BRITISH STANDARD

BS 3602-2: 1991

Steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties —

Part 2: Specification for longitudinally arc welded tubes

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.
British Compressed Air Society
British Forging Industry Association
British Gas plc
British Steel Industry
Electricity Supply Industry in United Kingdom
Engineering Equipment and Materials Users' Association
Lloyd's Register of Shipping
Power Generation Contractors' Association (BEAMA Ltd.)
Process Plant Association
The 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 Welded Steel Tube Association
Confederation of British Industry
Energy Industries Council
Stainless Steel Fabricators' Association of Great Britain

This British Standard, having been prepared under the direction of the Iron and Steel Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 31 October 1991

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Contents

Foreword

This Part of BS 3602 has been prepared under the direction of the Iron and Steel Standards Policy Committee. It supersedes BS 3602-2:1978, which is withdrawn.

This Part of BS 3602 is one of a series specifying requirements for steel pipes and tubes for pressure purposes. Other standards in the series are as follows.

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

BS 3602, *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.*

BS 3603, *Specification for carbon and alloy steel pipes and tubes with specified low temperature properties for pressure purposes.*

BS 3604, *Steel pipes and tubes for pressure purposes: ferritic alloy steel with specified elevated temperature properties — Part 1 Specification for seamless and electric resistance welded tubes.*

BS 3605:1973, *Specification for seamless and welded austenitic stainless steel pipes and tubes for pressure purposes.*

BS 3605, *Austenitic stainless steel pipes and tubes for pressure purposes — Part 1 Specification for seamless tubes.*

This Part of BS 3602 takes account of current production procedures for longitudinally arc welded tubes, as well as pressure vessel quality grades of carbon and carbon manganese steel plate now in common industrial use.

The steels covered by this Part of BS 3602 are generally regarded as being weldable. However, care should be taken and welding should be carried out in accordance with the appropriate British Standards for welding.

The main technical differences between this edition and the previous edition are that, reflecting improvements in steelmaking practice, the steel types 430 and 490 show improvement in minimum specified room temperature tensile strength and 0.2 % proof stress at elevated temperatures. The chemical composition and mechanical properties at room temperature align with corresponding steels in BS 1501-1. Tubes to this Part of BS 3602 are available in a choice of supply conditions, depending on the class ordered, as detailed in clause **7**. The two test categories in BS 3602-2:1978 have been merged into one set of test requirements which include mandatory non-destructive testing of the weld. Arc welding processes, in addition to submerged arc welding, are now permitted.

The appendix showing elevated temperature stress rupture values has been deleted. Available values refer to parent metal only with little data available on weld metal. Elevated temperature stress rupture values for corresponding steels are given in BS 1501-1 (see Table 1, notes 5 and 7 of this Part of BS 3602).

The designations of steel tubes in this Part of BS 3602 and their nearest equivalent designations in ISO 2604-VI are given in Appendix A for information.

This Part of BS 3602 is aligned as far as possible with corresponding material requirements and test procedures now agreed for incorporation in documents by the International Organization for Standardization (ISO).

The specified elevated temperature yield or proof stress values are those derived from national data by the procedure described in BS 3920. Additionally, provision is made for the application of the related procedure for verifying that a product consistently meets specified levels of elevated temperature values.

It is recommended that the results of elevated temperature tests, together with information on the product thickness, the room temperature tensile properties and the chemical composition of the material, should be sent to the committee so that, for future revisions of this Part of BS 3602, minimum elevated temperature proof stress values can be derived from a continuously updated data bank. The address is Secretariat of ISM/73/-/1, British Standards Institution, 3 York Street, Manchester, M2 2AT, UK.

Impact test values are not specified in this Part of BS 3602 but if the purchaser requires an impact test to be carried out the Charpy impact test should be carried out in accordance with BS EN 10 045-1.

The appropriate British Standards for the design and construction of boilers, pressure vessels, pipework, etc. should be consulted for requirements relating to the application and permissible design stress for products made in accordance with this Part of BS 3602.

Assessed capability. Users of this British Standard are advised to consider the desirability of assessment and registration of a supplier's quality systems against the appropriate Part of BS 5750 by a third party certification body.

It is outside the scope of this Part of BS 3602 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 purposes of this Part of BS 3602, no difference is intended in meaning between "pipe" and "tube" though idiomatic use prefers sometimes the one and sometimes the other.

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 to iv, pages 1 to 16, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Part of BS 3602 specifies requirements for plain end, longitudinally arc welded, carbon and carbon manganese steel tubes suitable for pressure purposes.

Tubes manufactured in accordance with this Part of BS 3602 have specified room temperature properties and specified proof stress values at elevated temperatures.

In addition to the definitive requirements this specification 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 Part of BS 3602 both the definitive requirements and the documented items have to be satisfied.

NOTE 1 The range of diameters and thicknesses appropriate to this Part of BS 3602 is given in Appendix B.

NOTE 2 The titles of the publications referred to in this standard are listed on page 16.

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, i.e. the number and Part of this British Standard, the type of steel and the final supply condition (see clause **3**), e.g. BS 3602-2:430: class 10;

b) the tube outside diameter and thickness;

c) the tube length, if exact (see **10.9**);

d) the quantity in metres or numbers of lengths.

