equipment

NOTE The acceptance leak rate is specified for each component taking into consideration functional and safety aspects, which can differ significantly from one part to the other. This is part of the failure mode effects and criticality analysis (FMECA).

6.2.3.2 Leak test documentation

ECSS-Q-ST-70-15_1470063

a. The leak test documentation shall be in compliance with NDT report from the DRD from Annex B.

6.3 Penetrant testing

6.3.1 Overview

6.3.1.1 General process for penetrant testing

Penetrant testing is also known as liquid penetrant testing method to locate surface breaking discontinuities in non-porous materials, ferrous and non-ferrous metals including non-magnetic stainless steels and ceramics by covering the part with a penetrant liquid which is drawn into the discontinuity by capillary action.

Penetrant techniques can be used on materials independent of their physical properties provided the surface is normally non-absorbent and compatible with the penetrant process.

The efficiency of the process depends upon the ability to carry out each separate operation correctly. The inability to accomplish any single operation correctly can affect the validity of the testing. The effectiveness of the penetrant testing strongly depends on the technical competence of the personnel.

6.3.1.2 Penetrant testing process variations

There are several process variations defined in the applicable specifications. The product family used for penetrant testing is given a designation comprising the type, the method, the form and the sensitivity level.

The combination of the different variations depends on the type of application and the specific requirements.

a. Type: Fluorescent or non- fluorescent (colour contrast) penetrant.

b. Method: Different excess penetrant removers; water washable, lipophilic, solvent removable, hydrophilic, water and solvent removable.

c. Form: Different developers: dry powder, water-soluble, water-suspendable, solvent based for type I, solvent based for types II and III and special application

d. Sensitivity level: Different sensitivity levels: 0,5, 1, 2, 3, 4

e. Type of application of penetrant: spraying, brushing, flooding, dipping or immersion

f. Type of application of developer (dry powder): dust storm, electrostatic, spraying, flock gun, fluidized bed or storm cabinet.

g. Type of application of developer (water-suspendable and water-soluble); immersion, spraying

h. Type of application of developer (solvent- based); spraying

6.3.2 General penetrant testing requirements

ECSS-Q-ST-70-15_1470064

a. Products of a qualified product family shall not be mixed with products of another penetrant product family.

NOTE 1 As specified in AMS 2644:2016 or EN ISO 3452 only approved penetrant product families are used, as specified in 6.3.2d.

NOTE 2 As specified in EN ISO 3452-2:2013 only approved product families are used.

ECSS-Q-ST-70-15_1470065

b. Penetrant testing shall be performed in accordance with EN ISO 3452-1:2013, EN ISO 3452-2:2013, EN ISO 3452-3:2013 or ASTM E 1417:2016.

ECSS-Q-ST-70-15_1470066

c. Specific differences between EN ISO 3452-1:2013, EN ISO 3452-2:2013, EN ISO 3452-3:2013 and ASTM E 1417:2016 shall be discussed and agreed case by case.

ECSS-Q-ST-70-15_1470067

d. For penetrant testing, materials listed and qualified in QPL-AMS-2644:2016 shall be used.

ECSS-Q-ST-70-15_1470068

e. Inspection personnel shall be qualified in accordance with the company written practice and EN 4179:2017.

ECSS-Q-ST-70-15_1470069

f. A written instruction shall be prepared and approved by the responsible Level 3 dye penetrant testing.

ECSS-Q-ST-70-15_1470070

g. Penetrant testing shall be performed before any surface treatments, because they can have an unacceptable impact upon the sensitivity of the testing.

ECSS-Q-ST-70-15_1470071

h. For parts that are shot peened, dry vapour blasted, machine polished or burnished in the testing area the qualification programme shall demonstrate that discontinuities are not closed by the surface processes.

NOTE Examples of surface treatments include: shot peened, dry vapour blasted, machine polished or burnished in the testing area.

6.3.3 Penetrant testing equipment

6.3.3.1 Overview

In general there are two types of equipment for penetrant testing:

a. Equipment suitable for carrying out in situ penetrant testing techniques:
   1. Portable spray equipment
   2. Cloth
   3. Brushes
   4. Personnel protective equipment
   5. White light source
   6. UVA source (different UV source technologies can be used to achieve sufficient luminance for penetrant testing)
   7. Reference test block

b. Equipment for fixed installations (in addition to the equipment listed in a):
   1. Tanks
   2. Pipework
   3. Ducting
   4. Ventilation
   5. Equipment for drying
   6. Cabinets.

6.3.3.2 Requirements for penetrant testing equipment

ECSS-Q-ST-70-15_1470072

a. Electrical equipment shall be serviced and calibrated at least once a year, within a period agreed with the customer.

ECSS-Q-ST-70-15_1470073

b. All electrical and mechanical measurement instruments shall be calibrated at least once a year, within a period agreed with the customer.

ECSS-Q-ST-70-15_1470074

c. All devices shall be listed and controlled in the user's measurement instruments calibration list.

6.3.4 Penetrant testing process application

ECSS-Q-ST-70-15_1470075

a. Penetrant testing sequence shall include the following:

1. An overview of the part to be tested:
   (a) Check the availability of required documentation
   (b) Check the test designation
2. Check the testing conditions,
3. Check the product family behaviour by use of reference block.
4. Preparation and pre-cleaning of testing object:
   (a) Prior to penetrant testing clean the test surface to remove any dirt, paint, oil, grease or any loose scales which can lead to false or irrelevant indications.
   (b) Apply cleaning methods, including solvents, vapour degreasing or alkaline cleaning steps.
   (c) Etch machined or mechanically disturbed metallic surfaces prior to standard penetrant testing to remove smeared or masking material.
5. Application of penetrant:
   (a) Ensure that the surface is wetted by penetrant during the penetration time.
   (b) Establish the penetrant application time as part of the procedure development and verification.
   (c) Include the minimum and maximum penetrant application time within the procedure.
   (d) Include the dependence on the surface tension, contact angle, temperature and part geometry in the penetrant application time.

6. Excess penetrant removal:

   (a) Ensure that the testing surface is not over washed.

   (b) For use of fluorescent penetrant check the testing surface for penetrant residues under a UVA source.

   (c) Ensure that the drying temperatures after excess penetrant removal are specified and controlled according to relevant specifications.

7. Application of developer:

   (a) Apply the developer in that way, that a thin uniform layer is placed on the testing surface and that the surface shines through the developer layer.

8. Inspection of surface:

   (a) Ensure that the lighting conditions meet the illuminance requirements of the chosen specification.

   (b) Carry out the examination of the parts immediately after the application of the developer.

   (c) Carry out the final testing when the development time has elapsed.

   (d) Use equipment for visual examination.

9. Compliance with acceptance criteria:

   (a) While performing penetrant testing, check the compliance of found indications with acceptance criteria agreed between customer and supplier.

10. Post cleaning:

   (a) After final testing of the parts, clean all parts to eliminate remnant of penetrant which can affect the service specification of the actual part.

NOTE 1 For requirement 6.3.4a.3: check of availability of required documentation include testing specification, drawings.

NOTE 2 For requirement 6.3.4a.4(c): for further details see 6.3.7.2

NOTE 3 For requirement 6.3.4a.5(b): The penetration time depends on the tested material and penetrant system. The maximum time is typically 60 minutes, however longer times can be appropriate for titanium alloys.

NOTE 4 For requirement 6.3.4a.8(c): The equipment for visual examination can include: magnification instruments and contrast spectacles.

6.3.5 Penetrant testing documentation

ECSS-Q-ST-70-15_1470076

a. The penetrant testing documentation shall be in compliance with NDT report from the DRD from Annex B.

6.3.6 Penetrant testing process control

ECSS-Q-ST-70-15_1470077

a. To maintain the integrity of the penetrant testing process, the penetrant system shall be controlled according to the standards specified in the requirement 6.3.2a.

NOTE The system performance of the product family used for penetrant testing is checked by use of a reference block (control panel 2 or PSM-5).

ECSS-Q-ST-70-15_1470078

b. The process and control test results for each penetrant method shall be documented and stored.

ECSS-Q-ST-70-15_1470079

c. Deviations from the procedure shall be reported and subject to the company's NCR process.

6.3.7 Penetrant testing process limitations and peculiarities

6.3.7.1 Overview

Although the process distinguishes between non-linear and linear indications, it is not possible to make a conclusion about the real discontinuity type and size. Therefore it is recommended to combine the penetrant testing with a visual testing, however, this combination is not necessarily enough for reliable classification and sizing of the discontinuity.

6.3.7.2 Etching requirements

ECSS-Q-ST-70-15_1470080

a. An etching procedure shall be developed by the supplier.

ECSS-Q-ST-70-15_1470081

b. The etching procedure shall specify the minimum amount of material to be removed to ensure that smeared metal does not mask cracks.

ECSS-Q-ST-70-15_1470082

c. The etching process shall not affect engineering drawing tolerances for part dimensions and finishes.

NOTE When very close tolerances are required, critical surfaces can be machined near final dimensions, etched and tested, and finish machined.

ECSS-Q-ST-70-15_1470083

d. Etching process shall be applied to remove smeared or masking material or mechanically disturbed metallic surfaces prior to the standard penetrant testing or mechanically disturbed metallic surfaces.

ECSS-Q-ST-70-15_1470084

e. The required metal thickness removal shall be specified, controlled and demonstrated using comparable tokens.

NOTE For example, for stainless steel and nickel-based alloys, the minimum metal to be removed is 5 μm.

ECSS-Q-ST-70-15_1470085

f. The etching process shall be selected, developed and controlled to prevent damage to the parts and materials undergoing test.

NOTE Excessive etching can seriously increase the risk of pitting, intergranular attack, surface roughness, cladding removal and dimensional degradation.

ECSS-Q-ST-70-15_1470086

g. Etching shall not be applied on close tolerance holes, close tolerances and faying surfaces where the functionality of the part or assembly degrade.

NOTE Etching is not always needed for intermediate examination when the surface is not retained in final configuration of the part, depending on the purpose of the intermediate testing.

ECSS-Q-ST-70-15_1470087

h. Etching may be omitted depending on the material and process if it is demonstrated that discontinuities are not smeared over.

ECSS-Q-ST-70-15_1470088

i. Alternative preparation techniques shall be subject to RFD.

6.3.8 Standard penetrant fracture control NDT

6.3.8.1 Overview

Standard testing methods, for which the initial crack sizes of Table 9-1 apply are to a large extent based on the heritage obtained in the frame of fracture control implementation for manned spaceflight. Tailoring can be acceptable for unmanned applications.

Further references can be found in PRC-6506 Rev. F, 30/03/2020 "Liquid Penetrant Inspection", PRC-5010 Rev. D, 25/06/2020 "Pickling, Etching, and Descaling of Metals", PRC-5009 Rev. B, 30/10/2019 "Electropolishing of Corrosion-Resistant Steel".

6.3.8.2 Standard fracture control NDT requirements

ECSS-Q-ST-70-15_1470089

a. Penetrant NDT standard discontinuity sizes shall be applied to fluorescent dye penetrants of minimum Level 3 sensitivity as specified in one of the following standards: ASTM E 1417:2016, SAE-AMS-2644:2006, SAE-AMS-2647:2009, EN ISO 3452-2:2013 or customer approved supplier internal specifications.

ECSS-Q-ST-70-15_1470090

b. For metals other than titanium, tested with fluorescent penetrant to Level II sensitivity as specified in requirement 6.3.8.2a, the standard crack sizes of Table 9-1, specified for titanium alloys shall be applied.

ECSS-Q-ST-70-15_1470091

c. All machined, or mechanically disturbed surfaces, to be penetrant tested, shall be etched to ensure removal of masking material prior to penetrant application for all processes and materials, where masking can appear.

NOTE The final penetrant testing can be performed prior to metal finishing operations such as buffing or sanding that do not by themselves produce discontinuities.

ECSS-Q-ST-70-15_1470092

d. For welds, the standard crack sizes of Table 9-1, specified for titanium alloys, shall be used in all cases, unless the weld surface is smoothened after welding to a level agreed with the customer.

NOTE Limited verification of the crack detection capability of the actual weld testing can be appropriate. Etching can be necessary after weld surface treatment.

ECSS-Q-ST-70-15_1470093

e. Interface surface finish shall be Ra=3,2 μm or lower.

ECSS-Q-ST-70-15_1470094

f. If the surface quality is not fulfilling the requirement 6.3.8.2e, additional justification shall be provided and agreed with the customer.

6.4 Eddy-current testing

6.4.1 Overview

6.4.1.1 General process for eddy-current testing

The eddy-current method is based on the principle of electromagnetic induction. An alternating current, typically with a frequency in the range of 1 kHz – 6MHz, is passed through an excitation coil generating an external primary magnetic field. If another electrical conducting material or part is brought into the close proximity to this primary magnetic field, current will be induced in this second conductor (eddy currents). The induced electrical currents flow in a circular path inducing a secondary field in opposition to the primary field. The reaction can be measured as a change of the impedance of the coil that is shown, in its simplest form, by the needle deflection of a meter.

The alternating current frequency, supplied to the coil, is modified for detecting surface and sub-surface discontinuities. High frequency concentrates the eddy current below the surface by detecting surface discontinuities, while reducing the frequency it can be possible to detect sub-surface discontinuities. Most eddy current equipment have an impedance plane display on which the variations of the probe impedance are shown by the movement of a dot; the analysis, in terms of phase and amplitude, of the dot movement is used for discontinuity characterization.

The method is very good at detecting fine surface cracks and discontinuities like cracks, coatings, for example, paint need not be removed provided they are reasonably uniform in thickness and are taken into account during calibration. Testing ferromagnetic materials is not always reliable due to the ferrous effects within the material and changes in surface coatings such as cadmium can give spurious indications. Eddy current testing can only be applied to metallic substrates.

The testing of magnetic or ferromagnetic materials can use specific eddy current techniques.

6.4.1.2 Eddy-current process limitations and peculiarities

Reported limitations of the eddy-current method are:

a. Only conductive materials can be tested

b. The penetration depth of the eddy current is limited

The peculiarities of the eddy current method are:

a. Detection of surface and sub-surface discontinuities;

b. Physical contact with the part tested is not required.

c. Automatization and high throughput speeds are applicable.

d. Additional measures can be carried out simultaneously (conductivity, heat treatment, thickness of coating).

6.4.2 Eddy-current testing general requirements

ECSS-Q-ST-70-15_1470095

a. Except the cases specified in the requirements 6.4.2b and 6.4.2c, eddy current inspections shall be performed in accordance with EN ISO 15549:2019 or a standard approved by the customer.

ECSS-Q-ST-70-15_1470096

b. Fastener holes shall be tested in accordance with SAE-ARP-4402:2013 or SAE-AS-4787:2013 or an equivalent standard approved by the customer.

ECSS-Q-ST-70-15_1470097

c. Tubular products shall be tested in accordance with ASTM E 426:2016 or an equivalent standard approved by the customer.

NOTE Standardised terminology for eddy current testing is given in EN ISO 12718:2019.

ECSS-Q-ST-70-15_1470098

d. The interface surface finish shall be Ra = 3,2 μm (125 μin) or lower.

NOTE Eddy current test does not require a coupling medium.

6.4.3 Eddy current testing process variations

ECSS-Q-ST-70-15_1470099

a. Array probe may be used to perform the eddy-current testing for large surfaces.

NOTE Examples of large surface are flat surface, weld surface and product with specific shape

6.4.4 Eddy current equipment

6.4.4.1 General

ECSS-Q-ST-70-15_1470100

a. Eddy-current equipment, instrument, probe and test set-up shall be verified in accordance with the EN ISO 15548-1:2013, EN ISO 15548-2:2013 and EN ISO 15548-3:2008.

6.4.4.2 Instruments for the eddy-current testing

ECSS-Q-ST-70-15_1470101

a. The instrument for the eddy-current testing shall be equipped with complex plane and time-synchronous display.

ECSS-Q-ST-70-15_1470102

b. The instrument for the eddy-current testing shall be able to operate at least in the range between 100 kHz and 4 MHz.

NOTE Instruments having a fixed operation frequency within the mentioned range are also acceptable.

