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**Space systems — Pressure  
components and pressure system  
integration**

*Systèmes spatiaux — Intégration des composants sous pression et des  
systèmes sous pression*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

This second edition cancels and replaces the first edition (ISO 24638:2008), which has been technically revised.

The main changes compared to the previous edition are as follows:

- [6.8.4](#) was revised to make the requirement a more general statement;
- corrections were made to [Tables 1](#) and [A.1](#).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

Space vehicles and their launch systems usually have a series of engines to use for both primary propulsion and secondary propulsion functions, such as attitude control and spin control.

Different engines have different propellant feed systems. For example, the gas-pressure feed system is typically used for liquid propellant engines; it consists of a high-pressure gas tank, a fuel tank and an oxidizer tank, valves and a pressure regulator. All these components are referred to as pressurized hardware.

Due to their specific usage, the liquid propellant tanks and the high-pressure gas bottles are often referred to as pressure vessels, while valves, regulators and feed lines are usually called pressure components.

ISO 14623 sets forth the standard requirements for pressure vessels in order to achieve safe operation and mission success. However, the requirements for pressure components are not covered in ISO 14623. Furthermore, the standard requirements for pressure system integration are lacking.

Significant work has been done in the area of design, analysis and testing of pressure components for use in space systems. This document establishes the preferred methods for these techniques and sets forth the requirements for the assembly, installation, test, inspection, operation and maintenance of the pressure systems in spacecraft and launch vehicles.

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# Space systems — Pressure components and pressure system integration

## 1 Scope

This document establishes the baseline requirements for the design, fabrication and testing of space flight pressure components. It also establishes the requirements for the assembly, installation, test, inspection, operation and maintenance of the pressure systems in spacecraft and launch vehicles. These requirements, when implemented on a particular space system, ensure a high level of confidence in achieving safe and reliable operation.

This document applies to all pressure components other than pressure vessels and pressurized structures in a pressure system. It covers lines, fittings, valves, bellows, hoses and other appropriate components that are integrated to form a pressure system.

The requirements for pressure vessels and pressurized structures are set forth in ISO 14623.

This document does not apply to engine components.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14623, *Space systems - Pressure vessels and pressurized structures — Design and operation*

ISO 21347, *Space systems — Fracture and damage control*

ISO 24113, *Space systems — Space debris mitigation requirements*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

### 3.1

#### **A-basis allowable**

mechanical strength value above which at least 99 % of the population of values is expected to fall, with a confidence level of 95 %

Note 1 to entry: See also *B-basis allowable* (3.3).

[SOURCE: ISO 14623:2003, 2.1, modified — Note 1 to entry has been added.]

### 3.2

#### **applied load**

applied stress

actual load (stress) imposed on the hardware in the service environment

[SOURCE: ISO 14623:2003, 2.4, modified — “the structure” has been changed to “the hardware”.]

### 3.3

#### **B-basis allowable**

mechanical strength value above which at least 90 % of the population of values is expected to fall, with a confidence level of 95 %

Note 1 to entry: See also *A-basis allowable* (3.1).

[SOURCE: ISO 14623:2003, 2.6, modified — Note 1 to entry has been added.]

### 3.4

#### **component**

set of materials, assembled according to defined and controlled processes, which cannot be disassembled without destroying its capability and which performs a simple function that can be evaluated against expected performance requirements

[SOURCE: ISO 10795:2019, 3.48, modified — The preferred term "part" has been removed.]

### 3.5

#### **damage tolerance**

ability of a material/structure to resist failure due to the presence of flaws for a specified period of unrepaired usage

[SOURCE: ISO 21347:2005, 3.7]

### 3.6

#### **damage tolerance analysis**

#### **safe-life analysis**

fracture mechanics-based analysis that predicts the flaw growth behaviour of a flawed hardware item which is under service *loading spectrum* (3.15) with a pre-specified *scatter factor* (3.24)

### 3.7

#### **design burst pressure**

burst pressure

ultimate pressure

differential pressure that pressurized hardware must withstand without burst in the applicable operational environment

Note 1 to entry: Design burst pressure is equal to the product of the *maximum expected operating pressure (MEOP)* (3.17) or *maximum design pressure (MDP)* (3.16) and a design burst factor.

[SOURCE: ISO 14623:2003, 2.16, modified — In Note 1 to entry, "the MEOP or MDP" has been changed to "the maximum expected operating pressure (MEOP) or maximum design pressure (MDP)".]

### 3.8

#### **design safety factor**

#### **safety factor**

design factor of safety

factor of safety

multiplying factor to be applied to *limit loads* (3.13) and/or *maximum expected operating pressure (MEOP)* (3.17) or *maximum design pressure (MDP)* (3.16)

[SOURCE: ISO 14623:2003, 2.17, modified — The preferred term "safety factor" has been added; "MEOP (or MDP)" has been changed to "maximum expected operating pressure (MEOP) or maximum design pressure (MDP)".]

### 3.9

#### **detrimental deformation**

structural deformation, deflection or displacement that prevents any portion of the structure or some other system from performing its intended function or that jeopardizes mission success

[SOURCE: ISO 10786:2011, 3.16]

### 3.10 fitting

*pressure component* (3.18) of a pressurized system used to connect *lines* (3.14), other pressure components and/or *pressure vessels* (3.19) within the system

### 3.11 hazard

existing or potential condition of an item that can result in an accident

Note 1 to entry: This condition can be associated with the design, fabrication, operation or environment of the item, and has the potential for introducing an accident.

Note 2 to entry: “Item” can include human beings.

[SOURCE: ISO 10795:2019, 3.120, modified — In note 1 to entry, “the potential for accidents” has been changed to “the potential for introducing an accident”.]

