

LONGITUDINALLY ARC-WELDED PRESSURE TUBES

STEEL PRESSURE TUBES FERRITIC ALLOY STEEL ARC-WELDED ELEVATED-TEMP DATA

BS 3604-2:1991

Part 2 | Chemical composition, mechanical properties, tests and acceptance criteria

LONGITUDINAL ARC WELDING

FERRITIC ALLOY STEEL

ELEVATED TEMPERATURE

CHEMICAL COMPOSITION

MECHANICAL PROPERTIES

NDT ACCEPTANCE LIMITS

BS 3604-2:1991

Technical data navigation

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REFERENCE NOTE

Source dimensional values and footnotes are retained. Confirm the applicable material, grade, schedule and project specification before ordering.

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Foreword

This Part of BS 3604 has been prepared under the direction of the Iron and Steel Standards Policy Committee. It complements BS 3604-1 which specifies seamless and electric resistance welded alloy tubes, and BS 3602-2 which specifies carbon and carbon manganese steel longitudinally arc welded tubes.

This Part of BS 3604 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, *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: Longitudinally arc 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 3604 takes account of current production procedures for longitudinally arc welded tubes. It contains three chromium, molybdenum types of steel.

The steels covered by this Part of BS 3604 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 corresponding steels in BS 1501-2 meet the requirements of the steels in this Part of BS 3604. Tubes complying with this Part of BS 3604 are subject to non-destructive testing of the weld seam.

The designation of steel tubes in this Part of BS 3604 and their nearest equivalent designations in ISO 2604-VI are given in Appendix A for information purposes.

This Part of BS 3604 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).

For class 40 tubes, 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 Secretary of ISM/73/-/1, British Standards Institution, 3 York Street, Manchester M2 2AT, UK, so that, for future revisions of this Part of this Standard, minimum elevated temperature proof stress values can be derived from a continuously updated data bank.

Impact test values are not specified in this Part of BS 3604 but if the purchaser requires an impact test to be carried out then it is recommended that the Charpy impact test should be carried out in accordance with BS EN 10045-1.

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 this Standard.

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 3604 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 Part of BS 3604, no difference is intended in the 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 3604 specifies requirements for plain end, longitudinally arc welded ferritic alloy steel tubes suitable for pressure purposes.

Tubes manufactured in accordance with this Part of BS 3604 have specified room temperature properties and specified proof stress values at elevated temperatures.

In addition to the definitive requirements this Part of BS 3604 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 3604 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 3604 is given in Appendix B for guidance.

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, 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 3604-2:622: class 20;
- 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 be documented

A number of options are permitted by this Part of BS 3604 as listed below and the purchaser shall identify the options required. Both the definitive requirements specified throughout this Part of BS 3604 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 3604 can be made and verified by the manufacturer. 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 k)];
- b) whether welding procedure details and evidence of welding procedure approval 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 l)];

f) whether the content of selected chemical elements additional to those specified are to be reported [see 6.3 and 15 m)];

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

h) whether end sizing is required (see 10.8);

i) whether lengths other than random are required (see 10.9);

j) whether the hydraulic test is to be carried out at a pressure in excess of 140 bar¹⁾ and the pressure required (see 13.3);

k) the method of non-destructive testing to be used (see 13.4);

l) whether additional non-destructive testing of the weld is required (see 13.5.1);

m) the quality grade to which the plate is to be tested (see 13.5.2);

n) whether verification of elevated temperature proof stress values is required for class 40 tubes (see 13.6.1);

o) whether verification of elevated temperature proof stress values by testing is required (see 13.6.2) and the temperature selected from Table 5 at which this is to be carried out;

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

q) whether 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 3604-2, by a number which indicates the type of steel (see Table 1) and the class number which indicates the final supply condition (see clause 7).

For example, BS 3604-2:622:class 20, designates longitudinally arc welded tube made from steel type 622, in the stress relieved condition.

NOTE The designations for tubes in this Part of BS 3604 and their nearest equivalent designations in ISO 2604-VI are listed in Appendix A for information.