ECSS-Q-ST-70-15_1470103

c. Instrument for the eddy-current testing shall be equipped with an audio and visual alarm system.

ECSS-Q-ST-70-15_1470104

d. The selection of the eddy current instruments and their set-up for a particular testing shall be under responsibility of the responsible Level 3 method.

6.4.4.3 Probes for the eddy-current testing

ECSS-Q-ST-70-15_1470105

a. The probes for the eddy current testing shall be marked with their operating frequency or frequency range.

NOTE The probes can have an absolute or differential coil arrangement and can be shielded or unshielded.

ECSS-Q-ST-70-15_1470106

b. The scan direction shall be indicated on the differential probes.

6.4.4.4 Test-setup for the eddy current testing

ECSS-Q-ST-70-15_1470107

a. The eddy current techniques implemented shall be specified.

NOTE The test set-up is designed to examine a defined product or perform a defined measurement

A reference test set-up comprises

- Instrument
- Interconnecting elements
- Probe arrangement
- Mechanical arrangement
- Accessories
- Reference block

6.4.5 Eddy-current testing process application

ECSS-Q-ST-70-15_1470108

a. Eddy-current testing instruction shall be performed in accordance with DRD in Annex D.

6.4.6 Eddy current testing documentation

ECSS-Q-ST-70-15_1470109

a. The Eddy current testing documentation shall be in compliance with NDT report from the DRD from Annex B.

6.4.7 Eddy current testing process control

6.4.7.1 Overview

Utilization of reference material blocks, in accordance with EN ISO 15549:2019, is used to perform a correct eddy current testing, calibration and set of the equipment. It is important to use and realize the reference material blocks in correct way as they can be used as acceptance standard.

6.4.7.2 Reference material blocks for the eddy-current testing

ECSS-Q-ST-70-15_1470110

a. The non-ferrous reference material blocks used to standardize the eddy current equipment for detection of surface and subsurface discontinuities shall be of an alloy having the same major base metal and the electrical conductivity, surface texture, configuration and discontinuity location of the part to be tested.

ECSS-Q-ST-70-15_1470111

b. Ferrous reference material blocks shall be of the same alloy and heat treatment or temper condition and surface texture, configuration and discontinuity location like the part to be tested.

NOTE Discontinuities utilised in the reference material blocks can be either natural or artificial.

ECSS-Q-ST-70-15_1470112

c. Artificial discontinuities shall be cut in the reference material blocks with suitable equipment that does not increase the surface roughness of the reference material blocks.

NOTE 1 Artificial cracks can be produced by electric discharge machining.

NOTE 2 Reference material blocks can be fabricated from actual parts or from test blocks.

ECSS-Q-ST-70-15_1470113

d. The reference material blocks shall be reheat treated if machining or drilling changes the conductivity and affects coil response.

ECSS-Q-ST-70-15_1470114

e. The equipment setting and item testing shall be performed with the same probe.

ECSS-Q-ST-70-15_1470115

f. The reference material blocks shall be identified with the following information:

1. Drawing or specification number
2. Serial number
3. Alloy and heat treatment
4. Type and dimension of each discontinuity
5. Applicable program
6. Applicability for eddy current equipment calibration.

ECSS-Q-ST-70-15_1470116

g. The reference material blocks shall be certified and approved by the Company ET/Level 2 as the minimum.

6.4.8 Standard eddy-current fracture control NDT

6.4.8.1 Overview

Standard testing methods, for which the initial crack sizes of Table 9-1 apply, are to a large extent based on the heritage obtained in the frame of fracture control implementation for manned spaceflight. Tailoring can be acceptable for unmanned applications.

Eddy current testing can only be applied to non-magnetic, non-ferromagnetic and conductive metals.

Further references can be found in PRC-6509 Rev. E", 16/12/2019 "Eddy Current Inspection."

6.4.8.2 Standard eddy current testing requirements

ECSS-Q-ST-70-15_1470117

a. Eddy current inspections shall be in accordance with ASTM E 426:2016, SAE-ARP-4402:2013, SAE-AS-4787:2013, or customer approved internal supplier specifications.

ECSS-Q-ST-70-15_1470118

b. The influence of coatings and lift-off variations on the reliability of an eddy-current Standard fracture control NDT process shall be evaluated and included in the procedure.

NOTE Lift-off variations can be experienced as well with thickness variations when inspecting through the thickness.

ECSS-Q-ST-70-15_1470119

c. A minimum signal-to-noise ratio of 3:1 shall be achieved for the standard eddy-current NDT.

NOTE 1 Considering credible worst case conditions (of lift-off, discontinuity opening).

NOTE 2 The reference standard used and associated with acceptance criteria (see also 5.1c), which are defined in the procedure and agreed with the customer, need to be in line with the actual ratio. A commonly accepted approach, as defined for example in NASA-STD-5009B and PRC-6509, result in a signal to noise ratio target 4:1.

ECSS-Q-ST-70-15_1470120

d. For automated eddy-current testing or testing with signal recording and analysis a reduction of the ratio specified 6.4.8.2c, as approved by the customer, may be applied.

ECSS-Q-ST-70-15_1470121

e. For performing the standard eddy-current NDT, the interface surface finish shall be Ra = 3,2 μm or lower.

6.5 Magnetic particle testing

6.5.1 Overview

6.5.1.1 General magnetic particle testing process

Magnetic particle testing (MT) is applied to detect surface and subsurface discontinuities in ferromagnetic materials such as Stainless Steels S143, S144, S145, S80, Iron, Nickel alloys, Cobalt alloys. The process of MT is a magnetic field induced into the part. The part can be magnetized either by direct or indirect magnetization.

The process can be used on raw materials and at any stage during component manufacture. The final magnetic discontinuity detection of any part is applied after final heat treatment, plating and de-embrittlement stages but before painting stages unless stated otherwise on the job card or drawing.

6.5.1.2 Magnetic particle testing process variations

The magnetic particle testing can be selected within the following main options:

a. Instrumentation
   1. Direct current
   2. Half-wave rectified
   3. Pulsating DC
   4. Alternating current
b. Application of particles
   1. Dry
   2. Wet
   3. Fluorescent
   4. Non fluorescent
c. Method of magnetization
   1. Yoke
   2. Prod
   3. Wrapped coil
   4. Stationary coil
   5. Contact plates

6.5.2 General magnetic particle testing requirements

ECSS-Q-ST-70-15_1470122

a. MT shall be performed in accordance with ASTM E 1444/E 1444M:2016 or EN ISO 9934-1:2016, EN ISO 9934-2:2015, EN ISO 9934-3:2015.

ECSS-Q-ST-70-15_1470123

b. On phosphated parts MT shall be applied after final heat treatment, but before phosphating, de-embrittlement and painting stages.

6.5.3 Magnetic particle testing equipment

6.5.3.1 General

ECSS-Q-ST-70-15_1470124

a. Equipment used for the MT shall be in accordance with EN ISO 9934-1:2016, EN ISO 9934-2:2015, EN ISO 9934-3:2015.

ECSS-Q-ST-70-15_1470125

b. The magnetic particles shall be fluorescent or non-fluorescent.

ECSS-Q-ST-70-15_1470126

c. The detection media shall be traceable and in compliance with EN ISO 9934-1:2016, EN ISO 9934-2:2015, EN ISO-3:2015 or ASTM E 1444/E 1444M:2016.

NOTE The detection media can be either in dry powder or liquid form.

6.5.3.2 Dry particles

ECSS-Q-ST-70-15_1470127

a. The colour of the dry particles shall provide contrast with the surface of the part being examined.

NOTE Dry particles can be of either fluorescent or non-fluorescent type.

ECSS-Q-ST-70-15_1470128

b. When dry particles are used, ensure the surface temperature of the part shall be in accordance with EN ISO 9934-1:2016, EN ISO 9934-2:2015, EN ISO 9934-3:2015.

6.5.3.3 Wet particles

ECSS-Q-ST-70-15_1470129

a. The colour of the wet particles shall have contrast with the surface being examined.

NOTE 1 Wet particles can be both in fluorescent and non-fluorescent concentrates.

NOTE 2 The particles are suspended in a suitable liquid medium such as water or petroleum distillates.

ECSS-Q-ST-70-15_1470130

b. Limitations of wet particle systems shall be applied in compliance with requirements from EN ISO 9934-1:2016, EN ISO 9934-2:2015, EN ISO 9934-3:2015.

ECSS-Q-ST-70-15_1470131

c. The checking of wet particles concentration shall be performed in accordance with requirements from EN ISO 9934-1:2016, EN ISO 9934-2:2015, EN ISO 9934-3:2015.

6.5.3.4 Fluorescent particles

ECSS-Q-ST-70-15_1470132

a. The testing of parts with use of fluorescent particle shall be performed in a dedicated darkroom.

NOTE This is performed under an ultraviolet light which is called "Black Light".

6.5.4 Magnetic particle testing process application

ECSS-Q-ST-70-15_1470133

a. The following steps for the magnetic particle preparation and testing shall be performed:

1. Demagnetize the part prior to testing.
2. Ensure that the surface condition and finish is smooth, clean, dry, free of oil, scale, machining marks and any other contaminants which can cause interference with the efficiency of the magnetic field.
3. Apply masking and plugging of the parts as specified in the engineering drawing.
4. Ensure where electrical contact is made, the parts are cleaned to prevent electrical arcing.

5. For magnetization current application use:
   (a) Full wave, rectified current (1 or 3 phase),
   (b) Half wave direct current and AC- alternating current.
6. Ensure that yokes and permanent magnets are dead weight checked at 6 month intervals as specified in Table 1 of ASTM E 1444/E 1444M:2016.
7. Magnetize each part in a minimum of two directions at a right angles to each other, to ensure the detection of a discontinuity in any orientation.
8. Limit the electrical current to prevent overheating in any area of the part.

NOTE 1 For requirement 6.5.4a.5(a): Full wave, rectified current has the deepest penetration

NOTE 2 For requirement 6.5.4a.6: Full wave rectified current is used for sub-surface discontinuity detection only when using wet MT of sub-surface discontinuities.

NOTE 3 For requirement 6.5.4a.6: Half wave direct current is also used for inspecting sub-surface discontinuities and it is due to the pulsating nature of the waveform.

NOTE 4 For requirement 6.5.4a.6: AC-alternating current is only used for the detection of discontinuities near to the surface.

NOTE 5 For requirement 6.5.4a.7: Magnetic field direction- discontinuities are difficult to detect by MT at angle of <45° to the direction of magnetization. Detection of a discontinuity in any orientation is also dependant on the geometry of the part. For further reference, refer to ASTM E 1444/E 1444M:2016.

NOTE 6 For requirement 6.5.4a.8: Direct magnetization is applied by passing a current directly through the part to be tested. Electrical contact is made by using head and tail stock, prods, clamps, magnetic leeches.

ECSS-Q-ST-70-15_1470134

b. Unless agreed between customer and supplier prods shall not be used to examine aerospace parts, flight hardware and on finished surfaces.

6.5.5 MT documentation

ECSS-Q-ST-70-15_1470135

a. The MT documentation shall be in compliance with NDT report from the DRD from Annex B.

6.5.6 MT process control

ECSS-Q-ST-70-15_1470136

a. The MT process control shall include:

1. Measurement of magnetization,
2. Function control with standardized reference samples according to MT standards specified in the requirement 6.5.2a including characterization of appearance conditions.

6.5.7 MT process limitations and peculiarities

ECSS-Q-ST-70-15_1470137

a. The magnetic particle testing shall be applied only to ferromagnetic materials and open or closed surface or near surface discontinuities.

NOTE Magnetization and carrier fluid can change material characteristics.

6.5.8 Standard magnetic particle fracture control NDT

6.5.8.1 Overview

Standard testing methods, for which the initial crack sizes of Table 9-1 apply, are to a large extent based on the heritage obtained in the frame of fracture control implementation for manned spaceflight. Tailoring can be acceptable for unmanned applications.

Further references can be found in PRC-6505, Magnetic Particle Inspection, Rev. E, 21/04/2020.

6.5.8.2 Standard magnetic particle NDT requirements

ECSS-Q-ST-70-15_1470138

a. Magnetic particle inspections shall be in accordance with ASTM-E-1444/E 1444M:2016, or customer-approved supplier internal specifications.

ECSS-Q-ST-70-15_1470139

b. The magnetic particle testing shall be the wet, fluorescent, continuous, or multimag method.

ECSS-Q-ST-70-15_1470140

c. The interface surface finish shall be Ra = 3,2 μm or lower

ECSS-Q-ST-70-15_1470141

d. A QQI shall be used to validate the local field intensities.

ECSS-Q-ST-70-15_1470142

e. Hall probes may be applied provided that they are verified with a QQI.

ECSS-Q-ST-70-15_1470143

f. Pie gages shall not be used for measuring field intensities.

6.6 X-ray radiographic testing

6.6.1 Overview

6.6.1.1 General process

This clause establishes the quality specifications for X-ray radiographic examination on parts, components, structures, metallic or non-metallic, in order to detect internal discontinuities.

The process is based on an electromagnetic wave beam passing through the entire thickness of the part to be examined: the residual radiation is more or less reduced in respect to the transmitted one which is used to show the internal structure of the part and its internal discontinuities.

X-ray radiographic testing is mainly intended to detect volumetric discontinuities, cavities, pores and inclusions.

6.6.1.2 X-ray radiographic testing process variations

The following additional RT techniques are available:

a. The standard film technique

b. Digital RT technique (DR). This is an advanced method of testing, which is dependent on digital detection systems the resultant image being displayed on a computer screen. The X-Ray radiation is converted into an electrical charge and then to a digital image through the detector sensor. The flat panel detector (DDA) produces high quality digital images when it is compared with other imaging devices. Flat panel detection uses:

    1. Indirect conversion utilizes a photographic diode matrix of amorphous silicon;

2. Direct conversion uses a photographic conductor such as amorphous selenium or Cadmium telluride, giving sharpness and better resolution.

c. Computed Radiography (CR). This is a DR technique utilizing photo stimulated luminescence (PSL) foil as an intermediate storage media prior to the final digital image.

d. Computed tomography (CT) is able to produce a complete 3-D volumetric model of the test object.

6.6.2 General X-ray radiographic testing requirements

ECSS-Q-ST-70-15_1470144

a. X-ray radiographic testing shall be in accordance with the following standards or customer-approved, supplier internal specifications.

1. For film techniques ASTM E 1742/E1742M:2018, EN ISO 17636-1:2013 or EN ISO 5579:2013.

2. For digital RT techniques EN ISO 17636-2:2013 or ASTM E 2698:2018-e1.

3. For computed Radiography EN ISO 17636-2:2013 or ASTM E 2445/M2445M:2020 or EN 14784-2:2005.

4. Computer tomography EN 13068-3:2001.

6.6.3 X-ray radiographic equipment

ECSS-Q-ST-70-15_1470145

a. Use of radioactive substances and electrical equipment emitting ionization radiation shall be in compliance with national regulations.

6.6.4 X-ray radiographic testing process application

ECSS-Q-ST-70-15_1470146

a. For X-ray radiographic testing of welds, the valleys between beads weld ripples or other surface irregularities shall be smooth to a degree such that the resulting X-ray contrast due to surface irregularities cannot mask or confused with any other discontinuities.

ECSS-Q-ST-70-15_1470147

b. Each radiograph shall be traceable on the area being tested and examined.

ECSS-Q-ST-70-15_1470148

c. Each radiograph shall include the following identification:

1. Identification of the part;
2. Viewing number;
3. Date of examination;
4. NDT facility inspecting the part.

NOTE Number of times that repairs were carried out is optional.

ECSS-Q-ST-70-15_1470149

d. Radiographs and unexposed film shall be stored in conditions in compliance with requirements from ASTM E 1254:2013(2018) and ensuring that the film is used within the expiry date.

6.6.5 X-ray radiographic testing documentation

ECSS-Q-ST-70-15_1470150

a. The X-ray radiographic testing documentation shall be in compliance with the NDT report from the DRD Annex B.

6.6.6 X-ray radiographic testing process control

ECSS-Q-ST-70-15_1470151

a. Image quality indicators shall be used to evaluate quality of X-ray images.