### 3.12 hydrogen embrittlement

mechanical-environmental process that results from the initial presence or absorption of excessive amounts of hydrogen in metals, usually in combination with residual or applied tensile stresses

[SOURCE: ISO 14623:2003, 2.31]

### 3.13 limit load

design limit load

maximum expected load, or combination of loads, which a structure or a *component* (3.4) in a structural assembly is expected to experience during its *service life* (3.25), in association with the applicable operating environments

Note 1 to entry: Load is a generic term for thermal load, pressure, external mechanical load (force, moment, or enforced displacement) or internal mechanical load (residual stress, pretension, or inertial load)..

Note 2 to entry: The corresponding stress or strain is called limit stress or limit strain.

[SOURCE: ISO 10786:2011, 3.30, modified — “design limit load” has been added as an admitted term; Note 3 to the entry describing “design limit load” has been deleted.]

### 3.14 line

tubular *pressure component* (3.18) of a *pressure system* (3.21) provided as a means for transferring fluids between *components* (3.4) of the system

Note 1 to entry: Flexible hoses are included.

### 3.15 loading spectrum

representation of the cumulative loading levels and associated cycles anticipated for the structure or *component* (3.4) of a structural assembly according to its *service life* (3.25) under all expected operating environments

Note 1 to entry: Significant transportation, test, and handling loads are included in this definition.

[SOURCE: ISO 10786:2011, 3.32]

### 3.16

#### maximum design pressure

##### MDP

highest pressure, as defined by maximum relief pressure, maximum regulator pressure and/or maximum temperature, including transient pressures, at which a pressurized hardware item retains two-fault tolerance without failure

[SOURCE: ISO 21347:2005, 3.20, modified — “pressure vessel” has been changed to “pressurized hardware item”.]

### 3.17

#### maximum expected operating pressure

##### MEOP

maximum allowed working pressure

MAWP

maximum operating pressure

MOP

highest differential pressure which a pressurized hardware item is expected to experience during its *service life* (3.25) and retain its functionality, in association with its applicable operating environments

Note 1 to entry: MEOP includes the effects of temperature, transient peaks, relief pressures, regulator pressure, vehicle acceleration, phase changes, transient pressure excursions, and relief valve tolerance.

Note 2 to entry: Some projects may replace MEOP with *maximum design pressure (MDP)* (3.16), which takes into account more conservative conditions.

Note 3 to entry: The terms MAWP and MOP are used when required to replace the term MEOP in a specific application.

[SOURCE: ISO 14623: 2003, 2.41, Modified — “maximum allowed working pressure”, “MAWP”, “maximum operating pressure”, “MOP” have been added as admitted terms; notes 1, 2 and 3 to entry have been added.]

### 3.18

#### pressure component

*component* (3.4) in a *pressure system* (3.21), other than a *pressure vessel* (3.19), or *pressurized structure* (3.20) that is designed largely by the internal pressure

EXAMPLE *Lines* (3.14), *fittings* (3.10), pressure gauges, valves, bellows and hoses.

### 3.19

#### pressure vessel

container designed primarily for the storage of pressurized fluids, which either contains gas/liquid with high energy level, or contains gas/liquid that will create a mishap (accident) if released, or contains gas/liquid with high pressure level

Note 1 to entry: This definition excludes *pressurized structures* (3.20) and *pressure components* (3.18).

Note 2 to entry: Energy and pressure levels are defined by each project and approved by the procuring authority (customer). If appropriate values are not defined by the project, the following levels are used:

- stored energy is at least 19 310 J, based on adiabatic expansion of perfect gas;
- *MEOP* (3.17) is at least 0,69 MPa.

### 3.20

#### pressurized structure

structure designed to carry both internal pressure and vehicle structural loads

EXAMPLE Launch vehicle main propellant tank, crew cabins, manned modules.

**3.21****pressure system**

system that consists of *pressure vessels* (3.19) or *pressurized structures* (3.20), or both, and other *pressure components* (3.18) such as *lines* (3.14), *fittings* (3.10), valves and bellows, which are exposed to, and structurally designed largely by, the acting pressure

Note 1 to entry: The term “pressure system” does not include electrical or other control devices required for system operations.

**3.22****proof factor**

multiplying factor applied to the *limit load* (3.13) or *MEOP* (3.17) (or *MDP* (3.16)) to obtain proof load or *proof pressure* (3.23) for use in the acceptance testing

**3.23****proof pressure**

product of *MEOP* (3.17) (or *MDP* (3.16)) and a *proof factor* (3.22)

Note 1 to entry: The proof pressure is used to provide evidence of satisfactory workmanship and material quality and/or to establish maximum initial flaw sizes for *damage tolerance* (3.5) life (safe-life) demonstration.

**3.24****scatter factor**

multiplying factor to be applied to the number of load/pressure cycles, for the purpose of covering the scatters that potentially exist in the material's fatigue or crack growth data

**3.25****service life**

period of time (or cycles) that starts with item inspection after manufacturing and continues through all testing, handling, storage, transportation, launch operations, orbital operations, refurbishment, re-testing, re-entry or recovery from orbit, and reuse that can be required or specified for the item

[SOURCE: ISO 10786:2011, 3.56]

**3.26****safety-critical**

any condition, event, operation, process, equipment or system with a potential for personnel injury, fatality or damage to, or loss of, equipment or property

[SOURCE: ISO 14625:2007, 3.1.6, modified — The term has been changed from "safety critical" to "safety-critical".]

**4 Abbreviated terms**

For the purposes of this document, the following abbreviated terms apply.