¹⁾ 1 bar = 10⁵ N/m² = 10⁵ Pa.

Table 1 — Chemical composition and mechanical properties at room temperature

Steel type	Type number	Chemical composition (ladle analysis) (see notes 1 and 2)															Mechanical properties at room temperature (see note 7)			
		C		Si		Mn		P	S	Cr		Mo		Cu	Ni	Others	R_m		R_e	A
		min	max	min	max	min	max	max	max	min	max	min	max	max	max	(see note 6)	min	max	min	min
1 % chromium 0.5 % molybdenum	620 (see note 3)	0.09	0.18	0.15	0.40	0.40	0.65	0.025	0.015	0.80	1.15	0.45	0.60	0.30	0.30	Al _{met} 0.02 max.	480	600	340	18
1.25 % chromium 0.5 % molybdenum	621 (see note 4)	0.09	0.17	0.50	0.80	0.40	0.65	0.025	0.015	1.00	1.50	0.45	0.60	0.30	0.30	Al _{met} 0.02 max.	515	690	340	18
2.25 % chromium 1 % molybdenum	622 (see note 5)	0.09	0.15	—	0.50	0.30	0.60	0.025	0.015	2.00	2.50	0.90	1.10	0.30	0.30	Al _{met} 0.02 max.	515	690	310	16
NOTE 1 Elements not quoted in Table 1 shall not be intentionally added without the agreement of the purchaser, 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. 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 Steel complying with BS 1501-2:620 meets the requirements of steel type 620.																				
NOTE 4 Steel complying with BS 1501-2:621 meets the requirements of steel type 621.																				
NOTE 5 Steel complying with BS 1501-2:622/515 meets the requirements of steel type 622.																				
NOTE 6 Where a maximum Al _{met} of 0.02 % is specified, determination of the total aluminium content, provided it does not exceed the specified value, shall be deemed to meet this requirement. In cases of dispute, the metallic aluminium content shall be determined.																				
NOTE 7 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).																				

4 Manufacture of the steel

4.1 Steelmaking process

The steel shall be produced by an electric process or 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 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 2493 as appropriate.

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

NOTE 1 The dimensional limits generally applicable to this Part of BS 3604 are shown in Appendix B and the tolerances in clause 10.

NOTE 2 The terms “hot formed” and “cold formed” apply to the condition of the tube before final heat treatment in accordance with clause 7.

5.2 The welding procedure including 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 in accordance with BS 4871-1 and the welding machine operator shall be qualified in accordance with 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 on the enquiry and order [see 2.2 d)].

5.3 Repair to the weld shall be permitted. Defects in the weld shall be completely removed by flame gouging, grinding or chipping and the cavity 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 seam.

6 Chemical analysis

6.1 Ladle analysis

The ladle analysis of steel shall meet the requirements of Table 1 appropriate to the steel type number specified.

6.2 Product analysis

6.2.1 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.

6.2.2 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.

6.2.3 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.

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 ^a from specified ladle analysis (see 6.2.1)
	%	%
Carbon	≤ 0.20	± 0.02
Silicon	≤ 0.35	+ 0.05
	> 0.35	+ 0.06
Manganese	≤ 1.0	± 0.05
Phosphorus	≤ 0.025	+ 0.005
Sulphur	≤ 0.005	+ 0.001
	> 0.005 ≤ 0.010	+ 0.002
	> 0.010 ≤ 0.015	+ 0.005
Chromium	≤ 1.00	± 0.05
	> 1.00 ≤ 2.50	± 0.10
Molybdenum	≤ 0.35	± 0.03
	> 0.35 ≤ 1.10	± 0.04
Nickel	≤ 0.30	+ 0.05
Copper	≤ 0.30	+ 0.05
Aluminium	≤ 0.02	+ 0.005

^a Where both minimum and maximum deviations are shown in Table 2, they 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.

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

7 Final supply condition

7.1 The forming process and final supply condition for each steel type specified in Table 1 shall be in accordance with one of the classes given in Table 3 unless the final supply condition is otherwise specified by the purchaser (see note to 7.2).

For class 20 tubes, the inside diameter shall be not less than 36 times the plate thickness.