NOTE The diameter of the holes or the diameter of the wires of each IQI is associated to a numerical value indicating the quality and sensitivity of the resultant X-ray.

ECSS-Q-ST-70-15_1470152

b. The application of RT discontinuity detection shall be qualified in agreement with the customer as follows:

1. On pre-cracked specimens X-ray tests are performed in order to verify the sensitivity of the testing with respect to a discontinuity located in specific parts;
2. Specimen definition and selection is agreed with the customer.

6.6.7 Standard X-ray radiographic fracture control NDT

6.6.7.1 Overview

Standard testing methods, for which the initial crack sizes of Table 9-1 apply are to a large extent based on the heritage obtained in the frame of fracture control implementation for manned spaceflight. Tailoring can be acceptable for unmanned applications.

The requirements for Standard fracture control NDT are based on film radiography. Tailoring for digital techniques like digital radiography or computed radiology can be proposed, based on for example NASA-STD-5009B.

Further references can be found in refer to PRC-6503, Radiographic Inspection, Rev. E, 01/01/2020.

6.6.7.2 X-ray radiographic testing requirements

ECSS-Q-ST-70-15_1470153

a. X-ray radiographic testing shall be in accordance with ASTM E 1742/E1742M:2018, or customer-approved supplier internal specifications.

ECSS-Q-ST-70-15_1470154

b. Film density shall be 2,5 to 4,0.

ECSS-Q-ST-70-15_1470155

c. The X-ray radiographic quality level shall be equal or better than 2-1T in conformance with clause 6.9 of ASTM E 1742/E1742M:2018.

ECSS-Q-ST-70-15_1470156

d. The radiation of the beam shall be within ±5° of the orientation of the plane of the linear discontinuities to be detected.

NOTE X-ray exposures at different orientations can be needed to ensure that the complete volume of an item is sufficiently tested for potentially critical cracks that can be in a wide range of orientations. When agreed with the customer, the orientation of the crack plane can be assumed along and perpendicular to the fusion plane or planes.

6.7 Ultrasonic testing

6.7.1 Overview

6.7.1.1 General process for ultrasonic testing

Ultrasonic testing is applicable to a wide range of materials covering metallic, non-metallic and composite structures.

The testing typically requires a coupling medium between the probe and the test object. A common practice is local coupling in water or non-water coupling media. Another practice is to test the parts in a water bath where the size, function and material of the part to be tested allow complete immersion with water.

The most common ultrasonic testing technique is the impulse-echo technique. The principle is to generate and introduce an ultrasonic impulse (mechanical waves) into a test object and evaluate the receiving signals, which are reflected at interfaces between different media. With knowledge of the specific velocity of sound the position of the reflector can be determined. The characteristic of the received signal is compared to a reference reflector and delivers information about a comparable shape and size of the reflector. The equipment for ultrasonic testing primarily consists of an ultrasonic instrument, probes, connecting cables, couplant and reference or calibration blocks.

6.7.1.2 Ultrasonic testing process variations

6.7.1.2.1 Types of ultrasonic testing

Main types of ultrasonic testing are:

a. Longitudinal Wave/Straight Beam- Guided Waves are covered in text and are typically sent down the length of continuous parts like tubes.

NOTE An example of Longitudinal Waves are Guided Waves.

b. Shear / Transverse Wave

NOTE Examples of Shear/Transverse Wave are straight beam or angled beam]

c. Rayleigh / Surface Wave

d. Phased Array

The ultrasonic testing can be performed manually, semi-automated or automated mostly in immersion, by squirter (through-transmission technique) or by contact technique.

The straight beam ultrasonic testing (same method used for wall-thickness measurement) is applied perpendicular to the testing surface and is very effective in finding embedded (laminar) discontinuities in various materials (for example, metals, composites).

Angle beam (refracted waves in the test object of typically 45°, 60° and 70°) testing is effective in finding discontinuities not parallel to the testing surface.

For example weld testing, cracking propagating from holes, forging flash line defects.

Phased-array testing operates an array of elements (transducers) in one probe. These elements can be controlled separately and so by electronic steering can perform a sector scan (sweep through a range of refracted angles), a linear scan (at a fixed beam angle) or change the focusing of the sound beam at varying depth.

Guided-wave testing has been identified within the industry as an effective screening technology for constant thickness and continuous parts, such as long pipelines or panels. The technique is capable of assessing damaged areas over extended lengths. Recent technological improvements mean that guided-wave testing can be deployed in an array of environments and product temperatures.

Typical displays of ultrasonic testing results for single-transducer operation and for phased-array testing are shown in Figure 6-1 to Figure 6-4.

In Figure 6-1 the echoes are shown in amplitude (reflected signal strength) over time (sound path or depth).

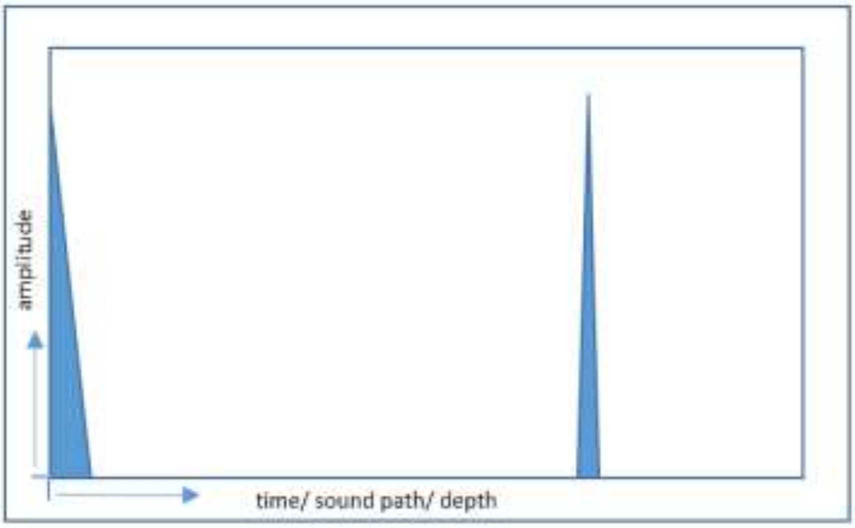
A-Scan:
Used in manual single transducer angle/ straight beam and phased array.


Figure 6-1: A-Scan, typical display of ultrasonic signals

In Figure 6-2 the echoes are shown in depth over linear position. Cross-sectional view and amplitude (colour chart).

B-Scan:

Used in automated single transducer angle/ straight beam and phased array.

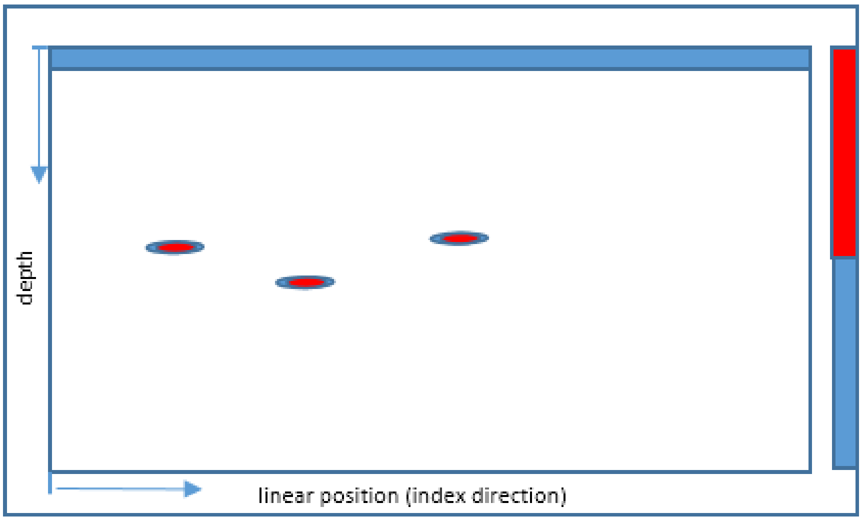


Figure 6-2: B-Scan, typical display of ultrasonic signals

In Figure 6-3: 2D. Similar to an X-ray image. Top view. The echoes are shown in their x-y position and amplitude (colour chart).

C-Scan:

Used in automated single transducer angle/ straight beam and phased array.

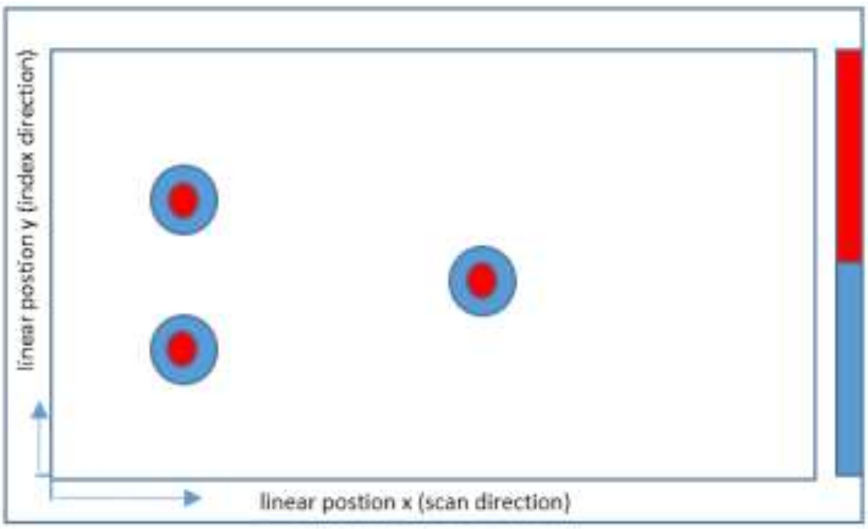


Figure 6-3: C-Scan, typical display of ultrasonic signals

In Figure 6-4: Sector Scan. The echoes are shown in depth over linear position. Cross-sectional view and amplitude (colour chart).

S-Scan:
Used in phased array.

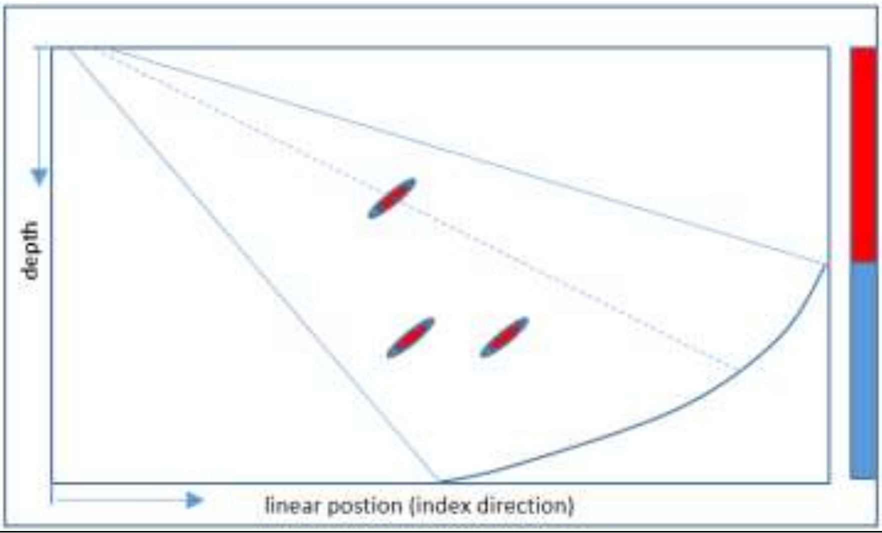


Figure 6-4: S-Scan, typical display of ultrasonic signals

6.7.1.2.2 Range of detectable discontinuities

Range of detectable discontinuities:

a. Volumetric discontinuities

b. Voids, cavities, pores

c. Inclusions

d. Cracks, delamination or any further material separation vertical to the ultrasonic beam

The ability to detect the listed discontinuities is limited by their size.

6.7.1.2.3 Major characteristics of the testing probe

The major characteristics of an ultrasonic probe are:

a. Single-transducer operation (transmitting and receiving)

b. Twin crystal operation (separate transmitter and receiver),

c. Frequency

d. Active element size (circular or rectangular)

e. Sound beam characteristics

f. For phased array probes: number and size of transducers (elements) and pitch (centre to centre distance between two successive elements)

g. Focal

6.7.1.2.4 Discontinuity evaluation

The result of a conventional ultrasonic testing (straight- or angle beam) shows reflected signals which are compared to those artificial reflectors in reference blocks. For metallic materials and parts the artificial discontinuities can include flat bottom holes (FBH), side drilled holes (SDH) and EDM notches, whereas for composite materials and parts artificial discontinuities can also include PTFE or metallic inserts. It is important that artificial discontinuities are precisely manufactured and accurately positioned within the calibration/reference standard. This is because the acceptance or rejection of the part is often determined by direct comparison of the signals between the calibration/reference standard and the part under testing.

Additional details of discontinuities size and geometry can be evaluated by the use of adapted ultrasonic testing techniques, depending on the type and position of the discontinuity. Examples of adapted techniques include phased array technique or a combination of conventional ultrasonic testing and local scanner techniques. In this case the testing is applied pixel by pixel on a predefined surface grid, which allows the determination of the geometry of the discontinuity over the pixel grid. This is called defect edge scanning comparable to -6dB method used in manual ultrasonic testing.

This is called edge scanning comparable to -6dB method used in manual ultrasonic testing.

Discontinuities with orientation perpendicular or near perpendicular to the surface need angle beam testing.

6.7.2 General

ECSS-Q-ST-70-15_1470157

a. The ultrasonic testing shall be performed in compliance with requirements from SAE AMS-STD-2154D:2020, ASTM E 2375:2016 or EN ISO 17640:2018 and agreed with the customer.

NOTE These documents cover raw material testing.

6.7.3 Ultrasonic testing equipment

6.7.3.1 General requirements

ECSS-Q-ST-70-15_1470158

a. The ultrasonic system shall produce frequencies and energy levels with sufficient measurement sensitivity as specified, in order to perform NDT examination and readout of the result.

ECSS-Q-ST-70-15_1470159

b. The ultrasonic system shall be calibrated in accordance with ASTM E 127:2019 or EN 12668–1:2010 and EN 12668–2:2010.

6.7.3.2 Couplants

ECSS-Q-ST-70-15_1470160

a. Couplants shall not degrade or cause an adverse effect to the material on the part to be tested.

ECSS-Q-ST-70-15_1470161

b. Water based couplants shall not be used with materials prone to corrosion.

6.7.3.3 Search units

ECSS-Q-ST-70-15_1470162

a. Transducers for pulse echo and immersion testing techniques shall transmit and receive ultrasound on the part to be tested.

ECSS-Q-ST-70-15_1470163

b. For near surface discontinuities a delay line probe shall be used.

ECSS-Q-ST-70-15_1470164

c. The face of a transducer known as the shoe may be shaped or curved to improve contact with the part to be tested.

NOTE Example of shape adapters are shoes.

6.7.4 Ultrasonic testing process application

6.7.4.1 General

ECSS-Q-ST-70-15_1470165

a. The surface finish of the part to be ultrasonically tested shall be free from scale, dirt, swarf, debris and corrosion.

ECSS-Q-ST-70-15_1470166

b. The surface finish of a part shall be smooth and clean.

ECSS-Q-ST-70-15_1470167

c. Ultrasonic testing for weld materials thicker than 8 mm shall be performed in accordance with requirement 9.1.5a of the ECSS-Q-ST-70-39 or supplier internal specification approved by the customer.

ECSS-Q-ST-70-15_1470168

d. Ultrasonic testing for weld materials thinner than 8 mm shall be performed in accordance with requirement 9.1.5b of the ECSS-Q-ST-70-39 or supplier internal specification approved by the customer.

ECSS-Q-ST-70-15_1470169

e. For discontinuities with randomly distributed orientations, automated phased-array or sampling phased-array testing shall be applied.

6.7.4.2 Scanning

ECSS-Q-ST-70-15_1470170

a. All accessible surfaces as identified in the Technique or Written Instruction of the part shall be scanned for ultrasonic testing of the part.

ECSS-Q-ST-70-15_1470171

b. In case scanning is restricted to one side then scanning shall be performed by using a twin crystal probe for the near surface scans and a single probe for the remaining and the scanning speed not exceed 100mm/s.

NOTE That allows the detection of all discontinuities in the reference standard blocks used to set up the equipment.

