ECSS-E-30 Part 8A
25 April 2000

EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

Space engineering

Mechanical — Part 8: Materials

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

Published by: ESA Publications Division
ESTEC, P.O. Box 299,
2200 AG Noordwijk,
The Netherlands

ISSN: 1028-396X

Price: € 10

Printed in The Netherlands

Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance 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 Mechanical Engineering Standard Working Group, reviewed by the ECSS Technical Panel and approved by the ECSS Steering Board.

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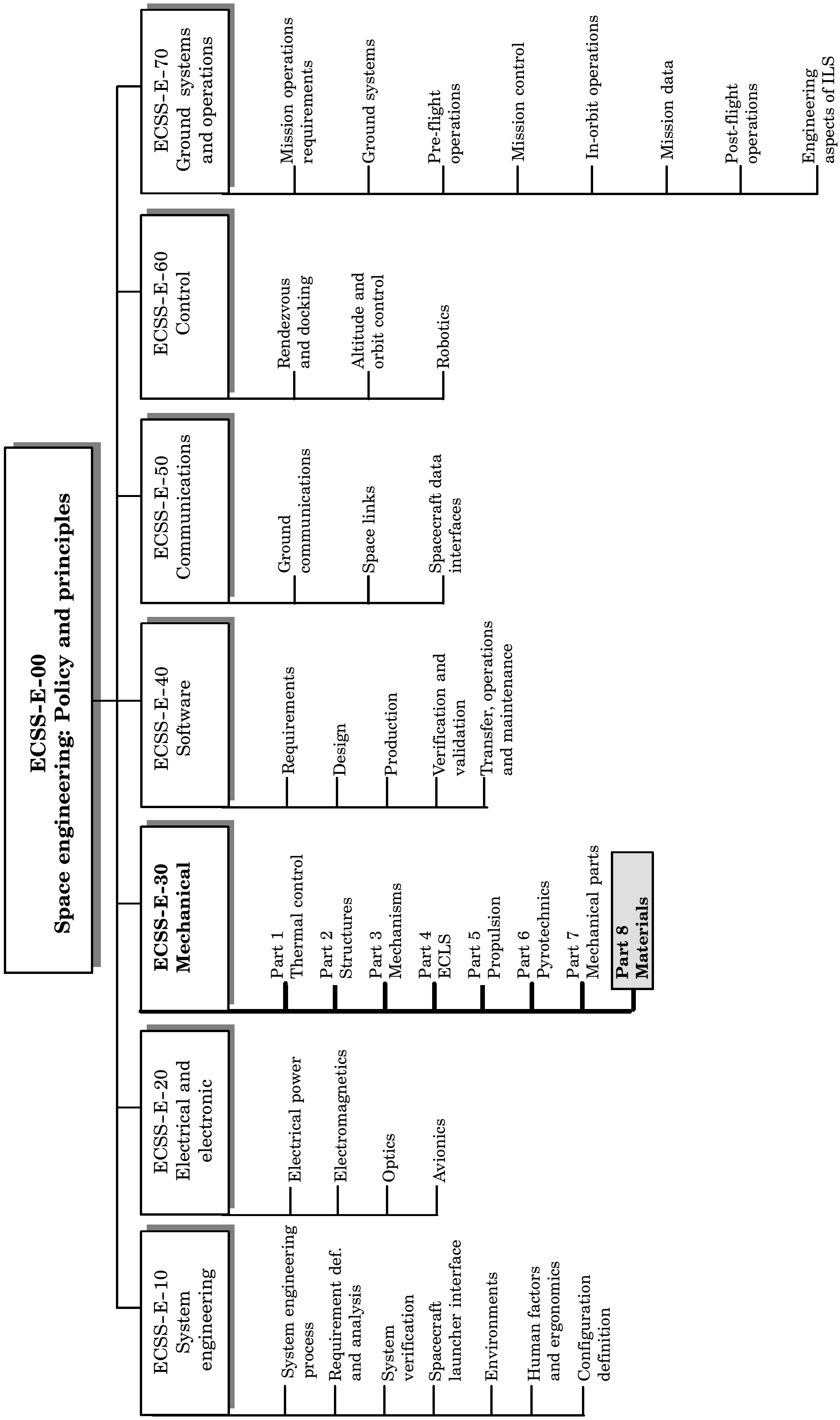

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Scope

Part 8 of ECSS-E-30 in the engineering branch of ECSS Standards defines the mechanical engineering requirements for materials.

This Standard also encompasses the effects of the natural and induced environments to which materials used for space applications can be subjected.

This Standard defines requirements for the establishment of the required mechanical and physical properties of the materials including the effects of the environmental conditions, material selection, procurement, production and verification. Verification includes destructive and non-destructive test methods. Material procurement and control is closely related to required quality assurance procedures and detailed references to ECSS-Q-70 are made.

When viewed from the perspective of a specific project context, the requirements defined in this Standard should be tailored to match the genuine requirements of a particular profile and circumstances of a project.

NOTE Tailoring is a process by which individual requirements of specifications, standards and related documents are evaluated, and made applicable to a specific project by selection, and in some exceptional cases, modification of existing or addition of new requirements.

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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 revisions 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 most recent editions of the normative documents indicated below. For undated references the latest edition of the publication referred to applies.

ECSS-P-001	Glossary of terms
ECSS-E-30 Part 2	Space engineering — Mechanical — Part 2: Structural
ECSS-Q-20	Space product assurance — Quality assurance
ECSS-Q-70	Space product assurance — Materials, mechanical parts and processes
NASA NHB 8060.1B	Flammability, odor and offgassing requirements and test procedures for materials in environments that support combustion
MIL-HDBK-5F	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-STD-410E	Nondestructive testing personnel qualification and certification
MIL-B-7883B	Brazing of Steels, Copper, Copper Alloys, Nickel Alloys, Aluminium and Aluminium Alloys

References to sources of approved lists, procedures and processes can be found in the bibliography.

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Terms, definitions and abbreviated terms

3.1 Terms and definitions

The following terms and definitions are specific to this Standard in the sense that they are complementary or additional with respect to those contained in ECSS-P-001.

3.1.1
A-basis design allowable
value which at least 99 % of the population of values is expected to fall with a confidence of 95 %

3.1.2
B-basis design allowable
value which at least 90 % of the population of values is expected to fall with a confidence of 95 %

3.1.3
composite sandwich construction
panels composed of a lightweight core material, such as honeycomb, foamed plastic, and so forth, to which two relatively thin, dense, high-strength or high stiffness faces or skins are adhered.

3.1.4
corrosion
reaction of the engineering material with its environment with a consequent deterioration in properties of the material

3.1.5
material design allowable
material property that has been determined from test data on a probability basis and has been chosen to assure a high degree of confidence in the integrity of the completed structure

3.1.6
micro-yield
applied force to produce a residual strain of $1x10^{-6}$ mm/m along the tensile or compression loading direction

3.1.7
polymer
high molecular weight organic compound, natural or synthetic, with a structure that can be represented by a repeated small unit, the mer

EXAMPLE Polyethylene, rubber, and cellulose.

3.2 Abbreviated terms

The following abbreviated terms are defined and used within this Standard.

Abbreviation	**Meaning**
ASTM	American Society for Testing Materials
CFRP	carbon fibre reinforced plastic
CMC	ceramic matrix composites
CME	coefficient of moisture expansion
CTE	coefficient of thermal expansion
DRD	document requirements definition
EB	electron beam
EN	European Standard
$\mathbf{K_{ic}}$	plane strain critical stress intensity factor
$\mathbf{K_{iscc}}$	plane strain critical stress intensity factor for a specific environment
LEO	low Earth orbit
MIG	metal inert gas
MMC	metal matrix composite
$\mathbf{MoS_2}$	molybdenum disulphide
NDE	non-destructive evaluation
NDI	non-destructive inspection
NDT	non-destructive test
PTFE	polytetrafluoroethylene
SCC	stress corrosion cracking
STS	space transportation system
TIG	tungsten inert gas
UD	uni-directional
UV	ultra violet

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Requirements

4.1 General

4.1.1 Overview

This group of requirements covers the interaction of materials engineering requirements with project management, product assurance, and related requirements.