Table 3 — Tube forming process and final supply condition

Class	Plate condition ^a	Forming process	Final supply condition
20	Normalized and tempered	Cold formed	Welded, stress relieved
40	Optional, at the discretion of the tube manufacturer	Cold formed or hot formed	Welded, normalized and tempered

^a This is the heat treatment condition of the plate prior to forming.

7.2 Final heat treatment of each tube after forming and welding shall be carried out at the temperature ranges specified in Table 4 appropriate to the class and type.

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).

Table 4 — Final heat treatment

Type	Class 20	Class 40	
	Stress relieving temperature	Normalizing temperature	Tempering temperature
	°C	°C	°C
620	650 to 720	890 to 960	650 to 720
621	650 to 720	890 to 960	650 to 720
622	700 to 750	900 to 960	700 to 750

8 Mechanical properties

8.1 Mechanical properties at room temperature

The mechanical properties at room temperature²⁾ 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.

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

NOTE Heat treatment carried out after the delivery of the tube 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 these 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

8.2.1 The elevated temperature minimum 0.2 % proof stress values shall be as specified in Table 5 when sampled as described in 12.6 and tested or verified as described in 13.6.

8.2.2 For class 20 tubes the values specified in Table 5 shall be verified (see 12.6 and 13.6).

NOTE For class 40 tubes, the values are not subject to verification unless required by the purchaser (see 13.6).

8.3 Weld bend test properties

For test pieces selected and 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 3604 (see 12.3).

9.2 Visual inspection shall be carried out on the external and internal surfaces. In the case of internal surfaces, 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.

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 Part of BS 3604.

9.5 Surface imperfections which encroach on the minimum wall thickness shall be considered defects and shall be deemed not to comply with the requirements of this Part of BS 3604.

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

Table 5 — Minimum 0.2 % proof stress ($R_{p0.2}$) values at elevated temperatures (see note)

Steel type	$R_{p0.2}$ min. at a temperature of:							
	100 °C	150 °C	200 °C	250 °C	300 °C	350 °C	400 °C	450 °C
	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²
620	280	270	258	247	228	215	211	206
621	315	305	291	280	266	255	251	245
622	292	283	275	266	260	252	245	231

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

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:

a) 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 g**];

b) 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 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 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** inclusive.

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 less.

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:

thicknesses up to and including 12.5 mm:	3 mm
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:

thicknesses up to and including 12.5 mm:	1.5 mm
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 outside of the pipe as defined in a) or b) shall be regarded as acceptable:

- undercuts up to a depth of 0.4 mm and of any length; or
- undercuts up to a depth of 0.8 mm with a maximum length of half the wall thickness.

10.7.2 Undercuts of greater dimension than those covered by **10.7.1** shall be considered defects and shall be dealt with in accordance with **10.7.4**.

10.7.3 Undercuts which encroach on the minimum thickness of the pipe shall be considered defects and shall be dealt with in accordance with **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 specified by the purchaser in the enquiry and order [see **2.2 h**)] 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 i**)] 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 with 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

12.2.1 The number of tubes on which mechanical tests at room temperature³⁾ 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 sample 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 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.

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.

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

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

Test piece preparation and testing shall be carried out 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 13.4.

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 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 temperature⁴⁾. 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 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 $L_0 = 5.65 \sqrt{S_0}$, where S_0 is the original cross-sectional area of the gauge length. If other gauge lengths are used, the corresponding percentage elongation on $5.65 \sqrt{S_0}$ shall be obtained by reference to BS 3894-1. In cases of dispute, a gauge length of $5.65 \sqrt{S_0}$ 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.

⁴⁾ In cases of dispute room temperature is taken as $20 \pm 5^\circ\text{C}$.

⁵⁾ $1 \text{ bar} = 10^5 \text{ N/m}^2 = 10^5 \text{ Pa}$.

13.2 Weld bend test

The test pieces shall be bent at room temperature⁴⁾ through an angle of 180° round a mandrel having a diameter of $4a$, where a is the specified thickness of the tube.

