

BS 4515-1:2009



BSI Standards Publication

Specification for welding of steel pipelines on land and offshore

Part 1: Carbon and carbon manganese
steel pipelines

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Foreword

Publishing information

This part of BS 4515 is published by BSI and came into effect on 1 January 2009. It was prepared by Subcommittee WEE/21/7, *Field welding of pipelines*, under the authority of Technical Committee WEE/21, *Pipework welding*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This part of BS 4515 supersedes BS 4515-1:2004, which is withdrawn.

Information about this document

This is a full revision of the standard, and introduces the following principal changes:

- removal of references to BS EN 288-9 which has been withdrawn. Where appropriate, requirements from BS EN 288-9 have been incorporated in the standard;
- revision of Clause 8 on testing, qualification and approval of welding procedures;
- revision of Annex A on hyperbaric welding.

If welding in accordance with this British Standard is agreed with a Statutory Authority as a basis for obtaining approval to operate a pipeline, the employer will need to obtain the Authority's agreement to any waivers of requirements. Where this standard provides for the employer to define requirements, the Authority's agreement might be necessary. Topics commonly involved include selecting the definition of the pipeline's starting and termination points, electing to use hardness limits higher than those in Table 4 or Table 7, selecting the methods and frequency of non-destructive testing, electing to use Engineering Critical Assessment to derive acceptance criteria, permitting multiple attempts at repair, or permitting single run or root repairs. The employer should ensure that all relevant points have been agreed with the Statutory Authority before welding begins.

In reflecting current industry practice, this British Standard places duties on, and allocates powers of approval to, the employer.

Consequently, the term "qualification" has been retained to describe the series of actions which demonstrate that the technical requirements of this British Standard have been met during the process of welding procedure, and welder approval.

Assessed capability. Users of this British Standard are advised to consider the desirability of quality system assessment and registration against the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body.

Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

It is also assumed that the Contractor will nominate a Welding Co-ordinator in accordance with BS EN ISO 14731.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is “shall”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Requirements in this standard are drafted in accordance with *The BSI guide to standardization – Section 2: Rules for the structure, drafting and presentation of British Standards*, subclause 11.3.1, which states, “Requirements should be expressed using wording such as: ‘When tested as described in Annex A, the product shall ...’”. This means that only those products that are capable of passing the specified test will be deemed to conform to this standard.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This British Standard specifies requirements for the welding of carbon, carbon manganese and low alloy steel pipelines with specified minimum yield strengths not exceeding 555 N/mm² (grade L555 as specified in ISO 3183:2007 and BS EN 10208-2:1997) and designed in accordance with PD 8010-1 and PD 8010-2.

The standard applies to pipes of outside diameter 21.0 mm and larger having a thickness of 3.0 mm or greater and is applicable to transmission pipelines for gases, liquids or slurries, both on land and offshore.

In addition to the definitive requirements, this standard also requires the items detailed in Clause 4 to be documented. For compliance with this standard, both the definitive requirements and the documented items have to be satisfied.

Information on hyperbaric welding is given in Annex A and information on brazing and aluminothermic welding of anode bonding leads is given in Annex B.

Additional recommendations for the welding of corrosion resistant alloy clad and lined pipelines are given in Annex G.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 499-1:1991+A1:1996, *Welding terms and symbols – Part 1: Glossary for welding, brazing and thermal cutting*

BS 7910:2005+A1:2007, *Guide to methods for assessing the acceptability of flaws in metallic structures*

BS EN 875, *Destructive tests on welds in metallic materials – Impact tests – Test specimen location, notch orientation and examination*

BS EN 895, *Destructive tests on welds in metallic materials – Transverse tensile test*

BS EN 970, *Non-destructive examination of fusion welds – Visual examination*

BS EN 1321, *Destructive test on welds in metallic material – Macroscopic and microscopic examination of welds*

BS EN 1435:1997+A2:2004, *Non-destructive examination of welds – Radiographic examination of welded joints*

BS EN 1714:1998+A2:2004, *Non-destructive examination of welded joints – Ultrasonic examination of welded joints*

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

BS EN 10160, *Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method)*

BS EN 10208-2:1997, *Steel pipes for pipelines for combustible fluids – Technical delivery conditions – Part 2: Pipes of requirement class B*

BS EN 13622:2002, *Gas welding equipment – Terminology – Terms used for gas welding equipment*

BS EN ISO 6507 (all parts), *Metallic materials – Vickers hardness test*
BS EN ISO 9934 (all parts), *Non-destructive testing – Magnetic particle testing*
BS EN ISO 14175, *Welding consumables – Gases and gas mixtures for fusion welding and allied processes*
BS EN ISO 14731, *Welding co-ordination – Tasks and responsibilities*
ISO 3183:2007, *Petroleum and natural gas industries – Steel pipe for pipeline transportation systems*
PD 8010-1, *Code of practice for pipelines – Part 1: Steel pipelines on land*
PD 8010-2, *Code of practice for pipelines – Part 2: Subsea pipelines*

3 Terms and definitions, and abbreviations

3.1 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS 499-1:1991+A1, BS EN 13622:2002 and the following apply.