NDI non-destructive inspection

QA quality assurance

**5 General requirements****5.1 General**

This clause presents the general requirements for a pressure system and pressure components in a pressure system regarding

— design and analysis,

- material selection and characterization,
- fabrication and process control,
- quality assurance (QA),
- operation and maintenance (including repair and refurbishment), and
- storage.

The general requirements for a pressure system are presented in [Clause 6](#). The integration requirements for specific pressure systems are presented in [Clause 7](#).

## 5.2 Design requirements

### 5.2.1 Loads, pressures and environments

The anticipated load-pressure-temperature history and other associated environments throughout the service life of the pressure system shall be determined in accordance with specified mission requirements. As a minimum, the following factors and their statistical variations shall be considered appropriately:

- a) environmentally induced loads and pressures;
- b) environments acting simultaneously with these loads and pressures with their proper relationships;
- c) frequency of application of these loads, pressures and environments, and their levels and durations.

These data shall be used to define the design load/loading spectrum, which shall be used for both design analysis and testing. The design loading spectrum shall be revised as the structural design develops and the loads analysis matures.

### 5.2.2 Strength

Pressure components and their interconnections in a pressure system shall possess sufficient strength to withstand limit loads and MEOP in the expected operating environments throughout the service life without incurring detrimental deformation. The pressure components shall sustain proof pressure without leaking or incurring detrimental deformation. They shall also withstand ultimate loads and design burst pressure in the expected operating environments without rupturing or collapsing.

The minimum proof factor for pressure components shall be 1,5. The minimum design burst factor varies depending on the type of pressure component. [Table A.1](#) presents recommended minimum proof factors and design burst factors for various pressure components.

A pressure system shall possess sufficient strength at the component interfaces, attachments, tie-downs and other critical points. The pressure system shall sustain proof pressure without experiencing leakage and incurring detrimental deformation.

### 5.2.3 Stiffness

The mounting and arrangement of all components in a pressure system shall provide adequate stiffness not to generate destructive vibration, shock and acceleration, and to prevent excess stresses at the interfaces between components and at mounting brackets when subjected to limit loads, MEOP and deflections of the supporting structures in the expected operating environments. Connections between adjacent components shall be designed to prevent excessive stresses at their interfaces from combined effects of limit loads, MEOP and deflections of the supporting structures in the expected operating environments.

#### 5.2.4 Thermal effects

Thermal effects, including heating and cooling rates, temperatures, thermal gradients, thermal stresses and deformations, and changes with temperature of the physical and mechanical properties of the material of construction, shall be factored into the design of the flight pressure system. Thermal effects shall be based on temperature extremes that simulate those predicted for the operating environment, plus a predefined design margin. The design margin shall be based on national industry heritage, including experience in thermal effects that are important to a specific pressure component.

#### 5.2.5 Stress analysis

A detailed stress analysis shall be performed on the pressure components and assembled and installed pressure system to demonstrate acceptable stress levels and deflections at the interfaces between components, at component attachments and tie-downs to support structures, and at other critical points in the system. The effects of flexure of lines, as well as supporting structures being acted on by the flight loads, pressures and temperature and thermal gradients, shall be accounted for in the analysis. The stress analysis shall also take into account the ground loads.

#### 5.2.6 Fatigue analysis/damage tolerance (safe-life) analysis

In addition to the stress analysis, conventional fatigue-life analysis shall be performed, as appropriate, on the pressure component and the assembly. Nominal (average) values of fatigue-life (S-N) data shall be used in the analysis. A scatter factor of four shall be used on service life as specified in ISO 14623. In some cases, fatigue analysis shall be replaced by damage tolerance (safe-life) analysis in accordance with ISO 21347.

#### 5.2.7 Analysis of survivability against space debris and meteoroid impacts

In accordance with ISO 24113, during the design and integration of a pressure system an impact risk analysis shall be performed to calculate the probability that a space debris or meteoroid impact will cause the pressure system to fail in such a way that a break-up occurs.

NOTE 1 It is possible to improve the survivability of a pressure system by shielding pressure components and positioning them so that they are not exposed directly to a high flux of impacts from space debris or meteoroids.

NOTE 2 This requirement is normally performed as a design analysis by the developer of the space system equipped with the pressure system to verify the validity of the space-debris shield placed to protect the pressure system. Based on this analysis, the design and integration of the pressure system takes into account the interface requirements with the space debris shield that space system is equipped with.

#### 5.2.8 Avoidance of accidental break-up caused by an on-board source of energy

In addition to the requirements in [Clauses 5, 6 and 7](#), the design and integration of the pressure system shall meet the project unique requirements which are derived from the specific requirements of ISO 24113 associated with avoiding “accidental break-up caused by an on-board source of energy”.

NOTE 1 ISO 24113 specifies requirements relating to the avoidance of “accidental break-up caused by an on-board source of energy”. The developer of the space systems equipped with the pressure systems can add the project unique requirements to the pressure system as needed to comply with ISO 24113 in this regard, based on the requirements analysis to the space system.

NOTE 2 The accidental break-up of the space system, either after the disposal manoeuvre or before re-entry, can be mitigated as needed by the implementation of design measures in the pressure system, such as:

- a) a function to discharge the residual energy source in the pressure system, at an appropriate time, in the event that the planned re-entry of the space system cannot be performed or the propellant cannot be used up in the disposal operation of the space system;
- b) an architecture which, in the event some parts fail, does not cause any mixing and combustion of the propellant in a the two-liquid propellant tank and piping system, especially in the case of a combination of self-igniting propellants;

- c) safe measures to minimise the risk of explosion or rupture in the event that the residual energy source cannot be discharged.