13.3 Hydraulic test

The hydraulic test pressure P , (in bar⁵⁾) shall be calculated from the equation:

$$P = \frac{20 S a}{D}$$

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.

The test shall be carried out at the pressure P or at 140 bar⁵⁾ whichever is lower but when 140 bar is lower than P , the purchaser has the option [see 2.2 j)] to specify that the test shall be carried out at a pressure higher 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 3604.

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 k)], 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 D; 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 test method in a).

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

13.4.3 Where an automatic ultrasonic method is used and part of the weld seam 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. Details given in Appendix E shall be used as the basis for radiographic acceptance; or
- 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 E 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 l)].

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 m)].

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 n)]. The method of verification shall be at the option of the manufacturer unless the purchaser specifies verification in accordance with 13.6.2 on the enquiry and order [see 2.2 o)].

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 5 and specified at the time of enquiry and order [see 2.2 o)].

NOTE The specified strain rate in BS 3688-1 is 0.001 to 0.003/min.

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 C).

14 Retests

Should a tube selected for testing fail in 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 the requirements of 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, 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 a) or b) proves unsatisfactory, the tubes represented are re-heat treated 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

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 of the weld in accordance with BS 709;
- f) the bend test report of 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)];
- i) the heat treatment times and temperatures (see clause 7);
- j) the elevated temperature test results (see 13.6.2) for class 20 tubes;

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

- k) the steelmaking process used (see 4.1);
- l) the product analysis (see 6.2);
- m) the content of selected elements in addition to those specified in Table 1 (see 6.3);
- n) the elevated temperature test results (see 13.6.2) or statement of verification of values (see 13.6.3) for class 40 tubes;
- o) 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 p)].

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 q**)], 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 designation⁶⁾ as given in clause **3**, e.g. BS 3604-2:622:class 20;
- 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 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. 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 on the enquiry and order [see **2.2 q**)] 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.

⁶⁾ Marking BS 3604-2 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 Designations of steel tubes in BS 3604-2 and the nearest equivalent designations in ISO 2604-VI

Table 6 lists the designations for tubes in BS 3604-2.

Table 6 — Designations of steel tubes in BS 3604-2 and the nearest equivalent steel numbers in ISO 2604-VI

BS 3604-2:1991 designation	Colour code in accordance with BS 5383	ISO 2604-VI designation
620 class 20	Red	—
620 class 40		TSAW 32 Cat VIII
621 class 20		—
621 class 40		—
622 class 20	Light blue	—
622 class 40		TSAW 34 Cat VIII

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 dependant on the outside diameter.

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

- Table 1 of BS 3600:1976;
- BS 1600-2:1970 (completely interchangeable with ANSI B36.10M).

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

Appendix C Procedure for 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 appropriate data relating to his product with the confidence lines that have been determined from the analysis of a large body of data that have been used to derive the specification minima given in this standard.

Information required for the construction of the lower confidence lines which are necessary for the application of the procedure are given in Table 7 and Table 8.

An example of confidence lines for steel type 622 is shown in Figure 1. 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 7 and Table 8.

Table 7 — Parameters for lower confidence lines: steel types 620 and 621

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	460 N/mm ²	560 N/mm ²
°C	N/mm ²	N/mm ²
100	230	330
150	220	320
200	210	306
250	200	294
300	172	283
350	158	272
400	154	268
450	150	262

Table 8 — Parameters for lower confidence lines: steel type 622

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	440 N/mm ²	540 N/mm ²
°C	N/mm ²	N/mm ²
100	164	286
150	158	277
200	151	269
250	140	260
300	137	254
350	134	246
400	130	240
450	118	226

