BRITISH STANDARD

BS 3603 : 1991

Specification for

Carbon and alloy steel pipes and tubes with specified low temperature properties for pressure purposes

Tubes et tuyaux pour utilisations sous pression en acier au carbone et en acier allié à propriétés spécifiées à basse température — Spécifications

Druckrohre aus legiertem oder unlegiertem Stahl für den Einsatz bei niedrigen Temperaturen

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Iron and Steel Standards Policy Committee (ISM/-) to Technical Committee ISM/73, upon which the following bodies were represented:

Associated Offices Technical Committee
BEAMA Ltd. (Power Generation Association)
British Compressed Air Society
British Gas plc
British Shipbuilders
British Steel Industry
Electricity Supply Industry in England and Wales
Engineering Equipment and Materials Users' Association
High Pressure Pipework Consultative Committee
Lloyd's Register of Shipping
Process Plant Association
Seamless Steel Tube Association
Water-tube Boilermakers' Association
Welding Institute
Coopted members

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

British Fluid Power Association
British Forging Industry Association
British Industrial Truck Association
British Welded Steel Tube Association
Confederation of British Industry
Energy Industries Council
Coopted member

This British Standard, having been prepared under the direction of the Iron and Steel Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 28 February 1991

First published December 1963
First edition November 1977
Second edition February 1991

The following BSI references relate to the work on this standard:
Committee reference ISM/73
Draft for comment 88/40071 DC

ISBN 0 580 18050 6

Amendments issued since publication

Amd. No.	Date	Text affected

Contents

Foreword

This British Standard has been prepared under the direction of the Iron and Steel Standards Policy Committee. It supersedes BS 3603 : 1977, which is withdrawn.

The standard takes account of current production procedures for seamless and electric resistance welded tubes for pressure purposes.

The steels covered by this standard are generally regarded as being weldable. However, care should be taken and welding should be in accordance with the appropriate British Standards for welding.

The main technical differences between this edition and the previous edition are that, for steel grade 410, values for minimum specified yield strength and tensile strength have been increased, and changes in chemical composition to take into account current steelmaking practice have been made. This steel has been re-designated grade 430. In addition, tolerances have been added for tubes supplied to inside diameter and thickness parameters. Furthermore, impact testing has now become a requirement of the standard.

This standard is one of a series specifying requirements for steel pipes and tubes for pressure purposes. Other standards in this series are as follows.

BS 3601	Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes
BS 3602	Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties Part 1 Specification for seamless and electric resistance welded including induction welded tubes Part 2 Submerged arc welded tubes
BS 3604	Steel pipes and tubes for pressure purposes: ferritic alloy steel with specified elevated temperature properties
BS 3605	Specification for seamless and welded austenitic stainless steel pipes and tubes for pressure purposes

Product certification. Users of this British Standard are advised to consider the desirability of third party certification of product conformity with this British Standard based on testing and continuing surveillance, which may be coupled with assessment of a supplier's quality systems against the appropriate Part of BS 5750.

Enquiries as to the availability of third party certification schemes will be forwarded by BSI to the Association of Certification Bodies. If a third party certification scheme does not already exist, users should consider approaching an appropriate body from the list of Association members.

It is outside the scope of this standard to specify formal qualifications for personnel engaged in testing but it is emphasized that the operation of all equipment should be supervised by competent, trained personnel.

For the purpose of this standard, no difference is intended in the meaning between 'pipe' and 'tube' though idiomatic use prefers sometimes the one and sometimes the other.

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

Specification

1 Scope

This British Standard specifies plain end, seamless and electric resistance welded, including induction welded, carbon and alloy steel tubes suitable for pressure purposes.

Tubes manufactured in accordance with this standard have specified low temperature impact properties.

In addition to the definitive requirements, this standard requires the items detailed in **2.1** to be documented. It also requires options selected by the purchaser from those detailed in **2.2** to be documented. For compliance with this standard both the definitive requirements and the documented items have to be satisfied.

This standard provides for two categories of room temperature test procedure, designated category 1 and category 2 (see clause **11**).

NOTE 1. The range of diameters and thicknesses appropriate to this standard is given in appendix A. However, it may be convenient to select from the discrete sizes given in the following standards:

(a) table 1 of BS 3600 : 1976;

(b) BS 1600 : Part 2 (completely interchangeable with ANSI B36.10M[1] and ANSI B36.19M[1]).

Tubes to diameters and thicknesses not covered by the above standards are also available, including those supplied by hot or cold finished seamless, and cold finished electric resistance weld processes.

NOTE 2. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Information to be supplied by the purchaser and options to be documented

2.1 Information to be supplied by the purchaser

The following information shall be supplied by the purchaser and shall be fully documented:

(a) the designation of the tubes as specified in clause **3**, i.e. the number of this British Standard, the method of manufacture of the tube, the type of steel and the category of test, e.g. BS 3603 : HFS 430 LT Cat. 1;

(b) the tube outside diameter and thickness for electric resistance welded tubes or the outside or inside diameter and thickness for seamless tubes and cold finished electric resistance welded tubes (see **10.2**);

(c) the tube length, if exact (see **2.2**(f) and **10.3**);

(d) the quantity in metres or number of lengths.

2.2 Options to be documented

A number of options are permitted by this standard as listed in this clause and the purchaser shall identify the options required. Both the definitive requirements specified throughout this standard and the following documented items stated by the purchaser shall be satisfied by the manufacturer before a claim of compliance with this standard can be made and verified. In the event that the purchaser does not indicate his requirements at the time of enquiry or order the manufacturer shall select the options where appropriate:

(a) the steelmaking process (see **4.1** and **15.2**(a));

(b) whether a product analysis is required (see **6.2** and **15.2**(b));

(c) whether selected chemical elements additional to those specified are to be reported (see **6.3** and **15.2**(c));

(d) the final supply condition of the tubes (see clause **7** and **15.2**(d));

(e) whether the upper limit above which the dressing of surface imperfections will be required will be 1.5 mm (see **9.8**);

(f) whether lengths other than random lengths are required (see **10.3**);

(g) whether the method of leak tightness test to be carried out on test category 2 tubes up to and including 180 mm outside diameter is the hydraulic test or the eddy current test (see **12.4** and **15.2**(e));

(h) the temperature at which the tubes shall be impact tested if other than at the lowest given (see **13.3**);

(i) whether the hydraulic test, if specified, is to be carried out at a pressure in excess of 140 bar[2] and the pressure required (see **13.4** and **15.2**(e));

(j) whether additional non-destructive testing is required (see **13.7** and **15.2**(f));

(k) whether the tubes are to be supplied uncoated or with the manufacturer's normal mill coating (see clause **16**);

(l) whether marking requirements in accordance with BS 5383 are required (see **17.1** and **17.4**).