2.2 Options to documented

A number of options are permitted by this Part of BS 3602 as listed below and the purchaser shall identify the options required. Both the definitive requirements specified throughout this Part of BS 3602 and the following documented items stated by the purchaser shall be satisfied by the manufacturer before a claim of compliance with this Part of BS 3602 can be made and verified. In the event that the purchaser does not indicate his requirements at the time of enquiry and order the manufacturer shall select the options where appropriate.

a) The steelmaking process [see **4.1** and **15.2** a)].

b) Whether welding procedure details and welding procedure approval details are required (see **5.2**).

c) Whether evidence of welder or welding machine operator approval is required (see **5.2**).

d) Whether additional procedure approval is required (see **5.2**).

e) Whether a product analysis is required [see **6.2** and **15.2** b)].

f) Whether the content of selected chemical elements additional to those specified are to be reported [see **6.3** and **15.2** c)].

g) Whether the maximum carbon equivalent value is to be reported (see **6.4**).

h) Whether the upper limit above which the dressing of surface imperfections is required will be 1.5 mm (see **9.8**).

i) Whether end sizing is required (see **10.8**).

j) Whether lengths other than random lengths are required (see **10.9**).

k) Whether the hydraulic test is to be carried out at a pressure in excess of 140 bar[1)] and the pressure required (see **13.3**).

l) The method of non-destructive testing to be used (see **13.4**).

m) Whether additional non-destructive testing of the weld is required (see **13.5.1**).

n) The quality grade to which the plate shall be tested (see **13.5.2**).

o) Whether verification of elevated temperature proof stress values is required (see **13.6.1**).

p) Whether verification of elevated temperature proof stress values by testing is required (see **13.6.2**) and the temperature selected from Table 4 at which this is to be carried out.

q) Whether the tubes are to be supplied uncoated or with the manufacturer's normal mill coating (see clause **16**).

r) Whether the marking requirements to BS 5383 are required (see **17.1** and **17.4**).

3 Designation

The tubes shall be designated by the number and Part of this British Standard, i.e. BS 3602-2, by a number which indicates the type of steel (see Table 1) and by the final supply condition (see clause **7**).

Example. BS 3602-2:430: class 10, designates longitudinally arc welded tube made from steel type 430 supplied in the as welded condition.

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

NOTE The designations for tubes in this Part of BS 3602 and their nearest equivalent designations in ISO 2604-VI are listed in Appendix A 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

All steels shall be fully killed.

5 Manufacture of the product

5.1 The tubes shall be manufactured from steel plate welded longitudinally and continuously across the abutting edges by either:

a) an automatic arc welding process; or

b) the manual metal arc process.

At least one pass on the inside and at least one pass on the outside of the tube shall be made. The filler metal shall comply with BS 2901-1, BS 4165 or BS 639 as appropriate.

The tubes shall be hot formed or cold formed prior to longitudinal welding.

NOTE 1 At the option of the manufacturer a final hot finishing operation may be carried out.

NOTE 2 The dimensional limits generally applicable to this Part of BS 3602 are shown in Appendix B and the tolerances are given in clause **10**.

NOTE 3 The terms "hot formed" and "cold formed" apply to the condition of the tube before final heat treatment, if required, in accordance with clause **7**.

5.2 The welding procedure including the repair procedure shall be specified and qualified in accordance with BS 4870-1 or BS 4870-4. If required by the purchaser, the manufacturer shall supply details of welding procedure and evidence of welding procedure approval [see **2.2** b)].

The welder shall be qualified to BS 4871-1 and the welding machine operator shall be qualified to BS 4870-4. If required by the purchaser, the manufacturer shall provide evidence of the welder or welding machine operator approval [see **2.2** c)].

If the purchaser requires additional procedure approval for his particular order, this shall be specified in the enquiry and order [see **2.2** d)].

5.3 Repairs to the weld shall be permitted. Defects in the weld shall be completely removed by flame gouging, grinding or chipping and the cavity shall be finished by grinding. The cleaned cavity shall be examined by magnetic particle inspection in accordance with BS 6072 to ensure the removal of defects. Repair to welds shall be by an arc welding process in accordance with **5.1** a) or b) and a procedure in accordance with **5.2**. Repair welds shall be subjected to hydraulic testing and the same type and level of non-destructive testing as used for examination of the full length of the weld.

6 Chemical analysis

6.1 Ladle analysis

The steel shall show on ladle analysis the composition given in Table 1 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** e)]. When an analysis on the product is carried out, the permitted deviations given in Table 2 shall apply to the specified ladle analysis in Table 1.

The number of samples to be taken shall be one per cast. The samples shall be taken either from the test piece used for the verification of the parent metal mechanical properties or from the parent 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 6200-3 as appropriate.

6.3 Additional elements

If required by the purchaser [see **2.2** f)] the content of elements, selected by the purchaser, in addition to those specified in Table 1, shall be reported.

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

Table 1 — Chemical composition and mechanical properties at room temperature

Steel type	Chemical composition (ladle analysis) (see notes 1 and 2)										Mechanical properties at room temperature (see note 3)							
	C	Si		Mn		P	S	Cr	Cu	Mo	Ni	Al_{met} (see note 4)	R_m		R_e min for thickness		A	Bend test mandrel daimeter
	max.	min.	max.	min.	max.	max.	max.	max.	max.	max.	max.	min.	min.	max.	⩽ 16 mm	> 16 mm ⩽ 40 mm	min.	
	%	%	%	%	%	%	%	%	%	%	%	%	N/mm^2	N/mm^2	N/mm^2	N/mm^2	%	
430 (see note 5)	0.25	0.10	0.35	0.60	1.40	0.030	0.030	0.25 (see note 6)	0.30 (see note 6)	0.10 (see note 6)	0.30 (see note 6)	—	430	550	250	240	23	4*a*
490 (see note 7)	0.22	0.10	0.40	0.90	1.60	0.030	0.030	0.25 (see note 8)	0.30 (see note 8)	0.10 (see note 8)	0.75 (see note 9)	0.015	490	610	325	315	21	6*a*

NOTE 1 Elements not quoted in this table shall not be intentionally added other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition of such elements from scrap or other materials used in the manufacture, but residual elements may be present provided that the mechanical properties and applicability are not adversely affected. Elements added for the purpose of finishing the heat shall be reported.