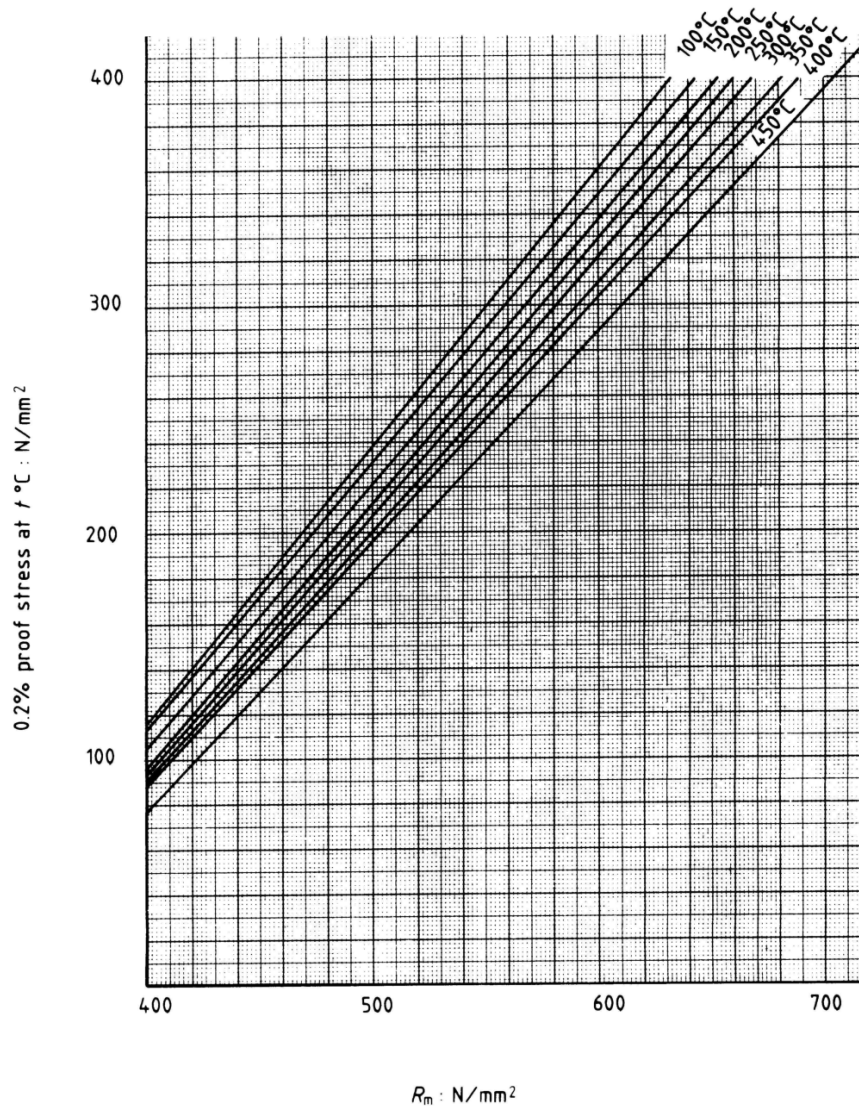


Figure 1 — Example of lower confidence lines for steel type 622

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

D.1 General

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

D.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 3889-1:1983.

During testing, the tubes and/or 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 1 a) of BS 3889-1:1983 for longitudinally oriented imperfections, and Figure 2 a) 2) for transversely oriented imperfections.

D.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 notches and hole shall be as given in Table 9 and Table 10 respectively.

Table 9 — 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 10 — Reference hole drill diameter and tolerance for transverse imperfections

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

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, 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 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 seam 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 D.4.1, D.4.2 and D.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 E Radiographic acceptance limits

E.1 Any one of the following imperfections shall be judged 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 of a size and distribution that exceed those in Table 11 and Table 12.

E.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 an application the purchaser shall ensure that these limitations are stated in the enquiry and order.

Table 11 — Elongated slag inclusion type discontinuities (see Figure 2)

Maximum dimensions	Minimum separation	^a Maximum number in any 150 mm
mm	mm	
1.5 × 10.0	150	1
1.5 × 5.0	75	2
1.5 × 3.0	50	3
^a The maximum accumulated length of elongated slag discontinuities in any 150 mm shall not exceed 10 mm.		

