INTERNATIONAL STANDARD

**ISO 18487-1**

First edition
2017-04

# Aerospace series — Titanium tube for 35 MPa operating pressure —

## Part 1: Inch series

*Série aérospatiale — Tubes en titane — Pression de service : 35 MPa — Partie 1: Série en inches*



Reference number
ISO 18487-1:2017(E)



ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

# Contents

Page

# 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).

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).

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

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 10, *Aerospace fluid systems and components*.

A list of all the parts in the ISO 18487 series can be found on the ISO website.



# Introduction

This document is intended to harmonize the technical requirements for titanium tubes used in aerospace with design operating pressure of 35 MPa.

It is noted that, while ISO standards should normally refer only to SI units, large segments of the aerospace industry refer to other measurement systems as a matter of common working practice. The mention of "inch series" in the title of this document reflects this. It recognizes the fact that the nominal sizes referred to in the document, which are in common use in the aerospace industry, were originally defined in terms of fractional inches.

Although the tube sizes were originally defined, and are frequently referred to, in terms of non-SI units, all dimensions used in this document are in SI units with inch units given in addition for the convenience of those users more familiar with these.

It is further noted that the standard ISO decimal symbol "," (comma) is not used as common working practice for inch dimensions. A decimal point is used in the inch dimensions in this document as in many other aerospace standards.

NOTE The use of non-SI units and the decimal point in this document does not constitute general acceptance of measurement systems other than SI within International Standards.

# Aerospace series — Titanium tube for 35 MPa operating pressure —

# Part 1: Inch series

## 1 Scope

This document is applicable to seamless tubing of circular cross-section made from titanium alloy and intended for use primarily in systems with system operating pressure of 35 MPa (5 080 psi) (Pressure Class J), but usage is not limited to such applications.

## 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 4287, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 6772, *Aerospace — Fluid systems — Impulse testing of hydraulic hose, tubing and fitting assemblies*

ISO 8492, *Metallic materials — Tube — Flattening test*

ISO 8575:2016, *Aerospace — Fluid systems — Hydraulic system tubing*

ISO 10583, *Aerospace fluid systems — Test methods for tube/fitting assemblies*

ISO 12573, *Aircraft — Tubing tolerances — Inch series*

EN 2003-010, *Aerospace series — Titanium and titanium alloys — Test methods — Part 010: Sampling for determination of hydrogen content*

EN 3718, *Aerospace series — Test method for metallic materials — Ultrasonic inspection of tubes*

AS 4076, *Contractile strain ratio testing of titanium hydraulic tubing*

AMS 2634, *Ultrasonic inspection, thin wall metal tubing superseding*

ASTM E112, *Standard test methods for determining average grain size*

ASTM E1409, *Standard test method for determination of oxygen and nitrogen in titanium and titanium alloys by inert gas fusion*

ASTM E1941, *Standard test method for determination of carbon in refractory and reactive metals and their alloys by combustion analysis*

ASTM E1447, *Standard test method for determination of hydrogen in titanium and titanium alloys by the inert gas fusion thermal conductivity/infrared detection method*

ASTM E2371, *Standard test method for analysis of titanium and titanium alloys by direct current plasma and inductively coupled plasma atomic emission spectrometry (Performance-based test methodology)*

## 3 Terms and definitions

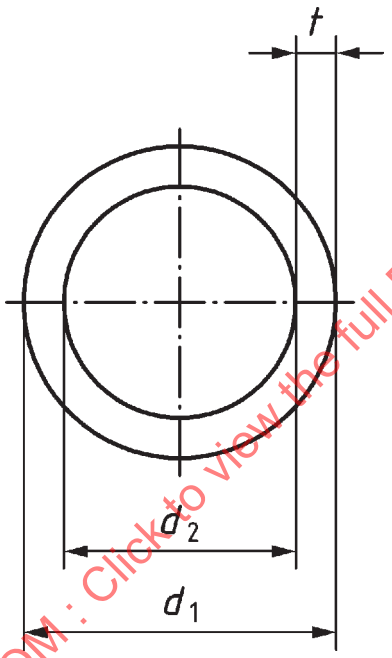
For the purposes of this document, the following terms and definitions apply.

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

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

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

**3.1**
**outside diameter**
$d_1$
distance between any two points at 180° to each other around the outside of a single section across the tube




**Key**

$d_1$ outside diameter
$d_2$ inside diameter
$t$ wall thickness

**Figure 1 — Outside diameter, inside diameter and wall thickness**

**3.2**
**inside diameter**
$d_2$
distance between any two points at 180° to each other around the inside of a single section across the tube

**3.3**
**wall thickness**
$t$
thickness measured at a right angle across the tube wall

## 4 Dimensions

Unless otherwise specified by purchaser, dimensions shall conform to ISO 8575:2016, Table 2 that is relevant to Pressure Class J.