3.1.1 approval

formal agreement by the employer that a qualification (or other proposal by the contractor) in accordance with this British Standard is acceptable for the proposed application

3.1.2 buffer layer

weld pass or passes, typically pure iron or pure nickel, separating the CRA and carbon steel parts of a weld

3.1.3 cap repair

single run repair to the external surface of the original weld

3.1.4 cladding

method whereby a CRA layer is metallurgically bonded to the pipe or fitting

3.1.5 contractor

firm undertaking the contract and any subcontractors engaged in work covered by this standard

3.1.6 employer

owner company or the engineering agency in charge of construction

NOTE The employer may act through a consultant, an inspector or other authorized representative.

3.1.7 full penetration repair

repair from the external surface of the original weld which penetrates to the bore of the pipe

3.1.8 internal backweld repair

repair from the internal surface of the original weld

NOTE Sometimes referred to as “backweld repair”.

- 3.1.9 joint**
completed weld joining two sections of pipe, a section of pipe to a fitting, or two fittings
- 3.1.10 lining**
method whereby a CRA shell is mechanically fixed within a pipe or fitting
- 3.1.11 mechanized welding**
welding process in which the welding parameters and torch guidance are controlled mechanically or electronically but may be manually varied during welding to maintain the required welding conditions
- 3.1.12 partial penetration repair**
multi-run repair from the external surface of the original weld which does not penetrate to the bore of the pipe
- 3.1.13 pipeline**
continuous line of pipes of any length without frequent branches, used for transporting fluids
NOTE It does not include piping systems such as process plant piping within offshore installations. [PD 8010-1 and PD 8010-2].
- 3.1.14 positional welding**
welding wherein the pipe or assembly is held stationary
- 3.1.15 provisional welding procedure specification
pWPS**
provisional tentative welding procedure specification, prepared by the contractor for acceptance and approval by the employer but which is subject to qualification
NOTE Welding of test pieces needed for approval of a welding procedure specification has to be carried out on the basis of a provisional welding procedure specification (pWPS).
- 3.1.16 qualification**
series of actions necessary to demonstrate that a proposal meets the technical requirements of this British Standard
- 3.1.17 re-repair**
second attempt at repairing a defect in the same location
NOTE For qualification purposes this is a repair of a repair, simulated by the sequence: original weld, excavate, repair, re-excavate and re-repair.
- 3.1.18 roll welding**
method of manipulation by rotating or rolling pipes or pipe assemblies so that all welding is carried out in or near the flat position [BS 499-1:1991+A1]
- 3.1.19 root run**
first run deposited in the root of a multi-run weld [BS 499-1:1991+A1]
- 3.1.20 seal weld**
weld used at the ends of lined pipe or fitting to close the gap between liner and substrate

3.1.21 semi-automatic welding

welding in which some of the welding variables are automatically controlled, but manual guidance is necessary [BS 499-1:1991+A1]

3.1.22 sour service

pipeline design conditions in which a risk of sulfide stress cracking exists

NOTE This is normally assessed using BS EN ISO 15156.

3.1.23 substrate

carbon steel section of the wall thickness onto which the CRA layer is applied

3.1.24 welder

operator who performs the welding [BS 499-1:1991+A1]

3.1.25 welding procedure

specific course of action followed in welding, including a list of materials and, where necessary, tools to be used [BS 499-1:1991+A1]

3.2 Abbreviations

For the purposes of this British Standard the following abbreviations apply.

SAW submerged arc welding

MAG metal active gas

FCAW flux-cored arc welding

4 Information and requirements to be approved and documented

4.1 Information to be supplied by the employer

The following information to be supplied by the employer shall be fully documented. For compliance with the standard both the definitive requirements specified throughout the standard and the following documented items shall be satisfied.

- a) Whether batch testing of electrodes and filler materials is required (see 7.1).
- b) Whether specific compositional controls are to be applied to the deposited weld metal (see 7.1).
- c) The degree of yield strength overmatching for welds in pipe materials where installation methods involve plastic deformation of the pipe or for welds in grade L555 pipe (see 7.1).
- d) Whether different batches of electrodes and filler materials are to be individually identifiable and completely separated (see 7.2).
- e) The type and number of re-tests required in the event of failure during testing and qualification of welding procedures [see 8.1k)].
- f) Whether an alternative location is specified for the excavation location for the repair weld test (see 8.4.1).
- g) Whether strain ageing data and/or additional tests are required as the basis for welding procedure approval for pipe-reeling [see 8.1i)].