[1] Published by the American National Standards Institute (ANSI) and available from BSI Sales Department, Linford Wood, Milton Keynes, MK14 6LE.

[2] 1 bar = 10^5 N/m^2 = 10^5 Pa.

3 Designation

The tubes shall be designated by the number of this British Standard, i.e. BS 3603 and, from table 1, by one of the references which indicates the method of manufacture (see clause **5**) and, from table 2, by a number which indicates the type of steel, and the test category (see clause **11**).

Example. BS 3603 : CFS 430 LT Cat. 1 designates cold finished seamless tube made from steel type 430 tested to category 1.

NOTE. The designations for tubes in this standard and their nearest equivalent designations in BS 3603 : 1977 and ISO 2604 : Parts II and III are listed in appendix B for information.

4 Manufacture of the steel

4.1 Steelmaking process

The steel shall be produced by an electric process or by one of the basic oxygen processes, at the option of the manufacturer unless otherwise specified by the purchaser (see **2.2**(a)).

4.2 Deoxidation

Steels shall be fully killed and fine grain.

5 Manufacture of the product

The tubes shall be manufactured by one of the following processes.

(a) *Seamless.* The tubes shall be manufactured by a seamless process and shall be hot finished or cold finished (see notes 1 and 3).

(b) *Electric resistance welded* (see notes 2 and 3). The tubes shall be manufactured from hot or cold flat-rolled strip, longitudinally welded continuously by the passage of an electric current across the abutting edges or along the edges prior to closure under welding pressure without the addition of filler metal. They shall be as-welded, hot finished or cold finished (see note 1). The finished tubes shall not include welds used for joining lengths of the hot or cold flat-rolled strip, prior to tube forming (see note 1).

Table 1. Method of manufacture of tubes and reference

Method of manufacture	Reference
Hot finished seamless	HFS
Cold finished seamless	CFS
Electric resistance welded	ERW[1)]
Cold finished electric resistance welded	CEW

[1)] The reference ERW includes as-welded or hot finished tubes (see (b) of clause **5**).

Table 2. Steel type and type number

Steel type	Type number
Carbon steel	430 LT
3½ % nickel steel[1)]	503 LT
9 % nickel steel[1)]	509 LT

[1)] Welded tubes to this standard are not available in these steels.

For tubes of both test categories, ultrasonic or other suitable non-destructive testing method shall be used for continuous examination of the weld area (see note 4).

NOTE 1. The terms 'as-welded', 'hot finished' and 'cold finished' apply to the condition of the tube before heat treatment, if required, in accordance with clause **7**.

NOTE 2. Electric resistance welded tubes cover those produced by both high frequency and low frequency techniques using either direct contact or induction.

NOTE 3. The range of dimensions and tolerances in which tubes are available is dependent upon the method of manufacture. The thicknesses available are also dependent upon the diameter. The dimensional limits generally applicable to this standard are shown in appendix A and the tolerances are specified in clause **10**.

NOTE 4. Non-destructive testing of the weld area is made for the purpose of quality control during the process of manufacture by a method and at a place chosen by the manufacturer.

Table 3. Chemical composition and mechanical properties at room temperature

Steel type	Type no.	Method of manufacture	Chemical composition (ladle analysis) (see notes 1 and 2)									
			C	Si		Mn		P	S	Ni		Al_{metal} (see no
			max.	min.	max.	min.	max.	max.	max.	min.	max.	min.
			%	%	%	%	%	%	%	%	%	%
Carbon	430 LT	Seamless or welded	0.20	—	0.35	0.60	1.20	0.035	0.035	—	—	0.020
3½ % Nickel	503 LT	Seamless	0.15	0.15	0.35	0.30	0.80	0.025	0.020	3.25	3.75	0.020
9 % Nickel	509 LT	Seamless	0.10	0.10	0.30	0.30	0.80	0.025	0.020	8.50	9.50	0.020

[1] For thicknesses over 65 mm, properties are subject to agreement between the supplier and the purchaser.

NOTE 1. Elements not quoted in this table shall not be intentionally added without the agreement of the purchaser other than for the purpose of finishing the heat. Elements added for the purpose of finishing the heat shall be reported. All reasonable precautions shall be taken to prevent the addition of such elements from scrap or other materials used in the manufacturer, but residual elements may be present provided that the mechanical properties and applicability are not adversely affected.

NOTE 2. For permissible deviations on product analysis, see table 4.

NOTE 3. Where a minimum $Al_{metallic}$ content of 0.020 % is specified, determination of the total aluminium content is deemed to comply with this requirement provided that the total aluminium content value obtained is not less than 0.023 %. In cases of dispute the metallic aluminium content is determined.

	Mechanical properties at room temperature (see note 4)					Final supply condition		
	R_m		Yield strength		A	Reference heat treatment (see note 5)	Austenitizing temperature	Tempering temperature
	min.	max.	Section thickness (where relevant)	R_e min.	min.			
	N/mm^2	N/mm^2	mm	N/mm^2	%		°C	°C
	430	570	≤16 >16≤40 >40≤65[1]	275 265 255	22	HF N	— 880 to 940	— —
	440	590	—	245	16	N N + T	840 to 900 840 to 900	— 580 to 620
	690	840	—	510	15	Q + T $N_1 + N_2 + T$	780 to 820 N_1 880 to 920 N_2 780 to 820	560 to 600

NOTE 4.

R_m is the tensile strength.