NOTE 2 For permitted deviations on product analysis, see Table 2.

NOTE 3

R_e is the yield strength. For acceptance purposes either the upper yield strength R_{eH} or the 0.5 % proof strength (total elongation) $R_{t0.5}$ may be used (see **13.1.2**).

R_m is the tensile strength.

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

NOTE 4 Where a minimum Al_{met} of 0.015 % is specified, determination of the total aluminium content, provided the value is not less then 0.018 %, shall be deemed to meet this requirement. In cases of dispute, the metallic aluminium content shall be determined.

NOTE 5 Steel conforming with BS 1501-1 161-430 meets the requirements of steel type 430.

NOTE 6 The total of % Cr + % Cu + % Mo + % Ni shall not exceed 0.70 %.

NOTE 7 Steel conforming with BS 1501-1 224-490 meets the requirements of steel type 490.

NOTE 8 The total of % Cr + % Cu + % Mo shall not exceed 0.50 % (see also note 9).

NOTE 9 The purchaser may specify a nickel content of 0.30 % max. In this case the combined total of % Cr + % Cu + % Mo + % Ni shall not exceed 0.70 % and suffix L shall be added to the designation of the steel type.

6.4 Carbon equivalent value

6.4.1 If the maximum carbon equivalent value is required by the purchaser, this shall be specified in the enquiry and order [see **2.2** g)].

NOTE The maximum carbon equivalent value should be agreed between the purchaser and the manufacturer

6.4.2 The actual carbon equivalent value (CEV) shall be based on the ladle analysis using the formula

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

Table 2 — 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[a]	0.05[a]
Manganese	≤ 2.0	0.10[a]	0.10[a]
Phosphorus	≤ 0.050	0.005	—
Sulphur	≤ 0.050	0.005	—
Chromium	≤ 0.25	0.05	—
Copper	≤ 0.30	0.05	—
Molybdenum	≤ 0.10	0.03	—
Nickel	≤ 0.30	0.05	—
Nickel	> 0.30 ≤ 0.75	0.10	—

[a] 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

7.1 Tubes shall be supplied in one of the final supply conditions given in Table 3, unless otherwise specified by the purchaser.

For cold formed class 10 tubes the inside diameter shall be not less than 20 times the plate thickness.

NOTE 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**).

7.2 Stress relieving of tubes shall be carried out in the range 580 °C to 620 °C.

7.3 Normalizing shall be carried out in the range 870 °C to 930 °C. It is permissible to straighten and round during cooling from normalizing temperature.

Table 3 — Final supply condition

Class	Final supply condition
10	As welded
20	Welded, stress relieved (see **7.2**)
30	Welded, normalized (see **7.3**)

8 Mechanical properties

8.1 Mechanical properties at room temperature

The mechanical properties at room temperature[2)] to be obtained on test pieces selected prepared and tested in accordance with clauses **12** and **13** respectively shall be as specified in Table 1.

NOTE Heat treatment carried out after the delivery of the pipe may have an adverse effect on the mechanical properties. The purchaser may therefore request, at the time of enquiry and order, additional mechanical tests on samples that have been given heat treatment different from, or additional to those given in clause **7**. 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 Elevated temperature minimum 0.2 % proof stress values

The elevated temperature minimum 0.2 % proof stress values shall be as specified in Table 4 when sampled as described in **12.6** and tested or verified as described in **13.6**.

NOTE The values are not subject to verification unless required by the purchaser (see **13.6**).

8.3 Weld bend test properties

When tested in accordance with **12.2.4** and **13.2**, the test piece shall show no crack or flaw exceeding 3 mm in length in any direction as measured on the surface of the test piece.

9 Visual inspection and appearance

9.1 The tubes shall be clean and free from such defects as can be established by visual inspection in accordance with this Part of BS 3602 (see **12.3**).

9.2 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 Visual inspection should be carried out in suitable lighting, i.e. an illuminance of 500 lx or greater.

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

Table 4 — Minimum 0.2 % proof stress ($R_{p0.2}$) values at elevated temperatures

Steel type	$R_{p0.2}$ min at a temperature of:					
	100 °C	150 °C	200 °C	250 °C	300 °C	350 °C
	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2
430	239	224	202	180	164	151
490	262	247	230	214	196	182

NOTE Values are based on tests carried out in accordance with BS 3688-1 at the specified strain rate of 0.001 to 0.003 per minute.

9.3 The tubes shall have a finish and 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 Part of BS 3602.

9.5 Surface imperfections which encroach on the minimum wall thickness shall be considered defects and shall be deemed not to comply with this Part of BS 3602.

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 limitation given in **9.4**, dress surface imperfections found by exploration in accordance with **9.7** to be deeper than 5 % of the nominal thickness but not less than 0.5 mm. The purchaser shall have the option to specify an upper limit of 1.5 mm above which dressing of surface imperfections shall be carried out [see **2.2** h)]. The manufacturer shall, subject to the limitations given in **9.4**, dress mechanical marks, abrasions or pits caused by the manufacturing process which are deeper than 1.5 mm.

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, the 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 square with the axis of the tube within ± 1.5 mm and shall be free from excessive burrs.

10 Tolerances

10.1 General

The maximum tolerances on the dimensions of the tubes shall be as specified in **10.2** to **10.6**.

10.2 Outside diameter

The outside diameter of the body of the tube, as measured by taping the circumference, shall not deviate from the specified diameter by more than ± 0.5 % or ± 4 mm, whichever is the smaller.

