International Standard

ISO 10785

Space systems — Bellows — Design and operation

Systèmes spatiaux — Soufflets — Conception et fonctionnement

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Foreword

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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 document 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).

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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.

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 10785:2011), which has been technically revised.

The main changes are as follows:

— clarification of the Scope;

— updates of the normative references and their citations in the text;

— updates of the terms and definitions to harmonize with the other ISO structural related standards;

— harmonization of requirements with ISO 24638 and ISO 21347.

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.

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Introduction

The bellows for space systems is usually used under severe conditions, such as high pressure, extremely low temperatures, large deflection, or high inner flow speed. The design safety factor of the bellows tends to be small to satisfy two different function requirements simultaneously. One is the function of the pressure bearing component, which all pressure components have; and the other is the special function to accommodate installation misalignment, thermal expansion or contraction and displacement induced by large deformation of the pressurized propellant tank.

There are many items to be considered for design and manufacture such as hoop stress, bulging stress, buckling strength, flow-induced vibration, and cyclic deflection.

This document aims to ensure safe and reliable bellows hardware and operations.

Some examples of the design safety factors are shown in Annex A.

The requirements in this document are not intended to be different from the requirements also applicable for bellows included in ISO 24638.

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Space systems — Bellows — Design and operation

1 Scope

This document specifies general and detailed requirements for bellows used in space systems. It establishes requirements regarding material, design, analysis, fabrication, material, testing, inspection, and operation for space use.

This document is applicable to metallic bellows which are used as pressure bearing components and are integrated into a pressure system. This document is not applicable to engine bellows or valve bellows.

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 24638, *Space systems — Pressure components and pressure system integration*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
acceptance test
required formal test conducted on flight hardware to ascertain that the materials, manufacturing processes and workmanship meet specifications and that the hardware is acceptable for intended usage

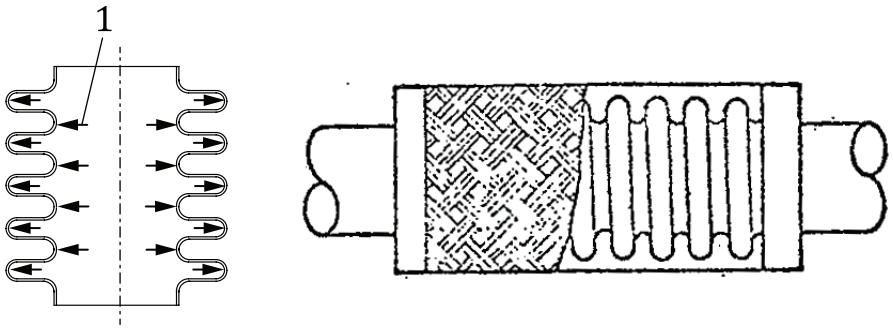
[SOURCE: ISO 14623:2003, 2.2]

3.2
bellows
corrugated single-layer or multi-layer elastic casing, when integrated into a duct assembly, capable of performing linear, shear and angular movements

Note 1 to entry: A bellows consists of both a convolution section and a *mechanical linkage section* (3.23), which serves as a bellows restraint. The most common mechanical linkage types are gimbal-type and braided-type. In some cases, a bellows contains an internal liner or flow tube for the purpose of improving flow capability.

Note 2 to entry: See Figure 1.

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Key
1 internal pressure

Figure 1 — Bellows

3.3
bellows stiffness
ratio between an applied force and the resulting *bellows* (3.2) displacement

3.4
bulging stress
meridional or axial stress at the convolution section induced by pressure

3.5
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: ISO24638:2021, 3.4]

3.6
damage tolerance life
safe life
<methodologies>

design criterion under which failure due to the presence of *flaws* (3.15) does not occur in the expected environment during the *service life* (3.29)

Note 1 to entry: In this design criterion, a *flaw* (3.15) is assumed consistent with the inspection process specified and it is shown that the largest undetected flaw that can exist in the structure will not grow to failure in durations multiplying *life factors* (3.19) to service lifetimes when subjected to the cyclic and sustained loads in the environments encountered.