## 5.3 Material requirements

### 5.3.1 Metallic materials

#### 5.3.1.1 General

Metallic materials used in the assembly and installation of pressurized system components shall be selected, evaluated and characterized to ensure all system requirements are met.

#### 5.3.1.2 Metallic material selection

Metallic materials shall be selected on the basis of proven environmental compatibility, material strength and fatigue characteristics. Unless otherwise specified, A-basis allowable materials shall be used in any application where failure of a single load path would result in loss of structural integrity to any part of the pressurized system. For applications where failure of a redundant load path would result in a safe redistribution of applied loads to other load-carrying members, B-basis allowable materials may be used.

#### 5.3.1.3 Metallic material evaluation

The selected metallic materials shall be evaluated with respect to material processing, fabrication methods, manufacturing operations, refurbishment procedures and processes, and other factors that affect the resulting strength and fracture properties of the material in the fabricated as well as the refurbished configurations.

The evaluation shall ascertain whether the mechanical properties, strengths and fatigue properties used in design and analyses will be realized in the actual hardware and verify that these properties are compatible with the fluid contents and the expected operating environments. Materials that are susceptible to stress-corrosion cracking or hydrogen embrittlement shall be evaluated by performing sustained load fracture tests when applicable data are not available.

#### 5.3.1.4 Metallic material characterization

The allowable mechanical and fatigue properties of all selected metallic materials shall be obtained from reliable sources approved by the procuring authority. Where material properties are not available, they shall be determined by test methods approved by the procuring authority.

### 5.3.2 Non-metallic material requirements

Non-metallic materials used in the pressure components and the assembly and installation of flight pressure components shall be selected, evaluated and characterized to ensure their suitability for the intended application.

## 5.4 Fabrication and process requirements

Proven processes and procedures for fabrication and repair shall be used to preclude damage or material degradation during material processing, manufacturing operations and refurbishment. Special attention shall be given to ascertaining whether the melting, welding, bonding, forming, joining, machining, drilling, grinding, repair operations and other processes applied to joining system components and hardware and attaching mounting hardware are within the state of the art and have been used on similar hardware.

The mechanical and physical properties of the parent materials, weld joints and heat-affected zones shall be within established design limits after exposure to the intended fabrication processes. The machining, forming, joining, welding, dimensional stability during thermal treatments and through-

thickness hardening characteristics of the material shall be compatible with the fabrication processes encountered.

Special precautions shall be exercised throughout the manufacturing operations to guard against processing damage or other structural degradation.

Bonding, clamping and joining at the interfaces and mountings of the flight pressure systems shall be controlled to ensure that all requirements are met.

## 5.5 Contamination control and cleanliness requirements

### 5.5.1 General contamination control requirements

Required levels of contamination control shall be established by the actual cleanliness needs and the nature of the flight pressure system and its components. Contamination includes solid, liquid and gaseous material unintentionally introduced into the system. General contamination control requirements are as follows:

- a) protection from contaminants shall be provided by adequate filtration, sealed modules, clean fluids and a clean environment during assembly, storage, installation and use;
- b) the design shall allow for verification that the lines and other components are clean after flushing and purging; and
- c) the design shall ensure that contaminants and waste fluids can be flushed and purged.

### 5.5.2 Design considerations

The following considerations shall be factored into the design of flight pressure systems to minimize and effectively control contamination:

- a) contamination shall be minimized from entering or developing within the system;
- b) the system shall be designed to include provisions to detect contamination;
- c) the system shall be designed to include provisions for removal of contamination and provisions for initial purge with fluid or gas that will not degrade future system performance;
- d) the system shall be designed to be tolerant of contamination;
- e) all pressurizing fluids entering the system shall be appropriately filtered before entering the system, to conform with the requirements derived from the property of the downstream components in the system (unless otherwise specified, a 10  $\mu\text{m}$  filter, or finer, should be applied);
- f) all pressure systems shall have fluid filters in the system, designed and located to reduce the flow of contaminant particles to a safe minimum;
- g) all of the circulating fluid in the system shall be filtered downstream from the pressure pump, or immediately upstream from safety-critical actuators;
- h) entrance of contamination at test points or vents shall be minimized by downstream filters;
- i) the bypass fluid or case drain flow on variable displacement pumps shall be filtered; and
- j) when the clogging of small orifices can cause a hazardous malfunction or failure of the system, each orifice shall be protected by a filter element (including servo valves) designed to prevent clogging.

## 5.6 Quality assurance programme requirements

### 5.6.1 General

A quality assurance (QA) programme shall be established to ensure that the product and engineering requirements, drawings, material specifications, process specifications, workmanship standards, design review records, failure mode analysis, non-destructive inspection (NDI) and acceptance tests are effectively used, such that the completed flight pressure system meets its specified requirements.

The programme shall ensure

- that materials, parts, subassemblies, assemblies and all completed and refurbished hardware conform to applicable drawings and process specifications,
- that no damage or degradation has occurred during material processing, fabrication, inspection, acceptance tests, shipping, storage, operational use and refurbishment, and
- that defects which can cause failure are detected, evaluated and corrected.

### 5.6.2 QA programme inspection plan requirements

An inspection master plan shall be established prior to the start of system assembly and installation for the first flight article or qualification test model. The plan shall specify appropriate inspection points and inspection techniques for use throughout the programme, beginning with material procurement and continuing through fabrication, assembly, acceptance testing, operation and refurbishment, as appropriate. In establishing inspection points and inspection techniques, consideration shall be given to the material characteristics, fabrication processes, design concepts and structural configuration. Acceptance and rejection criteria shall be established as part of the plan for each phase of inspection and for each type of inspection.