ECSS-Q-ST-70-15_1470172

c. For automated inspections the scan speed shall be stated in the Written Instruction.

6.7.4.3 Scanning index

ECSS-Q-ST-70-15_1470173

a. The scanning index shall be applied in accordance with NDT procedure specified in DRD in Annex C.

ECSS-Q-ST-70-15_1470174

b. When scanning a large area of a test object, a plastic straight edge shall be used in order to cover the scan map.

NOTE The scanning can be carried out as a continuous or spot to spot scan depending on the geometry of the test object.

6.7.4.4 Qualification

ECSS-Q-ST-70-15_1470175

a. The qualification of both Standard and Special fracture control NDT shall be performed as follows:

1. The 90 % probability and 95 % confidence level of an automated ultrasonic testing is demonstrated by a signal to noise ratio of 3:1.
2. In the case of a plane, two dimensional manual ultrasonic testing, the required POD level are demonstrated by the hit and miss method.

NOTE 1 For the requirement 6.7.4.4a.1: For standard fracture control NDT, tailoring can be proposed in accordance with clause 6.7.7.

NOTE 2 For the requirement 6.7.4.4a.1: For special fracture control NDT, the signal to noise ratio demonstration has to be considered as part of complying with the requirements of clause 9.2.2.2, especially 9.2.2.2f and 9.2.2.2g, as well as 9.1.3 and 5.5. The nature of the signal to noise ratio is to be agreed per demonstration plan of 9.2.2.2e, and can be subject of tailoring.

NOTE 3 For the requirement 6.7.4.4a.2: For standard fracture control NDT, there is no formal POD demonstration requirement, see also clause 9.

NOTE 4 For the requirement 6.7.4.4a.2: For special fracture control NDT, tailoring can be proposed in accordance with clause 9.

NOTE 5 POD (90 % probability and 95 % confidence level) evaluation example is given in the Annex F.

6.7.4.5 Ultrasonic test documentation

ECSS-Q-ST-70-15_1470176

a. The ultrasonic test documentation shall be in compliance with NDT report from the DRD from Annex B.

6.7.5 Ultrasonic testing process control

6.7.5.1 Ultrasonic testing calibration sensitivity and limitations

ECSS-Q-ST-70-15_1470177

a. Longitudinal wave-Straight Beam examination shall be calibrated on flat bottom holes according to SAE AMS-STD-2154D:2020, ASTM E 2375:2016, ASTM E 127:2019 or ASTM E 127:2019.

ECSS-Q-ST-70-15_1470178

b. When testing for surface or embedded crack- like discontinuities the test sensitivity shall be demonstrated and set on suitable reference reflectors.

NOTE 1 Standard practice is to introduce spark eroded notches to simulate discontinuities.

NOTE 2 Ultrasonic testing is not using fatigue cracks for demonstration. Size of representative notches is agreed between customer and supplier.

ECSS-Q-ST-70-15_1470179

c. If discontinuities are closed by compression between their faces, a dedicated ultrasonic testing procedure and justification shall be provided.

NOTE For example as "kissing bond" in friction stir welds.

6.7.5.2 Ultrasonic thickness gauge

ECSS-Q-ST-70-15_1470180

a. The reference block used for the calibration of the instrument used to perform the ultrasonic testing should:

1. Be of from the same material of the part to be tested.
2. Have the same surface finish and as thick as the maximum thickness of the part to be tested.

NOTE The principle of operation of an ultrasonic thickness gauge is that the instrument measures the time of flight of an ultrasonic pulse through the test piece and multiplies this time by the velocity of sound in the material. Thickness measuring error is minimized by ensuring that the sound velocity to which the instrument is calibrated is the sound velocity of the material being tested. Actual sound velocities in materials often vary significantly from the values found in published tables.

6.7.5.3 Digital ultrasonic thickness gauge

ECSS-Q-ST-70-15_1470181

a. The digital thickness gauge instrument shall be calibrated on a reference block made from the same material as the test piece.

NOTE Operators need to be aware that the sound velocity can vary from point to point and in different directions in the material being tested; heat treating, for example, can cause significant changes in sound velocity. This is important to consider when evaluating the accuracy of the thickness provided by this instrument.

6.7.5.4 Reference blocks

ECSS-Q-ST-70-15_1470182

a. For metals the reference standard blocks shall be flat bottom type or contain side drilled holes and notches as specified in ASTM E 127:2019, ASTM E 127:2019 and EN ISO 16811:2014.

ECSS-Q-ST-70-15_1470183

b. The reference standard blocks shall be representative in the terms of material specification and surface finish of the object to be tested.

ECSS-Q-ST-70-15_1470184

c. The reference blocks shall be permanently marked for identification and be listed in the equipment records.

ECSS-Q-ST-70-15_1470185

d. When testing composite materials, the reference blocks shall be constructed from the same materials, manufacturing process and lay up with artificial discontinuities built-in, to stimulate a response equivalent to the discontinuity to be detected.

NOTE Teflon foils (to simulate delaminations and debonding) can produce different signal characteristic than real delaminations and debondings.

ECSS-Q-ST-70-15_1470186

e. If there is a difference in the acoustic properties between the reference blocks and the part to be tested, a sensitivity correction shall be made to compensate the difference.

NOTE The transfer correction is achieved by noting the difference between the signals received from the same reference reflector, e.g. the back wall, in the reference block and the test object. Back wall reflection is corrected by adding or removing attenuation.

ECSS-Q-ST-70-15_1470187

f. When measuring on curvatures with diameters smaller than 25 mm, reference, standard blocks shall be used with similar geometry to ensure UTG accuracy.

NOTE This is to ensure UTG accuracy.

ECSS-Q-ST-70-15_1470188

g. The reference blocks with reflectors for instrument setting and for demonstration shall be manufactured representative for the conditions of the parts to be tested including the following specific aspects:

1. Material properties
2. Microstructure of the material
3. Surface conditions: roughness
4. Geometry of the test object
5. Thickness of the test object
6. Shape of the test object
7. Access of surfaces

6.7.6 Ultrasonic testing process limitations and peculiarities

6.7.6.1 Overview

It is important to consider the following limitations of the ultrasonic testing:

a. The dangers of not detecting discontinuities within the near and far field dead zones

b. Sufficient signal to noise ratio

c. Sufficient penetration depth (sound attenuation)

6.7.7 Standard ultrasonic fracture control NDT

6.7.7.1 Overview

Standard testing techniques, for which the initial crack sizes of Table 9-1 apply, are to a large extent based on the knowledge obtained in the frame of fracture control implementation for manned spaceflight.

Tailoring can be acceptable for unmanned applications.

Further references can be found in PRC-6504, Ultrasonic Inspection of Wrought Metals, Rev. G, 07/01/2020, and also: in PRC-6510, Ultrasonic Inspection of Welds, Rev. B, 14/05/2020.

6.7.7.2 Standard ultrasonic testing requirements

ECSS-Q-ST-70-15_1470189

a. Ultrasonic testing shall be in conformance with SAE-AMS-STD-2154D:2020 Class A, or supplier internal specifications approved by the customer.

NOTE Supplier internal specifications can address phased array ultrasonic technique, see also for example PRC-6510.

ECSS-Q-ST-70-15_1470190

b. Ultrasonic inspections for wrought products shall be in accordance with ASTM E 2375:2016 Class A, SAE AMS-STD-2154D:2020 Class A, or customer-approved supplier internal specifications.

ECSS-Q-ST-70-15_1470191

c. Linear discontinuities of any length shall not be accepted without proper justification accepted by the customer.

NOTE Guidance on how to justify relaxation of this requirement, taking into account specified acceptance criteria (see also 5.1c), can be found in for example NASA-STD-5009B, PRC-6504 or PRC-6510.

ECSS-Q-ST-70-15_1470192

d. Ultrasonic testing shall be performed using longitudinal or shear waves, applied via unobstructed bare, flat surfaces, at right-angles to all possible orientations of the discontinuities to be detected.

ECSS-Q-ST-70-15_1470193

e. Interface surface finish shall be Ra=3,2 μm or lower.

ECSS-Q-ST-70-15_1470194

f. Ultrasonic testing for surface or embedded discontinuities in welds or in parent material surrounding the welds shall be in conformance with ASTM E 164:2019 or supplier internal specifications approved by the customer.

6.8 Proof testing

6.8.1 Overview

Proof testing is in most cases applied as workmanship verification test without a clear and reliable relationship with discontinuities and cracks to be detected. In some cases proof tests are designed to screen for cracks of certain types and exceeding a specified sizes. There can be significant risk of causing damage during proof testing that can degrade the residual strength after proof testing below what is acceptable, without causing failure during proof testing. It can require significant effort to ensure that no such unacceptable damage occurs.

6.8.2 Proof testing requirements

ECSS-Q-ST-70-15_1470195

a. Application of proof testing for crack screening shall be only performed with approval of the customer.

ECSS-Q-ST-70-15_1470196

b. Proof testing for crack screening shall be in accordance with clauses 8.7 or 10.4.2.3 from ECSS-E-ST-32-01.

NOTE NASA/CR-1999-209427 and NASA/CR-1999-209426 give guidelines for Proof Test Analysis.

7 Non-destructive testing of welds

ECSS-Q-ST-70-15_1470197

a. Inspection of welds shall be performed in compliance with requirements from clause 9 of ECSS-Q-ST-70-39.

ECSS-Q-ST-70-15_1470198

b. The minimum amount of NDT to be performed for weld testing shall be in accordance with Table 12-2 of ECSS-Q-ST-70-39.

8 Non-destructive testing of products

8.1 Overview

This clause covers differences, limitations and peculiarities appearing during testing of:

- Raw material
- Final processing

The different materials and processing methods can have different influences on different testing methods mentioned in clause 6 and are therefore mentioned individually in this clause.

This clause contains requirements and recommendations only for performance of raw material testing at the material supplier.

NOTE The final condition of a new product can vary significantly between different materials and geometries such that specially adopted and very different testing methods can only be applied individually. This is specified and qualified individually within a specific procedure and cannot be specified generally.

8.2 General

ECSS-Q-ST-70-15_1470199

a. For the examination of wrought metals, forged and rolled, parts, the customer shall specify in consultation with Level 3:

1. Who is certified to inspect wrought products
2. The NDT method to be used
3. The class and acceptance criteria
4. The aerospace quality standards to be applied, and their applicability
5. The added and modified requirements to these standards.

NOTE The customer normally specifies in the purchase order or other contractual document, based on final piece part usage.

8.3 Wrought products

8.3.1 Overview

A wrought product is defined as a product that was subjected to mechanical working that include extruding, rolling, or other processes to get a rough and semi-finished shape configuration.

Two types of wrought product procurements typically apply:

a. Standard size, form and shape procured to international aerospace quality standards

b. Non-standard size, form and shape procured via dedicated procurement specification

Wrought rectangular products are generally classified into two categories:

- Sheet
- Plates

The difference in thickness between sheet and plate significantly affects ultrasonic testing and the resulting dead zones. These are specified in the Table 8-1 according to AMS standard definitions.

Table 8-1: Thickness differences between sheet and plate

Material	Sheet	Plate
Aluminium	T < 6,35mm	T > 6,35mm
Steel and Titanium	T < 4,76mm	T > 4,76mm

8.3.2 Raw material testing

ECSS-Q-ST-70-15_1470200

a. For standard wrought product, the following NDT shall be applied:

1. Ultrasonic testing
2. The NDT specified by the customer in accordance with requirement 8.2a.

   NOTE These NDT are specified based on part typology: typically Ultrasonic testing is applicable, but if necessary by a specific application or configuration, dedicated NDT can be specified by procurement or contractual documentation.

ECSS-Q-ST-70-15_1470201

b. For non-standards parts, volumetric discontinuities shall be verified by ultrasonic testing as defined in the procurement specification.

ECSS-Q-ST-70-15_1470202

c. Raw materials for all safe life, fail safe and low-risk fracture items shall be NDT tested to ensure conformance with the general material quality specification and absence of unacceptable embedded discontinuities.

NOTE These tests are performed in a manner that does not affect the future usefulness of the object or material.

ECSS-Q-ST-70-15_1470203

d. For safe life items requiring Special fracture control NDT, the raw material testing shall be performed in conformance with Class of ASTM E 2375:2016 Or SAE AMS-STD-2154D:2020.

NOTE Alternative equivalent testing methods are subject to customer review.

ECSS-Q-ST-70-15_1470204

e. In the case of thin material, ultrasonic testing may be performed in the intermediate conditions of the rolling process because of limitations of standard ultrasonic testing to reduce dead zones in case of limiting thickness or omitted.

NOTE This is a compromise of the physical limitations of the method.

8.3.3 Common wrought discontinuities

ECSS-Q-ST-70-15_1470205

a. The following discontinuities depending on their size shall be the cause for rejection of wrought products:

1. Inclusions
2. Delamination
3. Doublings
4. Folds
5. Cracks
6. Laps

8.4 Forgings

8.4.1 Overview

Forgings are classified as the following:

a. Die forgings

b. Drop forgings

c. Hand forgings

d. Rolled rings

e. Upset forgings

Forgings in general are non-standard products which are qualified individually.

8.4.2 Raw material testing

ECSS-Q-ST-70-15_1470206

a. Forgings and rolled rings shall be subjected to:

1. Caustic etch followed by visual examination of the product surfaces for indications,
2. Ultrasonic testing in accordance with ASTM B 594:2019,
3. In special cases, to fluorescent penetrant testing in accordance with ASTM E 1417:2016 or magnetic particle according EN ISO 9934-Part 3:2015 and ASTM E 1444/E 1444M:2016.

8.4.3 Common forging discontinuities

ECSS-Q-ST-70-15_1470207

a. The following discontinuities shall be the cause for rejection of forging:

1. Bursts, caused by insufficient soaking time at high temperatures prior to forging
2. Clinks, internal stress cracks
3. Flakes, hydrogen cracks or hairline cracks
4. Thermal stress cracks
5. Grain structure variation (including segregation)
6. Laps

ECSS-Q-ST-70-15_1470208

b. Acceptance criteria with regards to common forging discontinuities shall be agreed between customer and supplier.

NOTE Alternative equivalent testing methods are subject to customer review.

8.5 Castings

8.5.1 Overview

Casting is a manufacturing process used to form solid metal shapes out of molten metal. The molten metal is poured into a cavity or a mould. The solidified part is also known as a casting, which is ejected or broken out of the mould to complete the process.

8.5.2 Raw material testing

8.5.2.1 General

ECSS-Q-ST-70-15_1470209

a. Ferrous and non-ferrous castings shall be subject of NDT as part of the final production testing to detect internal or surface discontinuities, induced by the process that can subsequently alter its behaviour or its mechanical properties.

8.5.2.2 Penetrant testing of castings

ECSS-Q-ST-70-15_1470210

a. PT shall be carried out for the detection of discontinuities that are open or connected to the surface of the device under examination.

NOTE This NDT is especially dedicated to detect discontinuities like cracks, slag inclusions, cold shuts, open gas porosity, or shrink holes.

ECSS-Q-ST-70-15_1470211

b. Testing specified in the requirement 8.5.2.2a shall be performed according to ASTM E 1417:2016 or to the three ISOs: EN ISO 3452-1:2013, EN ISO 3452-2:2013, EN ISO 3452-3:2013.

8.5.2.3 Ultrasonic testing of castings

ECSS-Q-ST-70-15_1470212

a. Castings shall be subjected to ultrasonic testing in accordance with ASTM B 594:2019 or EN ISO 16810:2014.

8.5.2.4 X-ray radiographic testing of castings

ECSS-Q-ST-70-15_1470213

a. The radioscopic testing shall be used for detecting volumetric discontinuities and density variations that are resulting of the presence of gas porosity, inclusions, misrun, or shrink hole.

ECSS-Q-ST-70-15_1470214

b. Examination specified in the requirement 8.5.2.4a shall be performed according ASTM E1742/E1742M:2018 and ASTM E1734:2016.

8.5.2.5 X-Ray computed tomographic (CT) of castings

ECSS-Q-ST-70-15_1470215

a. CT for NDT of castings shall be carried out for locating and characterizing discontinuities.