- h) Whether specimens are to be allowed to cool for a duration other than 24 h before testing [see 8.1g)].
- i) The method of weld tensile testing when a minimum weld metal yield strength required is specified (see 8.3.2.3).
- j) The number and location of transverse tensile test specimens required for welding procedure testing on pipes up to and including 114.3 mm diameter (see 8.3.2.1).
- k) Whether Charpy impact tests are required for welding procedure approval of butt joints (see 8.3.2.1).
- l) The number and location of test specimens required for Charpy impact tests on pipes of diameter 114.3 mm or less (see 8.3.2.1).
- m) Charpy toughness and test temperature for conditions other than pipe and wall thicknesses up to and including 25 mm, minimum design temperatures not lower than -10°C and pipe grades up to L555 (see 8.3.2.6).
- n) Whether additional non-destructive testing (NDT) methods for fillet welds apply [see 8.5.1b)].
- o) Whether alternative hardness values to those given in Table 7 are required (see 8.5.2.4).
- p) Whether a proposed change to a welding procedure or equipment requires re-qualification of the welders [see 9.5i)].
- q) Whether prevailing weather conditions are such that quality of the completed weld would be impaired (see 10.9)¹⁾.
- r) The method(s) and frequency of visual inspection and NDT (see 11.1).
- s) Whether completed welds are to be ground (see 11.1).
- t) Whether alternative techniques are to be used for radiographic testing of welded butt joints (see 11.4.1).
- u) Ultrasonic testing acceptance criteria (see 11.5.3).
- v) Whether NDT acceptance criteria are to be based on quality control or engineering critical assessment (see 12.1.1).
- w) Whether the maximum planar defect dimension is to be less than 25 mm (see 12.1.2).
- x) Whether a more stringent limit for root penetration is required [see Table 9 flaw type c)].
- y) Whether different hardness limits for anode bonding joints are required (see B.2).
- z) The composition and thickness of the pipe CRA layer (see G.2.1).
- aa) The method of line pipe manufacture, including seal weld and longitudinal weld details where these items are present in CRA clad and lined pipelines (see G.2.1).
- bb) The maximum oxygen content of backing gas during welding or the corrosion tests that the weld is required to pass [see footnote G) of Table G.1, and G.6.4].
- cc) Whether the strength contribution of the CRA layer has been used in the design (see G.3.3.1).

¹⁾ Information for this item might not be able to be supplied until the appropriate stage of the work is reached.

- dd) Whether additional hardness traverses are required in CRA clad and lined pipelines (see **G.3.3.3**).
- ee) Hardness limits for CRA portions of the weldment (see **G.3.3.3** and **G.4.3**).
- ff) The composition limits for chemical analysis of the weld in CRA clad and lined pipelines (see **G.3.3.6**).
- gg) Whether a chemical analysis is required for seal weld qualification in CRA lined pipelines (see **G.4.4**).
- hh) Whether internal weld or cutting spatter in CRA clad and lined pipelines requires removal and the method to be used (see **G.6.1**).
- ii) Whether weld root acceptance criteria more onerous than those in Table 9 are required in CRA clad and lined pipelines (see **G.8.1**).
- jj) Whether full penetration repairs are permitted in CRA clad and lined pipelines (see **G.8.3**).

4.2 Items subject to approval by the employer

The following items to be subject to approval by the employer are specified in the clauses referred to and shall be fully documented. For compliance with the standard both the definitive requirements specified throughout the standard and the following documented items shall be satisfied.

- a) Welding consumables to be used (see **7.1**).
- b) The definition of a batch when batch testing of electrodes and filler materials is required (see **7.1**).
- c) The tensile strength of weld metal for joints between dissimilar materials if other than that of the higher strength parent metal (see **7.1**).
- d) Test weld production on pipes shorter than full length [see **8.1b**].
- e) Use of roll welding [see **8.1d**].
- f) Use of a test weld for destructive testing or rewelding to the same procedure following NDT failure [see **8.1h**].
- g) The type and number of re-tests of a welding procedure when they are permitted [see **8.1k**].
- h) Welding procedure qualification test details and welding procedure specification for production welding [see **8.1l**].
- i) Any deviations from the ranges given in Table 2 (see Table 1).
- j) Simulation of a fillet weld joint using flat plate fillet welds [see **9.4.1b**].
- k) Alternative methods of NDT for welder test pieces [see **9.6c**].
- l) Giving a welder a second opportunity to gain approval (see **9.8**).
- m) All documentation relating to welder qualification tests (see **9.9**).
- n) Use of manual thermal cutting for pipe end bevelling and the ability of the operator (see **10.2**).
- o) The blending out by grinding of minor imperfections within the joint preparation area [see **10.2a**].
- p) Method of marking datum points on a joint for ultrasonic testing (see **10.2**).

- q) Method of obtaining minimum misalignment other than rotation of the pipes (see **10.4**).
- r) Method of alignment of pipes other than internal line-up clamps (see **10.5.1**).
- s) The stage at which line-up clamps are removed (see **10.5.1**).
- t) The stage at which the pipe is lowered onto skids, or support is removed from fittings (see **10.5.2**).
- u) Repair of places where stray arcs have occurred (see **10.8**).
- v) Means of applying preheat (see **10.10.2**).
- w) Methods of attaching and removing thermocouples (see **10.10.4**).
- x) The welding procedure for branch connections where the angle between the main and branch is less than 60° (see **10.11.1**).
- y) Written ultrasonic examination procedure for pipe material around a planned cut-out (see **10.11.3**).
- z) All NDT procedures to be used for inspection and testing (see **11.1**).
- aa) All inspection personnel (see **11.2**).
- bb) The technique in BS EN 1435:1997+A2 to be used for radiographic examination (see **11.4.1**).
- cc) Any method for magnetic particle testing to be used at above ambient temperature [see **11.7a**].
- dd) Any alternative standard to be used for engineering critical assessment (see **12.1.3**).
- ee) Any proposal to repair a weld (see **12.2.1**).
- ff) Any alternative limits on repair weld length (see **12.2.1**).
- gg) Use of root sealing or single run repair deposits (see **12.2.4**).
- hh) More than one attempt at a repair (see **12.2.4**).
- ii) The position of the longitudinal seam weld (if applicable) on the subsea pipeline at the hyperbaric weld location (see **A.9.2**).
- jj) Joining technique and equipment for brazing and aluminothermic welding of anode bonding leads (see **B.1**).
- kk) Provisional brazing and aluminothermic welding procedure specification (see **B.2**).
- ll) Method of chemical analysis of butt welds in CRA lined pipelines (see **G.3.3.6**).
- mm) The location, elements to be analysed, method and acceptance criteria for seal weld chemical analysis in CRA clad and lined pipelines (see **G.4.4**).
- nn) Whether grinding, wire brushing or filing of the internal surface of CRA clad and lined pipelines is permitted (see **G.6.1**).
- oo) Cessation of oxygen monitoring immediately prior to completion of the root pass in CRA clad and lined pipelines (see **G.6.4**).
- pp) The method of flaw removal in CRA clad and lined pipelines (see **G.8.2**).