### 5.6.3 QA inspection technique requirements

Inspections shall include both visual inspection with appropriate magnification and NDI, as necessary.

### 5.6.4 QA inspection data requirements

As a minimum, inspection data shall be dealt with as follows:

- a) inspection data, in the form of flaw histories, shall be maintained throughout the life of the flight pressure system;
- b) these data shall be reviewed and assessed periodically to evaluate trends and anomalies associated with the inspection procedures, equipment, personnel, material characteristics, fabrication processes, design concept and structural configuration; and
- c) the result of this assessment shall form the basis of any required corrective action.

### 5.6.5 Acceptance test requirements

#### 5.6.5.1 General

Prior to first use, all newly assembled flight pressurized systems shall pass, in the following order,

- a proof pressure test,
- a leak test,
- a grounding test, and
- a functional test.

This test sequence shall be repeated after the system's arrival at the launch processing facility. In repeated test sequence after the system's arrival at the launch processing facility, a proof pressure test may be excluded when the structural integrity of the pressure system after system's arrival are sufficiently assured by the proof pressure test performed before the system transportation to the launch processing facility.

### 5.6.5.2 Proof pressure test requirements

The flight pressure system shall be tested at the system-level proof pressure prior to first use. For systems with zones operating at different pressures, each zone shall be tested to its proof pressure level. Proof pressure testing shall demonstrate whether the flight pressure system will sustain proof pressure without distortion, damage, leakage or loss of functionality. The system-level proof pressure tests can be excluded when there is sufficient successful experience and all the components have been proof-tested at the component level. The exclusion of system-level proof pressure tests shall be approved by the procuring authority.

### 5.6.5.3 Leak test requirements

The flight pressure system shall be leak-tested at the system MEOP prior to first use. For systems with zones operating at different pressures, each zone shall be at its MEOP for the leak test. The gas used during the leak test shall be the same as the system operating fluid to the extent possible. Gas with higher permeability and reliable leakage detection is allowed as the replacement. For the systems or zones intended to be filled with a liquid, a suitable leak check gas shall be used. For systems intended to operate with hazardous fluids, a non-hazardous gas may be substituted. All mechanical connections, gasketed joints, seals, weld seams and other items susceptible to leakage shall be tested. The leak rates through fill and drain valves, thruster valves and pressure relief valves shall be measured and verified within specification. Any method demonstrated capable of detecting and/or measuring leakage is acceptable.

## 5.7 Qualification test requirements

Internal/external pressure testing shall be conducted on all pressure components to demonstrate no failure at the design burst pressure. [Annex A](#) presents recommended minimum design burst factors for various pressure components.

## 5.8 Operation and maintenance requirements

### 5.8.1 Operating procedure

Operating procedures shall be established for the pressurized system, taking into account the safety requirements and personnel control requirements at the facility where the operations are conducted. Step-by-step directions shall be written with sufficient detail to allow a qualified technician or mechanic to accomplish the operations. Schematics that identify the location and pressure limits of all components and their interconnections into a system shall be included in the procedure or shall be available at the time it is running. Prior to initiating or performing a procedure involving hazardous operations with flight pressure systems, practice runs shall be conducted on non-pressurized systems until the operating procedures are well rehearsed. Initial tests shall then be conducted at pressure levels not in excess of 50 % of the normal operating pressures until operating characteristics can be established and stabilized. Only qualified and trained personnel shall be assigned to work on, or with, high-pressure systems. Warning signs identifying the hazards shall be posted at the operations facility prior to pressurization.

### 5.8.2 Safe operating limits

Safe operating limits shall be established based on the pressure capabilities of all components and the effects of assembly into a completed system. For flight pressure systems with several zones operating at different pressure levels, safe operating levels shall be established for each zone. The safe operating

limits shall be summarized in a format that will provide rapid visibility of the important structural characteristics and capability of the flight pressure system.

### 5.8.3 Inspection and maintenance

The results of the stress analysis (see 5.2.5) and the fatigue life or damage tolerance (safe-life) analysis (see 5.2.6) shall be used in conjunction with the appropriate results from the structural development and qualification tests to develop a quantitative approach to inspection and repair. The allowable damage limits for each component of the flight pressure system shall be used to establish the required inspection interval and repair schedule in order to maintain the hardware to the requirements of this document. NDI methods and inspection procedures to reliably detect defects and determine flaw size under the condition of use shall be developed for use in the field and depot levels, as appropriate. Procedures shall be established for recording, tracking and analysing operational data as they are accumulated in order to identify critical areas requiring corrective actions. Analyses shall include prediction of remaining life and reassessment of required inspection intervals.

### 5.8.4 Repair and refurbishment

When inspections reveal structural damage or defects exceeding the permissible levels, the damaged hardware shall be repaired, refurbished or replaced, as appropriate. All repaired or refurbished flight pressure systems shall be recertified in accordance with 5.8.8 after each repair and refurbishment, by means of the applicable acceptance test procedure for new hardware, in order to ensure their structural integrity and to establish their suitability for continued service.

### 5.8.5 Storage

A flight pressure system put into storage shall be protected against exposure to environments that can cause corrosion or other forms of material degradation. It shall be protected against mechanical degradation resulting from scratches, dents or accidental dropping of the hardware. Induced stresses caused by storage fixture constraints shall be minimized by suitable storage fixture design. In the event that storage requirements are violated, recertification specified in 5.8.8 shall be required prior to return to use.