NOTE Example of such discontinuities are gas porosity, inclusions, misrun and shrink hole.

ECSS-Q-ST-70-15_1470216

b. Examination specified in requirement 8.5.2.5a shall be performed in accordance with ASTM E 1814:2014, or EN ISO 15708-2:2019 and EN ISO 15708-4:2019.

8.5.2.6 Common casting discontinuities

ECSS-Q-ST-70-15_1470217

a. The following discontinuities shall be the cause for rejection of castings as follows:

1. Slag
2. Slag Inclusions
3. Slurry
4. Shrink hole
5. Gas porosity
6. Hot tears
7. Pouring metal discontinuities
8. Sink

ECSS-Q-ST-70-15_1470218

b. Acceptance criteria with regards to common casting discontinuities shall be agreed between customer and supplier.

NOTE Alternative equivalent testing methods are subject to customer review.

8.6 Laminated composite materials

8.6.1 Overview

Composite materials are comprised of two or more constituent materials that are chemically combined into a single material that exhibits characteristics and properties that are different from the individual components.

For space structures and applications, the most common form of composite material is that of an organic polymer matrix reinforced with short or continuous fibres and can feature another form of nano or micro-additive particles that enhance material characteristics such as toughness or conductivity.

Other types of composite are also used, such as ceramic matrix or metal matrix composites, which are expensive to produce and are usually used for very specific applications. Laminated composite materials are the main focus for this revision of the standard. Other types of composite are planned to be covered in future updates of the standard.

Further references can be found in PRC-6501, Ultrasonic Inspection of Composites, Rev. G, 01/01/2020 and NASA/TM-2020-220568 'Nondestructive Evaluation (NDE) Methods and Capabilities Handbook'.

8.6.2 Raw material testing

8.6.2.1 Overview

In practice, NDT of composite is only relevant for the final cured laminate or product, as that is the form which is used for the final application and have to satisfy strict fracture control requirements for loading and quality.

The raw materials of matrix (typically considered here as organic resin) and fibre reinforcement require some destructive material testing to assess the quality and properties. There is an intermediate phase of the raw materials for laminated composites which is the pre-impregnated sheet form (or ‘pre-preg’ form). Pre-preg is available in rolls of pre-impregnated lengths of fibre-reinforcement, which is cured to a beta stage, so that just enough polymer cross-linking occurs to retain the tackiness and shape of the pre-preg sheet, which enables the sheet to be stored, handled and manufactured into a part much more easily than for the constituent raw resin and fibre. It is important to store the pre-preg rolls at very specific refrigerated conditions and have a maximum stated period that the roll can be outside of refrigeration. These conditions are specified in the MSDS or material safety data sheet and the material can be considered ‘expired’ and unsuitable for use if the requirements for storage or out-time are exceeded.

The NDT of such a pre-preg is necessary at incoming inspection of the material after purchase and before each manufacturing activity involving the pre-preg. Visual testing, as specified in clause 6.1, is required, with intent to look for discontinuities such as:

a. Localized fibre deformation or breakage, cuts in the fibres

1. Dry areas of fibre mat without sufficient impregnation of resin
2. Cuts or discontinuities in the sheet of pre-preg

b. Areas that appear to be less tacky

1. Checking material safety data sheet for expiration date
2. Checking maximum total out-time that the pre-preg has spent outside refrigeration against time specified in material safety data sheet

8.6.2.2 Testing of intermediate products

ECSS-Q-ST-70-15_1470219

a. The NDT of a composite laminate or part that is cured and ready for further assembly or use shall be conducted using ultrasonic techniques to check for delamination cracks or voids which can reduce material performance.

8.6.3 Inspection techniques for composites

8.6.3.1 General

ECSS-Q-ST-70-15_1470220

a. Operator training shall be conducted in accordance with requirements from clause 5.1.2 of ECSS-Q-ST-20.

ECSS-Q-ST-70-15_1470221

b. Laminated composites shall be subjected to ultrasonic testing in accordance with ASTM E2533-17e1 for Aerospace Applications.

ECSS-Q-ST-70-15_1470222

c. Specific situations where manufactured parts include joining processes and joining of metallic to composite materials shall be tested in accordance with the requirements from clause 8.6.4.

8.6.3.2 X-Ray Radiographic testing of composites

ECSS-Q-ST-70-15_1470223

a. The radioscopic testing shall be used for detecting volumetric discontinuities and density variations that are resulting of the presence of gas porosity, delamination cracks or inclusions.

ECSS-Q-ST-70-15_1470224

b. Examination specified in the requirement 8.6.3.2a shall be performed according to ASTM E1742/E1742M:2018 and ASTM E1734:2016.

8.6.3.3 X-ray Computed Tomographic (CT) Inspection of Composites

ECSS-Q-ST-70-15_1470225

a. Before selecting CT scan as a valid NDT method, the part geometry shall be checked as to whether it can be accommodated into the CT scan chamber of the hardware available.

ECSS-Q-ST-70-15_1470226

b. CT for NDT of composite materials shall be carried out for locating and characterizing discontinuities.

NOTE Example of such discontinuities are gas porosity, inclusions or delamination cracks.

ECSS-Q-ST-70-15_1470227

c. Examination specified in requirement 8.6.3.3a shall be performed in accordance with ASTM E 1814:2014 or EN ISO 15708-2:2019.

8.6.3.4 Guided In-Plane Wave Inspection of Composites

ECSS-Q-ST-70-15_1470228

a. Before selecting In-plane waves as a valid NDT method, the part geometry shall be checked as to whether it is compatible with the assumptions made for successful in-plane scanning.

NOTE 1 Successful in plane scanning implies sufficient region of constant thickness.

NOTE 2 No specific standard exists for the application of guided in-plane waves to aerospace components, but a general guideline for requirements exists in ASTM E2533-17e1.

8.6.3.5 Ultrasonic C-Scan and Phased Array (PAUT) of Composites

ECSS-Q-ST-70-15_1470229

a. Ultrasound C-Scan and PAUT testing shall be conducted in accordance with ASTM E2533-17e1.

8.6.3.6 Common discontinuities of Composites

ECSS-Q-ST-70-15_1470230

a. The following discontinuities shall cause rejection of the composite parts:

1. Dents, any area indented with respect to its original contour
2. Scratches, a line of damage in the material which changes the net cross-section area of the part

3. Gouges, a damage area that changes the cross-section area with a channel-like groove
4. Debonding, a separation of materials due to failure of the adhesive or resin bond between them
5. Delamination, a separation of plies in the laminated area, caused by resin failure or impact
6. Voids, areas where resin is absent in the cured matrix including cavities and pores
7. Porosity, areas where resin is displaced in the cured matrix due to presence of gases during manufacture process
8. Volumetric discontinuities
9. Inclusions with Young’s modulus different to the surrounding material
10. Cracks, the separation of any part of the material into two or more pieces under the action of stress

ECSS-Q-ST-70-15_1470231

b. Acceptance criteria with regards to common discontinuites of composites shall be agreed between customer and supplier before any composite parts are manufactured.

NOTE This is to reduce unexpected iterations in the quality acceptance process.

8.6.4 NDT for joining dissimilar materials

8.6.4.1 Overview

When dealing with composite parts in Space applications, it is very common to find that the composite laminate is attached to other materials, typically metallic parts for high load introduction regions, using adhesive bonding and mechanical fasteners. Often for space structures, the composite exists in a sandwich configuration (laminated composite skins bonded to metallic honeycomb cores) and high load input areas are managed by addition of metallic inserts that are potted into holes in the sandwich using specific epoxy potting resins.

In some of these areas, the NDT technique can be ineffective in providing adequate resolution of output for quality control purposes. This eventuality needs to be taken into account when selecting the NDT technique for the part to be tested, especially considering the precise types of materials and geometry involved.

In the specific situations featuring complex parts mentioned in this section, when NDT methods can result in inconclusive outcomes, it is still possible to assess the quality of the manufacturing process of the part by means of combining NDT with destructive physical testing of demonstration parts.

To achieve this, several demonstration specimens of the complex features to be investigated are manufactured and NDT performed at the part level. For the destructive physical testing, the part is then cut carefully into pre-defined portions (and if practical, may be potted in transparent resin before cutting) and NDT performed on each cut portion, to provide a more detailed assessment of the discontinuities around the key features of each cut portion.

8.6.4.2 Steps for specifying NDT for difficult features

ECSS-Q-ST-70-15_1470232

a. NDT techniques used shall be calibrated for the regions of monolithic materials and for the regions where other materials are joined to the main part.

NOTE Regions where NDT can be ineffective or require special techniques include, but are not limited to:

- Metallic to Composite joints with adhesive bonding
- Metallic to Composite joints with mechanical fasteners
- Bolted joint regions
- Bonded joint regions
- Regions of strong changes in contour or geometry of the part (stiffener run-out, corner radius, steep thickness ramps)

8.6.4.3 NDT Coupled with Destructive Testing as Quality Control

ECSS-Q-ST-70-15_1470233

a. In specific cases where destructive physical inspections of complex features are approved by the customer, demonstration specimens of the complex features to be investigated shall be manufactured and NDT performed at the specimen level.

ECSS-Q-ST-70-15_1470234

b. A plan for the destructive physical testing of the specimens shall be prepared and approved by the customer before starting any activity.

ECSS-Q-ST-70-15_1470235

c. Joined interfaces shall be tested accounting for the presence of cracking or porosity, using the pre-defined success criteria.

NOTE Examples of success criteria are: minimum detectable discontinuity size and maximum acceptable discontinuity size.

ECSS-Q-ST-70-15_1470236

d. The number of demonstration samples required shall respect any requirement to account for statistical variation of material characteristics during manufacturing and agreed between customer and supplier.

ECSS-Q-ST-70-15_1470237

e. If the aim of the quality control is to demonstrate the part survives space environmental conditions, then the appropriate Environmental, Mechanical or Thermal testing shall be conducted on the demonstration samples, before performing the progressive destructive physical testing.

NOTE 1 By such a process it is possible to establish a catalogue of discontinuity type and size detected and how it correlates to any effect on material properties or part strength.

NOTE 2 This process is one way to establish manufacturing quality of complex parts, where NDT alone cannot be able to provide a conclusive pass/fail result.

9 Non-destructive testing of PFCI

9.1 General

9.1.1 Overview

The application of NDT for fracture control can be performed with different objectives.

In general, NDT with major focus on quality control of parts is performed without demonstration of a minimum required sensitivity in terms of discontinuity sizes. The feasibility and validity of the testing, in this case, is justified by the proper application of relevant NDT standards as specified in the previous clauses. The whole standard applies, with clarifications as defined in this clause.

When NDT applied for parts which are justified by damage tolerance (crack-like defects growth) approaches, it is necessary to demonstrate the minimum required NDT limits in terms of discontinuity sizes.

Two different general NDT classes are defined based on current state-of the-art of NDT and available POD studies:

- Standard fracture control NDT
- Special fracture control NDT

The Standard fracture control NDT limits according to Table 9-1 can be applied without formal POD demonstration under following conditions:

a. The method is properly applied and calibrated in accordance with the relevant standard(s) and meeting the requirements of clause 9.2.3.

b. The part of testing shows a noise comparable to the smooth samples which have been used for the determination of these POD proven NDT limits. Violation of these conditions can appear, for example, in the case of rough or irregular surface conditions or in the case of material conditions with complex microstructure (coarse and or irregular grain).

c. This applies also for welds in the case both above conditions are met (noise, surface, microstructure).

NOTE The definition of noise can differ significantly between different NDT methods. For ET and UT testing, noise can be quantified from the signal amplitude, whereas for PT testing noise is the disturbance of the visual testing caused by surface effects.

Even if formal capability demonstration is not required for Standard fracture control NDT, requirements 9.2.1a and 9.2.1b specify that customer and supplier need to agree on the limited verification applied, on the method of instrument setting and on accept or reject criteria in order to ensure that the testing procedure is adequate to reliably detect the targeted standard discontinuity size, as well as to ensure that discontinuities smaller than the targeted size are reported as "detected" in line with ECSS-E-ST-32-01 clause 10.7 (for example >50 % of the targeted crack size). This allows to consider the standard crack sizes as improbable to exist in the hardware in the case that no detected crack or crack-like discontinuity is reported.

The detection capability relies significantly on the knowledge in detecting cracks and crack-like discontinuities on NASA programs like Space Shuttle and ISS, for example reflected in NASA-STD-5009. The requirements intend to meet the requirements of NASA-STD-5009 for cracks and crack-like discontinuities and therefore the requirements for Standard fracture control NDT are rather precise. Deviations from such requirements can be agreed between customer and supplier, especially in case of less critical applications, for example unmanned applications.

Capability demonstration for the testing method and testing personnel in accordance with clause 9.1.3 is necessary in the case that Special fracture control NDT applies:

a. Either for NDT limits smaller than specified for Standard fracture control NDT in accordance with Table 9-1.

b. Procedures that do not conform to the ones that are specified in clause 9.2.3.

NOTE This applies to methods and materials other that those specified in requirements from clause 9.2.3. Example: composite materials, ceramic materials, visual testing procedures from cracks.

c. Or even in the case of Standard fracture control NDT limits if the conditions of the test objects strongly deviate from the backgrounds of these definitions which can be:

1. Complex surface conditions (welds, roughness, shot peened)

2. Complex geometry conditions (notches, transitions, wall thickness gradients).

9.1.2 General requirements

ECSS-Q-ST-70-15_1470238

a. The applied NDT procedures and the justification of their crack detection capability shall be approved by the customer.

NOTE This applies to all NDT procedures used for implementation of fracture control, including Standard fracture control NDT procedures.

ECSS-Q-ST-70-15_1470239

b. NDT procedure instrument setting on simulated or real crack-like discontinuities shall demonstrate detection of the minimum detectable crack size.

NOTE The setting also ensures that accept and reject criteria (specified in requirement 5.1c) can be implemented with sufficient reliability and with acceptable risk of false indications.

ECSS-Q-ST-70-15_1470240

c. Rolled threads of fasteners shall not be etched.

NOTE This refers to both the testing for cracks of safe life fasteners (where eddy current testing is preferred in conformance with clause 6.4), and penetrant testing of other fasteners which is sometimes performed as part of process control.

9.1.3 Capability demonstration

ECSS-Q-ST-70-15_1470241

a. NDT capability demonstration specimens shall be used for determining the detection capability for all Special fracture control NDT applications, as specified in clause 9.2.2.2 and requirement 9.2.1d.

ECSS-Q-ST-70-15_1470242

b. NDT capability demonstration specimens may be used to validate the capabilities of Standard fracture control NDT procedures.

ECSS-Q-ST-70-15_1470243

c. Capability demonstration test specimens shall be agreed between customer and supplier.

ECSS-Q-ST-70-15_1470244

d. Specimens shall be representative of the material to be tested and the critical test area for the applicable hardware, and of the discontinuity size, type, location, and orientation.

NOTE The list of parameters can vary by NDT method.

ECSS-Q-ST-70-15_1470245

e. All relevant linear and non-linear discontinuities shall be measured and reported by the supplier.

ECSS-Q-ST-70-15_1470246

f. Any unintended discontinuities identified during the capability demonstration shall be reported in the final NDT verification report.

9.1.4 Testing of raw material

ECSS-Q-ST-70-15_1470247

a. For metallic items, the raw material testing shall be performed in conformance with SAE AMS-STD-2154D:2020, Class A.

ECSS-Q-ST-70-15_1470248

b. Alternative equivalent testing methods shall be subject to customer approval.

ECSS-Q-ST-70-15_1470249

c. For safe life items requiring Special fracture control NDT, the raw material testing shall be performed in conformance with SAE AMS-STD-2154D:2020, Class AA.

ECSS-Q-ST-70-15_1470250

d. For the case specified in requirement 9.1.4c, only alternative procedures shall be agreed on case by case basis between customer and supplier.

NOTE 1 The standard testing applied at raw material suppliers is Class A. Application of Class AA can either not be available at the supplier or lead to increased raw material cost. In some cases even a Class A testing is not available at suppliers for thin sheet material.

NOTE 2 For critical human spaceflight applications Class AA can be mandatory.

