

Procedure for

# Inspection and testing of wrought titanium and titanium alloys

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# Foreword

This British Standard covers the general inspection and testing requirements for wrought titanium and titanium alloys for aerospace purposes. The procedure set out herein is for use in conjunction with the relevant specifications in the “TA” series of British Standards. The procedure is also applicable to other materials, where appropriate, such as those in the Ministry of Defence (Procurement Executive) D.T.D. Series and those approved in writing by the Ministry of Defence (Procurement Executive).

The first edition of this British Standard was published in July 1967. This revision has been undertaken primarily to take account of metrication in the titanium industry and all references to imperial units have been deleted. In addition, the standard now includes reference to an Inspection Schedule for certain products.

NOTE BS M 46, “*Tubing outside diameters and thicknesses*”<sup>1)</sup>, lists the outside diameters and thicknesses of tubes to be selected for all uses in aircraft design. Recommended thicknesses for sheet and diameters for wire, in the metric series, are given in Reference Sheets RS 701 and RS 702, respectively, published by the Society of British Aerospace Companies Limited.

This standard makes reference to the following British Standard.

BS A 4, *Test pieces and test methods for metallic materials for aircraft — Part 1: Tensile tests — Part 3: Bend tests — Part 4: Drifting tests on tubes.*

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

**Compliance with a British Standard does not of itself confer immunity from legal obligations.**

## Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 25 and a back cover.

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<sup>1)</sup> Implements ISO 2964.

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## Amendments issued since publication

| Amd. No. | Date of issue  | Comments                              |
|----------|----------------|---------------------------------------|
| 1557     | September 1974 |                                       |
| 2495     | March 1978     |                                       |
| 3307     | November 1980  |                                       |
| 4620     | July 1984      | Indicated by a sideline in the margin |
| 10739    | June 2000      | New clause 1.2.1.3 included           |

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## 1 General requirements

NOTE 1 Where reference is made to British Standards or other specifications the latest issue shall be used.

NOTE 2 Whenever agreement between the manufacturer and the purchaser is required by this British Standard, the onus is on the purchaser to obtain the concurrence of the parent design authority. If such concurrence is mandatory, the word “purchaser” is marked with an asterisk.

### 1.1 Definitions

For the purposes of this British Standard and associated material specifications the following definitions apply.

#### 1.1.1 Materials

##### 1.1.1.1

##### **bar**

a length of rolled, forged, drawn or extruded material of uniform round, square, rectangular or regular polygonal cross section

##### 1.1.1.2

##### **coil**

a continuous length of a product wound into a cylindrical or annular form for convenient handling

##### 1.1.1.3

##### **extruded section**

a length of material manufactured to size by passing through a die under pressure

##### 1.1.1.4

##### **forging**

a product obtained by hot working under a hammer or press. The term includes drop forgings, open die forgings and stampings, and also pressings and forgings made from tubular material

##### 1.1.1.5

##### **ingot**

the product of one furnace charge

NOTE In this British Standard the terms ingot and cast are synonymous.

##### 1.1.1.6

##### **plate**

a rolled product of rectangular section of thickness greater than 5 mm, supplied flat

##### 1.1.1.7

##### **rolled section**

a length of material produced by rolling, having a cross section not covered by the term “bar” as defined in 1.1.1.1, nor in the form of plate, sheet or strip

##### 1.1.1.8

##### **sheet**

a rolled product of rectangular section of thickness up to and including 5 mm, supplied flat with sheared or slit edges

##### 1.1.1.9

##### **strip**

a rolled product of rectangular section, normally supplied in coil and with slit edges, of thickness up to and including 5 mm

##### 1.1.1.10

##### **tube**

a hollow product of uniform wall thickness

##### 1.1.1.11

##### **wire**

a round, square, or regular polygonal solid section of not more than 10 mm diameter or width across flats, finished by drawing

### 1.1.2 Other terms

#### 1.1.2.1

##### **batch**

material from the same ingot, manufactured by the same process, of the same nominal dimensions and, if heat treated, heat treated together

#### 1.1.2.2

##### **edge straightness**

the deviation from straightness of the edge of a sheet, strip or plate when laid flat

#### 1.1.2.3

##### **harmful defect**

any defect prejudicial to the subsequent manufacture, fabrication or use of the material

#### 1.1.2.4

##### **heat treated**

subjected to heat treatment as stipulated in the material specification

#### 1.1.2.5

##### **inspection schedule**

a schedule of any special requirements agreed between the manufacturer and the purchaser

#### 1.1.2.6

##### **limiting ruling section**

the ruling section in which the specified properties can be guaranteed in the titanium alloy concerned by the specified heat treatment. Unless otherwise stipulated, it is a maximum

#### 1.1.2.7

##### **manufacturer**

the firm that is responsible for the production of the material in the form (bar, forging, sheet, etc.) in which it is consigned to the purchaser

#### 1.1.2.8

##### **overheating**

heating to a high temperature which results in a deleterious effect on the final properties and structure of the material

#### 1.1.2.9

##### **ruling section**

the cross-sectional dimensions, at the time of heat treatment, of the product at the location which is most important from the point of view of mechanical properties. The ruling section is expressed as the diameter of the equivalent round bar

#### 1.1.2.10

##### **supplier**

the firm that consigns the material to the purchaser

#### 1.1.2.11

##### **hot work reduction ratio**

the ratio of ingot cross section to product cross section after hot working

## 1.2 Manufacture and freedom from defects

### 1.2.1 Manufacture

**1.2.1.1** The material shall be made in accordance with the requirements of this British Standard and the material specification.