### 5.8.6 Documentation

Inspection, maintenance and operation records shall be kept and maintained throughout the life of the flight pressure system. As a minimum, the records shall contain the following information:

- a) temperature, pressurization history and pressurizing fluid for both tests and operations;
- b) number of pressure cycles experienced, as well as number of pressure cycles allowed in safe-life analysis;
- c) results of any inspection conducted, including inspector, inspection dates, inspection techniques employed, location and character of defects, and defect origin and cause; this shall include inspection made during fabrication;
- d) storage condition;
- e) maintenance and corrective actions performed from manufacturing to operational use, including refurbishment;
- f) sketches and photographs to show areas of structural damage and extent of repairs;
- g) acceptance and recertification tests performed, including test conditions and results; and
- h) analyses supporting the repair or modification that may influence future-use capability.

### 5.8.7 Reactivation

A flight pressure system reactivated for use after a period in an unknown, unprotected or unregulated storage environment shall be recertified according to 5.8.8 in order to ascertain its structural integrity, functionality and suitability for continued service before reuse.

### 5.8.8 Recertification

#### 5.8.8.1 Requirements

Any flight pressure system requiring recertification prior to return to service shall meet the following requirements:

- a) the documentation of affected components or portions of the flight pressure system shall be reviewed to establish the last known condition;
- b) the pressure system shall be inspected and subjected to appropriate NDI to detect any previously unknown flaws;
- c) the pressure system shall pass all the acceptance test requirements for new systems in accordance with 5.6.5.

#### 5.8.8.2 Test after limited modification and repair

If any system elements, such as valves, regulators, gauges or tubing, have been disconnected or reconnected for any reason, the affected system or subsystem shall be leak-tested in accordance with 5.6.5.3 as a minimum. For more extensive modifications or repairs that may affect its ability to meet the requirements of this document or its required functions, the flight pressure system shall meet the full recertification requirements in accordance with 5.8.8.

## 6 General pressurized-system requirements

### 6.1 System analysis requirements

#### 6.1.1 System pressure analysis

A thorough analysis of the pressure system shall be performed to establish the correct MEOP, leak rates, etc. for each pressure component. The effects of the operating parameters of each component on the MEOP shall be determined. When applicable, pressure regular lock-up characteristics, valve actuation and water hammer shall be considered for the entire service life of the pressure system.

NOTE Throughout this document, limit load and MEOP are used as the baseline load and pressure. The terms MAWP, MOP and MDP are used when required to replace MEOP in a specific application.

#### 6.1.2 System functional analysis

A detailed system functional analysis shall be performed to determine whether the operation, interaction and sequencing of components within the pressure system

- are capable of supporting all required actions, and
- do not lead to damage to flight hardware or ground support equipment.

The analysis shall identify all possible hardware malfunctions, software errors and personnel errors in the operation of any component that may create conditions leading to an unacceptable risk to operating personnel or equipment. The analysis shall evaluate any secondary or subsequent occurrence, failure, component malfunction or software errors initiated by a primary failure, which can result in an unacceptable risk to operating personnel or equipment.

The analysis shall also show that:

- a) all pressures are maintained at safe levels in the event of a process or control sequence being interrupted at any time during test or countdown;
- b) redundant pressure relief devices have mutually independent pressure escape routes during all stages of operation;
- c) when the hazardous effects of safety-critical failures or malfunctions are prevented through the use of redundant components or systems, all such redundant components or systems shall be operational prior to the initiation of irreversible portions of safety-critical operations or events.

### **6.1.3 System hazard analysis**

A system hazard analysis shall be performed on all hazardous pressure system components to identify hazards to personnel and facilities. All prelaunch and launch operations and conditions shall be included in the analysis. The results of the system functional analysis shall be used in the system hazard analysis to ensure that all operations and configurations are considered in the system hazard analysis.

Hazards identified by the analysis shall be designated safety-critical and shall be mitigated by one or more of the following methods:

- a) design modifications to eliminate the hazard;
- b) operating restrictions to minimize personnel exposure during hazardous periods;
- c) specific hazard identification and procedural restrictions to avoid hazardous configurations; or
- d) special safety supervision during hazardous operations and systems configurations.

## **6.2 Design features**

### **6.2.1 Assembly**

Components shall be designed so there is enough clearance to permit assembly of the components without damage to the O-rings or backup rings where they pass threaded parts or sharp corners.

### **6.2.2 Routing**

Straight tubing and piping runs between two rigid connection points shall be avoided. Where such straight runs are necessary, provision shall be made for expansion joints, motion of the units or similar compensation in order to ensure that no excessive strains are applied to the tubing and fittings. Line bends shall be used to ease stresses induced in tubing by alignment tolerance and vibration.

### **6.2.3 Separation**

Redundant pressure components and systems shall be physically separated for maximum advantage in case of damage or fire.

### **6.2.4 Shielding**

Pressurized systems shall be shielded from other systems, when required, to minimize all hazards caused by proximity to combustible gases, heat sources, electrical equipment, etc. Any failure in any such adjacent system shall not result in combustion or explosion of pressure fluids or components. Lines, drains and vents shall be shielded or separated from other high-energy systems, such as heat, high voltage, combustible gases and chemicals. Drain and vent lines shall not be connected to any other lines in any way that can expose hazardous substances to the components being drained or vented. Pressure fluid reservoirs shall be shielded or isolated from combustion apparatus and their heat sources.

### 6.2.5 Grounding

Lines and other components in a hydraulic system shall be electrically grounded to metallic structures.

### 6.2.6 Handling

Fixtures for safe handling and hoisting with coordinated attachment points in the system structure shall be provided.

### 6.2.7 Special tools

Safety-critical pressurized systems shall be designed so that special tools are not required for removal and replacement of components, unless it can be shown that the use of special tools is unavoidable.

### 6.2.8 Test points

Test points, when required, shall be provided so that disassembly for test is not needed. The test points shall be easily accessible for attachment of ground test equipment.