R_e is the yield strength. For acceptance purposes either the upper yield stress R_eH or the 0.5 % proof stress (total elongation) $R_{t\,0.5}$ may be used (see **13.1.2**).

A is the percentage elongation after fracture on gauge length of $L_o = 5.65\sqrt{S_o}$ (see **13.1**) (where S_o is the original cross-sectional area of the gauge length).

NOTE 5. Q = quenched; N = normalized; T = tempered; HF = hot finished.

6 Chemical analysis

6.1 Ladle analysis

The steel shall show on ladle analysis the composition given in table 3 appropriate to the steel type specified.

6.2 Product analysis

If a product analysis for acceptance purposes is required by the purchaser this shall be stated in the enquiry and order (see **2.2**(b)).

When an analysis on the product is carried out, the permitted deviations given in table 4 shall apply to the specified ladle analysis in table 3.

The number of samples to be taken shall be one per cast. The samples shall be taken either from the test pieces used for the verification of the mechanical properties or from the tube at the same location as for the mechanical test samples.

In cases of dispute the methods for chemical analysis shall be in accordance with British Standard Handbook 19 or BS 6200 : Part 3 as appropriate.

6.3 Content of elements

If required by the purchaser (see **2.2**(c)) the content of elements, selected by the purchaser, in addition to those specified in table 3 shall be reported.

NOTE. The purchaser may require, for example, to know the content of elements relating to weldability.

Table 4. Permitted deviations of the product analysis from the specified ladle analysis

Element	Upper limit of range in which the specified maximum for ladle analysis falls	Permitted deviations from specified limits	
		Greater than maximum	Less than minimum
	%	%	%
Carbon	≤0.25	0.03	—
Silicon	≤0.50	0.05[1)]	0.05[1)]
Manganese	≤2.0	0.10[1)]	0.10[1)]
Phosphorus	≤0.050	0.005	—
Sulphur	≤0.050	0.005	—
Nickel	≤5.0	0.07[1)]	0.07[1)]
	>5.0 ≤10	0.10[1)]	0.10[1)]
Aluminium	—	—	0.005

[1)] The deviations apply either above the specified maximum or below the specified minimum but both deviations shall not be applied to different samples from the same cast.

7 Final supply condition

The tubes shall be supplied in the final supply condition as given in table 3 unless otherwise specified by the purchaser (see note 1).

Unless otherwise specified by the purchaser on the enquiry and order (see **2.2**(d)) the manufacturer shall have the option of supplying tube in either of the supply conditions applicable to each of the steel types given in table 3.

Heat treatment temperatures shall be selected from within the temperature ranges specified in table 3 and shall refer to the metal temperature (see note 2).

NOTE 1. In the event that the tubes are required for subsequent manipulation, the purchaser may request delivery of the tubes in a condition other than the final supply condition given in table 3. In this case the purchaser should be informed of the heat treatment necessary to give the required properties (see clause **8**).

NOTE 2. The supplier should demonstrate if required that the appropriate heat treatment cycle has been achieved.

8 Mechanical properties

8.1 Mechanical properties at room temperature

The mechanical properties at room temperature[1] to be obtained on test pieces selected, prepared and tested in accordance with clauses **12** and **13** shall be as specified in table 3.

NOTE. If heat treatments different from, or additional to, the normal reference heat treatment (which may have an adverse effect on the mechanical properties) are to be carried out after the delivery of the tubes, the purchaser may request, at the time of enquiry and order, additional mechanical tests on samples that have been given heat treatments different from or additional to those given in table 3. The heat treatment of the samples and the mechanical properties to be obtained from tests on them should be agreed between the purchaser and the manufacturer at the time of enquiry and order.

8.2 Minimum Charpy V-notch impact properties at low temperature

8.2.1 The average of the impact values obtained from three standard 10 mm by 10 mm test pieces shall be not less than the appropriate value given in table 5 for the steel type ordered, when sampled as described in **12.2.3** and tested as described in **13.3**. One of the three individual values may be below the specified minimum average value given in table 5 but it shall be not less than 70 % of that value.

8.2.2 The average of the impact values obtained from three subsidiary standard test pieces shall be not less than the following:

(a) for a 10 mm by 7.5 mm subsidiary standard test piece, not less than 80 % of the values in table 5;

(b) for a 10 mm by 5 mm subsidiary standard test piece, not less than 70 % of the values in table 5.

One of the three individual values may be below the specified minimum average value given in table 5 but it shall be not less than 70 % of that value.

8.3 Flattening test properties

8.3.1 When tested in accordance with **13.2.2** the ring shall withstand being flattened without showing any cracks or flaws in the metal, except as specified in **8.3.2**, until the distance between the platens, H, is equal to or less than the value calculated using the constant specified.

8.3.2 Test pieces are normally tested without preparation of the cut edges and in this condition cracks originating at the edges of the test piece which are less than 6 mm long and which do not penetrate through the wall shall be deemed not to affect compliance with this standard.

8.4 Bend test properties

8.4.1 When tested in accordance with **13.2.3**, the test piece shall not show any cracks or flaws except as specified in **8.4.2**.

8.4.2 Test pieces are normally tested without preparation of the cut edges and, in this condition, cracks originating at the edges of the test piece which are less than 6 mm long and which do not penetrate the thickness of the piece shall be deemed not to affect compliance with this standard.

Table 5. Minimum Charpy V-notch impact properties at low temperature

Steel type	Type number	Reference heat treatment[1]	Thickness (see note)	Minimum Charpy V-notch impact test value (average of three tests) (10 mm by 10 mm test piece) at a temperature of (see 13.3 and 2.2(h))				
				−50 °C	−80 °C	−100 °C	−150 °C	−196 °C
			mm	J	J	J	J	J
Carbon	430 LT	HF, N	≤25	27	—	—	—	—
3½ % nickel	503 LT	N, N + T	≤25	—	39	27	—	—
9 % nickel	509 LT	Q + T $N_1 + N_2 + T$	≤25	—	—	55	47	40

[1] Q = quenched; N = normalized; T = tempered; HF = hot finished. (For temperatures see table 3.)

NOTE. Impact values for test pieces taken from thicknesses over 25 mm should be agreed at time of enquiry and order.