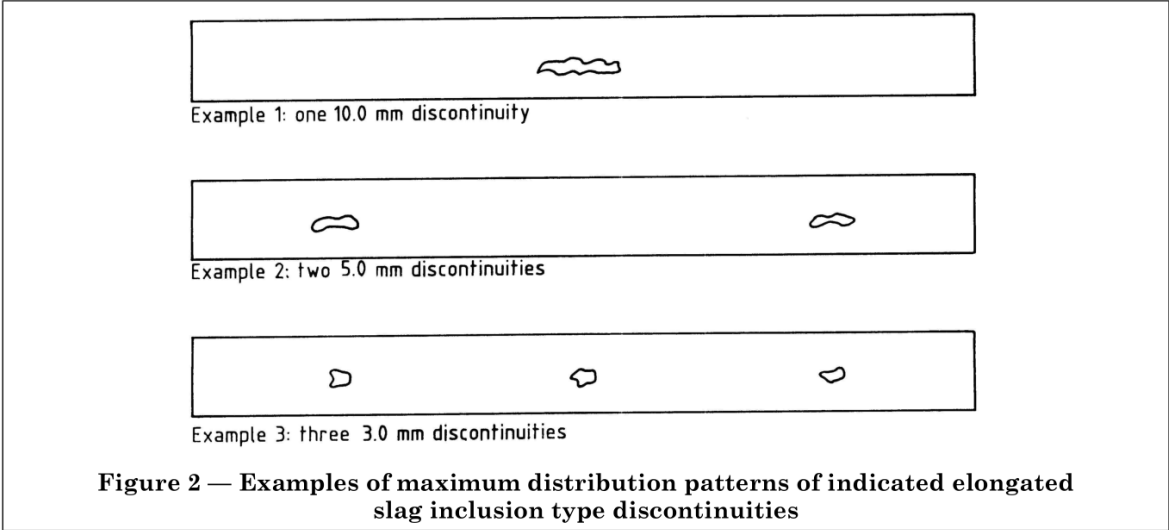
Table 12 — Circular slag inclusion and gas pocket type discontinuities (see Figure 3)

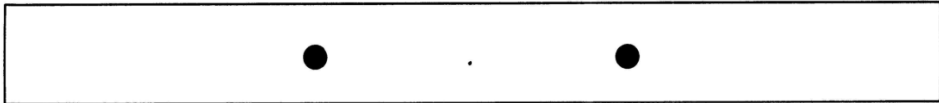
Size of discontinuity	Adjacent size	^a Minimum separation
mm	mm	mm
3.0 ^b	3.0 ^b	50
3.0 ^b	1.5	25
3.0 ^b	1.0	12
3.0 ^b	0.5	10
1.5	1.5	12
1.5	1.0	10
1.5	0.5	5
1.0	1.0	5 ^c
1.0	0.5	5 ^c
0.5	0.5	5 ^c

^a The sum of the diameters of all discontinuities in any 150 mm shall not exceed 6.5 mm.

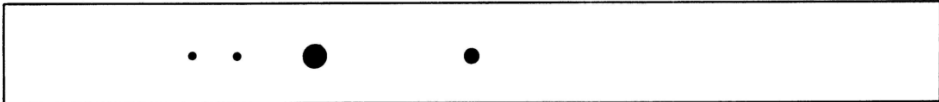
^b The maximum size of circular slag discontinuity for thicknesses of 6.5 mm and smaller shall be 2.5 mm.

^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 10 mm.

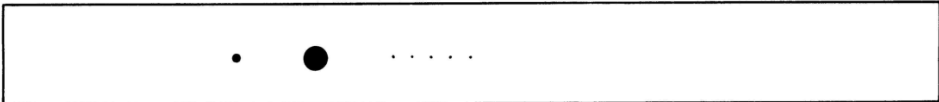




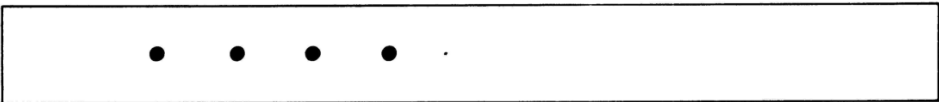
Example 1: two 3.0 mm; one 0.5 mm discontinuities