4.1.2 Applicability

This Standard applies to all materials used in all space and space related products. For certain projects, it can be necessary to include further (normative) standards in addition to those referenced within this Standard.

4.1.3 Controlling documentation

a. All materials and processes shall be defined by standards and specifications.

b. Suppliers shall select ECSS Standards, supplemented eventually by agency or company standards.

4.2 Mission

Mission requirements are covered in this Standard.

4.3 Functionality

4.3.1 Strength

a. Spacecraft design shall ensure the survival of the structure under the worst feasible combination of mechanical and thermal loads for the complete lifetime of the spacecraft.

b. A strength analysis shall be performed and demonstrate a positive margin of safety and include, if applicable, yield load analysis, ultimate load analysis and buckling load analysis (see ECSS-E-30 Part 2).

NOTE The strength of a material is highly dependant on the direction as well as on the sign of the applied load, e.g. axial tensile, transverse compressive, and others.

4.3.2 Elastic modulus

For composites the required elastic modulus shall be verified.

NOTE The elastic modulus defined as the ratio between the uniaxial stress and the strain (e.g. Young's modulus, compressive modulus, shear modulus) is for metals and alloys weakly dependant on heat-treatment and orientation. However, for fibre reinforced materials, the elastic modulus depends on the fibre orientation.

4.3.3 Fatigue

For all components subject to alternating stresses, it shall be demonstrated that the degradation of material properties over the complete mission conforms to the specification.

NOTE Fatigue fracture can form in components which are subjected to alternating stresses. These stresses can exist far below the allowed static strength of the material.

4.3.4 Fracture toughness

a. For homogeneous materials the K_{ic} or K_{iscc} shall be measured according to approved procedures.

b. Metallic materials intended for use in corrosive surface environments shall be tested for fracture toughness under representative conditions.

NOTE The fracture toughness is a measure of the damage tolerance of a material containing initial flaws or cracks. The fracture toughness in metallic materials is described by the plain strain value of the critical stress intensity factor. The fracture toughness depends on the environment.

4.3.5 Creep

When creep is expected to occur, testing under representative service conditions shall be performed.

NOTE Creep is a time-dependant deformation of a material under an applied load. It usually occurs at elevated temperature, although some materials creep at room temperature. If permitted to continue indefinitely, creep terminates in rupture. Extrapolations from simple to complex stress-temperature-time conditions are difficult.

4.3.6 Micro-yielding

a. Where dimensional stability requirements shall be met, micro-yielding shall be assessed.

b. When micro-yielding is expected to occur, testing and analysis in relation with the mechanical loading during the life cycle of the hardware shall be performed.

NOTE 1 Some materials can exhibit residual strain after mechanical loading.
Micro-yield is the force to be applied to produce a residual strain of 1×10^{-6} mm/m along the tensile or compression loading direction.

NOTE 2 In general the most severe mechanical loading occurs during launch.

4.3.7 Coefficient of thermal expansion and coefficient of moisture expansion

a. Thermal mismatch between structural members shall be minimized such that stresses generated in the specified temperature range for the item are acceptable.

b. The coefficient of thermal expansion (CTE) of composite materials intended for high stability structural applications shall be systematically determined by means of dry test coupons under dry test conditions.

c. For hygroscopic materials intended for high stability structural applications, the coefficient of moisture expansion (CME) shall be systematically determined.

d. A sensitivity analysis which takes in consideration the inaccuracies inherent in the manufacturing process shall be performed for all composite materials.

NOTE The difference in thermal or moisture expansion between members of a construction or between the constituents of a composite or a coated material can induce large stresses or strains and can eventually lead to failures.

4.3.8 Stress corrosion

a. Metallic structural products shall be selected from preferred lists (Table 1 of ECSS-Q-70-36A: Alloys with high resistance to stress corrosion cracking).

b. The metallic components proposed for use in most spacecraft shall be screened to prevent failures resulting from stress corrosion cracking (SCC).

NOTE Stress corrosion cracking (SCC), defined as the combined action of a sustained tensile stress and corrosion, can cause the premature failure of metals.

c. Only those products found to possess a high resistance to stress corrosion cracking shall have unrestricted use in structural applications.

d. Materials intended for structural applications shall possess a high resistance to stress corrosion cracking, if they are

- exposed to a long-term storage on ground (terrestrial),
- flown on the Space Transportation System (STS),
- classified as fracture critical items, or
- parts associated with the fabrication of launch vehicles.

e. The technical criteria, for the selection of materials, of ECSS-Q-70 shall apply.

4.3.9 Corrosion fatigue

For all materials in contact with chemicals and experiencing an alternating loading it shall be demonstrated that the degradation of properties over the complete mission is acceptable.

NOTE Corrosion fatigue indicates crack formation and propagation caused by the effect of alternating loading in the presence of a corrosion process. Because of the time dependence of corrosion, the number of cycles before failure depends on the frequency of the loading. Since chemical attack takes time to take effect, its influence is greater as the frequency is reduced.
No metals or alloys demonstrate complete resistance to corrosion fatigue.

4.3.10 Hydrogen embrittlement

The possibility of hydrogen embrittlement occurring during component manufacture or use shall be assessed. An appropriate material evaluation shall be undertaken including the assessment of adequate protection and control.

NOTE Metals can be embrittled by absorbed hydrogen to such a degree that the application of the smallest tensile stress can cause the formation of cracking.
The following are possible sources of hydrogen:
- thermal dissociation of water in metallurgical processes (e.g. casting and welding);
- decomposition of gases;
- pickling,
- corrosion;
- galvanic processes (e.g. plating);
- ion bombardment.

4.3.11 Mechanical contact surface effects

a. For all solid surfaces in moving contact with other solid surfaces it shall be demonstrated that the degradation of surface properties over the complete mission is acceptable from a performance point of view.

NOTE 1 The friction behaviour of polymers differs from that of metals. The surfaces left in contact under load can creep and high local temperatures can be generated by frictional heating at regions of real contact.

NOTE 2 When clean surfaces are placed in contact they do not touch over the whole of their apparent area. The load is supported by surface irregularities and the following interactions can occur:
- elastic deformation;
- adhesion;
- plastic deformation;
- material transfer and removal;
- heat transfer chemical reaction;
- transformation of kinetic energy into heat energy;
- diffusion or localized melting.

b. Structural applications shall be designed to avoid wear.

NOTE Wear is the progressive loss of material from the operating surface of a body occurring as a result of relative motion at the surface. Wear is generally considered to be detrimental, but in mild form it can be beneficial, e.g. during the running-in period of engineering surfaces.
The major types of wear are abrasive wear, adhesive wear, erosive wear, rolling wear and fretting.

c. For all solid surfaces in static contact with other solid surfaces and intended to be separated it shall be demonstrated that the increase in separation force during this physical contact conforms to the required performance.

NOTE For very clean surfaces strong adhesion occurs at the regions of real contact, a part of which can result from to cold-welding.

4.4 Mission constraints

4.4.1 General

Product assurance requirements on mission constraints shall be in accordance with ECSS-Q-70.

4.4.2 Temperature

a. Material properties shall be compatible with the thermal environment to which they are exposed.

b. The passage through transition temperatures (e.g. brittle-ductile transitions or glass transition temperatures including the effects of moisture or other phase transitions) shall be taken into account.

NOTE Cryogenic tanks and thermal protection systems for re-entry applications are examples of the extremes of the temperature range. Temperatures below room temperature generally cause an increase in strength properties, with a reduction in the ductility. Ductility and strength can however either increase or decrease at temperatures above room temperature. This change depends on many factors, such as temperature and time of exposure.