[1] In cases of dispute, room temperature is to be taken as 20 ± 5 °C.

9 Visual inspection and appearance

9.1 Visual inspection shall be carried out on the external and internal surfaces. In the case of the internal surface, the tube shall be viewed from each end.

NOTE 1. Visual inspection should be carried out in suitable lighting, i.e. an intensity of 500 lx or greater.

NOTE 2. It is recognized that the ability to visually examine the inner surface from the tube ends is limited in the case of small diameter tubes.

9.2 The tubes shall be clean and free from such defects as can be established by visual inspection in accordance with this standard (see **12.3**).

9.3 The tubes shall have a finish and a surface condition which permits surface imperfections or marks requiring dressing to be identified.

NOTE. Any special requirements for surface condition should be agreed between the purchaser and the manufacturer at the time of enquiry and order.

9.4 It shall be permissible to dress by grinding or machining surface marks and imperfections such as scabs, seams, tears, laps, slivers or gouges provided that the thickness of the tube after dressing does not fall below the nominal thickness by more than the tolerance specified in this standard.

9.5 Surface imperfections which encroach on the minimum wall thickness shall be considered defects and shall be deemed not to comply with this standard.

9.6 All dressed areas shall blend smoothly into the contour of the tube.

9.7 The manufacturer shall explore by grinding a sufficient number of surface marks and imperfections identified during visual inspection to provide assurance that these have been evaluated to ensure compliance with **9.8**.

9.8 The manufacturer shall, subject to the limitations given in **9.9**, dress surface imperfections found by exploration in accordance with **9.7** to be deeper than 5 % of the nominal thickness or 3 mm whichever is the lesser but not less than 0.5 mm. The purchaser shall have the option to specify 1.5 mm instead of 3 mm over which dressing surface imperfections shall be carried out (see **2.2**(e)).

9.9 If surface imperfections acceptable under **9.8** are not scattered and appear over a large area in excess of what is considered to be an acceptable surface condition then tubes shall be rejected or, alternatively, subjected to dressing as agreed at the time of the enquiry and order.

9.10 The tubes shall not deviate from straightness by more than 1 in 600 over the full length.

9.11 The ends shall be cut nominally square with the axis of the tube and shall be free from excessive burrs.

10 Tolerances

10.1 General

The tolerances on the dimensions of the tubes shall be as specified in **10.2** and **10.3**.

NOTE. Hot finished seamless (HFS), cold finished seamless (CFS) and cold finished electric resistance welded (CEW) tubes are produced to outside diameter and thickness dimensions or to inside diameter and thickness dimensions. Electric resistance welded (ERW) tubes are produced to outside diameter and thickness dimensions.

10.2 Outside or inside diameter, thickness and size of weld upset

The tolerances on outside or inside diameter shall include ovality and those on thickness shall include eccentricity.

(a) *Hot finished seamless* (HFS)

Tubes specified by outside diameter and thickness shall be subject to the following tolerances.

Outside diameter: ± 1 % with a minimum of ± 0.50 mm

Thickness:

Thickness to outside diameter ratio		Tolerance on thickness
≤3 %		± 15 %
>3 % ≤10 %		± 12.5 %
>10 %	≤168.3 mm outside diameter	± 12.5 %
	>168.3 mm outside diameter	± 10 %

Tubes specified by inside diameter and thickness shall be subject to the following tolerances.

NOTE. Such tubes are not normally available where the nominal outside diameter is less than 200 mm.

Inside diameter:

≤320 mm	± 1.5 %
>320 mm	± 1 %

Thickness:

Thickness to inside diameter ratio	Tolerance on thickness
≤7.5 %	± 15 %
>7.5 % ≤15 %	± 12.5 %
>15 %	± 10 %

(b) *Cold finished seamless* (CFS)

Tubes specified by outside or inside diameter and thickness shall be subject to the following tolerances.

Outside or inside diameter: ± 0.75 % with a minimum of ± 0.50 mm

Thickness: ± 7.5 %

Tubes 200 mm inside diameter and above, specified by the inside diameter and minimum thickness, shall be subject to the following tolerances.

Inside diameter: + 0.8 mm, − 1.6 mm

Thickness:

	Tolerance on thickness
≤6.5 mm	+ 15 %, − 0 %
>6.5 mm	+ 10 %, − 0 %

(c) *Electric resistance welded* (ERW) (applicable to as-welded and hot finished)

The outside diameter and thickness shall be subject to the following tolerances.

Outside diameter: ± 1 % with a minimum of ± 0.50 mm

Thickness: ± 7.5 %

The thickness tolerance shall not apply to the weld area.

The minimum thickness in the weld area shall be not less than that permitted in the body of the tube.

The external weld upset (flash) shall be removed completely, i.e. flush with the outside surface of the tube. Where practicable, the internal weld upset shall be trimmed throughout the length of the tube so that its maximum height shall not exceed 8 % of the specified thickness or 0.25 mm, whichever is the greater.

(d) *Cold finished electric resistance welded* (CEW)

Tubes specified by outside or inside diameter and thickness shall be subject to the following tolerances.

Outside or inside diameter: ± 0.75 % with a minimum of ± 0.50 mm

Thickness: ± 7.5 %

10.3 Length

Unless otherwise specified by the purchaser (see **2.2**(f)) tubes shall be supplied as random lengths.

NOTE. The actual range of the random lengths may be the subject of agreement between the purchaser and the manufacturer.

Where the length is specified as 'exact length' or 'cut length' the permissible deviation shall be + 6 mm, − 0 mm for lengths up to and including 6 m. For every 3 m increase in length above 6 m, the plus tolerance shall be increased by 1.5 mm with a maximum of 12.0 mm.

11 Tests

The tubes shall be subjected to the tests specified in table 6 appropriate to the test category.