10.3 Ovality

For tubes having a diameter to thickness ratio not exceeding 100, the difference between major and minor outside diameters shall not exceed 2 % of the specified diameter.

NOTE For diameter to thickness ratios exceeding 100 the tolerance on ovality should be agreed between the manufacturer and the purchaser.

10.4 Thickness (excluding weld reinforcement)

The tolerance on all thicknesses shall be ± 7.5 %.

10.5 Weld reinforcement

Neither the inside nor the outside weld reinforcement shall exceed the following values:

for thicknesses up to and including 12.5 mm:	3 mm
for thicknesses over 12.5 mm:	4.5 mm

10.6 Misalignment of plate edges at the longitudinal weld

The misalignment of the abutting plate edges shall not exceed the following limits:

for thicknesses up to and including 12.5 mm:	1.5 mm
for thicknesses over 12.5 mm:	12.5 % of specified thickness or 3 mm whichever is the smaller

10.7 Undercutting at the longitudinal weld

10.7.1 Minor undercutting on either the inside or the outside of the pipe shall be acceptable as follows:

a) undercuts up to a depth of 0.4 mm and of any length; or

b) undercuts up to a depth of 0.8 mm with a maximum length of half the wall thickness.

10.7.2 Undercuts of dimensions greater than those specified in **10.7.1** shall be considered defects and shall be dealt with as specified in **10.7.4**.

10.7.3 Undercuts that encroach on the minimum thickness of the pipe shall be considered defects and shall be dealt with as specified in **10.7.4** b), **10.7.4** c) or **10.7.4** d).

10.7.4 For pipes having undercut defects, one of the following actions shall be taken:

a) the defect shall be removed by grinding, 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;

b) the defect shall be repaired by welding in accordance with **5.3**;

c) the section of pipe containing the defect shall be cut off;

d) the full length shall be rejected.

10.8 End sizing

If end sizing is specified by the purchaser in the enquiry and order [see **2.2** i)] the tolerance on the outside diameter within 100 mm of the tube end shall not exceed + 2.5, – 1 mm as measured by taping the circumference.

10.9 Length

Unless otherwise specified by the purchaser [see **2.2** j)] tubes shall be supplied as random lengths with a tolerance of + 300, – 600 mm. Where the length is specified as "exact length" or "cut length" the permissible deviation shall be + 6, – 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 up to a maximum of 12.0 mm.

11 Tests

The tubes shall be subjected to the following tests:

a) visual inspection (see clause **9** and **12.3**);

b) tensile test on material (see **8.1**, **12.2** and **13.1**);

c) transverse tensile test on weld (see **8.1**, **12.2** and **13.1**);

d) bend test on weld (see **8.3**, **12.2** and **13.2**);

e) hydraulic test (see **12.4** and **13.3**);

f) non-destructive testing of weld (see **12.5** and **13.4**) by ultrasonic test or radiographic examination.

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, manufactured using the same weld procedure, and from the same cast. For tubes that are heat treated, a batch shall consist of tubes of the same diameter and thickness and from the same 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, it shall be rounded up to the next whole number.

12.2 Mechanical tests at room temperature[3)]

12.2.1 The number of tubes on which mechanical tests at room temperature are to be performed shall be 2 % of the tubes from each batch.

12.2.2 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 samples shall be in the appropriate reference heat treatment condition given in clause **7**.

From the test samples from each tube selected for testing, two test pieces shall be prepared for the weld bend test, and one test piece shall be prepared for each of the remaining mechanical tests specified in clause **11**.

12.2.3 For the tensile test on the material and weld (see **13.1**), the dimensions of the test piece shall comply with the appropriate requirements of BS EN 10002-1 and BS 709 respectively.

For the tensile test on the material, the test piece shall be cut transversely and clear of the weld.

For the tensile test on the weld, the test piece shall be cut with the weld at the centre of the test piece and at right angles to the longitudinal axis of the test piece.

12.2.4 For the weld bend test (see **13.2**) the test pieces shall be cut transversely from one end of each selected tube with the weld at the centre of the test piece.

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

For tubes up to and including 20 mm thick two test pieces shall be prepared, one for a face bend test and one for a root bend test. The test pieces shall be not less than 40 mm wide and of the full thickness of the tube. The weld reinforcement shall be removed from both faces.

For tubes over 20 mm thick two test pieces shall be prepared either for one face bend test and one root bend test or for two side bend tests.

Test piece preparation and testing shall be in accordance with BS 709.

NOTE The test pieces may be flattened before testing.

12.3 Visual inspection

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

12.4 Hydraulic testing

Each tube shall be subjected to a hydraulic test over its full length. If repair of the weld is carried out (see **5.3**), hydraulic testing shall be carried out after completion of the repair, in accordance with **13.3**.

12.5 Non-destructive testing

All tube welds shall be non-destructively tested. If repair of the weld is carried out (see **5.3**), non-destructive testing shall be carried out after completion of the repair, in accordance with **13.4**.

12.6 Elevated temperature proof stress testing

If elevated temperature proof stress testing is carried out (see **13.6**), one test shall be made on each cast using a test piece taken from the material at a position adjacent to the test pieces used for the tensile test at room temperature[4)]. If tubes of more than one thickness are to be supplied from one cast, the test piece shall be taken from a tube with the nominally thickest dimension.

13 Test methods

13.1 Tensile test

13.1.1 The tensile test on the material shall be carried out in accordance with BS EN 10002-1.

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 strength R_{eH} or the 0.5 % proof strength (total elongation) $R_{t0.5}$ 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 3894-1. In cases of dispute, a gauge length of $5.65\sqrt{S_o}$ shall be used.