- qq) A reduction in the number of mechanical test samples for qualification of repair weld procedures in CRA clad and lined pipelines (see **G.8.3**).

5 Equipment

Welding equipment shall be calibrated and maintained in a condition that allows production of acceptable welds, continuity of operation and safety of personnel. Equipment that does not meet this requirement shall be either repaired or replaced.

Arc welding equipment shall be capable of operating within the amperage and voltage ranges specified in the approved WPS.

Means of measuring current shall be available, either as part of the welding plant or by the provision of a portable ammeter. In the case of mechanized and semi-automatic welding, means shall be provided for measuring the arc voltage, since this can exert considerable influence on the form, composition and soundness (e.g. porosity) of the weld.

The welding equipment shall be capable of controlling the parameters given in Table 1 item j) to within the limits stated.

NOTE Copper contact tips and backing strips should be checked regularly for damage which could indicate copper contamination of welds.

Pipe handling equipment, rollers and line-up clamps shall be such that they avoid damage to the pipe, ensure that pipe axes are aligned in accordance with **10.4** and allow the welding procedure to be used.

For installation methods involving plastic deformation of the pipe, the installation equipment shall be capable of controlling the curvature of the pipe and the amount of displacement controlled strain.

6 Welding process

The process used shall be arc welding.

7 Welding consumables

7.1 General

Only welding consumables which have received the prior approval of the employer shall be used [see **4.2a**]]. When specified by the employer [see **4.1a**]], batch testing of electrodes and filler materials shall be carried out, in which case the definition of a batch shall be subject to the approval of the employer [see **4.2b**]].

The chemical composition of the deposited weld metal shall be selected to ensure adequate resistance to degradation from the pipeline contents under the intended operating conditions. The employer shall indicate whether specific compositional controls are to be applied to meet these requirements [see **4.1b**]].

When tested in accordance with **8.3.2**, the weld metal produced by electrodes, filler wires and shielding gases, and wire/flux combinations shall have a tensile strength greater than the minimum specified for the parent metal.

Unless an alternative value is approved by the employer [see 4.2c)], when tested in accordance with 8.3.2, the weld metal of joints between dissimilar materials shall have a tensile strength at least equal to that specified for the higher strength parent metal.

When tested in accordance with 8.3.2, the weld metal yield strength of welds in pipe grade L555, or for all pipe grades where installation methods involve plastic deformation of the pipe, shall be greater than the minimum specified for the parent material. For these cases, the degree of yield strength overmatching required shall be specified by the employer [see 4.1c)].

Shielding gases shall be in accordance with BS EN ISO 14175.

NOTE 1 In selecting the level of weld metal overmatching, consideration should be given to actual yield and tensile strength of the pipeline to be welded in production.

NOTE 2 Appropriate electrodes and filler materials conforming to 7.1 are specified in BS EN ISO 2560, BS EN ISO 3580, BS EN 757, BS EN ISO 17632, BS EN 756, BS EN 760 and BS EN ISO 16834. Carbon dioxide used as a shielding gas should conform to BS 4105.

NOTE 3 When welding pipe grade L555, it is recommended that if cellulosic coated electrodes are used they are restricted to the root and hot pass only.

7.2 Storage and handling

Different grades and, when specified by the employer [see 4.1d)], different batches of electrodes and filler materials shall be individually identifiable and be completely separated. Electrodes shall be stored in accordance with the manufacturer's recommendations. The electrodes and filler materials shall be stored and handled at all times during construction so as to avoid damage to them and to the containers in which they are transported. Storage and handling procedures shall be fully documented.

Electrodes, filler wires and fluxes that show signs of damage or deterioration, for example coating breakage, shall not be used.

Submerged-arc welding flux shall only be recycled in accordance with the manufacturer's recommendations.

Shielding gases shall be stored in the containers in which they are supplied.

Gases shall only be mixed in the field if this is an integral part of a mechanized process which utilizes a fail-safe cut-off when the proportions fall outside those specified in the approved welding procedure.

8 Testing, qualification and approval of welding procedures

8.1 General

Testing, qualification and approval of welding procedures shall consist of the following stages.