### 6.2.9 Common-plug test connectors

Common-plug test connectors for pressure and return sections shall be designed to have positive indication of the removal of the pressure connection prior to unsealing the return connections.

### 6.2.10 Individual test connectors

Individual test connectors for pressure and return sections shall be designed to prevent inadvertent cross-connections.

### 6.2.11 Threaded parts

All threaded parts in safety-critical components shall be securely locked to resist uncoupling forces by acceptable safe-design methods. Safety wiring and self-locking nuts are examples of acceptable safe design. Torques for threaded parts in safety-critical components shall be specified.

### 6.2.12 Friction-type locking devices

Friction-type locking devices shall be avoided in safety-critical applications. Star washers and jam nuts shall not be used as locking devices.

### 6.2.13 Internally threaded bosses

The design of internally threaded bosses shall preclude the possibility of damage to the component or the boss threads caused by screwing universal fittings to excessive depths in the bosses.

### 6.2.14 Retainer or snap rings

Retainer or snap rings shall not be used in pressurized systems where failure of the ring would allow connection failures or blowouts caused by internal pressure.

### 6.2.15 Snubbers

Snubbers shall be used with all bourdon-type pressure transmitters, pressure switches and pressure gauges, except air pressure gauges.

## 6.3 Component selection

### 6.3.1 Connections

Pressure components shall be selected to ensure that hazardous disconnections or reverse installations within the subsystem are not possible. Colour codes, labels and directional arrows are not acceptable as the primary means for preventing incorrect installation.

### 6.3.2 Fluid temperature

The maximum fluid temperature shall be estimated early in design as part of the data for selection of safety-critical components, such as system fluid, pressurizing gas, oil coolers and gaskets.

### 6.3.3 Actuator pressure rating

It shall be specified that components are capable of safe actuation under a pressure equal to the maximum relief valve setting in the circuit in which they are installed.

### 6.3.4 Pressure rating

Pumps, valves/regulators, hoses and all such prefabricated components of a pressure system shall have proven load/pressure ratings equal to, or higher than, the limit load, MEOP and rated service life of the system.

### 6.3.5 Pump selection

Appropriate national standards shall be applied in evaluating safety in pump selection.

### 6.3.6 Fracture and leakage

Where leakage or fracture is hazardous to personnel or critical equipment, design shall ensure that failure occurs at the outlet threads of valves before the body or the valve or the inlet threads fail under pressure.

### 6.3.7 Oxygen system components

Valves and other pressure components for oxygen systems of at least 20,7 MPa and which are slow-opening and slow-closing types shall be used to minimize the potential for ignition of contaminants. Such systems shall also require preventing from build-up of static electrical charges.

### 6.3.8 Pressure regulators

Pressure regulators destined to operate in the centre 50 % of their total pressure range shall be selected to avoid creep and inaccuracies at either end of the full operating range.

### 6.3.9 Manual valves and regulators

Manually operated valves and regulators shall be designed so that overtorque of the valve stem or regulator adjustment cannot damage soft seats to the extent that failure of the seat will occur as a result. Valve designs that use uncontained seats are not acceptable.

## 6.4 Design pressures

### 6.4.1 Overpressure or underpressure

Warning devices to indicate hazardous overpressure or underpressure to operating personnel shall be specified. These devices shall actuate at predetermined pressure levels designed to allow time for corrective action.

### 6.4.2 Back-pressure

Safety-critical actuation of pneumatic systems shall not be adversely affected by any back pressure resulting from concurrent operations of any other parts of the system under any set of conditions.

### 6.4.3 Pressure isolation

Pressure components that can be isolated and contain residual pressure shall be equipped with gauge reading and bleed valves for pressure safety checks. Bleed valves shall be directed away from operating personnel. Fittings or caps for bleeding pressure are not acceptable.

### 6.4.4 Gas/fluid separation

Pressurized reservoirs which are designed for gas/fluid separation with provision to entrap gas that may be hazardous to the system or safety-critical actuation and prevent its recirculation in the system shall be specified. This shall include the posting of instructions adjacent to the filling point for proper bleeding when servicing.

### 6.4.5 Compressed-gas bleeding

Compressed-gas emergency systems shall be bled directly to the atmosphere, away from the vicinity of personnel, rather than to the reservoir.

## 6.5 Mechanical-environment design

### 6.5.1 Acceleration and shock loads

All lines and other components shall be installed to withstand all expected acceleration and shock loads. Shock isolation mounts may be used, if necessary, to eliminate destructive vibration and interference collision.

### 6.5.2 Torque loads

Components, including valves, shall be mounted on structures having sufficient strength to withstand torque and dynamic loads. Only lightweight components that do not require adjustment after installation may be supported by the tubing, provided that a tube clamp is installed on each tube near the other component.

### 6.5.3 Vibration loads

Tubing shall be supported by cushioned steel tube clamps or by multiblock-type clamps that are suitably spaced to restrain destructive vibration loads.

## 6.6 Controls

### 6.6.1 Interlocks

Interlocks shall be used wherever necessary to prevent a hazardous sequence of operations and provide fail-safe capability at all times.

### 6.6.2 Multiple safety-critical functions

Pressure systems that combine several safety-critical functions shall have sufficient controls for isolating failed functions so that remaining functions can be operated safely.

### 6.6.3 Critical flows and pressures

Pressure systems shall have pressure-indicating devices to show safe upper and lower limits of the system pressure. The pressure indicators shall be readily visible to the operating crew.

