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Space systems — Pressure vessels and pressurized structures — Design and operation

Systèmes spatiaux — Réservoirs et structures sous pression — Conception et fonctionnement

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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Introduction

From the beginning of the space age, hazard control has been a prime consideration in manned or unmanned flights in outer space. The rapid development of space activities and their associated technologies required the implementation of ever-increasing amounts of energy sources. Space activities can be hazardous and could cause harm to people and damage to public and private property and the environment. It is therefore necessary to develop methods and tools that can analyse hazardous situations and provide realistic recommendations in terms of safety and safety risk control. Furthermore, building space systems such as telecommunication satellites and their launch systems is costly; it is necessary to achieve high mission reliability. The variety of professional disciplines linked to these activities requires international standards to protect Earth populations against the consequences of a possible mishap caused by the failure of a highly pressurized hardware item.

There is significant history to the analysis and design of pressure vessels and pressurized structures for use in space systems. This International Standard establishes the preferred methods for these techniques in both the traditional metallic tanks, and the newer composite overwrapped pressure vessels. The emphasis is equally on adequate design and safe, as well as reliable, operation.

Space systems — Pressure vessels and pressurized structures — Design and operation

1 Scope

This International Standard, based on general space experience and practice, specifies general and detailed requirements for metallic pressure vessels, composite overwrapped pressure vessels with metallic liners and metallic pressurized structures used in space systems. It is not applicable to pressure components (lines, fittings, valves, hoses, etc.) or to special pressurized hardware (batteries, heat pipes, cryostats and sealed containers).

2 Terms and definitions

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

2.1
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 %

cf. **"B" basis allowable** (2.6)

2.2
acceptance tests
required formal tests conducted on flight hardware to ascertain that the materials, manufacturing processes and workmanship meet specifications and that the hardware is acceptable for intended usage

2.3
allowable load (stress)
maximum load (stress) that can be accommodated by a material/structure without potential rupture, collapse or detrimental deformation in a given environment

NOTE Allowable loads (stresses) commonly correspond to the statistically based minimum ultimate strength, buckling strength, and yield strength, respectively.

2.4
applied load [stress]
actual load [stress] imposed on the structure in the service environment

2.5
autofrettage
vessel-sizing operation where pressure-driven deflection is used to plastically yield the metal liner into the overlying composite in order to induce initial compressive stress states in the metal liner

2.6
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 %

cf. **"A" basis allowable** (2.1)

2.7
brittle fracture
catastrophic failure mode in a material/structure that usually occurs without prior plastic deformation and at extremely high speed

NOTE The fracture is usually characterized by a flat fracture surface with little or no shear lips (slant fracture surface) and at average stress levels below those of general yielding.

2.8
burst factor
multiplying factor applied to the maximum expected operating pressure (MEOP), or maximum design pressure (MDP), to obtain the design burst pressure

NOTE 1 Burst factor is synonymous with *design factor of safety for burst*.

NOTE 2 **design burst pressure** (2.16) sometimes referred to as *burst pressure*, is synonymous with “ultimate pressure”.

2.9
burst strength after impact
BAI
actual burst pressure of a composite overwrapped pressure vessel after it has been subjected to an impact event

2.10
component
functional unit that is viewed as an entity for purpose of analysis, manufacturing, maintenance, or record keeping

2.11
composite overwrapped pressure vessel
pressure vessel with a fibre-based composite system fully or partially encapsulating a liner

NOTE The liner serves as a fluid permeation barrier and may or may not carry substantial pressure loads. The composite overwraps generally carry pressure and environmental loads.

2.12
critical condition
most severe environmental condition in terms of loads, pressures and temperatures or combination thereof imposed on systems, subsystems, structures and components during service life

2.13
critical flaw
specific shape of flaw with sufficient size such that unstable growth will occur under the specific operating load and environment

2.14
critical stress intensity factor
stress intensity factor at which unstable fracture occurs

2.15
damage tolerance
ability of a material/structure to resist failure due to the presence of flaws, cracks, delaminations, impact damage or other mechanical damage for a specified period of unrepaired usage

2.16
design burst pressure
burst pressure
“ultimate pressure”
differential pressure that pressurized hardware must withstand without burst in the applicable operational environment

NOTE Design burst pressure is equal to the product of the MEOP or MDP and a design burst factor.

2.17
design safety factor
design factor of safety
factor or safety
multiplying factor to be applied to the limit load and/or MEOP(or MDP)

2.18
destabilizing pressure
differential pressure that produces compressive stresses in pressure hardware

2.19
detrimental deformation
structural deformation, deflection, or displacement that prevents any portion of the structure or other system from performing its intended function

2.20
development test

test to provide design information that may be used to check the validity of analytic technique and assumed design parameters, to uncover unexpected system response characteristics, to evaluate design changes, to determine interface compatibility, to prove qualification and acceptance procedures and techniques, to check manufacturing technology, or to establish accept/reject criteria

2.21
ductile fracture
type of failure mode in a material/structure generally preceded by a large amount of plastic deformation

2.22
elastically responding metallic liner
metallic liner of a composite overwrapped pressure vessel that responds elastically (experiences no plastic response) at all pressure up to and including the vessel's acceptance proof pressure after the autofrettage operation