4.4.3 Thermal cycling

Materials subject to thermal cycling shall be selected to ensure they are capable of withstanding the induced thermal stresses and shall be tested according to approved procedures (see ECSS-Q-70-04).

NOTE Thermal cycling can induce thermal stresses and due to the difference in coefficient of thermal expansion between fibres and matrix for composites and between base metal and coating micro-cracks can form which could jeopardise long-term properties.

4.4.4 Vacuum (outgassing)

All materials intended for use in space systems shall be evaluated by thermal vacuum tests according to approved procedures to determine their outgassing characteristics (see ECSS-Q-70-02).

NOTE 1 Vacuum exposure can lead to outgassing. In some cases it can degrade the properties of the material and can raise corona problems or contamination on other parts due to evolved products.

NOTE 2 The screening process applied to materials depends on their intended application, e.g. near optics the requirements are more stringent, while materials used in a hermetically sealed container are not necessarily subjected to an outgassing test.

4.4.5 Manned environment

a. All materials intended for use in manned space flight systems shall be subject to product assurance, safety policy and basic specifications whose application shall be mandatory.

b. All materials intended for use in manned space flight systems shall be analysed for hazard and risk potential, both structural and physiological.

c. Safety of human life shall be the overriding consideration during design and operation of space systems, including all facilities and ground support systems.

4.4.6 Offgassing, toxicity and odour

a. Spacecraft and associated equipment shall be manufactured from materials, and by processes, that shall not cause an unacceptable hazard to personnel or hardware, either on the ground or in space.

b. Materials intended for use in manned compartments of spacecrafts, offgassing and toxicity analysis shall be required and the levels agreed with the customer (see ECSS-Q-70-29).

NOTE In a closed environment of a manned spacecraft, contaminants in the atmosphere are potentially dangerous with respect to toxicity.

4.4.7 Bacterial and fungus growth

a. Materials shall not support bacterial or fungus growth and shall be sterilizable without any deterioration of their properties.

b. The level of bacterial and fungus contamination shall be determined on the finally assembled hardware.

4.4.8 Flammability

a. Evaluation of materials flammability resistance, for the most hazardous environment envisaged for their use, shall be performed for:

- unmanned spacecraft launched by Space Transportation System (STS) when powered on during launch;
- manned spacecrafts;
- stored equipment;
- payload or experiments.

b. Materials shall be screened according to approved procedures.
(see NASA STS payloads to NHB 8060-1 and ECSS-Q-70-21).

4.4.9 Astronaut spacesuits

a. Spacesuits are made of many different materials: metallic materials, plastics, rubbers, lubricants and adhesives. The following effects shall be considered:

- vacuum (outgassing);
- offgassing and toxicity;
- thermal cycling;
- radiation;
- corrosion and stress corrosion;
- flammability;
- atomic oxygen;
- micrometeoroids and impacts.

b. Ignition sources shall be absent.

c. All materials used for every component shall be flame retardant.

d. Metallic materials used inside the spacesuit shall be assessed for their corrosion and stress corrosion susceptibility.

e. Materials used on the outside of the suit shall be assessed for their susceptibility of atomic oxygen.

f. Materials used at the outside of the spacesuit shall be assessed for their susceptibility to radiation.

g. All materials shall be assessed for their offgassing and toxicity properties.

h. Materials in the unpressurized part shall be assessed for their capability to withstand the induced thermal stresses, especially those stresses originating from the use of different interconnecting materials.

i. Materials used at the outside of the spacesuit shall be assessed for their abrasion resistance.

4.4.10 Radiation

For all materials on the external surface (e.g. thermal blankets materials, thermal paints, transparencies and windows) it shall be demonstrated that the degradation of properties due to radiation over the complete mission is acceptable to the required performance.

NOTE Radiation is not critical for most materials, except for thin transparencies, antennae and windows and thermal finishes. Cross-linking can occur at the surface of composites.

4.4.11 Electrical charge and discharge

a. External surfaces of the spacecraft shall have conductive grounding elements.

NOTE The external surface of a geostatic satellite can charge to several thousand volts, depending upon the plasma environment, the electrical properties of the surface materials and the geometrical configuration of the surface. Any subsequent discharge can cause malfunction of various subsystems.

b. To avoid electrical discharges, the surface voltage shall not exceed the breakdown voltage of the dielectric.

NOTE It is important to reduce charging on components with large surfaces (e.g. thermal blankets, optical solar reflectors and solar arrays) since the discharge amplitude is dependant on the area.

4.4.12 Lightning strike

a. Provision shall be made during design to ensure that the safety and functionality of the vehicle are not compromised by the occurrence of a lightning strike during launch or return.

b. It shall be demonstrated by appropriate analysis and test that the structure can dissipate static electrical charges.

c. Metallic components shall be bonded according to approved procedures to the structure to ensure an electrical path.

d. Components shall be designed to minimize the effects of a lightning strike.

e. Acceptable means of diverting the resulting electrical current shall be incorporated so as not to endanger the vehicle.

4.4.13 Chemical (corrosion)

For all materials which come into contact with cleaning fluids or other chemicals, it shall be demonstrated that the degradation of properties during their anticipated service-life is acceptable to the performance and integrity requirements.

NOTE The chemical environment to which a material is subjected in its life span can cause changes in the material properties. Corrosion includes the reaction of metals, glasses, ionic solids, polymeric solids and composites with environments that embrace liquid metal, gases, non-aqueous electrolytes and other non-aqueous solutions, coating systems and adhesion systems.

4.4.14 Fluid compatibility

a. Materials within the system exposed to liquid oxygen, gaseous oxygen or other reactive fluids, both directly and as a result of a single point failure shall be compatible with that fluid in their application.

NOTE In some occasions materials are in contact with liquid oxygen, gaseous oxygen or other reactive fluids or can come into contact with such a fluid during an emergency situation.

b. The compatibility of materials which are or can come into contact with liquid of gaseous oxygen shall be evaluated (see test no. 13 and test no. 14 of NASA NHB 8060.1B).

c. If no compatibility data are available tests shall be performed for reactive fluids other than oxygen (see test no. 15 of NASA NHB 8060.1B).

4.4.15 Galvanic compatibility

a. Material compatibilities shall be selected in accordance with approved lists and procedures (see ECSS-Q-70-71).

b. Maximum potential differences shall be in accordance with approved values and procedures (see ECSS-Q-70-71).

NOTE If two or more dissimilar materials are in direct electrical contact in a corrosive solution or atmosphere galvanic corrosion can occur. The least resistant material becomes the anode and the most resistant material becomes the cathode. The cathodic material corrodes very little or not at all, while the corrosion of the anodic material is greatly enhanced.

4.4.16 Atomic oxygen

a. All materials considered for use on the external surfaces of the spacecraft intended for use at low Earth orbit altitudes (between 200 km and 700 km) shall be evaluated for their resistance to atomic oxygen.

NOTE Spacecraft in low Earth orbit (LEO) altitudes are exposed to a flux of atomic oxygen. The flux level varies with altitude, velocity vector and solar activity. The fluence levels vary with the duration of exposure.

b. Test procedures shall be subject to approval by the customer.

4.4.17 Micrometeoroids and debris

The effect of impacts by micrometeoroids and debris on materials shall be reviewed and assessed on a case by case basis.

NOTE 1 Low energy impact occurs when a part impact the material with a velocity in a range of 1 m/s to 100 m/s. The effects of the impact is dependant upon the velocity, angle of impact and mass.

NOTE 2 Low energy debris can cause plastic deformation on metals surfaces as the primary effects and can lead to delamination within composites.

NOTE 3 High energy impact occurs at very high velocities in the range of several km/s. The effect of the impact depends among others on its mass of the debris. For impacts with low mass the primary effect is surface pitting and erosion. For impact with high mass significant impact damage can occur which can be catastrophic for the material.