## 6.7 Protection

Unless otherwise specified, all systems for pressure above 3,45 MPa in all areas where damage or other operational hazards can occur during servicing shall be protected. Hazardous piping line routes that invite use of handholds or climbing bars shall be avoided. Pressure lines and other components of at least 3,45 MPa and which are adjacent to safety-critical equipment shall be shielded to protect such equipment in the event of leakage or burst of pressure systems.

## 6.8 Electrical

### 6.8.1 Hazardous atmospheres

Electric components for use in potentially ignitable atmospheres shall be demonstrated to be incapable of causing an explosion in the intended application.

### 6.8.2 Radio frequency energy

Electrically energized hydraulic components shall not propagate radio frequency energy that is hazardous to other subsystems in the total system, or that interferes in the operation of safety-critical electronic equipment.

### 6.8.3 Grounding

Pressure system components, including lines to metallic structures, shall be electrically grounded.

### 6.8.4 Solenoids

All solenoids shall be capable of safely withstanding a specified test voltage, cycles and duration between terminals and case at the maximum operating temperature of the solenoid in the functional envelope. Unless otherwise specified, a test should be performed under a test voltage of no less than 1 500 V(r.m.s.) at 60 cycles per second for 1 min.

### 6.8.5 Electric motor-driven pumps

Electric motor-driven pumps used in safety-critical systems shall not be used for ground test purposes unless the motor is rated for reliable, continuous and safe operation.

## 6.9 Pressure relief

### 6.9.1 General requirements

Pressure relief devices shall be specified on any system having a pressure source that can exceed the MEOP of the system, or where the malfunction/failure of any component can cause the MEOP to be exceeded.

Relief devices are required downstream of all regulating valves and orifice restrictors unless the downstream system is designed to accept full source pressure. On space systems where operational or

weight limitations preclude the use of relief valves and where systems will operate in an environment not hazardous to personnel, relief valves may be omitted if the ground or support system contains such devices which cannot be isolated from the airborne system during the pressurization cycle and that the space system cannot provide its own protection.

### 6.9.2 Flow capacity

All pressure relief devices shall provide relief at full flow capacity at 110 % of the MEOP of the system or lower.

### 6.9.3 Sizing

The size of pressure relief devices shall be specified to withstand specified maximum pressure and flow capacities of the pressure source in order to prevent pressure exceeding 110 % of the MEOP of the system.

### 6.9.4 Unmanned flight vehicle servicing

Where it is around a system that is specifically designed to service an unmanned flight vehicle, pressure relief protection may be provided within the ground equipment if no capability exists to isolate the pressure relief protection from the flight vehicle during the pressurization cycle.

### 6.9.5 Automatic relief

#### 6.9.5.1 Low safety factor

Where safety factors of less than 2,0 are used in the design, means of automatic relief, depressurization and pressure verification of safety-critical vessels shall be provided in the event of launch abort.

#### 6.9.5.2 Confinement

Whenever any pressure volume can be confined and/or isolated, an automatic pressure relief device shall be provided, e.g. pop-valves, rupture discs, blowout plugs, armouring and construction, to contain the greatest possible overpressure that may develop.

### 6.9.6 Venting

Pressure relief devices for toxic or inert gases shall be vented to safe areas or scrubbers, away from the vicinity of personnel.

### 6.9.7 Relief valve isolation

Shutoff valves for the purpose of maintenance on the inlet side of pressurized relief valves are permissible if a means for monitoring and bleeding trapped pressure is provided and the provisions of [6.3](#) are met. The valve shall be locked open when the system is repressurized.

### 6.9.8 Negative-pressure protection

#### 6.9.8.1 Testing

Hydrostatic testing systems for vessels that are not designed to sustain negative internal pressure shall be equipped with fail-safe devices for relief of hazardous negative pressure during the period of fluid removal. Check valves and valve interlocks are examples of devices that can be used for this purpose.

### 6.9.8.2 Storage and transportation

Thin-wall vessels that can be collapsed by a negative pressure shall have negative pressure relief and/or prevention devices for safety during storage and transportation.

### 6.9.9 Reservoir pressure relief

Pressurized reservoirs shall be so designed that ullage volume is connected to a relief valve that shall protect the reservoir and power pump from hazardous overpressure or back pressure of the system.

### 6.9.10 Air pressure control

The air pressure control for pressurized reservoirs shall be an externally non-adjustable pressure-regulating device. If this unit also contains a reservoir pressure relief valve, the unit shall be so designed that no failure in the unit will permit over-pressurization of the reservoir.

## 6.10 Control devices

### 6.10.1 Directional control valves

Safety-critical pressure systems shall be designed to incorporate two or more directional control valves to preclude the possibility of inadvertently directing the flow or pressure from one valve into the flow or pressure path intended for another valve, with any combination of valve settings possible in the total system.

### 6.10.2 Overtravel

Control devices shall be designed to prevent overtravel or undertravel that may contribute to a hazardous condition or damage to the valve.

### 6.10.3 Pressure and volume control stops

All pressure and volume controls shall have stops, or an equivalent device, to prevent setting outside their nominal safe working range.

### 6.10.4 Manually operated levers

Integrated, manually operated levers and stops shall be capable of withstanding the limit torques shown in [Table 1](#). Other limits can be specified if approved by the procuring authority.

**Table 1 — Limit design torque for levers**

Lever radius <i>R</i> mm	Design torque N·m
$R < 76,2$	$0,223 \times R$
$76,2 \leq R < 152,4$	$0,334 \times R$
$152,4 \leq R$	$0,668 \times R$

## 6.11 Accumulators

### 6.11.1 Accumulator design

Accumulators shall be designed in accordance with the pressure vessel standards for ground systems and shall be located for minimal probability of mechanical damage and for minimum escalation of material damage or personnel injury in the event of a major failure such as vessel rupture.