**1.2.1.2** The material shall be fabricated from ingots produced by multiple melting using consumable electrode practice. At least the final melting cycle shall be under vacuum and the electrodes shall be of such quality as to ensure the required quality in the remelted product. At no time during remelting shall material of any other composition or type be introduced into the melting chamber, e.g. starter material and electrode stub ends shall be of the same chemical composition as the material being remelted.

**1.2.1.3** Alternatively to **1.2.1.2**, where permitted by the material specification, the material may be manufactured by electron beam cold hearth melting.

**1.2.1.4** If a method of production has been agreed between the manufacturer and the purchaser\*, this may only be altered significantly by mutual consent

**1.2.1.5** In the manufacture of material, all processing shall be controlled so as to avoid overheating and to ensure adequate working at all stages.

Because of the difficulty of setting acceptable standards for overheating for the various materials, such standards shall be agreed between the manufacturer and the purchaser\*.

**1.2.1.6** If required by the purchaser, the minimum hot work reduction ratio shall be stated on the drawing, order or Inspection Schedule.

## **1.2.2 Freedom from defects**

**1.2.2.1** The material shall be free from harmful defects.

**1.2.2.2** Adequate discard shall be made from each end of each rolled or extruded length to the satisfaction of the inspector.

**1.2.2.3** If the purchaser requires the material to be non-destructively tested, details of the method of examination, the stage in manufacture at which it is to be carried out and the standards of acceptance shall be agreed with the manufacturer and shall be stated on the drawing, order or Inspection Schedule.

**1.2.2.4** Notwithstanding, the previous acceptance of material as complying with the requirements of this British Standard, any material that is found at a later stage to contain harmful defects may be rejected.

## **1.2.3 Local dressing**

**1.2.3.1** Surface defects on material in the condition of supply may be removed by local dressing provided that such removal does not reduce the dimensions to below the minimum permitted. Dressed areas shall be blended smoothly into the surrounding material and the bottom radius of a dressed area shall be not less than three times the depth of the defect. Care shall be taken to avoid grinding abuse.

**1.2.3.2** On completion of local dressing, the dressed areas shall be re-inspected using the same method as that which revealed the original defect.

## **1.3 Preparation for inspection**

**1.3.1** Unless otherwise stated on the drawing, order or Inspection Schedule, all wrought products shall be either descaled and etched or machined all over and etched to enable them to be inspected to the satisfaction of the Quality Assurance Authority.

**1.3.2** Sufficient material shall be removed to ensure freedom from any contaminated layer.

**1.3.3** Unless otherwise stated on the drawing, order or Inspection Schedule, the sequence and methods of descaling and cleaning are at the option of the manufacturer.

## **1.4 Chemical composition**

### **1.4.1 General**

**1.4.1.1** The chemical composition of the material shall comply with the requirements of the material specification. The values specified in the specification shall be applied in accordance with the instructions of the Quality Assurance Authority.

**1.4.1.2** Elements not specified in the material specification shall not be added intentionally to the alloy.

**1.4.1.3** The samples selected for analysis shall be representative of the cast and, except as provided in **1.4.3**, they shall be taken from the final remelted ingot. The samples shall be chemically analysed for each of the specified elements except hydrogen.

The apparatus and method used for oxygen determination shall be calibrated against a standard acceptable to the Quality Assurance Authority.

**1.4.2** *Text deleted*

### 1.4.3 Analysis of hydrogen

Unless otherwise agreed between the manufacturer and the purchaser\*, the analysis for hydrogen shall be made on samples selected, after all manufacturing processes, including hot working, heat treatment and pickling, have been completed by the manufacturer, as follows.

1) *Forgings*: one sample taken from a forging in each batch.

2) *Other wrought products*: one sample from each batch.

The location and size of the sample shall be agreed between the manufacturer and the purchaser\*.

**1.4.4** The results of chemical analysis shall be supplied to the purchaser.

**1.4.5** Elements not quoted in the material specification shall not be intentionally added to the alloy without the agreement of the purchaser\*.

## 1.5 Heat treatment

**1.5.1** If a temperature with a tolerance is stated in a material specification, order or drawing, that temperature shall be mandatory. If a temperature range is stated, a suitable temperature within that range shall be selected to give the required properties and shall be stated on the release certificate.

**1.5.2** If an alloy is to be heat treated in a ruling section larger than its limiting ruling section, the mechanical properties shall be agreed between the manufacturer and the purchaser.

**1.5.3** Unless otherwise agreed between the manufacturer and the purchaser\*, no material shall be subjected to the specified heat treatments more than twice.