4.4.18 Moisture absorption and desorption

a. Precautions shall be taken to avoid moisture absorption during manufacture and storage. The relative humidity and temperature of the manufacture and storage environments shall be controlled and monitored.

NOTE The properties of composite materials are susceptible to changes induced by the absorption of moisture. Moisture absorption occurs during production of components and up to the launch of the spacecraft, desorption occurs in the space vacuum.

b. Induced stresses by moisture absorption and desorption of structural polymer-based materials occurring during the life cycle of the hardware shall be assessed and agreed with the customer.

c. Where dimensional stability requirements are specified, hygro strains shall be assessed and agreed with the customer.

4.5 Interfaces

4.5.1 General

The following covers the requirements for the interfaces (surface finishes) and methods of interfacing.

NOTE The surface finish of a component can influence its mechanical and environmental durability.

a. The surface finish shall be specified (e.g. composition and thickness).

b. The surface finish shall be free from clearly visible coating defects and shall not be stained or discoloured.

c. Materials applied to a substrate shall not cause the substrate to suffer degradation which can lead to an unacceptable loss of performance or integrity.

d. Coatings and substrates shall be evaluated in combination and not separately (e.g. CTE mismatches).

4.5.2 Passivation layers

When using passivation layers above their bakeout temperature water release can occur. The design shall take this into consideration.

4.5.3 Anodizing

a. When anodizing is used as the final surface treatment, the anodized layers shall be sealed and shall be continuous. When anodizing as a bonding pre-treatment, sealing need not be done.

b. Very thin products such as foils shall be anodized with caution.

NOTE Anodizing is an electrolytic process for thickening and stabilizing oxide films on base metals and anodizing grade alloys. It may be used as a pre-treatment for painting and dying or as a passivation treatment for an electrobrightened surface. Hard anodized layers are wear resistant and durable. Black anodizing is used for controlling the optical properties of surfaces. The anodized layer is electrically non-conductive. The bath constituents and process conditions can vary between organizations.

4.5.4 Chemical conversion

When chemical conversion layers are used as a final surface treatment, the chemical conversion layers shall be sealed and be continuous. When chemical conversion layers are used as bonding pre-treatment sealing need not be done.

NOTE 1 Chemical conversion depends upon the absorbtion of a protective metal oxide film into an existing oxide film (non-metal oxide films may sometimes be used).

NOTE 2 Chromating involves the formation of a mixed metal-chromium oxide film. It has good corrosion resistance and an excellent bond to subsequent organic coatings.

NOTE 3 Phosphating is used as an underlayer for paint finishes.

NOTE 4 Chemical conversion coatings can be either electrically conductive or non-conductive.

NOTE 5 The bath constituents and process conditions can vary between suppliers.

4.5.5 Metallic coatings (overlay and diffusion)

a. Components subject to fatigue or sustained loading stresses which are made of material susceptible to hydrogen embrittlement shall be heat treated after coating.

NOTE Metallic diffusion coatings modify the composition of the surface by enrichment with Cr, Al or Si, or the formation of their stable oxides.

b. Cadmium and zinc coatings shall not be used.

NOTE Cadmium and zinc coatings are not used because of their high vapour pressure.

c. Silver, copper and osmium coatings shall not be used on external surfaces.

NOTE Silver, copper and osmium coatings are not be used on external surfaces, because they are sensitive to atomic oxygen.

d. Porous coatings shall be sealed.

e. Electroplated tin shall be reflowed to avoid whisker growth.

4.5.6 Hard coatings

a. The combination of a hard coating and a soft substrate should be avoided since the coating can break under pressure.

NOTE Hard coatings are used to improve the abrasive properties of the surface.

b. Components subject to fatigue or sustained loading stresses, which are made of material susceptible to hydrogen embrittlement, shall be heat treated after coating.

NOTE Hard coatings reduce the ability to cold weld.

c. The deformation of the substrate under contact pressure shall be minimal to avoid breaking of the coating.

4.5.7 High temperature oxidation protective coatings

a. The requirements and conditions for high temperature oxidation protective coatings shall follow approved procedures (see ECSS-E-30-04).

b. Oxidation protection, thermal shock behaviour and erosion properties shall be considered.

NOTE Protective coatings are important in high temperature applications, such as re-entry surfaces and propulsion systems.

4.5.8 Thermal barriers

a. The thermal barrier coating shall not spall.

NOTE Thermal barrier coatings are used to retard component heating due to high heat fluxes. Thermal barrier coatings are ceramic overlay coatings, where the thickness is approximately 0,4 mm.

b. Spalling of the thermal barrier coating shall be verified by inspection.

NOTE Thermal coatings are applied to selected regions only.

c. The adequacy of the thermal barrier shall be demonstrated by test.

d. The properties of the substrate shall not be irreversibly changed due to the application of the thermal barrier.

NOTE The coating process can modify the condition of the substrate.

4.5.9 Moisture barriers

a. Moisture barrier coatings shall be non-porous and shall be impermeable to moisture and organic species.

b. The adequacy of the moisture barrier shall be demonstrated by test.

NOTE Coatings can be used to prevent moisture absorption or desorption of dimensionally stable structures or to prevent the release of organic volatiles which can affect the performances of some equipments.

4.5.10 Diffusion barriers

The diffusion barrier shall prevent or at least retard the diffusion of elements for the bulk material into the outer surface coating or vice versa.

NOTE High temperature service operation can result in compositional changes of the bulk material and of the coating due to diffusion. These compositional changes can result, for example, in formation of intermetallic compounds, which are brittle and can break under cyclic stresses.

4.5.11 Coatings on CFRP

a. Coating material shall be selected in accordance with approved procedures and tables (see ECSS-Q-70-71).

b. If the material coating combination cannot be found from approved procedures and tables, the coating shall be bonded to the CFRP substrate using a non-conductive adhesive or alternatively the coating shall be applied to a resin-rich CFRP surface.

NOTE Coatings on CFRP are used as moisture stoppers, as protection against atomic oxygen or for adjusting optical properties. In most cases these coatings are metallic. In dissimilar material contact, the CFRP usually behaves as the cathode and as such can corrode the coating material.

4.6 Joining

4.6.1 General

Joining methods requirements covered by this Standard are

- mechanical fastening,
- adhesive bonding,
- combined bonding and fastening, and
- fusion, including soldering, brazing, welding and diffusion bonding.

4.6.2 Mechanical fastening

4.6.2.1 General

a. The selection of fasteners shall be governed by panel thickness, loading, environmental exposure, disassembly and accessibility requirements.

b. Galvanic corrosion due to contact between dissimilar materials shall be precluded.

c. To avoid damage, tapped screws shall not be used with composite materials.

NOTE The function of the joint elements is to connect two or more parts together in order to transfer loads between them.

4.6.2.2 Bolted joints

Threaded fasteners shall conform to approved minimum requirements.

NOTE Bolts offer the greatest strength for mechanical fastening of joints. Providing they are not overtightened, no damage is done to the structure during assembly.

4.6.2.3 Riveted joints

a. Riveted joints shall not be used where access to internal or adjacent parts of the structure is either required or expected.

NOTE Riveted joints are permanent. Disassembly requires the drilling out of the rivets.

b. The riveted joints shall conform to approved guidelines (see MIL-HDBK-5F for metals and ECSS-E-30-04 for composites).

4.6.2.4 Inserts

a. Inserts shall be designed in accordance with approved procedures and guidelines (see ECSS-E-30-06).

NOTE An insert system consists of a removable threaded fastener and a fixture embedded into the honeycomb structure using a potting mass.

b. All inserts shall have their surfaces protected against corrosion.

4.6.3 Adhesive bonding

a. The adhesives shall attach the facings rigidly to the core to allow loads to be transmitted from one facing to the other.

b. Adhesives for load carrying structures shall have high strength and modulus.