13.1.3 The tensile test across the weld shall be carried out in accordance with BS 709. The test piece shall, if necessary, be flattened cold to the extent required to carry out the test. The tensile strength only shall be measured.

13.2 Weld bend test

The test pieces shall be bent at room temperature[4)] through an angle of 180° round a mandrel with a diameter as specified in Table 1.

13.3 Hydraulic test

The hydraulic 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 thickness (in mm);

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

The test shall be carried out at the pressure P or at 140 bar, whichever is the lower, but when 140 bar is lower than P the purchaser has the option [see **2.2** k)] 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 Part of BS 3602.

13.4 Non-destructive testing

13.4.1 Non-destructive testing of the weld shall be carried out in accordance with either **13.4.2** or **13.4.3** for ultrasonic testing or **13.4.4** for radiography. Unless otherwise specified in the enquiry and order [see **2.2** l)], the method of testing shall be at the manufacturer's option.

13.4.2 Ultrasonic testing of the full length of the weld for longitudinal and transverse imperfections shall be carried out by either:

a) an automatic method in accordance with Appendix C; or

b) a manual shear wave method using equipment with the same ultrasonic parameters and calibrated to give the same sensitivity as used in the automatic method in item a).

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

For both the automatic and manual methods, the assessment of the results shall be carried out in accordance with Appendix C.

13.4.3 Where an automatic ultrasonic method is used and part of the weld at the pipe ends is left untested, the manufacturer shall examine the untested ends by either:

a) radiographic testing in accordance with the technique specified in BS 2600-1, using details given in Appendix D as the basis for radiographic acceptance limits;

b) a manual ultrasonic method as specified in **13.4.2** b).

13.4.4 Radiographic testing of the full length of the weld shall be carried out in accordance with the technique specified in BS 2600-1. Details given in Appendix D shall be used as the basis for radiographic acceptance limits.

13.5 Additional non-destructive testing

13.5.1 The purchaser has the option to specify additional non-destructive testing of the weld [see **2.2** m)].

13.5.2 The purchaser has the option to specify a quality grade in BS 5996 to which the parent plate shall be ultrasonically tested [see **2.2** n)].

13.6 Elevated temperature proof stress tests or verification procedure

13.6.1 If the purchaser requires verification of elevated temperature proof stress values, this shall be carried out in accordance with **13.6.2** or **13.6.3** [see **2.2** o)]. The method of verification shall be at the option of the manufacturer unless the purchaser specifies verification in accordance with **13.6.2** in the enquiry and order [see **2.2** p)].

13.6.2 When the purchaser requires verification of elevated temperature proof stress values by testing, the tests shall be carried out in accordance with BS 3688-1 at a temperature selected by the purchaser from Table 4 and specified at the time of enquiry and order [see **2.2** p)].

NOTE The specified strain rate in BS 3688-1 is 0.001 to 0.003 per minute.

13.6.3 For verification of elevated temperature proof stress values without testing, the values shall be verified by the procedure given in BS 3920 (see Appendix E).

14 Retests

Should a tube selected for testing fail any of the tests specified in **13.1**, **13.2** or **13.6**, the tube and the batch of tubes that it represents shall be deemed not to comply with this part of BS 3602 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**, **13.2** and **13.6** 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 item a) or item (b) proves unsatisfactory, the tubes represented are suitably heat treated or re-heat treated (see clause **7**) and samples are selected and tested in accordance with all the tests specified in **13.1**, **13.2** and **13.6** 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 chemical analysis of the plate, i.e. a copy of the plate manufacturer's certificate;

c) the mechanical test results of the material for each of the batches tested (see **13.1**);

d) the hydraulic test pressure (see **13.3**);

e) the tensile test report for the weld in accordance with BS 709;

f) the bend test report for the weld in accordance with BS 709;

g) the method used for non-destructive testing of the weld (see **13.4**);

h) 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 1 (see **6.3**);

d) the heat treatment times and temperatures when applicable (see clause **7**);

e) the elevated temperature test results (see **13.6.2**) or statement of verification of values (see **13.6.3**);

f) the results of additional non-destructive testing (see **13.5**).

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** q)].

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 in the enquiry and order [see **2.2** r)], in accordance with **17.4**.

17.2 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[5)] as given in clause **3**, e.g. BS 3602-2:430: class 10;

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

d) the cast identity.

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 p.p.m. (*m*/*m*) of any of the following metals:

lead, tin, copper, zinc.

NOTE For certain applications limits may be required on the levels of sulfur 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** r)] 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 in the enquiry and order.

[5)] Marking BS 3602-2 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.

Appendix A Designation of steel tubes in BS 3602-2:1991 and the nearest equivalent designations in BS 3602-2:1978 and ISO 2604-VI

Table 5 lists the designations for tubes in BS 3602-2:1991 and the nearest equivalent designations in BS 3602-2:1978 and ISO 2604-VI.

Appendix B Dimensional limits of tubes

The range of dimensions shown below will cover most applications for which the standard will be used.

Outside diameter	Thickness
508 mm to 1 220 mm	⩽ 40 mm

The thicknesses available are dependent on the outside diameter.

It may however be convenient to select from the discrete sizes given in either:

a) Table 1 of BS 3600:1976; or

b) BS 1600-2 (completely interchangable with ANSI B36.10M).

Tubes to diameters and thicknesses not covered by the above standards are also available.

Appendix C Ultrasonic testing of the weld for the detection of longitudinal and transverse imperfections

C.1 General

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

C.2 Test procedure

The weld shall be tested for the detection of imperfections that are oriented longitudinally and transversely to the major axis of the tube in accordance with method B of BS 3889-1.