Table 6. Tests for test category 1 and test category 2

Category 1	Category 2
Visual inspection (see clause **9** and **12.3**)	Visual inspection (see clause **9** and **12.3**)
Tensile test (see **8.1**, **12.2** and **13.1**)	Tensile test (see **8.1**, **12.2** and **13.1**)
Flattening test or bend test (see **8.1**, **12.2** and **13.2**)	Flattening test or bend test (see **8.1**, **12.2** and **13.2**)
Impact test (see **8.2**, **12.2.7** and **13.3**)	Impact test (see **8.2**, **12.2.7** and **13.3**)
Ultrasonic test (see **12.5**)	Leak tightness test (see **12.4**)

12 Number, selection and preparation of samples and test pieces

12.1 Selection of 'batches' for testing purposes

For tubes not heat treated, a batch shall consist only of tubes of the same diameter and thickness and of the same steel cast. For tubes that are heat treated, a batch shall consist only of tubes of the same diameter and thickness and of the same steel cast subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch-type furnace. If the number of tubes to be tested, as determined by **12.2**, includes a fraction, the number of tubes shall be rounded up to the next whole number.

12.2 Mechanical tests

12.2.1 *General*

For test category 1 the number of tubes on which mechanical tests are to be performed shall be 2 % of the tubes from each batch.

For test category 2 the number of tubes on which mechanical tests are to be performed shall be as follows:

(a) ≤323.9 mm outside diameter: 0.5 % of tubes from each batch;

(b) > 323.9 mm outside diameter: 1.0 % of tubes from each batch.

Test samples shall be cut from the tube in the final supply condition. If the tubes are to be delivered in a condition different from the specified final heat treatment condition, the test sample shall be in the appropriate reference heat treatment condition given in table 3.

12.2.2 *Tests at room temperature*[1)]

12.2.2.1 From the test sample from each tube selected for testing, one test piece shall be prepared for each of the mechanical tests specified in clause **11**.

12.2.2.2 For the tensile test (see **13.1**), the dimensions of the test piece shall comply, as appropriate, with BS 18.

For welded tubes the tensile test piece shall not include the weld unless the tube is tested in full section.

NOTE. For the tensile test, the test piece may be taken longitudinally or transversely at the option of the manufacturer.

12.2.2.3 For the flattening test (see **13.2.2**), a ring not less than 40 mm in length shall be taken from one end of each selected tube.

12.2.2.4 For the bend test (see **13.2.3**), the test piece shall be cut circumferentially from one end of each selected tube. The test piece shall not be less than 40 mm wide and shall be of the full thickness of the tube or, for tubes greater than 20 mm thick, a test piece shall be machined from a circumferential strip to a rectangular cross section 40 mm wide by 20 mm thick.

The length of the test piece shall be selected by the manufacturer to suit the equipment on which the test is carried out.

NOTE. The edges of the test piece may be rounded to a radius of 1.6 mm.

12.2.3 *Charpy V-notch impact testing at low temperature*

Impact testing shall not be carried out on tubes less than 6 mm thick.

For the impact test (see **13.3**), the test pieces shall be cut parallel to the principal direction of rolling, and the axis of the notch shall be perpendicular to the rolled surface of the product.

The test pieces shall be prepared in accordance with BS 131 : Part 2 and shall be machined with the largest possible of the following dimensions:

(a) 10 mm by 10 mm;

(b) 10 mm by 7.5 mm;

(c) 10 mm by 5 mm.

NOTE. Test pieces should be machined such that they do not include material from nearer to the surface than 1 mm. Where, due to a combination of tube thickness and curvature, this is not possible, test pieces may be produced containing material up to and including the whole section thickness.

12.3 Visual inspection

Every tube shall be inspected visually (see clause **9**).

12.4 Leak tightness

All test category 2 tubes shall be subjected to a leak tightness test. This shall be by a hydraulic test in accordance with **13.4** for all tube sizes above 180 mm outside diameter. For sizes 180 mm outside diameter and below, this shall be by either a hydraulic test in accordance with **13.4** or by an eddy current test in accordance with **13.5**, at the discretion of the manufacturer unless otherwise specified by the purchaser (see **2.2**(g)).

NOTE 1. The hydraulic leak tightness test is capable of detecting defects of a size and disposition permitting the test fluid to leak through the tube wall. It may not detect through-wall defects that are tight or defects extending an appreciable depth into the tube wall without complete penetration. The test specified in **13.4** should not be regarded as a test of strength since the maximum pressure specified will develop only limited stress in the wall of tubes having low diameter to thickness ratio.

NOTE 2. Both the hydraulic test and the eddy current test may leave a short length at each end of the tube incompletely tested. If specified at the time of enquiry and order the length affected should be determined by the manufacturer and reported to the purchaser. Further, if specified at the time of enquiry and order, the manufacturer may either cut off the untested lengths or test them by an agreed alternative procedure.

12.5 Ultrasonic testing

All tubes to test category 1 shall be ultrasonically tested (see **13.6**).

NOTE. Automatic ultrasonic testing may leave a short length at each end of the tube incompletely tested. The manufacturer should either cut off any untested lengths or test them by an agreed alternative procedure.

13 Test methods

13.1 Tensile test

13.1.1 The tensile test shall be carried out in accordance with BS 18.

13.1.2 The tensile strength R_m, the yield strength R_e and the elongation A shall be determined. For the yield strength, either the upper yield stress R_eH or the 0.5 % proof stress (total elongation) $R_{t\,0.5}$ shall be determined.

The percentage elongation shall be reported with reference to a gauge length of $L_o = 5.65\sqrt{S_o}$ where S_o is the original cross-sectional area of the gauge length. If other gauge lengths are used, the corresponding percentage elongation on $5.65\sqrt{S_o}$ shall be obtained by reference to BS 3894 : Part 1. In cases of dispute, a gauge length of $5.65\sqrt{S_o}$ shall be used.

13.2 Flattening or bend test

13.2.1 *General*

At the option of the manufacturer, and dependent upon the dimensions of the tube and method of manufacture, either a flattening test (see **13.2.2**) or a bend test (see **13.2.3**) shall be carried out.

[1)] In cases of dispute room temperature is to be taken as 20 ± 5 °C.

13.2.2 ***Flattening test***

The test piece shall be flattened at room temperature[1)] between parallel, flat platens until the distance between the platens, H (in mm), measured under load is not greater than the value given by the equation:

$$H = \frac{(1 + C)a}{C + a/D}$$

where

a is the specified thickness (in mm);

D is the specified outside diameter (in mm);

C is the flattening test constant, equal to 0.08.