NOTE Good toughness and peel strength are important factors for adhesive bonding.

4.6.4 Fusion

4.6.4.1 General

Fusion techniques can be grouped as

- soldering,
- brazing, and
- welding, including diffusion bonding.

All fusion techniques shall require extensive quality control and inspection procedures to be followed.

NOTE All fusion methods produce permanent joints. Soldered joints and some braized joints can be disassembled with care.

4.6.4.2 Soldering

a. Soldered joints shall not be used for structural applications unless approved by the customer.

NOTE Soldered joints are used for electrical and thermal conducting paths and for low mechanical strength joints.

b. The selection of solder alloys and soldering techniques shall be in accordance with approved lists and procedures (see ECSS-Q-70-08 and ECSS-Q-70-38).

NOTE Soldering is commonly referred to as soft soldering in which low melting point alloys such as tin-lead or Indium based alloys are used.

4.6.4.3 Brazing

a. The effect of the brazing process on the strength of the parent or base metal shall be considered in the structural design.

NOTE 1 Brazing is preferred to soldering when stronger joints and an increase in heat resistance is required.

NOTE 2 Brazing usually refers to joining with alloys of copper, silver and zinc.

b. Subsequent fusion welding in the vicinity of brazed joints or other operations involving high temperatures which can affect the brazed joint shall be prohibited.

c. The selection of brazing alloys and brazing techniques shall be in accordance with MIL-HDBK-5F and MIL-B-7883B.

4.6.4.4 Welding

A fusion weld consists of three zones: the fusion zone, the unmelted heat affected zone and the unaffected base metal.

a. In the aerospace industry the following welding techniques shall be considered:

   - Tungsten Inert Gas (TIG) welding;
   - Metal Inert Gas (MIG) welding;
   - Plasma-arc welding;
   - Electron Beam (EB) welding;
   - Resistance welding (induction, spot, seam welding);
   - Diffusion welding;
   - Laser welding.

The choice of process shall be influenced by the type of component and its composition.

NOTE Welding is mainly dictated by the alloy composition.

b. The selection of alloys to be welded and the selection of welding techniques shall be in accordance with MIL-HDBK-5F.

NOTE The welding technique influences the ease for producing a satisfactory weldment.

c. Personnel, equipment and procedures used for welding shall be certified for their capability to produce welds and repair welds.

d. The fusion zone and the unmelted heat affected zone of a weld shall be accessible for inspection.

NOTE Frequently, the weld is stronger than the base metal and the greatest stress exists in the unmelted heat affected zone adjacent to the fusion zone.

e. All critical and highly stressed welds shall undergo 100 % radiographic inspection in accordance with approved specification, which shall be specified on the engineering drawing.

4.7 Design

4.7.1 General

a. The supplier shall present a detailed test plan for approval by the customer.

b. Fracture control shall be an integral part of the material selection and design.

4.7.2 Material design allowables

Material design allowables, A-basis design allowables and B-basis design allowables are defined in clause 3.

4.7.3 Metal design allowables

a. Minimum values for certain mechanical properties shall be assigned as part of the procurement specification requirements. A-basis allowables shall be required and in most cases, shall be obtained from MIL-HDBK-5F.

b. To determine the A-basis and B-basis design allowables for metallic materials which are not included in MIL-HDBK-5F, the data shall adequately represent the current process capability of the material.

c. A-basis and B-basis design allowables shall be determined taking into consideration representative materials and all factors relating to the processing and environmental effects shall be considered, applying to each significant variable, including:

   1. form (e.g. bar, sheet and plate);
   2. size, thickness range;
   3. manufacturing process (e.g. extrusion, rolling and forging);
   4. grain direction (longitudinal, longitudinal transverse and short transverse);
   5. temper condition (e.g. heat-treatment and cold-working);
   6. test direction.

4.7.4 Composite design allowables

a. Each of the following shall be taken into account during the design to establish the allowables for composite materials:

1. The composite material shall be created at the same time as the finished component, therefore the control of the manufacturing process has a very strong influence on the final material properties;
2. Lamina properties exhibit large differences in directional properties as well as small strain to failure with limited yielding or plastic behaviour;
3. Depending on the lay-up, the configuration can exhibit a number of different failure modes in either the fibre, the matrix or the fibre to matrix interface;
4. The size of residual strains due to the curing process can be a significant parameter;
5. It can be difficult to assess the effects of combined loading when applied to laminates;
6. There can be a greater scatter in compression strength properties compared to metals and in metal to composite joints;
7. The susceptibility to environmental effects (e.g. humidity, temperature, radiation and cyclic loading);
8. The degree of non-linearity is dependent on the specimen, load condition, and test environment.

b. The supplier shall justify his choice of composite material for approval by the customer, including the provision of the technical information on which the selection was based.

c. The supplier shall justify the allowables he shall use, in any pre-dimensioning phase, for approval by the customer.

d. The composite material shall be specified against a prepreg requirement or similar specification which covers both qualification and lot control and indicates the test methods and the accept or reject criteria including the minimum acceptable mechanical and physical properties.

e. The autoclave or other manufacturing process critical parameters shall be specified.

f. The supplier shall present a test plan for approval by the customer describing how the design allowables shall be established. The statistical basis for deriving the allowables shall require approval of the customer.

g. This test plan shall also indicate how any interpolation to allow for different lay up configurations are established.

h. The test methods used to establish the material engineering data shall be identified.

i. The requirement for any configuration related component testing, in support of the generation of design allowables, shall be established by the supplier.

4.7.5 Composite sandwich constructions

Sandwich structures shall be designed to meet the basic sandwich structural criteria listed below:

a. The facings shall be thick enough to withstand the tensile, compressive and in-plane shear stresses induced by the design loads.

b. The core shall have sufficient strength to withstand the shear stresses induced by the design loads. Adhesives shall have sufficient strength to transmit shear stress from face skin to core.

c. The core shall be thick enough and shall have sufficient shear modulus to prevent overall buckling of the sandwich under design load.

d. Compressive modulus of the core and compressive strength of the facings shall be sufficient to prevent wrinkling of the faces under the design load.

e. The core cells shall be small enough to prevent intra-cell dimpling of the facings under design load.

f. The core shall have sufficient compressive strength to resist crushing by design loads acting normal to the panel facings or by compressive stresses induced through flexure.

g. The sandwich structure shall have sufficient flexural and shear rigidity to prevent excessive deflections under design load.

h. The sandwich panel closeouts and attachment points shall have sufficient strength and tie-in with the core and the facings to transmit load to the rest of the structure.

i. The sandwich structure shall meet the stiffness requirements.

4.7.6 Aluminium

a. Maximum use shall be made of alloys, heat treatment and coatings that minimize susceptibility to general corrosion, pitting, integranular, and stress corrosion.

b. Heat treatment of aluminium alloys shall conform to national or international specifications for aerospace applications.

4.7.7 Steel

4.7.7.1 High strength steel

a. Heat treated steel to ≥ 1250 MPa ultimate tensile strength shall be approved for each application by the customer.

b. Heat treatment of steel shall conform to national or international specifications for aerospace applications.

c. Heat treatment procedures which are not included in any national or international specification shall be approved by the customer prior to their use.

d. All high strength heat treated steel parts to ≥ 1250 MPa ultimate tensile strength, which have been acid cleaned, plated, or exposed to other hydrogen producing processes shall be subjected to a baking procedure, which shall be agreed with the customer.

e. Machining (such as, drilling or grinding) of martensitic steel hardened to ≥ 1250 MPa ultimate tensile strength shall be avoided. When machining cannot be avoided, carbide tipped tooling and other techniques necessary to avoid formation of untempered martensite shall be used.