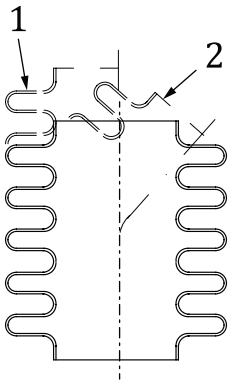
3.7
damage tolerance life
safe life
<time span>

required period during which a structural item, even containing the largest undetected *flaw* (3.15), is shown by analysis or testing not to fail catastrophically under the expected service load and environment

3.8
deflection
contraction or expansion along its longitudinal axis, angular rotation, or lateral offset

Note 1 to entry: See Figure 2.

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Key

1	axial deflection
2	angular rotation

Figure 2 — Deflection

3.9
design burst factor
multiplying factor applied to *maximum expected operating pressure (MEOP)* (3.22) or *maximum design pressure (MDP)* (3.21) to obtain the *design burst pressure* (3.10)

3.10
design burst pressure
burst pressure
differential pressure that pressurized hardware must withstand without bursting in the applicable operational environment

Note 1 to entry: Design burst pressure is equal to the product of the *maximum expected operating pressure (MEOP)* (3.22) or *maximum design pressure (MDP)* (3.21) and a *design burst factor* (3.9).

[SOURCE: ISO 24638:2021,3.7]

3.11
design safety factor
safety factor
design factor of safety
factor of safety
multiplying factor to be applied to *limit loads* (3.20) and/or *maximum expected operating pressure (MEOP)* (3.22)

Note 1 to entry: The factor is defined in order to account for the statistical variations of loads and structural strength, and inaccuracies in the knowledge of their statistical distributions.

Note 2 to entry: In this definition, the word *maximum expected operating pressure (MEOP)* (3.22) may be replaced by *maximum design pressure (MDP)* (3.21).

[SOURCE: ISO 24638:2021, 3.8, modified — "or maximum design pressure (MDP)" has been removed, and Note 1 and Note 2 to entry have been added.]

3.12
detrimental deformation
structural deformation, deflection or displacement that prevents any portion of the structure or other system from performing its intended function or that jeopardizes mission success

[SOURCE: ISO 24638:2021, 3.9]

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3.13
fatigue
process of progressive localized permanent structural change occurring in a material/structure subjected to conditions which produce fluctuating stresses and strains at some point or points and which may culminate in cracks or complete *fracture* (3.16) after a sufficient number of fluctuations

[SOURCE: ISO 14623:2003, 2.23]

3.14
fatigue life
number of cycles of stress or strain of a specified character that a given structure or component of a structural assembly can sustain [without the presence of *flaws* (3.15)] before failure of a specified nature occurs

[SOURCE: ISO 10786:2011, 2.24]

3.15
flaw
local discontinuity in a structural material

EXAMPLE Crack, cut, scratch, void, delamination disbond, impact damage and other kinds of mechanical damage.

[SOURCE: ISO 10786:2011, 3.23]

3.16
fracture
break occurring due to unstable extension of a *flaw* (3.15)

3.17
hoop stress
circumferential stress at the convolution section induced by pressure

3.18
leak-before-burst
LBB
design concept which shows that at *maximum expected operating pressure (MEOP)* (3.22) potentially critical *flaws* (3.15) will grow through the wall of a metallic pressurized hardware item and cause pressure relieving leakage rather than burst or rupture (catastrophic failure)

3.19
life factor
factor by which the *service life* (3.29) is multiplied to obtain total *fatigue life* (3.14) or *damage tolerance life* (3.7)

Note 1 to entry: Life factor is often referred to as a scatter factor that is normally used to account for the scatter of a material's fatigue or crack growth rate data.

Note 2 to entry: It can also account for the dispersion of loading spectra parameters and other uncertainties, when appropriate.