For electric resistance welded tubes the weld shall be positioned at 90° to the direction of flattening.

13.2.3 ***Bend test***

NOTE. The bend test is not applied to electric resistance welded including induction welded tubes.

The test piece shall be bent at room temperature[1)] in the direction of the original curvature through an angle of 180° around a bar of diameter equal to four times the thickness of the test piece.

13.3 Charpy V-notch impact test

The tests shall be carried out in accordance with BS 131 : Part 2 at a temperature selected from table 5.

The tests shall be undertaken at the lowest temperature given in table 5 unless specified otherwise by the purchaser (see **2.2**(h)).

13.4 Hydraulic test

For test category 2 tubes which are hydraulically tested for the verification of leak tightness (see **12.4**) the test pressure P (in bar) shall be calculated from the equation:

$$P = \frac{20Sa}{D}$$

where

D is the specified outside diameter (in mm);

a is the specified thickness (in mm);

S is a stress (in N/mm^2) which shall be taken as 80 % of the specified minimum yield strength appropriate to thickness at room temperature.

The test shall be carried out at the pressure P or at 140 bar whichever is lower, but when 140 bar is lower than P, the purchaser has the option (see **2.2**(i)) to specify that the test shall be carried out at a pressure greater than 140 bar but not greater than the value P determined from the equation.

The test pressure shall be maintained sufficiently long for any leakage to be observed. Any tube failing to withstand the hydraulic pressure test shall be deemed not to comply with this standard.

13.5 Eddy current test

For test category 2 tubes that are eddy current tested for verification of leak tightness (see **12.4**) the eddy current test and the assessment of results shall be carried out in accordance with appendix C.

13.6 Ultrasonic test

For test category 1, ultrasonic testing for longitudinal imperfections and the assessment of results shall be carried out in accordance with appendix D.

13.7 Additional non-destructive test

The purchaser has the option to specify additional non-destructive tests, e.g. those required for the detection of transverse and laminar defects. The additional methods of test and the basis of acceptance shall be stated on the enquiry and order (see **2.2**(j)).

14 Retests

14.1 Should a tube selected for testing fail in any of the tests specified in **13.1** or **13.2**, the tube and the batch of tubes that it represents shall be deemed not to comply with this standard unless:

(a) two further tests of the same kind as produced failure are made from the same tube and both these further tests prove satisfactory; or

(b) the first tube tested is rejected and all the tests specified in **13.1** and **13.2** are carried out on two further tubes from the batch and all these tests are satisfactory; or

(c) if either of the further tests required by (a) or (b) proves unsatisfactory, the tubes represented are suitably heat treated or re-heat treated and samples are selected and tested in accordance with all the tests specified in **13.1** and **13.2** and all these tests are satisfactory.

14.2 Should a tube selected for testing fail the test specified in **13.3**, the tube and the batch of tubes it represents shall be deemed not to comply with this standard unless either of the following applies.

(a) If the average value of the three impact tests is less than the minimum average specified in **8.2**, or if one individual value is less than 70 % of the specified minimum, three additional test pieces from the same sample shall be tested. The average value of the six tests shall not be less than the specified minimum average. Not more than two of the individual values shall be less than the specified value. Not more than one individual value shall be less than 70 % of the specified value.

[1)] In cases of dispute room temperature is taken as 20 ± 5 °C.

(b) If the test required by **4.2**(a) proves unsatisfactory, the tubes represented are suitably heat treated or re-heat treated and samples are selected and tested in accordance with all the tests specified in **13.1**, **13.2** and **13.3** and all these tests are satisfactory.

15 Test certificate

15.1 A manufacturer's test certificate shall be supplied giving the following information:

(a) the designation (see clause **3**);

(b) the ladle analysis for elements specified in table 3 for each of the casts used;

(c) the mechanical test results for each of the batches tested, listing separately the low temperature impact test results for each of the batches tested;

(d) the purchaser's order number or other appropriate mark (see **17.2**(c)).

15.2 The certificate shall also give the following information where appropriate for options selected by the purchaser (see **2.2**):

(a) the steelmaking process used (see **4.1**);

(b) the product analysis (see **6.2**);

(c) the content of selected elements in addition to those specified in table 3 (see **6.3**);

(d) the final supply condition (see clause **7**), including heat treatment times and temperatures where applicable;

(e) for category 2 tubes, the method of verification of leak tightness, either by eddy current or hydraulic and, in the latter case, the pressure applied (see **12.4**);

(f) the results of additional non-destructive testing (see **13.7**).

16 Protective coating

The tubes shall be supplied either uncoated or with the manufacturer's normal mill coating at the option of the purchaser (see **2.2**(k)).

NOTE. If the purchaser requires additional measures to protect the tubes during delivery or storage, then this should be the subject of agreement between the purchaser and the manufacturer.

17 Marking

17.1 Before dispatch from the manufacturer's works, the tube shall be marked in accordance with **17.2** or, if specified by the purchaser on the enquiry and order (see **2.2**(l)), in accordance with **17.4**.

17.2 Except as provided for below for tubes that are bundled, each tube shall be legibly marked at one end commencing not more than 300 mm from the end, by stencilling or other indelible marking.

The marking shall consist of the following in the sequence indicated:

(a) the manufacturer's name or identification mark;

(b) the designation[1] as given in clause **3**, e.g. BS 3603 : CFS 430 LT Cat. 1;

(c) the purchaser's order number or other appropriate mark to identify it with the test certificate;

(d) the cast identity.

For tubes that are bundled, the information in (a), (b), (c) and (d) shall be either stamped on one or more metal or other durable tags, or printed on banding clips or straps, which shall be securely attached to each bundle. Tubes of the same cast shall be included in any one bundle. The bundle shall not include tubes from more than one cast.

17.3 The quality of the paint or ink applied shall be such that it shall have a life of at least one year in unheated storage under cover.

The dried film shall contain not more than 250 ppm (0.025 %) of any of the following metals:

lead, tin, copper, zinc.