4.7.7.2 Corrosion resistant steel

a. Welded assemblies of corrosion resistant steels shall be heat treated after welding, except for steels with stabilized or low carbon grades.

b. Unstabilized austenetic steels shall not be used at temperatures of 370 °C or above.

c. Caution shall be exercised when using 400 series stainless steels to minimize hydrogen embrittlement, corrosion and stress corrosion.

4.7.7.3 Precipitation hardening steel

a. Tempers of precipitation hardening steels which are susceptible to stress corrosion and hydrogen embrittlement shall be avoided.

b. Designs using precipitation hardening steels shall ensure that controlled processing procedures are used for these steels and processing and procurement records, shall be maintained for reference as appropriate.

4.7.8 Titanium

a. Titanium alloys with limited hardenability with section size shall not be used in sections which exceed their specific limits.

b. Heat treatment of titanium and titanium alloys shall conform to appropriate national or international specification for aerospace applications.

c. The use of cleaning fluids and other chemicals that are detrimental to performance of titanium or titanium alloy parts shall be avoided.

NOTE Cleaning fluids which are detrimental to titanium include hydrochloric acid, cadmium, silver, chlorinated cutting oils and solvents, methyl alcohol, mercury and compounds containing mercury.

d. Structural applications of titanium shall be designed to avoid fretting.

4.7.9 Magnesium alloys

a. Magnesium alloys shall not be used except in areas where minimal exposure to corrosive environments can be ensured and protection systems can be maintained with ease and reliability.

b. Magnesium alloys shall not be used in primary flight control systems, for landing gear wheels, for the primary structures, or in other areas subject to wear, abuse, foreign object damage, abrasion, erosion or at any location where fluid or moisture entrapment is possible.

4.7.10 Beryllium and beryllium alloys

a. Beryllium and beryllium alloys shall be restricted to applications in which their properties offer definite performance and cost advantages over other materials.

b. The ability of beryllium parts to provide reliable service and predictable life shall be demonstrated by pre-production tests under simulated service conditions, including any expected corrosive environments.

c. The design of beryllium parts shall take into consideration the material's low impact resistance, notch sensitivity, its anisotropy and sensitivity to surface finish requirements.

d. National or international safety regulations shall be followed when manufacturing and handling beryllium products.

4.7.11 Mercury

The use of devices containing mercury or compounds of mercury shall be prohibited for installed equipment and for use during fabrication of flight structures and subsystems.

NOTE Mercury and many compounds containing mercury can cause accelerated cracking of aluminium and titanium alloys.

4.7.12 Refractory alloys

The application of refractory alloys shall be subject to approval by the customer.

NOTE Engineering data on refractory alloys are limited, especially under extreme environments encountered on spacecrafts.

4.7.13 Superalloys

a. The selection of a superalloy for a given application shall be based on tests of the material in a simulated environment to the in-service environment.

NOTE Nickel-base and cobalt-base superalloys possess various combinations of high temperature mechanical properties and oxidation resistance up to approximately 550 °C. Many of these alloys also have excellent cryogenic temperature properties.

b. Foreign material which contains sulphur, such as oils, grease and cutting lubricants shall be removed prior to heat treatment or high temperature service.

c. The effect of alloying element depletion at the surface in a high temperature, oxidizing environment shall be evaluated when thin sheet is used.

4.7.14 Other metals

In addition to the requirements of this Standard and ECSS-Q-70, the supplier shall comply with the metallic material requirements specified in the applicable contractual document for the particular hardware or subsystem.

4.7.15 Castings

Casting shall not be used without prior approval by the customer.

NOTE The shape of a casting can contribute to residual stresses if it entails sections of markedly different thickness, which can undergo different cooling rates in the mold.
Very high pouring temperatures retard the cooling rates of thick sections but may not affect significantly the cooling of thin sections.

4.7.16 Forgings

Forging techniques producing an internal flow pattern such that the direction of flow in all stressed areas is essentially parallel to the principle tensile stress shall be used.

NOTE The mechanical properties of forgings are maximum in the direction of material flow during forging.

4.7.17 Glass and ceramics

a. Glass and ceramics shall not be used in a structural application without the prior approval of the customer.

NOTE Glass and monolithic ceramics have a very limited role in structural applications. Demonstration of an adequate design can be difficult and require proof testing.

b. Structural applications of glass and ceramic materials shall be based on careful selection criteria and agreed with the customer.

c. Engineering data used to verify the selection and demonstrate the strength of glass and ceramics shall be subject to review and approval by the customer.

4.7.18 Ceramic Matrix Composites - CMC (including carbon-carbon)

All applications using advanced composite materials shall be reviewed and approved by the customer.

NOTE Ceramic matrix composite materials are used for structural applications providing design performance and economical requirements justify their selection.

4.7.19 Polymers (thermosets and thermoplastics)

a. A clear definition of all design constraints,(e.g. short-term loading, long-term loading, cyclic loading, impact loading, design life and critical dimensional tolerances) shall be established.

NOTE Synthetic polymers are formed by addition or condensation polymerization of monomers. Some polymers are elastomers, some are plastics, and some are fibres. The lengths of polymer chains, usually measured by molecular weight, have very significant effects on the performance properties of plastics and profound effects on processibility.

b. Environmental exposure (e.g. flammability requirements, electrical requirements, normal use temperature, abnormal use temperature excursions, chemical exposure and humidity levels) shall be considered.

c. The choice of material shall be subject to approval by the customer.

d. Part design shall be accomplished by using good engineering practice for the chosen material and processing method.

NOTE Design with plastics is often a more complex task than designing with metals.

e. A structural analysis shall be performed on all parts incorporating polymer materials, taking into account the viscoelastic nature of the chosen material.

NOTE Engineering plastics, which are viscoelastic, do not respond to mechanical stress in the linear, elastic manner.

f. Prototypes shall be produced and tested to qualify the design.

4.7.20 Rubbers (excluding adhesive rubbers)

a. Rubbers shall be selected in accordance with approved lists and procedures (see ECSS-Q-70-71).

b. Outgassing and contamination shall be measured for each formulation.

NOTE 1 Rubbers are used as mechanical damping systems, seals and gaskets, electrical insulants, membranes, bladders for fluids. They contain many additives, fillers, pigments.

NOTE 2 Outgassing of volatile additives but also depolymerization of the base polymer can change the mechanical and physical properties of rubber items. The risk of contamination in the vicinity of rubbers is high and the results of outgassing or contamination tests can in general not be generalized to a full series.

c. Rubbers can be sensitive to chemical attack by gas, liquids and solvents. The chemical resistance of rubbers in their environment shall be assessed.

d. Since some rubber mixtures contain corrosive products, the compatibility of rubbers with metals and alloys shall be assessed.

e. The tendency to set under stress shall be taken into account.

f. Cyclic stresses which can produce heat in rubber structures shall be taken into account.

NOTE Rubbers suffer from a non-reversible deformation under stress and cyclic stresses can produce heat, which can lead to thermal degradations.

4.7.21 Lubricants

a. Lubricants shall be selected in accordance with approved lists and procedures (see ECSS-Q-70-71).

b. Lubricants shall only be applied to clean surfaces.

c. Lubricated items shall be protected from contamination (e.g. dust and dirt).

d. Liquid lubricants shall be kept in place by a seal around the area concerned.

NOTE 1 Lubricants can be
- solid (e.g. MoS_2 and silver or PTFE, nylon or polyimide),
- liquids (e.g. hydrocarbons, silicones, diesters, polyglycols, fluorinated compounds), or
- semi-solid greases, which are based on the same oils with organic or inorganic gelling agents.

NOTE 2 Lubricants minimize friction and wear in moving contacts.

4.7.22 Thermal control insulants (including ablative materials)

The requirements and conditions for thermal control insulants shall follow approved procedures and guidelines (see ECSS-E-30-04).

NOTE The maximum temperature of external surfaces of recoverable vehicles requires control by thermal protection systems. These thermal protection systems can be either active, such as ablative coatings or passive, such as complex ceramic-based materials or paints.