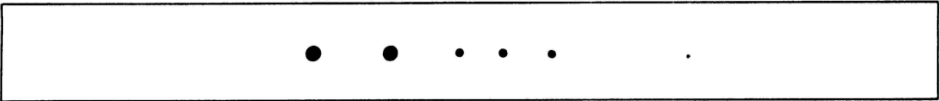
Example 2: one 3.0 mm; one 1.5 mm; two 1.0 mm discontinuities



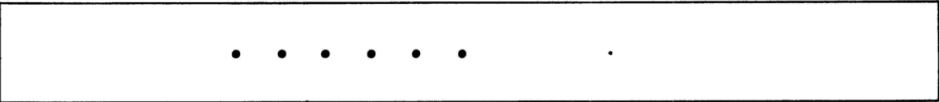
Example 3: one 3.0 mm; one 1.0 mm; five 0.5 mm discontinuities



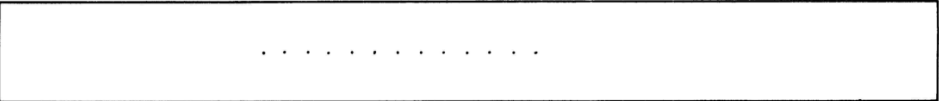
Example 4: four 1.5 mm; one 0.5 mm discontinuities



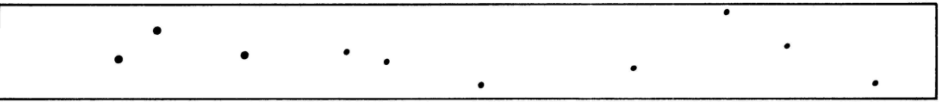
Example 5: two 1.5 mm; three 1.0 mm; one 0.5 mm discontinuities



Example 6: six 1.0 mm; one 0.5 mm discontinuities



Example 7: thirteen 0.5 mm discontinuities



Example 8: three 1.0 mm; seven 0.5 mm discontinuities (scattered)

Figure 3 — Examples of maximum distribution patterns of indicated circular slag inclusion and gas pocket type discontinuities

Publication(s) referred to

BS Handbook 19, *Methods for the sampling and analysis of iron, steel and other ferrous metals*.
BS 499, *Welding terms and symbols*.
BS 499-1, *Glossary for welding, brazing and thermal cutting*.
BS 709, *Methods of destructive testing of fusion welded joints and weld metal in steel*.
BS 1501, *Steels for pressure purposes: plates*.
BS 1501-2, *Specification for alloy steels*.
BS 1600, *Specification for dimensions of steel pipe for the petroleum industry*.
BS 1600-2, *Metric units*.
BS 2493, *Specification for low alloy steel electrodes for manual metal-arc welding*.
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 and tubes for pressure purposes*.
BS 3601, *Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes⁷⁾*.
BS 3602, *Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties*.
BS 3602-1, *Specification for seamless and electric resistance welded including induction welded tubes⁷⁾*.
BS 3602-2, *Submerged arc welded tubes⁷⁾*.
BS 3603, *Specification for carbon and alloy steel pipes and tubes with specified low temperature properties for pressure purposes⁷⁾*.
BS 3604, *Steel pipes and tubes for pressure purposes: ferritic alloy steel with specified elevated temperature properties*.
BS 3604-1, *Specification for seamless and electric resistance welded tubes⁷⁾*.
BS 3605:1973, *Specification for seamless and welded austenitic stainless steel pipes and tubes for pressure purposes⁷⁾*.
BS 3605, *Austenitic stainless steel pipes and tubes for pressure purposes*.
BS 3605-1, *Specification for seamless tubes⁷⁾*.
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, *Specification for approval testing of welding procedures*.
BS 4870-1, *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*.

⁷⁾ Referred to in the foreword only.

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, *Quality systems.*

BS 5750-2, *Specification for production and installation*⁸⁾.

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 of metallic materials — Part 1: Method of test at ambient temperature.*

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

ISO 2604-VI, *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 pipes.*

⁸⁾ Referred to in the foreword only.

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Longtan Industrial Zone, Yanta Road, Yanshan County, Cangzhou City,
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