2.23
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 after a sufficient number of fluctuations

2.24
fatigue life
number of cycles of stress or strain of a specified character that a given material or structure can sustain before failure of a specified nature could occur

2.25
flaw
local discontinuity in a structural material such as a scratch, notch or crack

2.26
flaw shape
shape of a surface crack or corner crack

NOTE For a surface crack, the flaw shape is expressed as $a/2c$, where a is the crack depth and $2c$ is the crack length. For a corner crack, the flaw shape is expressed as a/c, where a is the crack depth and c is the crack length

2.27
fracture control
application of design philosophy, analysis method, manufacturing technology, verification methodology, quality assurance, and operating procedures to prevent premature structural failure caused by the propagation of cracks or crack-like flaws during fabrication, testing, transportation, handling and service

2.28
fracture mechanics
engineering discipline that describes the behaviour of cracks or crack-like flaws in materials or structures under stress

2.29
fracture toughness
generic term for measures of resistance to the extension of a crack

2.30
hazard
existing or potential condition that can result in an accident

2.31
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

2.32
impact damage
induced fault in the composite overwrap or the metallic liner of a composite overwrapped pressure vessel that is caused by an object strike on the vessel or vessel strike on an object

2.33
impact damage protector
physical device that can be used to prevent impact damage

2.34
initial flaw
flaw in a structural material before the application of load and/or deleterious environment

2.35
leak-before-burst
LBB
design concept which shows that at MEOP potentially critical flaws will grow through the wall of a metallic pressurized hardware item or the metal liner of a composite overwrapped pressure vessel and cause pressure relieving leakage rather than burst or rupture (catastrophic failure)

2.36
limit load
highest predicted load or combination of loads that a structure can experience during its service life in association with the applicable operating environments

NOTE The corresponding stress is called *limit stress*.

2.37
loading case
particular condition of pressure/temperature/loads that can occur for some parts of pressurized structures at the same time during their service life

2.38
loading spectrum
representation of the cumulating loading anticipated for the structure under all expected operating environments

NOTE Significant transportation and handling loads are included.

2.39
margin of safety
MS
margin expressed by the following equation:

$$\text{MS} = \left(\frac{\text{Allowable load}}{\text{Limit load} \times \text{Factor of safety}} \right) - 1$$

NOTE Load can mean stress or strain.

2.40
maximum design pressure
MDP
highest pressure defined by maximum relief pressure, maximum regulator pressure, and/or maximum temperature, including transient pressures, at which a pressure vessel retains two-fault tolerance without failure

NOTE In this document, the term MDP is only applicable to pressure vessels.

2.41
maximum expected operating pressure
MEOP
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

2.42
mechanical damage
induced flaw in the composite overwrap or metallic liner of a composite overwrapped pressure vessel, caused by surface abrasions or cuts or impact

2.43
metal-lined composite overwrapped pressure vessel
composite overwrapped pressure vessel having a metallic liner

NOTE Throughout this document, the term “composite overwrapped pressure vessel” means metal-lined composite overwrapped pressure vessel.

2.44
metallic hardware items
hardware items made of metallic materials

NOTE In this document, the term covers metallic pressure vessels, metallic pressurized structures and metallic liners of composite overwrapped pressure vessels.

2.45
plastically responding metallic liner
metallic liner of a composite overwrapped pressure vessel that could at least once experience plastic response when pressurized to any pressure up to and including acceptance proof pressure after the autofrettage operation

2.46
pressure vessel
container designed primarily for the storage of pressurized fluid that fulfils at least one of the following criteria:

a) contains gas or liquid with high energy level;

b) contains gas or liquid which will create a mishap (accident) if released;

c) contains gas or liquid with high pressure level

NOTE 1 This definition excludes pressurized structures, pressure components and pressurized hardware.

NOTE 2 Energy and pressure level 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 19 310 J or greater based on adiabatic expansion of perfect gas;

— MEOP is 0,69 MPa or greater.

2.47
pressurized hardware
hardware items that contain primarily internal pressure

NOTE In this document, the term covers all pressure vessels and **pressurized structures** (2.48).

2.48
pressurized structure
structure designed to carry both internal pressure and vehicle structural loads

EXAMPLE Launch vehicle main propellant tanks, crew cabins or manned modules.

2.49
pressurized system
system which consists of pressure vessels, or pressurized structures, or both, and other pressure components such as lines, fittings, valves and bellows, which are exposed to, and structurally designed largely by, the acting pressure

NOTE Electrical or other control devices required for system operations are covered by this term.

2.50
proof factor
multiplying factor applied to the limit load or MEOP (or MDP) to obtain proof load or proof pressure for use in the acceptance testing

2.51
proof pressure
product of MEOP (or MDP) and a proof factor

NOTE The proof pressure is used to provide evidence of satisfactory workmanship and material quality and/or to establish maximum initial flaw sizes for the safe-life demonstration of a metallic hardware item.

2.52
qualification tests
required formal contractual tests used to demonstrate that the design, manufacturing, and assembly have resulted in hardware designs conforming to specification requirements

2.53
residual strength
maximum value of load and/or pressure (stress) that a cracked or damaged body is capable of sustaining