During testing, the tubes and transducer assembly shall be translated relative to each other and the transducer assembly shall be maintained in proper alignment with the weld such that the whole of the weld seam is scanned at the required sensitivity.

Scanning shall be carried out in both directions of beam travel in accordance with Figure 1a) of BS 3889-1:1983 for longitudinally oriented imperfections and Figure 2(a)(2) of BS 3889-1:1983 for transversely oriented imperfections.

C.3 Reference standards

The equipment shall be calibrated using four longitudinal notches, two on the outside and two on the inside surface, for the detection of longitudinal imperfections and a reference hole for the detection of transverse imperfections in accordance with **7.1**, **7.2.1** and **7.2.2** of BS 3889-1:1983. The dimensions of the reference standards shall be as given in Table 6 and Table 7.

Table 5 — Designation of steel tubes in BS 3602-2:1991 and the nearest equivalent designations in BS 3602-2:1978 and ISO 2604-VI

BS 3602-2:1991		BS 3602-2:1978	ISO 2604-VI
Designation	Colour code in accordance with BS 5383	Designation	Designation
430 class 10	White	—	—
430 class 20		—	—
430 class 30		SAW 410 Cat 1.	TSAW 9 Cat. VIII
490 class 10	Yellow	—	—
490 class 20		—	—
490 class 30		SAW 460 Cat. 1	TSAW 18 Cat. VIII

Table 6 — Reference notch dimensions and tolerances for longitudinal imperfections

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

Table 7 — Reference hole drill diameter and tolerances for transverse imperfections

Drill diameter	1.5 mm
Tolerance on diameter of reference hole	Not more than 0.2 mm greater than the specified drill

C.4 Assessment of results

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

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

C.4.3 If, upon retesting, 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".

C.4.4 For "suspect" tubes, one or more of the following actions shall be taken.

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) Defects in the weld shall be completely removed in accordance with **5.3**. Repair welds shall be by an arc welding process and shall be in accordance with **5.2**. Repair welds shall be subjected to the same type and level of non-destructive testing and shall be assessed against the requirements of **C.4.1**, **C.4.2** and **C.4.3**. If the repair welds are acceptable the tube shall be deemed to have passed the test.

c) The "suspect" area shall be cropped off. The manufacturer shall satisfy the purchaser that all of the suspect area has been removed and the remaining length shall be deemed to have passed the test.

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

Appendix D Radiographic acceptance limits

D.1 Any one of the following imperfections found during examination of the full weld or repair welds shall be unacceptable:

a) cracks, lack of penetration, lack of fusion (see BS 499-1) or piping as indicated by radiographic examination;

b) slag inclusion or gas pocket discontinuities assessed independently, and of a size and distribution that exceed those given in Table 8 and Table 9 and shown in Figure 1 and Figure 2.

D.2 Certain application standards or codes covering the use of tubes for pressure purposes place additional limits on slag inclusions and porosity for certain applications. For such application the purchaser shall ensure that these limitations are stated in the enquiry and order.

Table 8 — Elongated slag inclusion type discontinuities (see Figure 1)

Maximum dimensions	Minimum separation	Maximum number in any 150 mm[a]
mm	mm	
1.5 × 10.0	150	1
1.5 × 5.0	75	2
1.5 × 3.0	50	3

[a] Maximum accumulated length of discontinuities in any 150 mm shall not exceed 10 mm.

Table 9 — Circular slag inclusion and gas pocket type discontinuities (see Figure 2)

Size	Adjacent size	Minimum separation[a]
mm	mm	mm
3.0[b]	3.0[b]	50
3.0[b]	1.5	25
3.0[b]	1.0	12
3.0[b]	0.5	10
1.5	1.5	12
1.5	1.0	10
1.5	0.5	5
1.0	1.0	5[c]
1.0	0.5	5[c]
0.5	0.5	3[c]

[a] The sum of the diameters of all discontinuities in any 150 mm shall not exceed 6.5 mm.
[b] The maximum size of discontinuity for thicknesses of 6.5 mm and smaller shall be 2.5 mm.
[c] Two discontinuities 1.0 mm or smaller may be as close as one diameter apart provided that they are separated from any other discontinuity by at least l0 mm.

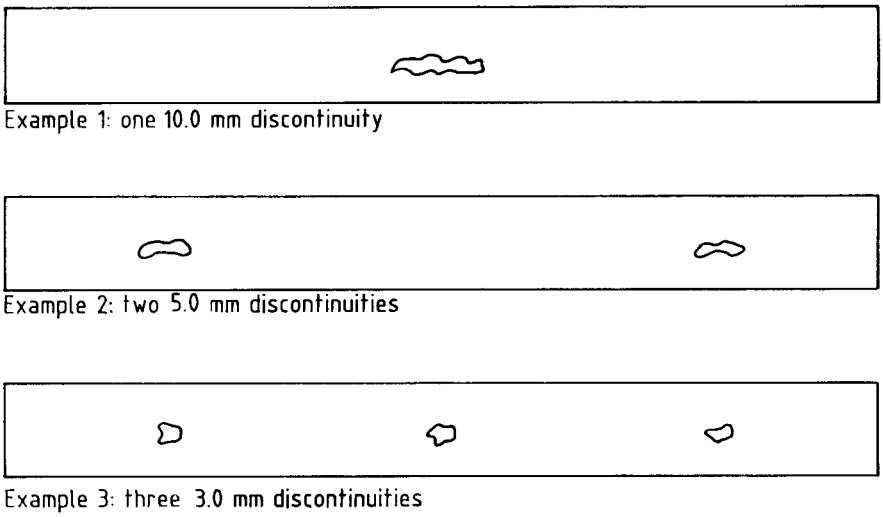

Figure 1 — Examples of maximum distribution patterns of indicated elongated slag inclusion type discontinuities