4.7.23 Optical materials

a. Optical glasses shall be chosen in accordance with the mission requirements.

NOTE Optical materials include organic glass such as polystyrene, acrylic and polycarbonate and inorganic glass such as silicates, alumino-silicates and boro-silicates.

b. Organic glasses shall not be used in high-precision equipment.

NOTE Organic glasses are easily scratched.

c. An assembly incorporating optical material shall be designed to compensate for the difference in CTE between the optical material and its mounting.

NOTE 1 Inorganic glasses are sensitive to mechanical and thermal shocks.

NOTE 2 Assembly methods are the most important points in the design of parts containing glass.

d. Optical glasses shall be assessed for their resistance to ionizing radiation, particle and UV radiation.

NOTE Glass is only transparent to a certain wavelength range.

4.8 Verification

4.8.1 General

a. Testing shall be used at all stages of the design, development and operation of a structure. Testing shall be either

1. non-destructive testing or monitoring, without the test destroying or unacceptably affecting the part (e.g. proof test, X-ray), or

2. destructive testing of material, components or structure (e.g. tensile test, fracture toughness).

b. Measurements of mechanical and physical properties of materials shall be performed under environmental conditions which are representative of those expected in service.

4.8.2 Metallic materials

a. Properties of metallic material shall be obtained using standard test methods.

NOTE 1 Metallic material properties are determined by the composition, including levels of impurities, by the forming technique (e.g. forging, plate, bar, cast), heat-treatment, level of mechanical working and surface finish. Material properties can be obtained from material suppliers.

NOTE 2 Material properties can change with the environment (e.g. temperature).

b. Alternative test methods may only be used if they have been proven to be appropriate and the test procedures are approved by the customer.

c. Metallic material properties shall be determined on samples or coupons having the same composition, including level of impurities, forming technique, heat-treatment, level of mechanical working and surface finish as the parts used for the construction of the flight hardware.

4.8.3 Composite materials - laminates

a. The overall performance characteristics of the laminate shall be predicted using laminated plate theory. Laminate plate theory works well in most cases, but care shall be taken to recognize its limitations.

b. Test coupons made with the proposed raw materials shall be evaluated to establish and verify the actual properties for a given lay-up or joint design before it can be used to manufacture a part. The analysis shall be verified by comparing multi-directional test data obtained with the behaviour predicted by theoretical models.

NOTE Material properties for unidirectional composite materials under room temperature and standard conditions can be obtained from material suppliers.

c. The designer shall consider to what degree the properties of the laminate will change throughout its life cycle and analyse it at each critical point.

NOTE Environmental effects can degrade mechanical properties to varying degrees, depending on the fibre-resin system.

d. Composite materials shall be characterized by elementary tests on samples. The production laminate shall be fabricated to a greater size than required, then cut down to the proper size. The excess pieces shall be used for quality control testing. This requirement is not applicable to near net shape manufacturing techniques, e.g. RTM (Resin Transfer Moulding).

4.8.4 Mechanical and physical test methods

This subclause gives requirements to measure the materials properties which are required for design purposes and for the validation of the material.

NOTE The mechanical test methods given are limited to the testing of coupons or specimens and do not apply to the testing of full sized or scale components, nor does it apply to multiaxial loading.

a. Samples submitted for destructive tests shall represent the population.

NOTE Destructive testing makes a part unusable.

b. The selected test method shall be representative of the structure and its intended operational life.

c. The material and the test condition shall be representative of its intended operational life.

d. Testing shall be performed on coupons or specimens as specified or components and assemblies to the intended design, produced by the intended processing methods.

e. Instruments used for the calibration of the measuring systems of testing machines shall be calibrated against either primary or secondary standards.

f. All test personnel shall be qualified or trained to a recognized acceptable level.

g. All test procedures and facilities shall be subject to approval by the customer.

4.8.5 Test methods on metals

a. The test specifications given by this subclause shall apply to metallic materials only. The tests include

1. tension tests,
2. compression tests,
3. hardness tests,
4. creep tests,
5. fracture toughness tests,
6. fatigue tests,
7. fatigue crack growth tests, and
8. stress corrosion tests.

b. Mechanical testing on metallic materials shall be conducted in accordance with approved procedures.

4.8.6 Test methods on composites

The test specifications given by this subclause apply to composite materials only.

a. Properties for each kind of ply shall be measured.

NOTE Supplier data sheets can be used for pre-design purposes.

b. For unidirectional ply, the properties shall be measured in the direction parallel to the fibres (called the 0° direction) as well as in the direction transverse to the fibres (the 90° direction). (ECSS-E-30-04 can also be used as guidelines.)

c. For fibre reinforced polymer composed of unidirectional layers, the most common properties shall be for design purposes the following:

1. tensile strength of the UD plies, in the 0° and 90° directions;
2. elastic modulus of the UD plies, in the 0° and 90° directions;
3. interlaminar shear strength;
4. CTE (Coefficient of Thermal Expansion) of the UD plies, 0° direction and 90° direction;
5. CME (Coefficient of Moisture Absorption) of the UD plies, 0° direction and 90° direction;
6. moisture content;
7. poisson's ratio.

d. The validation of the composite material shall be performed by measuring properties on test pieces having the hardware lay-up configuration. These properties shall be measured at ambient under standard conditions and under extreme conditions. The life cycle shall be taken into account. (e.g. property measurements after a representative number of thermal cycles).

e. Measurements shall be performed in the main direction of reinforcement and in the transverse direction. Where the material is quasi-isotropic, measurement in one direction shall be sufficient.

f. The most common properties to be assessed to validate a new generated composite material shall be the following:
   1. tensile strength;
   2. elastic modulus;
   3. compression strength;
   4. CTE (Coefficient of Thermal Expansion);
   5. CME (Coefficient of Moisture Absorption);
   6. through the thickness thermal conductivity.

g. Where the material is quasi-isotropic, measurements in the second direction can be useful to check the isotropicity of the material.

h. Well established but different test methods may be used, to obtain compression and shear strength. As a result, values may differ and care shall therefore be taken when establishing or comparing engineering values obtained from different test methods.

i. All supplied material used for the manufacture the test pieces shall conform to a procurement specification and the test pieces shall be prepared using the processes intended for the flight application.

j. Each supplier shall apply a traceability system for the test pieces.

k. Control process tests shall be part of any test programme.

l. The following tests shall be performed as a minimum:
   1. volume fibre, porosity and ply thickness measurements;
   2. in the case of thermoset resin matrix: degree of cure and glass transition temperature measurements;
   3. non-destructive inspection (NDI).

m. The test methods used shall be determined in relation to the kind of material to be tested and the property to be measured and shall be taken from the standards listed below:
   1. ECSS Standards where available;
   2. EN (European Standards), ASTM, other space agencies or national standards of the member states;
   3. supplier's procedures or other national standard.

4.8.7 Non-destructive inspection (NDI)

a. An NDI programme shall be developed which shall define the frequency, extent and methods of inspection for interpretation in requisite design development and maintenance plans.

   NOTE No single NDI technique is capable of detecting all types of defects in a given material. Consequently, techniques are complementary. Equipment configuration, operator competence and conditions of use, significantly affect the sensitivity of a particular technique.

b. Personnel conducting NDI shall be certified in accordance with MIL-STD-410E.

c. Inspection standards shall be established such that decisions to accept, rework or scrap parts are based on the probable effect that a given flaw has on the service life or product safety.

NOTE NDI techniques for defect detection and measurement and types of defects can be found in ECSS-E-30-04.

d. The customer and supplier shall agree in advance the design of the reference standard and to the procedure for using it.

NOTE Most non-destructive inspections rely on a reference standard to define acceptance limits or to estimate flaw sizes.

e. The NDI plan shall be available for review by the customer upon request.