- a) The provisional welding procedure specifications (pWPS) for the original weld and each of the proposed types of weld repair shall be submitted to the employer for information before the start of test welding.
- b) The test weld shall be produced in accordance with the provisional welding procedure specification under simulated site conditions on full pipe lengths unless otherwise approved by the employer [see 4.2d)]. Any deviations from the pWPS shall be recorded on a modified procedure specification.
- c) Welding and testing of the welding procedures shall be witnessed by the employer or their representative.
- d) Roll welding shall only be used with the employer's approval [see 4.2e)] and only when it can be demonstrated that the joint can be adequately supported to maintain its axial alignment.
- e) If tack welds are to be fused into the final joint they shall be included in the test piece.
- f) Repair welds shall be made using a sample of the original weld excavated to a suitable profile and depth (see 8.4).
- g) The quality of the test welds shall be determined by non-destructive and destructive testing after specimens have been allowed to cool to ambient temperature in simulated site conditions for 24 h unless an alternative duration is specified by the employer [see 4.1h)]. If water spraying to cool the pipe will be used in production to facilitate rapid inspection, the same conditions shall be simulated in the welding procedure approval.
- h) If NDT indicates the presence of flaws exceeding the levels permitted in 12.1, the reason shall be investigated and an explanation provided to the employer before they may approve the use of the test piece for the purposes of destructive testing or alternatively rewelding the test piece using the same pWPS [see 4.2f)]
- i) When a welding procedure is to be qualified and approved for installation processes involving plastic deformation, the welding procedure details shall include relevant previously-documented strain ageing data and/or any additional tests specified by the employer to characterize any possible degradation in properties. See 4.1g).

NOTE 1 Strain ageing is typically applied to material which is to be subjected to Charpy testing and might include representative strain cycles and accelerated ageing typically for 1 h at 100 °C for pipelines operating at less than 80 °C, or 250 °C for pipelines operating at higher temperatures.

NOTE 2 For installation processes involving plastic deformation, it might be necessary to implement additional controls for welds, in order to avoid the possibility of unstable fracture during installation or the stable extension of flaws to an extent that would be detrimental to the future operation of the pipeline. This should include consideration of all sources of strain concentration at the girth weld, for example, geometric mismatch, differences in pipe strength, weld overlunder matching and variations in coating stiffness.

- j) For the procedures to be qualified, the results of the tests on the welds shall show that sound welds having the required mechanical properties can be made using these procedures.
- k) In the event of failure the type and number of such re-tests shall be specified by the employer [see 4.1e) and 4.2g)].
- l) The details listed in Table 1 for each procedure shall be recorded in the welding procedure qualification record together with the complete results of the procedure tests and certificates for the material and welding consumables. Each welding procedure qualification record shall be submitted by the contractor together with the welding procedure specification for production welding to the employer for approval [see 4.2h)]. The welding procedure specification shall include the items listed in Table 1.

NOTE 3 Forms similar to those shown in Annex C should be used. The period for which records should be kept should be specified by the employer.

NOTE 4 When welding procedure qualification tests have been carried out in accordance with this standard and witnessed by an independent inspector, the results may be offered for consideration by other employers provided that the procedure remains valid within the changes affecting approval given in 8.2.

8.2 Changes affecting qualification and approval (essential variables)

When any of the changes given in Table 1 are made to a qualified welding procedure, it shall be regarded as a new welding procedure and as such shall be fully re-qualified. Re-repairs and single run repairs shall require qualification and approval.

Partial penetration and full penetration repairs shall only require procedure test welding when the pWPS details contain changes affecting the qualification and approval of the original welding procedure as specified in Table 1.

8.3 Testing of butt joints for procedure qualification

8.3.1 Non-destructive testing

After any required post-weld heat treatment and prior to the cutting of test specimens, all test pieces shall be examined visually (see BS EN 970) followed by:

- a) magnetic particle examination in accordance with 11.7;
- b) radiographic examination using one of the techniques given in 11.4;
- c) any additional method specified by the employer.

The results from the visual examination and NDT shall be assessed according to the appropriate acceptance criteria specified in 12.1.

Table 1 Welding procedure specification details and changes affecting approval

Item		Welding procedure specification details	Changes affecting approval (essential variables)
Welding process	a1	The specific arc welding process (or combination)	A change from one arc welding process to another
	a2	Whether manual, semi-automatic or mechanized	Any change between manual, semi-automatic and mechanized
Base material specification	b1	Specified strength grade	Any increase
	b2	Heat treatment condition ^{A)}	Any change
	b3	Composition ^{A)}	A change greater than that permitted by Table 2 [see 4.2i)]
Diameter	c	Nominal outside diameter, D , of pipe	A change outside the range $0.5D$ to $2D$
Thickness	d	Nominal wall thickness, t , of pipe	A change outside the range $0.75t$ to $1.5t$
Joint configuration (with a sketch, including tolerances)	e	Pipe end preparation including the following:	
	e1	Type of bevel	Any change
	e2	Angle(s) of bevel ^{B)}	Any change outside (unspecified) approved tolerances
	e3	Size of root face ^{B)}	Any change outside (unspecified) approved tolerances
	e4	Width of root gap ^{B)}	Any change outside (unspecified) approved tolerances
	e5	Any use of backing rings	Any addition or deletion, or change of material
	e6	Dimensions ^{B)} of fillet welds	Not restricted as an essential variable
Electrode or filler metal	f	The following information is needed for each run:	
	f1	Nominal diameter of filler/ electrode core wire	Any change for the capping layer or the first two layers Any increase for other runs
	f2	Trade name	Any changes when Charpy testing is required
	f3	Classification	Any change
	f4	Any drying or pre-treatment for hydrogen-controlled electrodes	Any relaxation
	f5	Number of wires for each run	Any change
Number of runs and number of sides welded	g1	Number of runs from each side	A change from single to multi-run or vice versa
	g2	Sides welded first and last (double sided welds only)	Any change
Shielding gas or flux	h1	Choice of shielding gas	Any change in the gas selected
	h2	Composition of any gas mixture	A change exceeding $\pm 10\%$ of the nominal addition in a mixture
	h3	Gas flow rate ^{B)}	Any change exceeding $\pm 10\%$
	h4	Trade name and type of flux	Any change