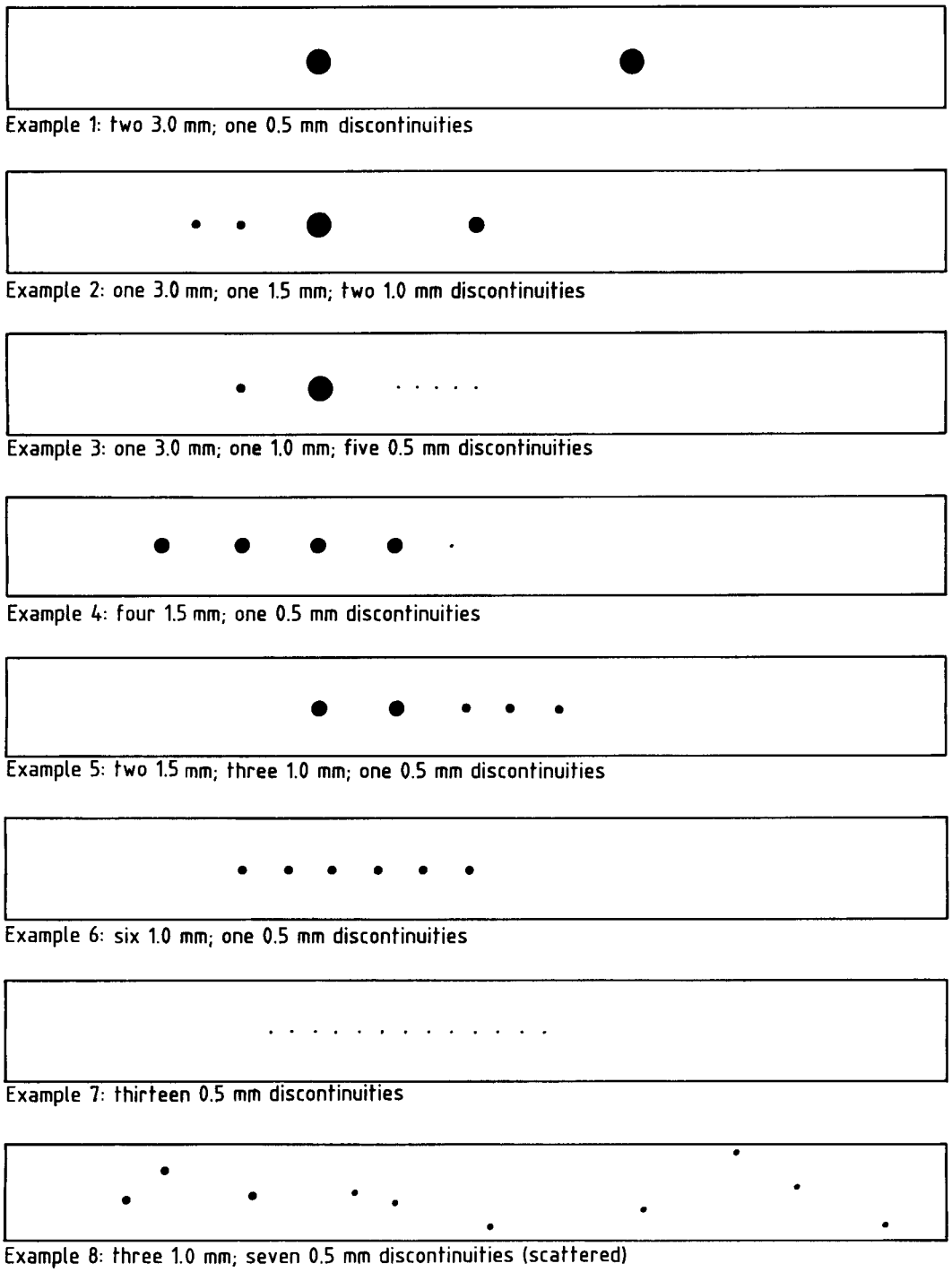

Figure 2 — Examples of maximum distribution patterns of indicated circular slag inclusion and gas pocket type discontinuities

Appendix E Procedure for the verification of elevated temperature proof stress values

As an alternative to verification of individual casts by testing at elevated temperatures, the manufacturer, unless otherwise specified by the purchaser, may verify that his product consistently meets the minimum elevated temperature proof stress values given in the specification for the relevant type of steel by adopting the procedure described in BS 3920.

The basis of the procedure is that the manufacturer compares data relating to his product with the confidence lines that have been determined from the analysis of a large body of data that has been used to derive the specification minimum given in this standard.

Information required for the construction of the lower confidence lines which are necessary for the application of the procedure is given in Table 10 and Table 11.

An example of lower confidence lines for steel type 430 is shown in Figure 3. To achieve the appropriate degree of accuracy, however, it is necessary to construct the confidence lines on a larger scale. To enable this to be done the coordinates of two suitably spaced points on the lines, appropriate to the various types of steel at each temperature, are given in Table 10 and Table 11.