# 5 Tolerances

Unless otherwise specified by purchaser, dimensional tolerances shall conform to ISO 12573.

# 6 Technical requirements

## 6.1 General

Except as mentioned below, testing to establish compliance with all of the technical requirements below shall be conducted on a single sample per batch of tubes.

## 6.2 Composition

Chemical composition shall conform to the percentages by weight given in Table 1. Suitable methods of determination of composition are also given in Table 1. Other analytical methods may be used by agreement with the purchaser.

**Table 1 — Chemical composition**

Values in percentages

| Element | Al | V | Fe | $O_2$ | $N_2$ | $H_2$ | C | Y | Others | | Ti |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Each | Total | |
| Minimum | 2,50 | 2,00 | | | | | | | | | Remainder |
| Maximum | 3,50 | 3,00 | 0,3 | 0,120 | 0,020 | 0,005 0 | 0,05 | 0,005[a] | 0,10[a] | 0,40[a] | |
| Method of determination | ASTM E2371 | | | ASTM E1409 | | ASTM E1447 or EN 2003–10 | ASTM E1941 | ASTM E2371 | | | |

[a] Determination not required for routine acceptance.

## 6.3 Melting practice

Multiple melts are required. Inert gas flooding shall be used for all steps. Open air furnace melting is not permitted. Only vacuum arc remelting (VAR) is permissible for second and subsequent melts.

## 6.4 Heat treatment and delivery condition

Cold worked and stress relieved by heating in vacuum or inert atmosphere at a temperature of at least 370 °C and maintained for 30 min minimum.

Rotary straightening after final heat treatment is not permitted.

## 6.5 Tensile properties

Tensile properties at 15 °C for four samples per batch taken in the longitudinal direction shall meet the requirements set out in Table 2. Test method should be according to EN 2002-001 (or ASTM E8a). The method used shall be reported in the certificate. The length of the sample between the clamping jaws of the test equipment shall be at least 300 mm.

**Table 2 — Tensile properties**

| Property | | For tubing of diameter in mm (in) | |
|---|---|---|---|
| | | $6,35 < d_1 \leq 38,1$ ($0.250 < d_1 \leq 1.500$) | $d_1 = 6,35$ ($d_1 = 0.250$) |
| Tensile strength MPa (ksi) | Maximum | 1 030 (149) | 920 (133) |
| | Minimum | 870 (126) | 690 (100) |
| 0,2 % Proof stress MPa (ksi) | Minimum | 730 (106) | 655 (95) |
| Elongation %[a] | Minimum | 16[b] | 14 |

[a] Measured over 50 mm or 50,8 mm (2 inches).

[b] For tube diameters ≤ 9,53 mm, 14 % elongation is permissible.

## 6.6 Microstructure

### 6.6.1 General

Microstructure shall be determined by microscopic examination at a minimum of 400× magnification of both longitudinal and transverse sections. The microstructure shall consist of a stretched wrought structure with some areas of partially transformed beta. There shall be no oxygen rich layer such as alpha case or other surface contamination.

### 6.6.2 Grain size

The grain size shall be determined in accordance with ASTM E112 in the stress-relieved condition. If this is impossible due to excessive grain elongation caused by cold working, complete recrystallization heat treatment prior to grain size determination is permitted. Annealing temperature and holding time shall be stated in the certificate.

### 6.6.3 Contractile strain ratio (CSR)

When required by the purchaser, the CSR value shall be determined on the finished tube size by the method defined in AS 4076.

The CSR value shall be between 1.3 and 3.5.

When impulse pressure fatigue test (see 6.13) is carried out with samples according to configuration 1, testing to determine the CSR value may be waived by agreement with the purchaser.

## 6.7 Surface condition and texture

### 6.7.1 Surface treatment

OD surface shall be chemically milled to remove a minimum of 0,025 mm (0.001 inch) from the surface. Polishing prior to chemical milling is permissible, with traces of polishing operation remaining after the chemical milling.

ID surface shall be chemically milled to remove a minimum of 0,013 mm (0.0005 inch) from the surface. Abrasive grit blasting prior to chemical milling is permissible.

### 6.7.2 Surface condition

OD and ID surfaces shall be free of diffusion zones, cracks, seams, overlapping, lamination and organic surfaces films such as greases or lubricants.

Individual pits with rounded bottom are acceptable provided the maximum depths in Table 3 are not exceeded.