Table 1 Welding procedure specification details and changes affecting approval (*continued*)

Item		Welding procedure specification details	Changes affecting approval (essential variables)
Electrical characteristics	i	Current (a.c. or d.c.) and polarity	Any change
Welding parameters	j	The following information is needed for each wire size (different values ^{B)} may be used for different runs):	
	j1	Electrical stick-out (SAW, MAG, FCAW) ^{B)}	Any change exceeding ± 5 mm
	j2	Arc voltage ^{B)}	Any change exceeding $\pm 10\%$
	j3	Wire feed speed (SAW, MAG, FCAW) ^{B)} or welding current ^{B)}	Any change exceeding $\pm 10\%$ ($\pm 15\%$ for cellulosic electrodes)
	j4	Travel speed ^{B)}	Any change exceeding $\pm 10\%$
	j5	Calculated value of heat input ^{B)}	No separate restriction
Welding position	k	Angle of pipe axis to the horizontal	Any change exceeding $\pm 25^\circ$
Direction of welding	l	Vertical up, vertical down or horizontal	Any change
Welding technique	m	The following information is needed for each wire size (different values ^{B)} may be used for different runs):	
	m1	Maximum amplitude of any mechanized weave	To be agreed between the contracting parties
	m2	Frequency of any mechanized weave	To be agreed between the contracting parties
	m3	Dwell time at the side of any mechanized weave	To be agreed between the contracting parties
Number of welders	n	Number of welders for each pass	Any reduction
Time lapse between runs (cellulosic electrodes only)	o	Time lapse between the start of the root run and the start of the second run	Any increase
Partially completed joint	p	Number of runs before cooling to ambient	Any reduction
Line-up clamp	q1	Internal, external, or alternative method (detail)	A change from internal to external, or from clamp to alternative
	q2	Number of runs before removal of clamp	Any reduction
Lowering off (on land), or barge move-up (offshore)	r	Number of runs before this activity commences	Any reduction
Cleaning of bevel and weld ^{A)}	s	Whether by power driven or hand tools	No restriction
Preheating	t1	Preheat temperature	Any reduction, or an increase exceeding 50°C
	t2	Method of applying heat	Any change
	t3	Method of controlling temperature	Any change
	t4	Method of measuring temperature	Any change
	t5	Initial temperature of pipe not requiring preheat	Any reduction

Table 1 Welding procedure specification details and changes affecting approval (*continued*)

Item		Welding procedure specification details	Changes affecting approval (essential variables)
Preheating	t6	Maximum and minimum interpass temperature for each run	Any change
Post-weld heat treatment ^{A)}	u1	Method of applying heat	Any change
	u2	Soaking temperature	Any change
	u3	Soaking time	Any change
Repair welds	v1	Welding procedure details for repair welding	Any of the changes affecting approval listed above
	v2	Welding procedure details for the weld to be repaired	Any change affecting the approval of the procedure for the weld on which the repair welding procedure was qualified

^{A)} These items shall be specified on the provisional WPS but are not mandatory for the production WPS if they are controlled through other procedures.

^{B)} These parameters shall be specified as single nominal values on the provisional WPS but as qualified ranges (nominal values $\pm$ permitted variation) on the production WPS. In cases where the mean value measured in qualification differs from the nominal value, the qualified range shall be calculated from the mean value measured in qualification.

Table 2 Qualified ranges of chemical analysis

Element	Value tested	Values qualified ^{A)}
Carbon	Any	Value tested $\pm 0.04\%$
Manganese	Any	Value tested $\pm 0.25\%$
Silicon	Any	Value tested $\pm 0.20\%$
Sulfur	Not over 0.008%	0 to value tested +0.015%
	Over 0.008%	0.009% to value tested +0.015%
Phosphorus	Any	0 to value tested +0.015%
Carbon equivalent ^{B)} (non-sour service)	Any	Value tested -0.06% or $+0.03\%$
Carbon equivalent ^{B)} (sour service)	Any	Value tested -0.06% or $+0.00\%$
Aluminium	Not over 0.015%	Not less than value tested
	Over 0.015%	Value tested $\pm 0.030\%$ but shall be between 0.016% and 0.060%
Vanadium	Any	Value tested $\pm 0.03\%$
Nickel	Any	Value tested $\pm 0.10\%$
Copper	Any	Value tested -0.20% or $+0.10\%$
Chromium	Any	Value tested -0.10% or $+0.05\%$
Molybdenum	Any	Value tested -0.10% or $+0.05\%$
Titanium	Any	Value tested $\pm 0.005\%$
Nitrogen	Any	Value tested $\pm 0.004\%$
Calcium	Not over 0.004%	Not over 0.004%
	Over 0.004%	Not over value tested
Niobium	Any	Value tested -0.02% or $+0.01\%$

NOTE 1 Re-qualification is required for carbon manganese steels if the ladle analysis differs from that tested by more than the amounts given in this table. Alternatively the tolerances may be applied to the differences in product analysis.

NOTE 2 The "values qualified" for aluminium through to niobium apply only where Charpy testing at temperatures below 0 °C is required, or where the specified minimum yield strength of the pipe exceeds 360 MPa.