Table 10 — Parameters for lower confidence lines: steel type 430

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	360 N/mm^2	550 N/mm^2
°C	N/mm^2	N/mm^2
100	147	262
150	140	245
200	127	221
250	108	199
300	90	183
350	79	169
400	72	161
450	70	153

Table 11 — Parameters for lower confidence lines: steel type 490

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	360 N/mm^2	550 N/mm^2
°C	N/mm^2	N/mm^2
100	203	273
150	192	258
200	177	240
250	155	225
300	124	209
350	104	197
400	99	186
450	85	180

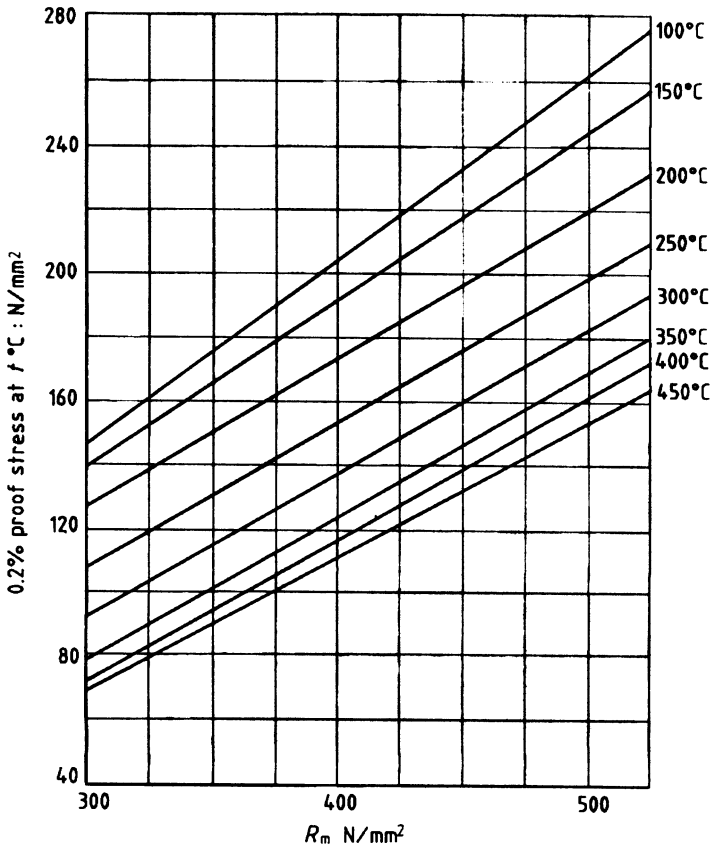

Figure 3 — Example of lower confidence lines (for steel type 430)

Publication(s) referred to

BS 499, *Welding terms and symbols.*

BS 499-1, *Glossary for welding, brazing and thermal cutting.*

BS 639, *Specification for covered carbon and carbon manganese steel electrodes for manual metal-arc welding.*

BS 709, *Methods of destructive testing fusion welded joints and weld metal in steel.*

BS 1501, *Steels for pressure purposes: plates.*

BS 1501-1, *Specification for carbon and carbon manganese steels.*

BS 1600, *Specification for dimensions of steel pipe for the petroleum industry.*

BS 1600-2, *Metric units.*

BS 2600, *Radiographic examination of fusion welded butt joints in steel.*

BS 2600-1, *Methods for steel 2 mm up to and including 50 mm thick.*

BS 2901, *Filler rods and wires for gas-shielded arc welding.*

BS 2901-1, *Ferritic steels.*

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

BS 3601, *Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes*[6)].

BS 3602, *Steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties*[6)].

BS 3602-1, *Specification for seamless and electric resistance welded including induction welded tubes.*

BS 3603, *Specification for steel pipes and tubes for pressure purposes: carbon and alloy steel with specified low temperature properties*[6)].

BS 3604, *Steel pipes and tubes for pressure purposes: ferritic alloy steel with specified elevated temperature properties*[6)].

BS 3604-1, *Specification for seamless and electric resistance welded tubes.*

BS 3605, *Austenitic stainless steel pipes and tubes for pressure purposes*[6)].

BS 3605-1, *Specification for seamless tubes.*

BS 3605:1973, *Specification for seamless and welded austenitic stainless steel pipes and tubes for pressure purposes*[6)].

BS 3688, *Methods for mechanical testing of metals at elevated temperatures.*

BS 3688-1, *Tensile testing.*

BS 3889, *Methods for non-destructive testing of pipes and tubes .*

BS 3889-1, *Methods of automatic ultrasonic testing for the detection of imperfections in wrought steel tubes.*

BS 3894, *Method for converting elongation values for steel.*

BS 3894-1, *Carbon and low alloy steels.*

BS 3920, *Derivation and verification of elevated temperature properties for steel products for pressure purposes.*

BS 4165, *Specification for electrode wires and fluxes for the submerged arc welding of carbon steel and medium-tensile steel.*

BS 4870, *Approval testing of welding procedures.*

BS 4870-1, *Specification for fusion welding of steel.*

BS 4870-4, *Specification for automatic fusion welding of metallic materials, including welding operator approval.*

BS 4871, *Specification for approval testing of welders working to approved welding procedures.*

BS 4871-1, *Fusion welding of steel.*

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

[6)] Referred to in the foreword only.

BS 5750, *Quality systems*[7)].

BS 5750-2, *Specification for production and installation.*

BS 5996, *Methods for ultrasonic testing and specifying quality grades of ferritic steel plate.*

BS 6072, *Method for magnetic particle flaw detection.*

BS 6200, *Sampling and analysis of iron, steel and other ferrous metals.*

BS 6200-3, *Methods of analysis.*

BS EN 10002-1, *Tensile testing for metallic materials — Part 1 Method of test at ambient temperature*[7)].

BS EN 10045-1, *Charpy impact test on metallic materials — Part 1 Test method (V- and U- notches)*[7)].

BS Handbook No. 19, *Methods for the sampling and analysis of iron, steel and other ferrous metals.*

ISO 2604, *Steel products for pressure purposes — Quality requirements — Part VI Submerged arc longitudinally or spirally welded steel tubes.*

ANSI B36.10M, *Welded and seamless wrought steel pipe.*

[7)] Referred to in the foreword only.

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