## 1.6 Mechanical properties

**1.6.1** The specified mechanical properties normally refer to test pieces selected and prepared in accordance with **1.7**, **1.8** and **1.9**. In the event of a departure from these requirements, the properties shall be agreed between the manufacturer and the purchaser\* and shall be stated on the drawing, order or Inspection Schedule.

**1.6.2** Where values for mechanical properties are stipulated in the material specification or are agreed between the manufacturer and the purchaser in accordance with this standard, they shall be applied in accordance with the instructions of the Quality Assurance Authority.

**1.6.3** Where fracture toughness tests are required, the selection and preparation of test pieces, the method of test and the criteria for acceptance shall be agreed between the manufacturer and the purchaser and shall be stated on the drawing, order or Inspection Schedule.

## 1.7 Selection and preparation of test samples

**1.7.1** Test samples shall be selected, in accordance with the relevant section of this standard, and shall be identified, as directed by the inspector, before being removed from the material they represent.

**1.7.2** Except as otherwise stipulated in this standard.

1) Test samples representing heat treated material shall not be further heat treated.

2) Test samples representing material in a condition other than that stipulated in the material specification shall be heat treated.

3) Test samples shall not be mechanically worked after having been separated from the material they represent.

## 1.8 Location and direction of test pieces

### 1.8.1 General

Unless otherwise stated in the material specification, drawing, order or Inspection Schedule, the following requirements govern the location and direction of test pieces for the determination of mechanical properties.

### 1.8.2 Forging stock, bar for machining, section, forgings and wire

**1.8.2.1** Except as provided in **1.9.1.2** and **1.9.2.2**, for test samples up to and including 30 mm diameter or minor sectional dimension, the test piece shall be machined coaxially from the test sample.

**1.8.2.2** For test samples over 30 mm and up to and including 75 mm diameter or minor sectional dimension, the longitudinal axis of the test piece shall be not less than 15 mm from the surface of the test sample.

**1.8.2.3** For test samples over 75 mm or minor sectional dimension, the test piece shall be prepared in accordance with **1.8.2.2** or, at the option of the manufacturer, shall be taken in the transverse direction.

**1.8.2.4** The direction of the test piece shall be stated on the test certificate.

### **1.8.3 Sheet and strip**

**1.8.3.1** Unless otherwise agreed between the manufacturer and the purchaser, the test samples from material over 200 mm wide shall be cut so that the longitudinal axis of the test piece is in a direction at right angles to the direction of final rolling.

**1.8.3.2** The test samples from material 200 mm wide and under shall be cut so that the longitudinal axis of the test piece is in a direction parallel to the direction of final rolling.

**1.8.3.3** The direction of the test samples shall be stated on the test certificate.

### **1.8.4 Plate**

**1.8.4.1** For plate up to and including 25 mm thick, sufficient material shall be selected to enable two test pieces to be machined as follows.

- 1) *Longitudinal*: with the axis parallel to the direction of final rolling.
- 2) *Transverse*: with the axis at right angles to the direction of final rolling.

**1.8.4.2** For plate thicker than 25 mm, sufficient material shall be selected to enable three test pieces to be machined as follows.

- 1) *Longitudinal*: with the axis parallel to the direction of final rolling.
- 2) *Transverse*: with the axis at right angles to the direction of final rolling.
- 3) *Short transverse*: with the axis normal to the plate surface.

### **1.8.5 Tube**

Test samples shall be selected so as to enable test pieces to be prepared in accordance with the requirements of British Standard A4, Section One or Section Two, as appropriate.

## **1.9 Preparation and testing of test pieces**

### **1.9.1 Tensile test at room temperature**

**1.9.1.1** The test piece shall be prepared from the selected test sample (see **1.7** and **1.8**) in accordance with the requirements of British Standard A4, Part 1, Section One. The standard proportional round test piece shall be the 5.64 mm diameter test piece shown in British Standard A4, Part 1, Section One.

**1.9.1.2** Samples of bar, section and wire not exceeding 10 mm diameter or major sectional dimension shall be tested in full section or, at the option of the manufacturer, on machined test pieces. For material tested in full section, the elongation shall be measured on a gauge length equal to five times the original diameter of the test piece or, for material of other than circular section, on a gauge length of 50 mm.

**1.9.1.3** The test pieces shall be tested in accordance with the requirements of British Standard A4, Part 1, Section One.

**1.9.1.4** In the plastic range of the tensile test, the rate of strain up to the proof stress determination shall be between 0.001 per minute and 0.005 per minute.

**1.9.1.5** The fracture faces shall be free from harmful defects.

**1.9.1.6** The results of the specified tests and the dimensions of the test pieces shall be stated on the release note.

### **1.9.2 Tensile test at elevated temperature**

**1.9.2.1** The test piece shall be prepared from the selected test sample (see **1.7** and **1.8**) in accordance with the requirements of British Standard A4, Part 1, Section Two. The standard proportional round test piece shall be the 5.64 mm diameter test piece shown in British Standard A4, Part 1, Section Two.