NOTE 3 Preliminary welding tests should always be considered for pipeline steels with carbon equivalent values $>0.4\%$.

^{A)} For example, for carbon, if value tested was 0.10% then values qualified are 0.06% to 0.14%.

^{B)} Carbon equivalent = $C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$ (in %)

8.3.2 Destructive testing

8.3.2.1 Test specimens

Test specimens shall be cut from the test joint at the locations shown in Figure 1. The minimum number of specimens and the tests to which they shall be subjected shall be as given in Table 3. For outside diameters of pipe up to and including 114.3 mm, the number and location of transverse tensile test specimens shall be specified by the employer [see 4.1j)].

When required by the employer, Charpy impact testing shall be carried out in accordance with 8.3.2.6 [see 4.1k)]. For pipes of outside diameter up to and including 114.3 mm the number and location of test pieces shall be specified by the employer [see 4.1l)].

NOTE When post-weld heat treatment is carried out, it may be necessary to verify the properties of the pipe and all welded joints affected by the heat treatment.

Test specimens from test joints made with the pipe fixed in the vertical position, or with the pipe rolled in the horizontal position, or when composite welding procedures are utilized (e.g. root pass vertical-up, and the remainder of the weld passes in the vertical-down direction) shall be taken from the same locations as for vertical-down welding.