[SOURCE: ISO 21648:2008, 2.1.24, modified —Note 1 to entry has been separated to Note 1 to entry and Note2 to entry.]

3.20
limit load
design limit load
maximum load, or combination of loads, which a structure or a component in a structural assembly is expected to experience during its service life, 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 24638:2021, 3.13]

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3.21
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 24638:2021, 3.16]

3.22
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 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)* (3.21), 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 24638:2021, 3.17]

3.23
mechanical linkage section
section within *bellows* (3.2) assembly that will serve as the bellows restraint for thrust force by pressure, deflection, or other factors

3.24
proof factor
multiplying factor applied to the *limit load* (3.20) or *maximum expected operating pressure (MEOP)* (3.22) or *maximum design pressure (MDP)* (3.21) to obtain proof load or *proof pressure* (3.25) for use in *acceptance test* (3.1)

[SOURCE: ISO 24638:2021, 3.22, modified —The wording, “acceptance testing” has been replaced by “acceptance test”.]

3.25
proof pressure
product of *MEOP* (3.22) [or *MDP* (3.21)] and a *proof factor* (3.24)

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* (3.15) sizes for *damage tolerance life* (3.7) demonstration.

[SOURCE: ISO 24638:2021, 3.23, modified— The wording, “damage tolerance life (safe life)” has been replaced by “damage tolerance life”.]

3.26
qualification test
required formal contractual test conducted to demonstrate that the design, manufacturing, and assembly have resulted in hardware conforming to specification requirements

Note 1 to entry: Qualification tests are conducted on a flight-quality article at load levels and durations sufficient to demonstrate that all design requirements have been met under the specified environmental conditions. Both protoflight and prototype tests are considered qualification tests.

Note 2 to entry: The qualification test may also validate the planned acceptance programme, including test techniques, procedures, equipment, instrumentation, and software.

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[SOURCE: ISO 10795:2019, 3.187, modified — The word, “used “, has been replaced by “conducted”. Note 1 to entry and note 2 to entry have been added.]

3.27
refurbishment
renovation and restoration to intended use condition

3.28
repair
action on a nonconforming product or service to make it acceptable for the intended use

Note 1 to entry: A successful repair of a nonconforming product or service does not necessarily make the product or service conform to the requirement. It can be that in conjunction with a repair a concession is required.

Note 2 to entry: Repair includes remedial action taken on previously conforming product or service to restore it for use, for example as part of maintenance.

Note 3 to entry: Repair can affect or change parts of the nonconforming product or service.

[SOURCE: ISO 10795:2019, 3.199]

3.29
service life
period of time (or number of cycles) that starts with item inspection after the manufacturing and continues through all testing, handling, storage, transportation, launch operations, orbital operations, *refurbishment* (3.27), re-testing, re-entry or recovery from orbit, and reuse that may be required or specified for the item

[SOURCE: ISO 24638:2021, 3.25, modified —The wording, “(or cycles)” has been replaced by “(or number of cycles)”.]

3.30
work hardening effect
effect of strengthening material by plastic deformation

Note 1 to entry: The representative material is 300 series corrosion-resistant steel.

4 Abbreviated terms

NDI non-destructive inspection

QA quality assurance

S-N stress versus number of cycles to failure

5 Requirements

5.1 General

This clause presents the requirements for design, stress analysis, material selection and characterization, fabrication and process control, and quality assurance, as well as operational requirements including maintenance, repair, refurbishment, and storage for bellows in a pressure system.

The design safety factors and related test factors shall comply with the following requirements.

a) For a crewed space system, the minimum bellows proof factor shall be 1,5 and the minimum design burst factor shall be 2,5.

b) For uncrewed space systems, if the presence of a ground crew is allowed during pressurization of the bellows (up to MEOP), the minimum proof factor for the bellows shall be 1,5 and the minimum design burst factor shall be 2,5. If the presence of ground crew is not allowed during pressurization of the

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