9.1.5 Testing of safe life finished parts

ECSS-Q-ST-70-15_1470251

a. Metallic safe life items shall be tested in conformance with clause 9.2.

ECSS-Q-ST-70-15_1470252

b. Items to be tested using penetrant, shall have their mechanically disturbed surfaces etched prior to testing.

NOTE See also clause 6.3 for the case of standard penetrant testing.

ECSS-Q-ST-70-15_1470253

c. Where etching or testing cannot be performed on the finished part, etching and penetrant-testing may be performed at the latest practical stage of finishing.

NOTE For example, before final machining of parts with precision tolerances, or at the assembly level before holes are drilled.

ECSS-Q-ST-70-15_1470254

d. Etching may be omitted, in agreement with the customer, for materials and processes where it can be demonstrated that pre-existing discontinuities cannot be smeared by the applied process.

ECSS-Q-ST-70-15_1470255

e. Composite, bonded and sandwich safe-life items shall be tested and proof tested in conformance with clause 9.3.

9.2 Non-destructive testing of metallic materials

9.2.1 General requirements

ECSS-Q-ST-70-15_1470256

a. NDT classes shall be categorized as Standard fracture control NDT, Special fracture control NDT or Proof testing NDT.

ECSS-Q-ST-70-15_1470257

b. The responsible for planning, definition and supervision of Special fracture control NDT activities shall be qualified as Level 3 in conformance with NAS 410:2014 or EN 4179:2017.

ECSS-Q-ST-70-15_1470258

c. Personnel performing Special fracture control NDT activities shall be qualified and certified for each Special fracture control NDT method in accordance with NAS 410:2014 Level 2 and EN 4179:2017.

ECSS-Q-ST-70-15_1470259

d. The demonstration of 90 % probability of detection at a 95 % confidence level of the written procedure and that of the inspector performing the Special fracture control NDT shall be performed on NDT capability demonstration specimens, except for cases specified in requirements 9.2.2.2f and 9.2.2.2g.

ECSS-Q-ST-70-15_1470260

e. In case there is a failure to demonstrate capability specified in the requirement 9.2.1d, then improved inspector skills shall be demonstrated prior to a retest.

ECSS-Q-ST-70-15_1470261

f. All the following conditions shall be met for personnel qualification, except for cases specified in requirements 9.2.2.2f and 9.2.2.2g:

1. Qualification for Special fracture control NDT are specific to the procedure and the inspector.
2. Special fracture control NDT testing are not transferable to another procedure or inspector.
3. The period of Special fracture control NDT certification is 3 years, with skills demonstrated during the certification period.

9.2.2 NDT categories versus initial crack size

9.2.2.1 Standard fracture control NDT

ECSS-Q-ST-70-15_1470262

a. The initial crack sizes and geometries as specified in Table 9-1 shall apply for Standard fracture control NDT of metallic materials.

NOTE Initial crack geometries are shown in Figure 9-1, Figure 9-2 and Figure 9-3.

ECSS-Q-ST-70-15_1470322

Table 9-1: Initial crack size summary, Standard fracture control NDT

NDT method	Crack location	Part thickness *t* [mm]	Crack configuration number (see NOTE 1)	Crack type	Crack depth *a* [mm]	Crack length *c* [mm]
Eddy current NDT	Open surface	$t \leq 1,27$ $t > 1,27$	4 1, 3, 8	Through surface	*T* 0,51 1,27	1,27 2,54 1,27
	Edge or hole	$t \leq 1,91$ $t > 1,91$	5, 9 2, 7	Through corner	*t* 1,91	2,54 1,91
	Cylinder	N/A	10	Surface	see Note 2	1,27
Penetrant NDT Sensitivity Level ≥3	Open surface	$t \leq 1,27$ $1,27 \leq t \leq 1,91$ $t > 1,91$	4 4 1, 3, 8	Through surface	*t* *t* 0,81 1,91	2,54 3,82 - *t* 4,05 1,91
	Edge or hole	$t \leq 2,54$ $t > 2,54$	5, 9 2, 7	Through corner	*t* 2,54	3,81 3,81
	Cylinder	N/A	10	Surface	see Note 2	1,91
Penetrant NDT of welds with Sensitivity Level 3 or better. Sensitivity Level 2 for all other materials in unmanned applications	Open surface	$t \leq 3,0$ $t > 3,0$	4 1, 3, 8	Through surface	*t* 3,00 1,50	3,00 3,00 7,50
	Edge or hole	$t \leq 3,0$ $t >3,0$	5, 9 2, 7	Through surface	*t* 3,00	3,81 3,81
	Cylinder	N/A	10	Surface	see Note 2	3,00

NDT method	Crack location	Part thickness *t* [mm]	Crack configuration number (see NOTE 1)	Crack type	Crack depth *a* [mm]	Crack length *c* [mm]
Magnetic Particle NDT	Open surface	$t \leq 1,91$ $t > 1,91$	4 1, 3, 8	Through surface	t 0,97 1,91	3,18 4,78 3,18
	Edge or hole	$t \leq 1,91$ $t > 1,91$	5, 9 2, 7	Through corner	t 1,91	6,35 6,35
	Cylinder	N/A	10	Surface	see Note 2	3,18
X-ray radiographic NDT	Open surface	$0,63 \leq t \leq 2,72$ $t > 2,72$	1, 2, 3, 7, 8	Surface	$0,7 \times t$ $0,7 \times t$	1,91 $0,7 \times t$
	Internal	$t > 2,72$	6	Embedded	$0,35 \times t$	$0,7 \times t$
Ultrasonic NDT	Open surface	$t \geq 2,54$	1, 2, 3, 7, 8	Surface	0,76 1,65	3,81 1,65
	Internal	$t \geq 2,54$	6	Embedded	0,43 0,99	2,21 0,99

NOTE 1 The crack configuration numbers refer to the crack configurations shown in Figure 9-1, Figure 9-2 and Figure 9-3.

NOTE 2 For cylindrically shaped items (see Figure 9-3) the crack depth a can be derived from the crack length c of this table for a/c = 1,0 with the following formula:

$$a = r(1 + \tan\frac{c}{r} - \sec\frac{c}{r})$$

Exception: Fastener thread and fillets, to which the crack size for a/c=1,0 applies.

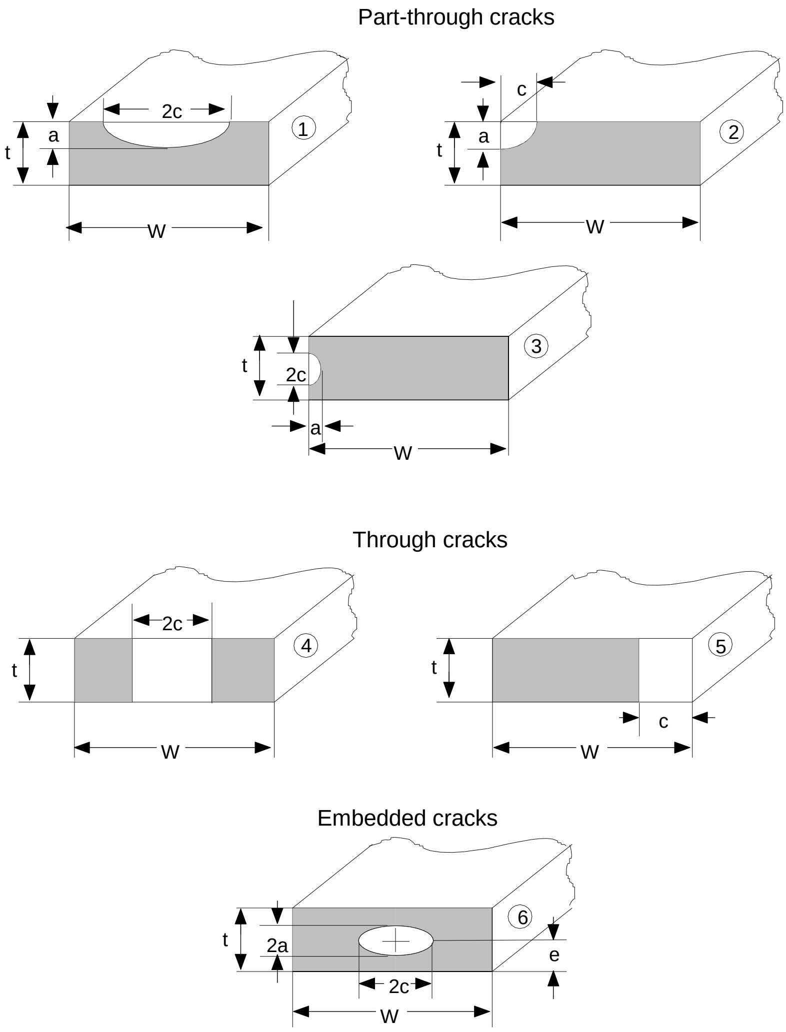


Figure 9-1: Initial crack geometries for parts without holes

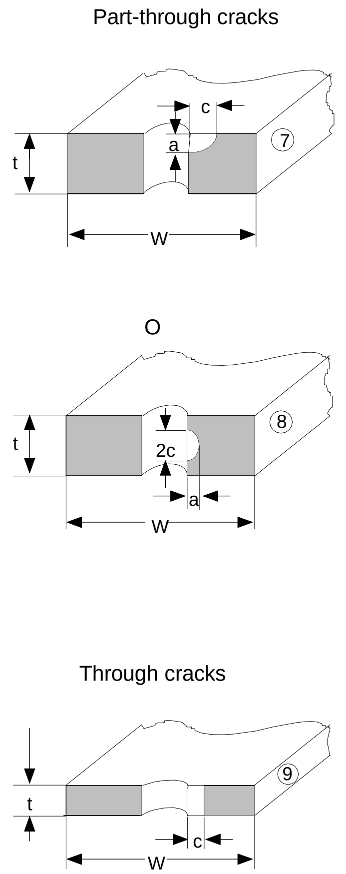


Figure 9-2: Initial crack geometries for parts with holes

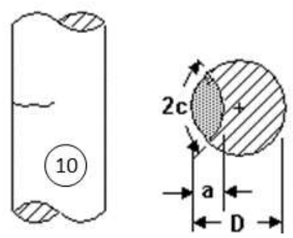


Figure 9-3: Initial crack geometries for cylindrical parts

ECSS-Q-ST-70-15_1470263

b. For Standard fracture control NDT one or more of the following standard industrial NDT techniques for metallic materials shall be used in accordance with the requirements of clause 9.2.3:

1. Fluorescent penetrant testing
2. X-ray radiographic testing
3. Ultrasonic testing
4. Eddy current testing

5. Magnetic particle testing.

ECSS-Q-ST-70-15_1470264

c. Implementation of Standard fracture control NDT on metallic parts based on the crack sizes specified in Table 9-1 may be performed without a formal demonstration of the crack detection capability specified in requirements of clause 9.2.2.2 and requirement 9.1.3a.

NOTE The crack size data in Table 9-1 are based principally on NDT capability studies that were conducted on flat, fatigue cracked panels. When the component’s geometrical features, such as sharp radii, fillets, recesses, surface finish and cleanliness, material selection, reduced accessibility and other conditions can influence the detection capability of the applied Standard fracture control NDT method, the method is evaluated based on similarity with proven applications or demonstration testing on a small number of samples representative of the minimum detectable crack size. This is done to ensure that the detection capability of the applied Standard fracture control NDT testing is not influenced.

ECSS-Q-ST-70-15_1470265

d. Standard fracture control NDT shall provide crack detection to at least 90 % probability and 95 % confidence level.

NOTE 1 For various NDT techniques and part geometries Table 9-1 gives the largest crack sizes that can remain undetected at these probability and confidence levels.

NOTE 2 Dedicated capability demonstration is not needed for the method specified in clause 9.2.3 if not required by 9.2.2.1c.

ECSS-Q-ST-70-15_1470266

e. For X-ray radiographic testing the standard discontinuity sizes shall not apply to very tight discontinuities.

NOTE For example, tight discontinuities are: forging imperfections, discontinuities induced by heat treatment, cracks induced by welding , fatigue cracks, discontinuities in compressive stress field especially when performed before proof testing.

ECSS-Q-ST-70-15_1470267

f. For tight discontinuities as specified in 9.2.2.1e, Special fracture control NDT requirements shall apply as specified in the requirement 9.2.2.2.

ECSS-Q-ST-70-15_1470268

g. All deviations from Standard fracture control NDT requirements shall be approved by the customer.

9.2.2.2 Special fracture control NDT

ECSS-Q-ST-70-15_1470269

a. A statistical demonstration of 90 % probability of detection with 95 % confidence shall be performed for the Special fracture control NDT method.

NOTE The demonstration is specific to the relevant procedure, the test object and individual inspector.

ECSS-Q-ST-70-15_1470270

b. The demonstration specified in requirement 9.2.2.2a shall be carried out on specimens representative of the actual configuration to be tested.

ECSS-Q-ST-70-15_1470271

c. The detection capability of the Special fracture control NDT method shall be demonstrated by testing with specimens containing artificial or simulated discontinuities.

ECSS-Q-ST-70-15_1470272

d. The NDT capability demonstration tests shall be approved by the customer.

NOTE Examples of applied methods are Point-Estimate Method, the Probability-of-Detection Method

ECSS-Q-ST-70-15_1470273

e. Special fracture control NDT capability demonstration plan shall be approved by the customer.

NOTE The preparation and control of demonstration specimens and how to administer demonstration tests normally meets the intent of MIL-HDBK-1823:1999.

ECSS-Q-ST-70-15_1470274

f. When approved by the customer, for NDT processes which are fully automated, the statistical demonstration specified in requirement 9.2.2.2a may be replaced by verification by test of process parameters and their tolerances which can affect the sensitivity.

NOTE 1 For example, automated eddy current scanning.

NOTE 2 Further guidance on alternative approaches to the full statistical demonstration on a large number of specimens can be found in for example JSC-67203.

ECSS-Q-ST-70-15_1470275

g. In the verification by test specified in requirement 9.2.2.2f, a minimum of five samples shall be used, which cover the full range of parameters of the crack-like defects to be detected by the automated process, in combination with the structural details to be tested.

NOTE Depending on, for example, the complexity of the object to be tested, variability in response to structural variations and calibration strategy and the criticality of the discontinuity to be found, the number of samples to be used can be significantly higher than 5. Example: human space flight.

ECSS-Q-ST-70-15_1470276

h. Special fracture control NDT testing procedures shall be approved by the customer.

ECSS-Q-ST-70-15_1470277

i. Special fracture control NDT demonstration specimen selection shall be justified and approved based on the similarity between the components to be tested and the demonstration specimen.

NOTE For penetrant testing Special fracture control NDT capability can be demonstrated with fatigue-cracked specimens, whereas spark eroded notches can be applicable for UT, ET and MT.

ECSS-Q-ST-70-15_1470278

j. The justification specified in requirement 9.2.2.2i shall be documented in the NDT summary report.

ECSS-Q-ST-70-15_1470279

k. Subject to customer approval, in special cases, discontinuities or crack types other than fatigue cracks that are more representative of the application may be used for the demonstration.

NOTE The most accepted method of demonstrating Special fracture control NDT capability is with fatigue-cracked specimens.

ECSS-Q-ST-70-15_1470280

l. The underlying assumptions of the point-estimate method shall be demonstrated or verified by documented evidence before the point-estimate method can be implemented.

NOTE The point-estimate method approach assumes that the capability of detection increases with the size of discontinuities in the neighbourhood of the size of the reference discontinuity. Since only a small number of discontinuities are required by this method, the minimum detectable discontinuity size is not always a determinant.

9.2.2.3 Crack screening proof test

ECSS-Q-ST-70-15_1470281

a. Crack screening proof testing shall be performed in accordance with requirements from clause 10.4.2.3 of ECSS-E-ST-32-01.

9.2.3 Inspection procedure requirements for Standard fracture control NDT

9.2.3.1 Overview

Standard fracture control testing methods, for which the initial crack sizes of Table 9-1 apply, are to a large extent based on the knowledge obtained in the frame of fracture control implementation for manned spaceflight. Tailoring can be acceptable for unmanned applications.

9.2.3.2 Requirements

ECSS-Q-ST-70-15_1470282

a. Standard penetrant fracture control NDT shall be performed in accordance with requirements from clause 6.3.8.