**Table 3 — Maximum permissible depth of round-bottom pit**

| Tube diameter ($d_1$) | Maximum permissible depth |
|---|---|
| <15,875 mm (0.625 inch) | 25 µm (0.001 inch) |
| ≥15,875 mm (0.625 inch) | 50 µm (0.002 inch) |

Appropriate destructive and non-destructive methods shall be defined and applied by the supplier to check the outer and inner surfaces for surface defects using agreed reference standards. These can include non-destructive reference standards and visual standards.

For a visual assessment, at least five samples per batch with a 200 mm length, longitudinally cut, shall be examined visually against the criteria in Table 3.

### 6.7.3 Surface texture, $R_a$

Surface roughness ($R_a$) measured in the longitudinal direction using electrical stylus instruments according to ISO 4287 shall not exceed 0,8 µm (32 microinch) for external and internal surface.

## 6.8 Ultrasonic inspection

Ultrasonic inspection of each tube according to EN 3718 or AMS 2634 shall be used to verify that OD and ID are free of defects.

The maximum permissible defect levels are listed in Table 4.

**Table 4 — Maximum permissible defect levels for ultrasonic inspection**

| Class[a] | Nominal wall Thickness, $t$ mm | Maximum size of defect | | |
|---|---|---|---|---|
| | | Depth[b] mm (in) | Length[b] mm (in) | Width[b] mm (in) |
| 5 | ≤1,14 | 0,05 (0.002) | 1,50 (0.060) | 0,10 (0.004) |
| 4 | 1,14 < a ≤ 1,52 | 0,05 (0.002) | 3,00 (0.125) | 0,10 (0.004) |
| 3 | 1,52 < a ≤ 2,03 | 0,08 (0.003) | 3,00 (0.125) | 0,10 (0.004) |
| 2 | 2,03 < a ≤ 2,54 | 0,10 (0.004) | 3,00 (0.125) | 0,10 (0.004) |

[a] As defined in EN 3718.

[b] In case of doubt, mm values shall be used.

## 6.9 Flarability

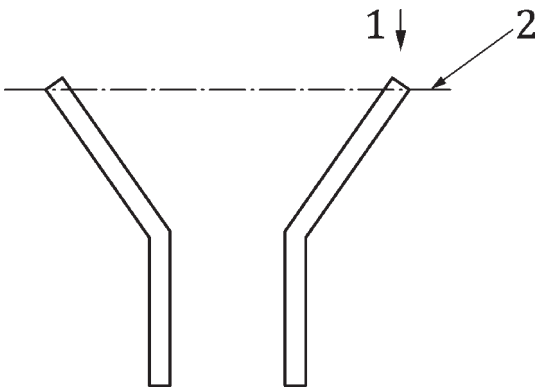
### 6.9.1 General

Samples cut from 10 % of the tubes in each batch (minimum of four samples) shall be subject to flaring test. Samples shall be cut from full tube section with cut end smooth and free from burrs, but not chamfered.

Samples shall withstand flaring at room temperature with a 74° included angle drift to produce an OD at least 20 % greater than the original OD without cracks or other visible defects when examined at 10× magnification.

### 6.9.2 Surface contamination

The absence of diffusion zones shall be determined metallographically by taking a transverse section from the flarability test sample at its extremity as shown in Figure 2.




**Key**

1 examination

2 polished section (P2400)

**Figure 2 — Position of transverse section**

The section shall be polished at a grit of P2400 or finer and examined via an optical microscope at a magnification of 500.

No micro-cracks as observed in Figure 4 are permissible.


**Figure 3 — Optical micrographs showing Ti3Al2.5V tube surfaces of deformed sections — No diffusion zones**

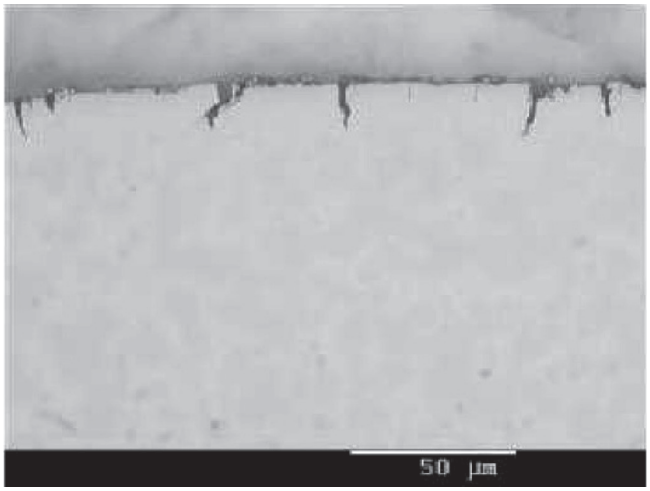



**Figure 4 — Optical micrographs showing Ti3Al2.5V tube surfaces of deformed sections micro-cracks initiated in a diffusion zone**



## 6.10 Bending

Testing shall be carried out with a 3D bending radius and a 180° bending angle. A retractable mandrel shall be used to support the tubes internally so that the ovality after bending shall not exceed 3 % of the nominal outer diameter.