4.8.8 Proof testing

a. Testing using a proof load or pressure shall be conducted on a flight structure in order to give evidence of satisfactory workmanship and material quality or to establish the initial crack size in a structure.

b. No failures that influence the behaviour of the structure shall be allowed when the structure is tested at proof level.

c. Proof testing of pressure vessels shall be conducted according to approved test procedures (see ECSS-E-30-01).

4.9 Production and manufacture

4.9.1 General

The successful design and manufacture of space structures rely on the guaranteed supply of materials and parts of specified and acceptable quality, as confirmed by test or inspection.

4.9.2 Procurement

a. Procurement shall be made to specifications derived by the user and in accordance with any relevant specification or a fully detailed purchase order.

b. The specification of items to be procured shall be sufficiently detailed to avoid confusion and can require extensive detail. All procured parts shall be identified and shall conform to quality management requirements.

c. The product assurance requirements for procurement shall conform to ECSS-Q-70.

4.9.3 Manufacturer

a. In realizing a procurement specification, the manufacturer shall follow approved guidelines (see ECSS-E-30-04 and ECSS-Q-70-01).

b. The manufacturer shall ensure that procurement specifications shall not be changed or modified without making sure that all their effects on the quality of the structure have been checked.

c. The manufacturer shall ensure the strict application of procurement specifications in order to guarantee the quality and reproducibility of the product.

4.9.4 Supplier

a. Only recognized suppliers with appropriate acceptance certificates shall be selected.

b. The supplier shall indicate the types of testing used to establish material properties, their typical values and their variation.

4.10 In-service

4.10.1 General

During operational life all materials show some level of degradation. This degradation can be due to

- metal fatigue (mechanical or thermal),
- corrosion or erosion,
- microcracking of composites,
- outgassing of volatiles,
- radiation; particle or UV,
- impact by debris,
- fretting or wear, and
- moisture take-up.

The result is a progressive deterioration of properties, initially centred around the damaged zone, but this can spread if the conditions are right, e.g. corrosion of metals beneath coating materials, material erosion by atomic oxygen, oxidation in composites or moisture penetration into composites and sandwich panels, outgassing of plastisers which can embrittle polymers and deposition of outgassing products on optical coatings.

4.10.2 Maintenance

a. Maintenance requirements shall be divided into

- requirements on preventive maintenance, e.g. replacement of parts approaching the end of their stated lives, repainting, oiling and greasing moving parts, and
- requirements on corrective maintenance, e.g. replacing or repairing parts which have been damaged.

b. Maintenance schedules shall be determined during the design process.

c. All maintenance activities shall be defined by and shall be subject to approved procedures.

d. Replacement shall not cause intolerable levels of damage to the surrounding structure.

e. Replacement parts shall be appropriately identified and be stored in an appropriate manner, as dictated by product assurance requirements.

4.10.3 Inspection

a. The inspection technique used shall not damage or contaminate the material.

NOTE Inspection ensures that a material has not so degraded in use, that further operation may renders it unsafe.

b. The inspection techniques used shall identify surface defects as well as bulk damage.

4.10.4 Repair

a. Materials with damaged areas or surface disruptions, larger than the specified allowed limits or those which could reach critical sizes before the next inspection shall be repaired or replaced.

b. Repair shall not cause intolerable levels of damage to the surrounding structure or to the material itself.

c. Repair concepts shall take into account the accessibility of the damaged material.

4.11 Data exchange

a. Sufficient data shall be compiled to establish that all known factors influencing the deterioration of the candidate materials have been evaluated in the design.

b. Compliance shall be recorded by reference to the applicable paragraph in this Standard.

c. All data compiled to meet the requirements of this Standard, shall be subject to review and approval by the customer on request.

d. Materials and processes data shall be transmitted to the customer according to an approved format.

4.12 Product assurance

a. Product assurance associated to materials and processes shall ensure that their use conforms to the mission performance requirements.

b. Product assurance and mechanical engineering activities shall be interfaced with regard to

   1. the implementation of the PA requirements in the technical specification of the materials and processes,
   2. the capability of NDE techniques to reliable detect initial flaws defined by engineering,
   3. incoming inspection,
   4. quality review and reporting,
   5. failure documentation,
   6. traceability,
   7. personnel certification, and
   8. assessment of the proposed design solution concerning materials and processes.

c. Materials or processes which can contribute to deterioration of structural members shall receive special consideration which shall include

   1. galvanic corrosion,
   2. stress corrosion,
   3. hydrogen embrittlement,
   4. creep,
   5. fatigue,
   6. flaw growth,
   7. oxidation,
   8. space vacuum, and
   9. radiation exposure.

d. The supplier shall insure that any potential deterioration mechanisms are evaluated, reviewed, and resolved prior to production of the related hardware.

4.13 Deliverables

The documents required for the control of materials shall include but not be limited to the documents listed in Table1, where applicable reference is provided to the document requirements definition (DRD) title and the DRD controlling standard.

Table 1: Document requirements for materials

Term used in this Standard	Document title	Controlling DRD reference
Material selection	Preferred materials list	-
Material identification	Declared materials list	ECSS-Q-70
External processes	Declared processes list	ECSS-Q-70
Material properties	Materials database	-
Material testing and inspection	Inspection record Test plan Test procedure Test report Test specification	ECSS-E-10-02 ECSS-E-10-02 ECSS-E-10-02 ECSS-E-10-02 ECSS-E-10-02

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Bibliography

MIL-HDBK-17B	Polymer Matrix Composites, volume 1: Guidelines
MIL-HDBK-23A	Structural Sandwich Composites
MSFC-STD-506C	Material and Process Control Standard
MSFC-SPEC-522A	Design Criteria for Controlling Stress Corrosion

The requirements defined in this ECSS Standard, provide references to lower level ECSS Standards. These detailed standards and guidelines are identified below:

ECSS-E-30-01	Space engineering — Fracture control
ECSS-E-30-04 [1)]	Space engineering — Structural materials handbook
ECSS-E-30-05 [1)]	Space engineering — Adhesive bonding handbook for advanced structural materials
ECSS-E-30-06 [1)]	Space engineering — Insert design handbook
ECSS-Q-70-02	Space product assurance — Thermal vacuum test for screening of space materials
ECSS-Q-70-04	Space product assurance — Thermal cycling test for the screening of space materials and processes
ECSS-Q-70-08	Space product assurance — The manual soldering of high-reliability electrical connections
ECSS-Q-70-21	Space product assurance — Flammability testing for the screening of space materials
ECSS-Q-70-29	Space product assurance — The determination of offgassing products from materials and assembled articles to be used in a manned space vehicle crew compartment
ECSS-Q-70-36	Space product assurance — Material selection for controlling stress corrosion cracking
ECSS-Q-70-38 [1)]	Space product assurance — High-reliability soldering for surface-mount and mixed technology printed circuit boards
ECSS-Q-70-71 [1)]	Space product assurance — Data for selection of space materials

1) To be published.

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ECSS Document Improvement Proposal

1. Document I.D.	2. Document date	3. Document title
ECSS-E-30 Part 8A	25 April 2000	Mechanical — Part 8: Materials

4. Recommended improvement (identify clauses, subclauses and include modified text or graphic, attach pages as necessary)

5. Reason for recommendation

6. Originator of recommendation

Name:	Organization:	
Address:	Phone: Fax: e-mail:	**7. Date of submission:**

8. Send to ECSS Secretariat

Name: W. Kriedte ESA-TOS/QR	Address: ESTEC, P.O. Box 299 2200 AG Noordwijk The Netherlands	Phone: +31-71-565-3952 Fax: +31-71-565-6839 e-mail: wkriedte@estec.esa.nl

Note: The originator of the submission should complete items 4, 5, 6 and 7.

This form is available as a Word and Wordperfect-Template on internet under
http://www.estec.esa.nl/ecss/improve/

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