ECSS-Q-ST-70-15_1470283

b. Standard eddy current fracture control NDT shall be performed in accordance with requirements from clause 6.4.8.

ECSS-Q-ST-70-15_1470284

c. Standard magnetic particle fracture control NDT shall be performed in accordance with requirements from clause 6.5.8.

ECSS-Q-ST-70-15_1470285

d. Standard X-ray radiographic fracture control NDT shall be performed in accordance with requirements from clause 6.6.7.

ECSS-Q-ST-70-15_1470286

e. Standard ultrasonic fracture control NDT shall be performed in accordance with requirements from clause 6.7.7.

9.3 NDT for composites, bonded and sandwich parts

9.3.1 Overview

NDT testing of composites is very complex and is rarely standardized. Therefore it is always classified as Special fracture control NDT if applied to fracture critical items.

9.3.2 Testing requirements

9.3.2.1 General requirements

ECSS-Q-ST-70-15_1470287

a. The NDT methodology and rationale shall be provided in the fracture control plan, in conformance with DRD from Annex F of ECSS-E-ST-32, and approved by the customer in compliance with requirement 5.2.b of ECSS-E-ST-32-01.

ECSS-Q-ST-70-15_1470288

b. Analogy to knowledge of testing of metallic material may be used.

ECSS-Q-ST-70-15_1470289

c. The hardware used and the minimum detectable limits of the hardware shall be specified in NDT process qualification documents, either within existing documents or as a stand-alone NDT process document, as specified in clause 6.7.5.

9.3.2.2 Close visual testing

ECSS-Q-ST-70-15_1470290

a. The maximum distance to perform the visual testing shall be 0,3 m.

ECSS-Q-ST-70-15_1470291

b. A testing procedure shall be written, which specifies:

1. Access requirements
2. Distance between eyes and tested area
3. Optimum lighting
4. Cleaning

5. The location of the successive tested area
6. The minimum testing time needed to inspect each area.

NOTE A formal statistical capability demonstration of the detectability of the VDT by means of close visual testing is not needed, but the procedure is agreed between customer and supplier.

ECSS-Q-ST-70-15_1470292

c. When an indication is found, optical magnification, lenses, and other NDT methods shall be applied to classify as detected discontinuity in conformance with requirements from clause 10.7 of ECSS-E-ST-32-01.

9.3.2.3 NDT methods other than close visual testing

ECSS-Q-ST-70-15_1470293

a. The capability of an NDT method to reliably detect the specified discontinuity size shall be demonstrated on test specimens with induced artificial discontinuities.

ECSS-Q-ST-70-15_1470294

b. Specimens with induced discontinuities shall be used when performing non-destructive testing as standard for calibration.

ECSS-Q-ST-70-15_1470295

c. The capability of the testing method shall be investigated on at least five specimens in order to analyse all parameters of discontinuities.

NOTE 1 Parameters of a discontinuity to be investigated include defect type, position, size, shape and orientation.

NOTE 2 Depending on, for example, the complexity of the part to be tested and the criticality of the discontinuities to be found, the number of samples to be used can be significantly higher than five. Example: human space flight.

ECSS-Q-ST-70-15_1470296

d. The minimum detectable discontinuity sizes for each type of discontinuity and for each NDT method shall be recorded in the NDT process qualification documents specified in clause 9.3.2.1.

ECSS-Q-ST-70-15_1470297

e. The minimum acceptable discontinuity sizes for each type of discontinuity shall be provided by the structure responsible team, as a target success criteria for the NDT testing team.

NOTE 1 The minimum acceptable discontinuity size is a different parameter to the minimum detectable discontinuity size for that type of discontinuity.

NOTE 2 The detectable discontinuity size is determined by the capability of the hardware, the technique used and the operator skill.

NOTE 3 However, the acceptable discontinuity size is determined by the structures team in charge of the final design of the part, as this is the largest size of discontinuity that can be present in the part before key material properties are degraded in a way that lowers reserve factors to unacceptable levels. Key parameters vary depending on the material used and mission requirements, so the key parameters are defined by the structures team based on available test data, previous heritage of effect of discontinuities and mission requirements.

ECSS-Q-ST-70-15_1470298

f. Detection targets shall be agreed with the testing teams before conducting any inspections.

NOTE Discontinuity parameters include discontinuity type, position, size, shape and orientation.

ECSS-Q-ST-70-15_1470299

g. Depending on, the complexity of the item under testing and the criticality of the discontinuities, the number of samples needed shall be higher than five.

NOTE Example human space flight.

Annex A (normative) NDT plan - DRD

A.1 DRD identification

A.1.1 Requirement identification and source document

This DRD is called from ECSS-Q-ST-70-15, requirement 5.1f.

A.1.2 Purpose and objective

The purpose of the NDT plan is to have a detailed plan of the NDT method chosen for a part to be tested.

In the case the customer identifies opportunities to tailor the NDT plan, Annex A.2.2 describes the potential tailoring and reduction of the documentation effort.

A.2 Expected response

A.2.1 Scope and content

ECSS-Q-ST-70-15_1470300

a. An NDT plan shall be developed which addresses the following as a minimum:

1. Applicable specifications and standards;
2. Calibration artefact traceability;
3. Inspector training, qualification, and certification;
4. NDT responsibility;
5. Method selection, qualification, application, and process control;
6. Description of procedure to demonstrate robust process parameters, working operation field;
7. Acceptance criteria including minimum detectable discontinuity size;

8. Application of requirements during manufacturing, maintenance, and operation including maximum acceptable discontinuity size;
9. NDT applied to safe life PFCI;
10. NDT applied to structural parts;
11. Standard fracture control NDT selection, application, and control;
12. Special fracture control NDT selection, application, and configuration control.

A.2.2 Special remarks

A.2.2.1. Overview

The main objective of the NDT plan is to establish how the contents of the standard can be met. In some cases, where the customer determines that a supplier has sufficient heritage and experience in control of NDT processes, it is possible to tailor the content of the required NDT plan.

Tailoring includes reducing the effort required to generate new documentation, such as using other types of existing documentation to ensure the traceability of the training of the supplier and work to be done. Examples of other documents that can be used include: Minutes of Meeting, written practices, internal instructions or documentation from inspections done on similar products and programmes and test and documentation requirements in Product Assurance documents.

A.2.2.2. Requirements

ECSS-Q-ST-70-15_1470301

a. The tailoring of NDT plan shall contain the minimum requirements specified in A.2.1.

ECSS-Q-ST-70-15_1470302

b. Tailored NDT plan specified in A.2.2.2a may be requested by the customer.

Annex B (normative) NDT report - DRD

B.1 DRD identification

B.1.1 Requirement identification and source document

This DRD is called from ECSS-Q-ST-70-15, requirements 6.1.5a, 6.2.3.2a., 6.3.5a, 6.4.6a, 6.5.5a, 6.6.5a and 6.7.4.5a.

B.1.2 Purpose and objective

The purpose of the NDT report is to record all necessary details that are needed for traceability of testing conditions and results.

The layout for NDT report can be prepared as per the example shown in EN ISO 3452-1:2013 Annex C.

B.2 Expected response

B.2.1 Scope and content

<1> General

ECSS-Q-ST-70-15_1470303

a. The NDT report shall be developed and include, but not limited to, the following:

1. Reference to a test procedure or a plan
2. Environment
    - (a) Date and place of testing
    - (b) Facility
    - (c) Temperature
    - (d) Humidity
    - (e) Illumination
3. Description of the object

(a) Part ID number

(b) Object classification

(c) Dimensions

(d) Material

(e) Quantity

(f) Batch number

(g) Surface condition

(h) Manufacturing stage process details

4. Designation of test object

(a) Conditions of testing

(b) Inspection of equipment used

5. Manufacturer and model number of all instruments to be used for NDT testing

6. Calibration status

7. Consumables

8. Critical zones testing

9. Classification and justification of Standard fracture control NDT or Special fracture control NDT inspections.

10. Registration level

11. Acceptance criteria

(a) Indications above registration level

(b) Indications above acceptance level

12. Appraisal of indications against acceptance criteria

13. Any detected cracks or crack-like discontinuities regardless of their size or disposition

14. Non-acceptance of testing object

(a) discontinuities descriptions

(b) locations

(c) sizes

(d) non-conformances and problems encountered

(e) any detected cracks or crack-like discontinuities regardless of their size or disposition

15. Personnel of inspectors and approvals

(a) name and qualifications level of inspector

(b) signature

16. Evaluation of special conditions that affect Standard fracture control NDT

17. Applied software and its version
18. Data storage
19. Anomalies

ECSS-Q-ST-70-15_1470304

b. Responsible Level 3 shall approve the following:

1. Relevant NDT procedure,
2. Release of a part with indication.

ECSS-Q-ST-70-15_1470305

c. Presence of peculiarities identified by inspectors shall be recorded in non-conformance reports if confirmed to be nonconforming by Level 3.

<2> Additional requirements for different testing types

<2.1> Visual test

ECSS-Q-ST-70-15_1470306

a. The visual test report shall contain information in accordance with documentation requirements from EN ISO 17637:2016 and EN ISO 17635:2016.

<2.2> Leak test

ECSS-Q-ST-70-15_1470307

a. The leak test report shall include:

1. Leak testing method,
2. Leak testing devices,
3. Leak test medium and gas concentration,
4. Test pressure and test time,
5. Leak detection threshold,
6. Ambient gas concentration,
7. Determined leak rate,
8. Sketch of the test set-up and leakage plan,
9. Evaluation.

<2.3> Dye penetrant test

ECSS-Q-ST-70-15_1470308

a. The dye penetrant test report shall contain information in accordance with documentation requirements from all of the ISOs, (EN ISO 3452-1:2013, EN ISO 3452-2:2013, EN ISO 3452-3:2013) or ASTM E 1417:2016.

<2.4> Eddy current test

ECSS-Q-ST-70-15_1470309

a. The eddy current test report shall contain details of the test carried out and include the following information:

1. Technique identification,
2. Results of test, including sketches, instrument settings,
3. Test set used.

<2.5> Magnetic particle test

ECSS-Q-ST-70-15_1470310

a. The magnetic particle test report shall contain information in accordance with documentation requirements from ASTM E 1444/E 1444M:2016 and EN ISO 9934-1:2016.

<2.6> X-ray radiographic test

ECSS-Q-ST-70-15_1470311

a. The X-ray radiographic test report shall contain information in accordance with documentation requirements from ASTM E 1742/E1742M:2018 or EN ISO 17636:2013-1 and EN ISO 17636-2:2013.

<2.7> Ultrasonic test

ECSS-Q-ST-70-15_1470312

a. The ultrasonic testing report shall include the following:

1. Inspection method:
   (a) frequency
   (b) sensitivity level
2. Inspection equipment:
   (a) device
   (b) probes
   (c) software
3. Sensitivity calibration (reference)
4. Discontinuity characteristics:
   (a) discontinuity amplitude, size
   (b) location (position, depth)
   (c) type
   (d) geometry
   (e) peculiarities

5. Sketch for non-standard discontinuities and peculiarities
6. Scanning speed and index in case of automatic testing

B.2.2 Special remarks

ECSS-Q-ST-70-15_1470313

a. In the case of application of proprietary processes and methods restriction of documentation shall be clarified between supplier and customer prior to program.

ECSS-Q-ST-70-15_1470314

b. The documents supporting the NDT Report shall be kept as agreed between customer and supplier.

ECSS-Q-ST-70-15_1470315

c. In the case of NDT qualification test reports the following additional information shall be provided:
   1. Certification of inspectors
   2. Demonstration of required POD

ECSS-Q-ST-70-15_1470316

d. In case there is no discontinuity to report, a chart with the stamp of NDT personnel may be accepted instead of a NDT report, provided the traceability to the part and process is given.

ECSS-Q-ST-70-15_1470317

e. A simplified reporting procedure may be agreed between customer and supplier if the following conditions are met:
   1. There is a traceability of the inspector Level 3 qualification.
   2. There is traceability to the data from NDT report.

      NOTE Example of simplified reporting procedure is certificate with a digital stamp.

Annex C (normative) NDT procedure - DRD

C.1 DRD identification

C.1.1 Requirement identification and source document

This DRD is called from ECSS-Q-ST-70-15, requirements 5.1a, 5.1d, 5.4a and 6.7.4.3a.

C.1.2 Purpose and objective

The purpose of the NDT procedure is to ensure the proper application of all testing are detailed with relevance to inspectors as specified in the NDT plan and qualified in subsequent test programs.

C.2 Expected response

C.2.1 Scope and content

ECSS-Q-ST-70-15_1470318

a. The NDT Procedure shall include, date, issue and revision number.

ECSS-Q-ST-70-15_1470319

b. The NDT Procedure shall include the following information:

1. Normative references
2. Definitions
3. NDT methods and techniques, describing the limitations within the methods
4. NDT Level and certification of personnel
5. Equipment and accessories, calibration of equipment
6. Detailed description of parameters
7. Process control and acceptance criteria
8. Inspection report

C.2.2 Special remarks

ECSS-Q-ST-70-15_1470320

a. Any change of NDT procedure shall be submitted to the customer for approval.

NOTE The NDT procedure in most cases is supplier proprietary and is not released to the customer.

Annex D (normative) Eddy-current testing instruction - DRD

D.1 DRD identification

D.1.1 Requirement identification and source document

This DRD is called from ECSS-Q-ST-70-15, requirement 6.4.5a.

D.1.2 Purpose and objective

The purpose of the eddy-current testing instruction is to define necessary steps to perform eddy-current testing.

D.2 Expected response

D.2.1 Scope and content

ECSS-Q-ST-70-15_1470321

a. A written instruction on how to perform the eddy-current testing shall be prepared by supplier and include the following information:

1. Reason for examination;
2. Part number and description of part to be examined;
3. Application documents;
4. Area to be examined;
5. Details of qualification and certification of personnel;
6. Equipment required;
7. Preparation of component;
8. Calibration procedure: to be documented in testing instruction and to be reported in case of change of status and equipment;
9. Examination procedure: sketches or photographs where appropriate to show the area of examination and scanning details;
10. Acceptance procedure;
11. Acceptance criteria;
12. Recording of results;

13. Reporting procedure;
14. The instruction.

D.2.2 Special remarks

None.

Annex E (informative) Catalogue of potential discontinuities

NDT planning and selection of appropriate methods and sensitivity always includes the assumption of existing discontinuities in the material or structure. These existing discontinuities can differ significantly within different materials as for example cast (inclusions, pores) or composite (delamination, porosity), but also for different processes such as welding-TIG, or FSW.

A catalogue of potential discontinuities can be established by the material or processes responsible person to give the basis for the NDT planning and implementation that include:

a. Designation of each discontinuity type to be used in the documentation

b. Clear and unique description of each potential discontinuity

c. Schematic figures supporting the description

d. Its expected size and orientation

e. Any potential peculiarity

In the case of new material and/or processes a preliminary catalogue can be established at the beginning of the program based on

a. Preliminary results

b. Open literature

c. Engineering judgement

d. Similar materials or processes

This catalogue can be updated based on experience gained with time to allow best possible calibration or adoption of the selected NDT method and potential reduction of testing or testing steps in the case that sufficient reliability can be demonstrated

Weld discontinuities and imperfections can be designated according to the definitions given in the following standards in order to allow unique understanding:

a. EN ISO 6520-1: 2007: Welding and allied processes - Classification of geometric imperfections in metallic materials - Part 1: Fusion welding

b. ISO 17659: 2002: Welding - Multilingual terms for welded joints with illustrations

c. CEN ISO/TS 17845: 2004: Welding and allied processes - Designation system for imperfections

Weld imperfection acceptance limits can be as specified in the following standards:

a. AIA NAS 1514-1972: Radiographic Standard for Classification of Fusion Weld Discontinuities (Rev. 2) R(2011)

b. DIN 29595:2007-04: Welding in aerospace - Fusion welded metallic components – Requirements

c. MSFC-SPEC-3679 (October 2011): MSFC Technical Standard, Process Specification, Welding Aerospace Hardware

d. EN ISO 25239-5:2011: Friction stir welding - Aluminium - Part 5: Quality and inspection requirements

e. AWS D 17.3: 2010. Specification for Friction Stir Welding of Aluminium Alloys for Aerospace Applications

f. AWS D 17.1 2001 (19 Jan) Specification for Fusion welding for aerospace applications

g. AWS C 7.4:2008 (13 March) Process Specification and Operator Qualification for Laser Beam welding

h. AMS 2680 (issue C April 2006) electron Beam welding for fatigue critical application

i. AMS 2681 (issue B 2006 April) Welding electron beam

Annex F (informative) Example for POD evaluation , software and documentation

F.1 Theory

The crack size is defined by the three dimensions length *c*, depth *a* and width *w*. The first two dimensions are important for damage tolerance assessment of spacecraft structures, whereas the width is an important parameter for penetrant testing. This is the reason why special reference samples with discontinuities of minimized width are manufactured for the POD demonstration.