Subsequent to the examination of the external surface, the samples shall be cut longitudinally for visual inspection of the internal surface. Tubes shall not show cracks, tears, breaks or other flaws. Folds or other minor surface defects shall not exceed 1 % of the external diameter in depth.

## 6.11 Flattening

Testing shall be carried out in accordance with ISO 8492.

One 50 mm (2 in) length of tube placed between two parallel plates is flattened slowly by applying a load perpendicular to the longitudinal axis until the separation between these two plates is less than or equal to values given in Table 5.

**Table 5 — Flattening values**

| Ratio of outside diameter to wall thickness ($d_1/t$) | Distance between plates expressed in multiples of actual wall thickness ($t$) |
|---|---|
| ≤10 | 8 $t$ |
| >10 ≤ 13 | 10 $t$ |
| >13 ≤ 16 | 12 $t$ |
| >16 ≤ 20 | 15 $t$ |

Subsequent to an examination of the outer surfaces, the sample shall be cut longitudinally (perpendicularly to the two parallel plates) and the inner surfaces examined. When checked at 5× to 10× magnification, the inner and outer surfaces shall reveal no cracks, tears, breaks, opened die marks or opened polishing marks.

## 6.12 Deformation under pressure test

A pressure test shall be performed on two tube sections per batch having a minimum length of 300 mm (12 in). The pressure shall be applied evenly and smoothly on straight tubes and shall be held for a

minimum period of 2 min. Tubes shall show no bulges, leaks, pin holes, cracks or other defects when subjected to an internal hydrostatic pressure ($P$) sufficient to cause a tensile stress equal to $R_{p0,2}$.

The average outer diameter shall not increase by more than 0,2 %.

The test pressure, $P$, is calculated on the basis of tube dimensions and the elastic limit of the material using Formula (1):

$$P = R_{p0,2} \frac{{d_1}^2 - {d_2}^2}{{d_1}^2 + {d_2}^2} \quad (1)$$

where

$P$ is the test pressure in MPa;

$d_1$ is the outer diameter in mm;

$d_2$ is the inner diameter in mm;

$R_{p0,2}$ is the minimum 0,2 % proof stress in MPa (as defined in Table 2).

## 6.13 Impulse pressure fatigue test

### 6.13.1 General

Table 6 gives the sequence, number of cycles and temperature for this sequence of tests.

**Table 6 — Test sequence and samples**

| Test | Temperature °C | Test specimen number | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| Proof | | x | x | x | x | x | x |
| Pressure impulse test 300 000 cycles | −40 °C < θ < 95 °C | x | x | x | x | x | x |
| Ultimate pressure test and burst test | 15 °C | x | x | | | | |
| | 95 °C | | | x | x | | |
| Additional pressure impulse test up to 450 000 cycles | 95 °C | | | | | x | x |