NOTE. For certain applications limits may be required on the levels of sulphur and halogens in the paint. These limits should be the subject of agreement between the supplier and the purchaser.

17.4 If specified by the purchaser in the enquiry and order (see **2.2**(l)) each tube shall be marked in accordance with BS 5383 and shall include the information specified in **17.2**(a), (b), (c) and (d).

NOTE. Colour coding is an optional additional requirement in BS 5383 and, if required, should be specified by the purchaser on the enquiry and order.

[1] Marking BS 3603 : 1991 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is therefore solely the responsibility of the person making the claim. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

Appendices

Appendix A. Dimensional limits of tubes in relation to the method of manufacture

The range of dimensions shown in table 7 will cover most applications for which the standard will be used for the tubes supplied to outside diameter and thickness. However, tubes supplied to inside diameter and thickness are also available in the seamless and cold finished electric resistance welded ranges.

Table 7. Dimensional limits of tubes in relation to the method of manufacture

Method of manufacture	Outside diameter	Maximum thickness
	mm	mm
Hot finished seamless (HFS)	33.7 to 1200	200
Cold finished seamless (CFS)	12.7 to 235	25
Electric resistance welded (ERW)	12.7 to 508	12.7
Cold finished electric resistance welded (CEW)	12.7 to 235	10

Appendix B. Designations of steel tubes in BS 3603 : 1991 and the nearest equivalent designations in BS 3603 : 1977 and ISO 2604 : Parts II and III

Table 8 provides a comparison of designations for tubes in this standard with nearest equivalents in BS 3603 : 1977 and ISO 2604 : Parts II and III.

Appendix C. Eddy current testing of tubes for verification of leak tightness

C.1 General

Eddy current testing shall be used only on tube sizes up to and including 180 mm outside diameter. The tubes shall be tested in accordance with BS 3889 : Part 2A with the options of BS 3889 : Part 2A as specified in **C.2** and **C.3**, and with the modification to BS 3889 : Part 2A as specified in **C.4**.

C.2 Test procedure

The tubes shall be tested for verification of leak tightness using a concentric coil or a rotating tube/rotating coil eddy current technique as described for methods A and B of BS 3889 : Part 2A.

C.3 Reference standards

The equipment shall be calibrated using reference standards prepared in accordance with **5.2.4**(a) for method A and **5.2.4**(b) for method B of BS 3889 : Part 2A : 1986. The dimensions of the reference

Table 8. Designations of steel tubes in BS 3603 : 1991 and the nearest equivalent designations in BS 3603 : 1977 and ISO 2604 : Parts II and III.

BS 3603 : 1991		BS 3603 : 1977	ISO 2604 : 1975 : Parts II and III
Designation	Colour code in accordance with BS 5383	Designation	Steel number
HFS 430 LT Cat. 1	Light green	HFS 410 LT50 Cat. 1	TS10 Cat IV
CFS 430 LT Cat. 1		CFS 410 LT50 Cat. 1	TS10 Cat IV (cold finished)
ERW 430 LT Cat. 1		ERW 410 LT50 Cat. 1	TW10 Cat IV
CEW 430 LT Cat. 1		CEW 410 LT50 Cat. 1	TW10 Cat IV (cold finished)
HFS 430 LT Cat. 2		HFS 410 LT50 Cat. 2	TS10 Cat II
CFS 430 LT Cat. 2		CFS 410 LT50 Cat. 2	TS10 Cat II (cold finished)
ERW 430 LT Cat. 2		ERW 410 LT50 Cat. 2	TW10 Cat II
CEW 430 LT Cat. 2		CEW 410 LT50 Cat. 2	TW10 Cat II (cold finished)
HFS 503 LT Cat. 1	Not colour coded	HFS 503 LT100 Cat. 1	TS43 Cat IV
CFS 503 LT Cat. 1		CFS 503 LT100 Cat. 1	TS43 Cat IV (cold finished)
HFS 503 LT Cat. 2		HFS 503 LT100 Cat. 2	TS43 Cat II
CFS 503 LT Cat. 2		CFS 503 LT100 Cat. 2	TS43 Cat II (cold finished)
HFS 509 LT Cat. 1		HFS 509 LT196 Cat. 1	TS45 Cat IV
CFS 509 LT Cat. 1		CFS 509 LT196 Cat. 1	TS45 Cat IV (cold finished)
HFS 509 LT Cat. 2		HFS 509 LT196 Cat. 2	TS45 Cat II
CFS 509 LT Cat. 2		CFS 509 LT196 Cat. 2	TS45 Cat II (cold finished)

hole (method A) and the reference notch (method B) shall be as specified in tables 9 and 10 of this standard.

C.4 Assessment of results

The results of the test shall be assessed in accordance with clause 7 of BS 3889 : Part 2A : 1986, except that **7.3**(b) shall be replaced by the following:

'Explore the suspect area of the tube by dressing. If the tube thickness within the dressed area remains within the thickness tolerance, either:

(1) retest the tube using the selected eddy current method in accordance with this appendix and if no signals are obtained that give a trigger/alarm condition the tube shall be deemed to have passed the test; or

(2) subject the suspect area to magnetic particle inspection in accordance with BS 6072 to ensure that dressing has resulted in complete removal of the imperfection; the tube shall then be deemed to have passed the test.

If the tube thickness within the dressed area does not remain within the thickness tolerance or, if on retesting using the eddy current test method signals are obtained that give a trigger/alarm condition, either:

(3) cut off the suspect area, the remaining length being deemed to have passed the test; or

(4) the tube shall be deemed not to have passed the test.'

Appendix D. Ultrasonic testing of tubes for detection of longitudinal imperfections

D.1 General

The tube shall be tested in accordance with BS 3889 : Part 1 with the options of BS 3889 : Part 1 as specified in **D.2** and **D.3**, and with the modification to BS 3889 : Part 1 as specified in **D.4**.

D.2 Test procedure

The tube shall be tested for the detection of imperfections that are oriented predominantly longitudinally to the major axis of the tube in accordance with method A of BS 3889 : Part 1. Scanning shall be carried out in both directions of beam travel in accordance with figure 1(a) of BS 3889 : Part 1.