By general experience, it is well known that a certain value of measurement can be achieved only with an uncertainty, which often increases with the decrease of the value until it is impossible even to detect the discontinuity. The probability of detecting and making the correct measurement is specified by the probability of detection (POD). In a conservative approach, the POD is a step function of the variable like length *c* (Figure F-1). Below a critical value c_c, the POD is zero and above the value 1,0.

In a modern approach, the function is smeared out showing also some POD below and a POD smaller than 1,0 above the value c_c with an asymptotic approach to 1,0. The function of POD can be established for a defined problem by tests. Because the tests are always performed with a limited number of tests the result contains uncertainties and for conservative estimation limit curves which grant a certain confidence can be statistically calculated. The crack length c_0 which can be detected with the pre-defined probability and confidence can be determined from this curve.

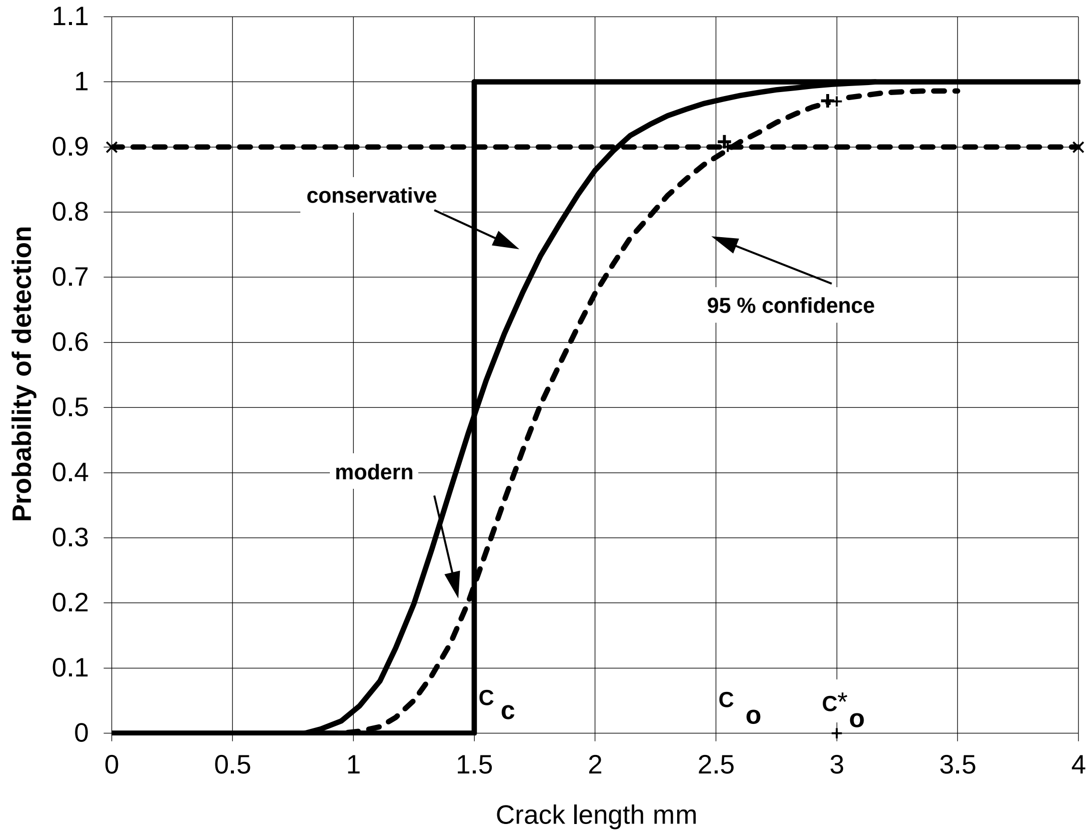


Figure F-1: Example for the probability of detection

F.2 POD demonstration

The POD demonstration can be performed in two ways [Metals Handbook Vol.17]

- method of hit and miss

  In this method only the hits are counted for each testing site.

- method of <c> data

  In this method the value <c> of the testing variable c is measured for each testing site during test. This test method is more flexible, uses less test specimens but the evaluation is much more complex and difficult.

In general, the test performance is complicated by combining several attributes like length, depth, and inspectors as well as multiple inspections with reproduced settings and different probes of the same type of the equipment. If necessary all are subjected to a factorial test plan if precise analysis is necessary to determine the different influences.

Only the hit and miss method is considered as the <c> data method is too complex.

F.2.1 Sample size for Method "Hit/Miss"

Two approaches can be chosen:

- The full POD curve can be evaluated or
- A so-called "one point procedure" delivers a tested POD valid for the maximum crack size 2c of the test samples

Full POD Curve:

For this method, most of the samples are in the supposed interval between a (P=0,10) and a (P=0,90). Cracks outside this interval do not provide much information because they belong to the almost certain miss respectively detection range. Because this interval is not certainly known and specimens are often applied for multiple use, discontinuity sizes should be uniformly distributed between the minimum and maximum of the sizes of potential interest. A minimum of 60 discontinuities should be distributed in this range. The number of unflawed testing sites should be at least twice of that of flawed sites.

One-Point Procedure:

If all cracks are detected, the number of discontinuity to be tested is at least 29 (for 90/95 see F.2.2).

F.2.2 Test evaluation for method "Hit/Miss" (90 % probability with 95 % confidence)

F.2.2.1. Full POD curve

The POD curve can be determined applying the methods in W.D. Rummel "Recommended Practice for a Demonstration of Non-Destructive Evaluation (NDE) Reliability on Aircraft Production Part" with available software. However, depending on the distribution of the discontinuity sizes, the software sometimes does not converge. In this case no results can be evaluated.

F.2.2.2. One-point procedure

The POD can be calculated from the test results by the formula of the binomial distribution:

$$POD = 1 - \frac{1}{1 + \frac{(n-f)}{(f+1)\, F_{1-\alpha}\,(2(f+1), 2(n-f))}}$$

In the chosen test procedure no failure is expected and the equation simplifies to:

$$POD = 1 - \frac{1}{1 + \frac{n}{F_{95}(2,2n)}}$$

By solving the equation for n, the lowest number of discontinuities to be tested can be estimated (F_{95} (2, 2n) depends only weakly on n):

$$n \approx F_{95}(2,2n)\frac{POD}{1 - POD} \approx 29$$

c	actual length of discontinuity
<c>	measured length of defect
C	confidence
P	probability
POD	probability of detection
$F_{1-\alpha}$ (x, y)	figure of F – distribution (from F distribution type) with degree of freedom 2(*f*+1), 2(*n*-*f*)
n	number of tests
f	number of failures
s	standard deviation
(1-α)	confidence

In order to demonstrate testing capability of 90 % probability and 95 % confidence the following results are achieved during testing:

a. 29 successes in 29 trials

b. 45 successes in 46 trials

c. 59 successes in 61 trials

For each trial a separate sample with appropriate discontinuity is required.

Example 1: POD (90/95) is demonstrated if 29 samples are successfully tested.

Example 2: If one sample of 29 is missed during testing, additional 17 samples are tested successfully to achieve the require number of 45 successes.

F.2.3 POD software and documentation

Recommendations and instructions for POD evaluation can be found in the following web sites:

http://www.statisticalengineering.com/mh1823/index.html

http://www.r-project.org/

http://www.cnde.iastate.edu/mapod

http://www.jsm.or.jp/ejam/Vol.4No.3/AA/AA45/AA45.pdf

Considerations for Statistical Analysis of Nondestructive Evaluation Data: Hit/Miss Analysis Jeremy KNOPP1,*, Ramana GRANDHI2,†, Li ZENG3, and John ALDRIN49

http://www.dtic.mil/dtic/tr/fulltext/u2/a393073.pdf

(AFRL-ML-WP-TR-2001-4010 Probability of detection (POD) analysis for the advanced retirement for cause (RFC)/engine structural integrity program (ENSIP) non-destructive evaluation (NDE) system development, volume 1 – POD analysis, Alan P. Berens

Annex G (informative) Complementary material information

G.1 Overview

This clause contains information specific to different materials which supports selection and application of testing methods.

Discontinuities that are summarized in this clause can appear mostly in non-optimized processes. For optimized and mature processes it can be possible to eliminate discontinuity types from the list of probable discontinuities to be addressed by the applied NDT when agreed between customer and supplier.

G.2 Forgings and rolled products

In the forging process, metal is shaped by pressing, pounding, or squeezing under very high pressure, to form parts called forgings. Forging processes include cold forging or heading, impression or closed die, open die, and seamless rolled ring. Forged parts usually require further processing to achieve a finished part.

The product, as received by purchaser, can be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the product.

Two types of forging product procurements typically applies:

- Standard size, form and shape procured to international aerospace quality standards
- Non-standard size, form and shape procured via dedicated procurement specification

Common discontinuities in forging are:

- Bursts – forging discontinuity which occurs due to insufficient soaking time at high temperature prior to forging.
- Clinks – internal stress cracks. Cracks (internal) – these are arrowhead in appearance shaped fractures caused by impurities in the material or an incorrect die angle. These are also known as chevron cracking or cupping.

- Excessive Flash – this is caused by using a too large blank billet size in closed die forgings.
- Flakes (hydrogen cracks or hairline cracks) – Small pockets of hydrogen gas builds up within the structure in forgings. The trapped hydrogen gas pressure causes rupturing along the grain boundaries.
- Lack of fill – caused by too small billet size in closed die forgings.
- Mechanical tool marks – surface marks caused by damaged or worn our equipment (damaged roll)
- Mismatch – this occurs in closed die forgings when two halves of the die fail to engage properly.
- Underfill – this is caused by when an undersized blank is placed in the die, resulting the forging to be incomplete.

Rolling can be performed by either on hot or cold metal. The material is passed between cast or forged steel rolls which compresses the metal before moving it forward.

Common discontinuities in rolling are:

- Banding – caused by segregation in the original cast billet, bloom or slab
- Cracks – (cold rolling) caused when the rate of deformation is too great or when attempting to reduce a section too greatly in one operation. Cracks can be either on the surface of a part or sub-surface.
- Folds – this occurs when the corner of the material folds over and rolled but it is not welded into the material.
- Inclusions – (Non Metallic) – resulting from oxides, nitrides, silicates which are commonly found in the molten metal.
- Laminations – slag, sand, oxides or porosity from the original cast billet, bloom or slab.
- Laps – found when oversize or faulty rolls and dies are used where there is an overfill on the forming process and the material folds over. The material is flattened but it is not fused together onto the surface of the material on subsequent passes.
- Rokes – a discontinuity found on the exterior of bar sections which consist of fissures which become elongated in the direction of the rolling process. Rokes originate from blow holes which are formed below the surface of the ingot that have broken during the rolling process.
- Seams – these are shallow groves or striations that are formed by elongation during rolling of oxidized surface, sub-surface blow holes or the result of splashes of molten metal. Seams can also occur during a poor rippled surface.
- Slugs – this is a piece of foreign material from a splash of molten metal within the ingot which occur during the teeming. The slug does not fuse which is removed by blasting or pickling process.

- Stringers and Reeds – found in rolled sections such as I beams, angles or channels.

G.3 Castings

Typical surface and inner discontinuities are as follows:

a. Slag

It is a film that forms on top of molten metal as a result of impurities. Slag is composed of non-metal elements.

b. Slag Inclusions

They are imperfections of the surface of metal caused by slag (impurities in the molten mix).

c. Slurry

It is a product resulting from the casting operation including : watery mixture such as the gypsum mixture for plaster moulding, moulding medium used for investment casting, core dips, and mould washes.

d. Shrink hole

It is a cavity that forms in a metal part when there was not enough source metal fed into the mould during the casting process.

e. Gas porosity

It is the formation of bubbles within the casting after it has cooled. This occurs because most liquid materials can hold a large amount of dissolved gas, but the solid form of the same material cannot, so the gas forms bubbles within the material as it cools. Gas porosity may present itself on the surface of the casting as porosity or the pore may be trapped inside the metal.

f. Hot tears

This is a very rough discontinuity usually occurs during changes in sections.

g. Pouring metal discontinuities

They include misruns, cold shuts, and inclusions. A misrun occurs when the liquid metal does not completely fill the mould cavity, leaving an unfilled portion. Cold shuts occur when two fronts of liquid metal do not fuse properly in the mould cavity, leaving a weak spot.

h. Sink

This is a dished area on the surface of a casting caused by shrinkages.

G.4 Composite products

A composite material is made from two or more constituting materials, having different physical or chemical properties. Ultrasonic testing is the most appropriate method for testing of sub-surface discontinuities.

Typical composite materials are as follows:

a. Composite building materials, such as cements, concrete

b. Reinforced plastics, such as fibre-reinforced polymer, carbon fibre reinforced plastics, resin systems, solid laminate and cored structures

c. Metal composites

d. Solid laminates

e. Sandwich structures

f. Metal matrix composites

G.4.1 Metal Matrix Composites (MMC)

MMC are highly resistant at elevated temperatures with high ductility and remain tough comparison with polymer based matrix composites.

G.4.2 Sandwich structures

A sandwich structure composite is fabricated by attaching two thin-stiffened skins to a light weight but with a thicker core.

Although the core material is low in strength but due to high thickness giving the sandwich structure a high bending stiffness with overall low density.

During the manufacturing processes, there are many discontinuities which can be introduced into the material. Commonly found discontinuities are follows:

a. Incorrect fibre volume fraction

b. Bonding discontinuities

c. Fibre and ply misalignment

d. Incomplete cured matrix caused by incorrect curing

e. Wavy fibres

f. Ply cracking

g. Delaminations

h. Fibre discontinuities

i. Ingress of moisture

j. Fracture or buckling of fibres

k. Failure of interface between the fibres and matrix.

G.4.3 Common discontinuities found in composite material

a. Common discontinuities found in composite material are as follows:

    1. Inclusions

    2. Unbonds and Disbonds

3. Delaminations
4. Voids
5. Porosity
6. Volume fraction – Dry fibres – Resin rich areas
7. Fibre breakage
8. Matrix cracking
9. Other discontinuity types

G.5 Ceramics

The term Ceramics covers a wide range of materials, such as oxides, carbides, nitrides, refractory materials, glasses, brick, concrete and clay.

Ceramics are usually very hard and brittle materials but have excellent electrical and thermal insulating properties as well as good resistance to chemical attack.

The properties of ceramics are determined by the composition and the microstructure produced as a result of its fabrication. Ceramics do not behave in the same manner as metallic materials, i.e. it is not possible to change the microstructure by working or further heat treatment. The majority of ceramics start as powders or a mixture of powders which are shaped in order to be subjected to the required temperature in consolidation.

Ceramics are grouped in the following categories:

a. Domestic ceramics: these are porcelain, earthenware, stoneware and cement.

b. Natural ceramics: stones are classed as natural ceramic material.

c. Engineering ceramics: these are oxides, nitrides, silicon carbides, borides, and silicates. These are widely used in furnace components, combustion tubes, tool tips and grinding tools.

d. Glasses: these include various types of glass and glass ceramics. Ceramics are crystalline but amorphous states are possible.

e. Electronic ceramic materials: these are ferrites, ferroelectrics and semiconductors.

For ceramics testing Dye penetrant testing is the most appropriate method of NDT with the exception of visual testing. For surface breaking discontinuities, PT is the most appropriate method of NDT.

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