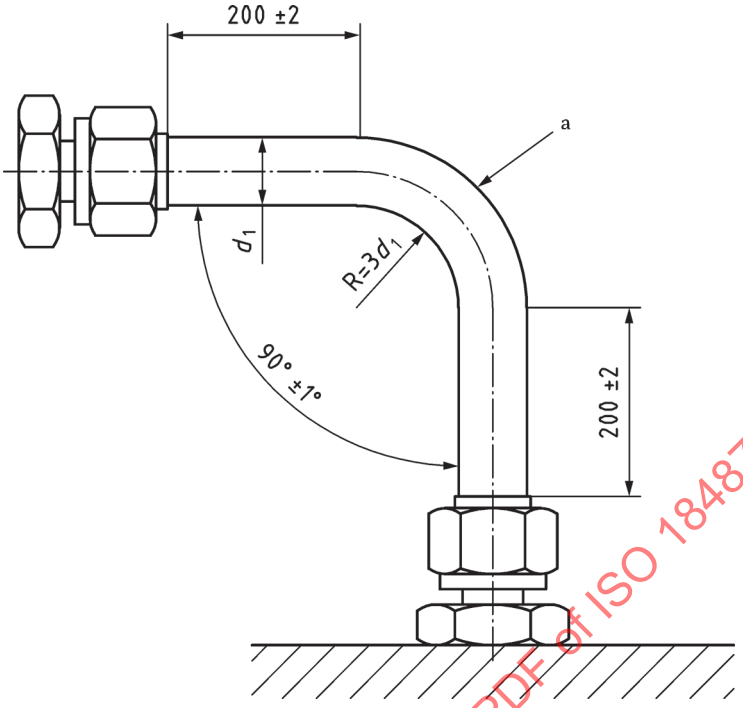
### 6.13.2 Proof test

Samples shall be bled of air before testing. Before performing the pressure impulse test, carry out on all six samples a proof test at ambient temperature, at a pressure 52,5 MPa (1,5 times design operating pressure), for 5 min, according to ISO 10583. No leakage or permanent deformation of the tube or fittings is permissible.

### 6.13.3 Pressure impulse test

Except where specified by the purchaser, this test may be conducted with samples according to any of the three configurations (see Figure 5 to Figure 7).

Dimensions in millimetres

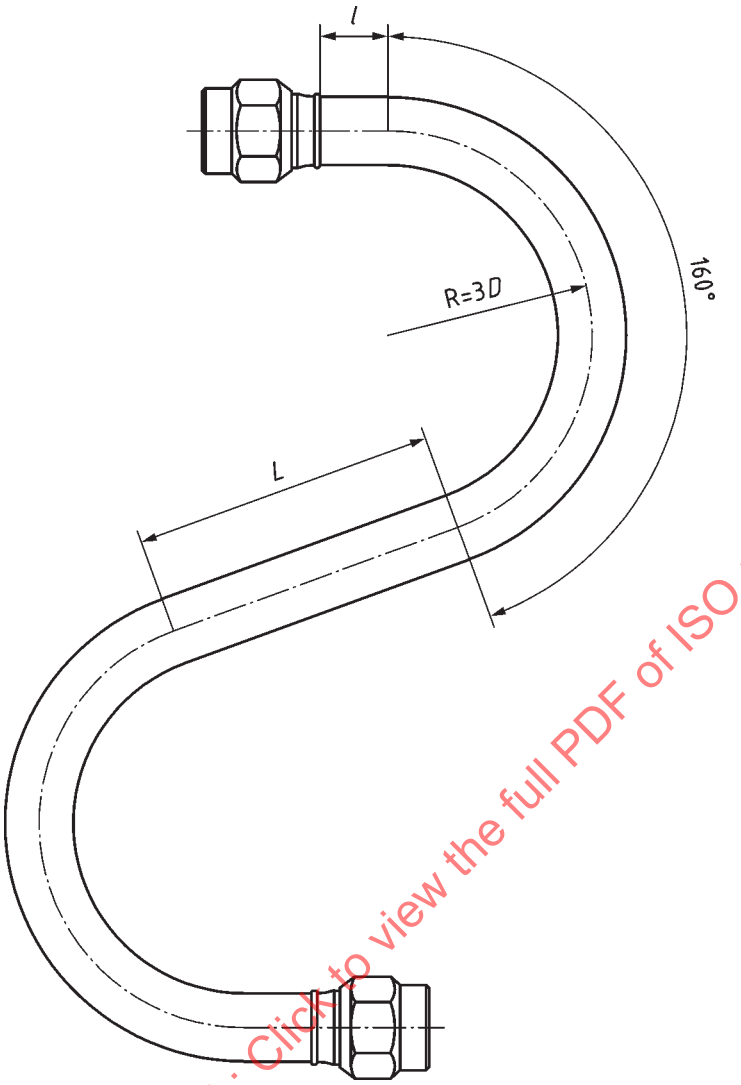



**Key**

a ovality

**Figure 5 — Configuration 1 for impulse pressure fatigue test samples**

Ovality shall be representative of worst case scenario as defined by the purchaser.




**Key**

*l* 31,75 mm to 38,1 mm (1.25 in to 1.50 in)

**Figure 6 — Configuration 2 for impulse pressure fatigue test samples**

**Table 7 — Straight length between bends for Configuration 2**

| Tube OD (mm) | Tube OD (in) | L (mm) +12.7/−0,00 | L (in) +0.50/−0.00 |
|---|---|---|---|
| 6,35 | 0.250 | 63,5 | 2.50 |
| 9,52 | 0.375 | 63,5 | 2.50 |
| 12,70 | 0.500 | 88,9 | 3.50 |
| 15,87 | 0.625 | 139,7 | 5.50 |
| 19,05 | 0.750 | 139,7 | 5.50 |
| 25,4 | 1.000 | 139,7 | 5.50 |
| 31,75 | 1.250 | 139,7 | 5.50 |