D.3 Reference standards

The equipment shall be calibrated using longitudinal notches parallel to the major axis of the tube, in accordance with **7.1**, **7.2.1**, **7.2.2** and **7.2.5** of BS 3889 : Part 1 : 1983. The dimensions of the reference notches shall be as given in table 11.

Table 9. Drill diameter sizes

Outside diameter	Drill diameter
mm	mm
≤ 25	1.20
> 25 ≤ 45	1.70
> 45 ≤ 65	2.20
> 65 ≤100	2.70
>100 ≤140	3.20
>140 ≤180	3.70

Table 10. Notch dimensions for method B

Depth	12½ % of the specified tube thickness
Minimum depth	0.6 mm
Maximum depth	1.5 mm
Tolerance on depth	± 15 % of notch depth
Width	Not greater than notch depth with a minimum of 0.50 mm
Length	A convenient length selected by the manufacturer for calibration and checking purposes

Table 11. Reference notch dimensions and tolerances

Depth	5 % of specified tube thickness
Minimum depth	0.3 mm
Maximum depth	1.5 mm
Tolerance on depth	± 15 % of notch depth or ± 0.05 mm whichever is the larger
Maximum width	1.5 mm
Length	A convenient length, selected by the manufacturer for calibration and checking purposes

D.4 Assessment of results

D.4.1 Any tube that does not produce signals giving a trigger/alarm condition shall be deemed to have passed the test.

D.4.2 Any tube that produces signals giving a trigger/alarm condition shall be designated 'suspect', or, at the manufacturer's option, shall be retested on the same automatic equipment as used in the original test.

D.4.3 If upon retesting (see **D.4.2**), no signal giving a trigger/alarm condition is obtained, the tube shall be deemed to have passed the test. Tubes giving a trigger/alarm condition upon retesting shall be designated 'suspect'.

D.4.4 For 'suspect' tubes, one or more of the actions specified in (a) to (e) shall be taken, or (f) shall apply.

(a) The manufacturer shall show to the satisfaction of the purchaser that the trigger/alarm condition arises from a combination of minor imperfections, individually not serious enough to cause a trigger/alarm condition and the tube shall then be deemed to have passed the test.

(b) For inside surface imperfections, the 'suspect' area shall be explored by dressing, using an acceptable method and, after checking that the remaining thickness is within tolerance, the 'suspect' area shall be retested by an ultrasonic shear wave method using equipment with the same ultrasonic parameters and calibrated to give the same test sensitivity as used in the original ultrasonic test. If no signals are obtained that give a trigger/alarm condition, the tube shall be deemed to have passed the test.

(c) For outside surface imperfections, the 'suspect' area shall be explored by dressing using an acceptable method and, after checking that the remaining thickness is within tolerance, the 'suspect' area shall be retested in accordance with BS 6072 until it can be shown that the imperfection has been completely removed.

The 'suspect' area shall then be retested by an ultrasonic shear wave method using equipment with the same ultrasonic parameters and calibrated to give the same test sensitivity as used in the original ultrasonic test. If no signals are obtained that give a trigger/alarm condition, the tube shall be deemed to have passed the test.

(d) The full circumference of the surface of the tube shall be dressed using an acceptable method, either completely or locally along its length to include the 'suspect' area and, after checking that the thickness is within tolerance, the tube shall be retested on the same automatic equipment as that used in the original test. If no signals are obtained that give a trigger/alarm condition, the tube shall be deemed to have passed the test.

(e) The 'suspect' area shall be cropped off, the remaining length being deemed to have passed the test.

(f) The tube shall be deemed not to have passed the test.

Publication(s) referred to

BS 18 Method for tensile testing of metals (including aerospace materials)

BS 131 Methods for notched bar tests
Part 2 The Charpy V-notch impact test on metals

BS 1600 Specification for dimensions of steel pipe for the petroleum industry
Part 2 Metric units

BS 3600 Specification for dimensions and masses per unit length of welded and seamless steel pipes and tubes for pressure purposes

BS 3601 Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes

BS 3602 Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties
[1)]Part 1 Specification for seamless and electric resistance welded including induction welded tubes
Part 2 Submerged arc welded tubes

BS 3604 Steel pipes and tubes for pressure purposes: ferritic alloy steel with specified elevated temperature properties

BS 3605 Specification for seamless and welded austenitic stainless steel pipes and tubes for pressure purposes

BS 3889 Methods for non-destructive testing of pipes and tubes
Part 1 Methods of automatic ultrasonic testing for the detection of imperfections in wrought steel tubes
Part 2A Automatic eddy current testing of wrought steel tubes

BS 3894 Method for converting elongation values for steel
Part 1 Carbon and low alloy steels

BS 5383 Specification for material identification of steel, nickel alloy and titanium alloy tubes by continuous character marking and colour coding of steel tubes

BS 5750 [1)]Quality systems

BS 6072 Method for magnetic particle flaw detection

BS 6200 Sampling and analysis of iron, steel and other ferrous metals
Part 3 Methods of analysis

BS Handbook 19 Methods for the sampling and analysis of iron, steel and other ferrous metals

ANSI B36.10M Welded and seamless wrought steel pipe

ANSI B36.19M Stainless steel pipe

ISO 2604 Steel products for pressure purposes — Quality requirements
Part II Wrought seamless tubes
Part I Electric resistance and induction-welded tubes

[1)] Referred to in the foreword only.

BS 3603 : 1991

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Contract requirements

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.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

Any person who finds an inaccuracy or ambiguity while using this British Standard should notify BSI without delay so that the matter may be investigated swiftly.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying British Standards

Orders for all British Standard publications should be addressed to the Sales Department at Milton Keynes.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library, the Standardline Database, the BSI Information Technology Service (BITS) and its Technical Help to Exporters Service. Contact Enquiry Section at Milton Keynes: Tel: 0908 221166.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact the Manager, Membership Development at Milton Keynes: Tel: 0908 220022.

Copyright

BSI
2 Park Street
London
W1A 2BS

BSI
Linford Wood
Milton Keynes
MK14 6LE

9102—7—0.9k— JWD

ISM/73