Figure 1 Location of test specimens

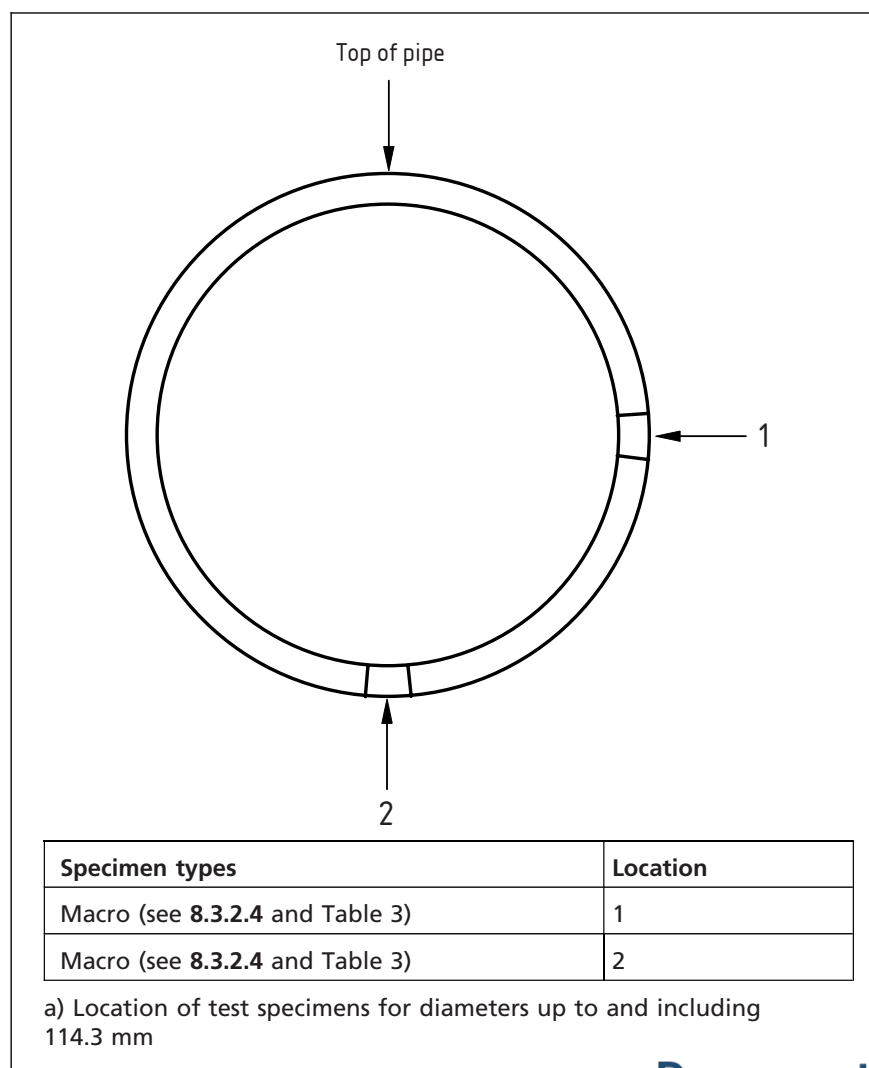


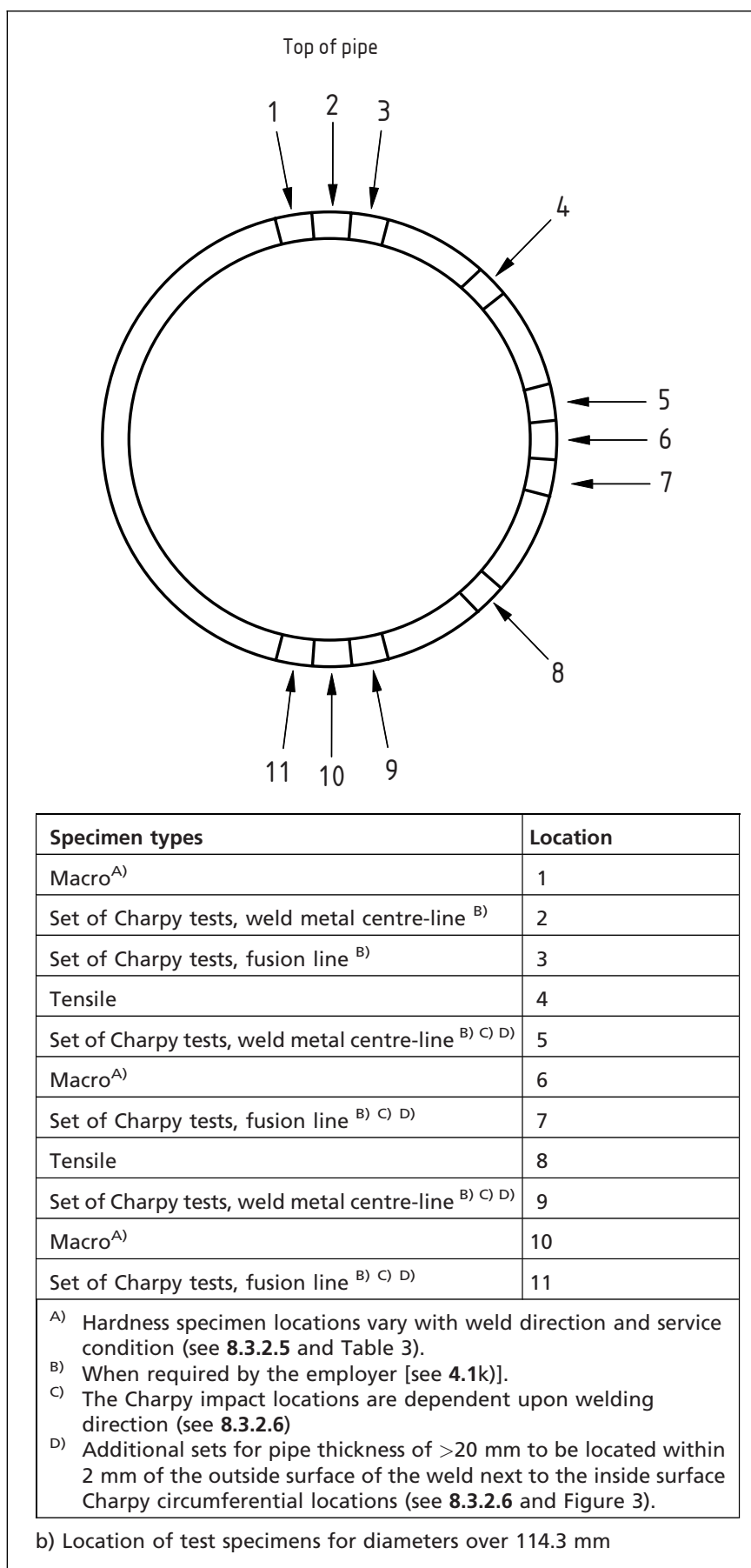
Figure 1 Location of test specimens (*continued*)

Table 3 Number of specimens for tensile tests, macro-examination and hardness survey and number of sets of specimens for Charpy tests, for procedure approval of butt joints

Specimen type	Outside diameter of pipe mm	
	≤ 114.3	> 114.3
Transverse tensile	See 8.3.2.1	2
Macro-examination	2	3
Hardness survey		
Non-sour service	1	1
Sour service	2	3
Weld root Charpy	See 8.3.2.1	2
Fusion line root Charpy	See 8.3.2.1	2
Weld cap Charpy (for wall thickness >20 mm) ^{A)}	See 8.3.2.1	1
Fusion line cap Charpy (for wall thickness >20 mm) ^{A)}	See 8.3.2.1	1

^{A)} See 8.3.2.6 and Figure 3.

8.3.2.2 Transverse weld tensile testing

Test specimens and testing for transverse tensile testing for butt joints shall be in accordance with BS EN 895.

For pipes >50 mm outside diameter, the weld reinforcement shall be removed on both faces to give the test specimen a thickness equal to the wall thickness of the pipe.

The tensile strength of the weld, including the fusion zone of each specimen, shall be equal to or greater than the specified minimum tensile strength of the pipe material. Where installation methods involve plastic deformation of the pipe, the specimen shall break outside of the weld and fusion zone to be deemed acceptable.

If a specimen breaks outside the weld or fusion zone at a tensile strength not less than 95% of that of the specified minimum tensile strength of the pipe material, that specimen shall be deemed to meet the test requirement.

8.3.2.3 Weld metal tensile testing

When a minimum weld metal yield strength requirement is specified, i.e. for welds in pipe grade L555 or where installation methods involve plastic deformation of the pipe [see 7.1], all weld tensile testing shall be performed in accordance with the method specified by the employer [see 4.1i)].

8.3.2.4 Macro-examination

Macro-examination shall be in accordance with BS EN 1321. The specimens shall be polished and etched. Examination shall be at ×5 magnification.

The specimens shall be free from cracks and lack of fusion. Any other defects shall be within the limits specified in 12.1.

8.3.2.5 Hardness

Hardness testing shall be in accordance with BS EN ISO 6507, preferably with a 10 kg load, although a 5 kg load will often be necessary for the narrow heat-affected zones in some welds made by mechanized processes. The indentations shall be made in the weld, the HAZs and the parent material with the object of measuring and recording the range of values in the weld joint. This will include rows of indentations one of which shall be 2 mm maximum below each surface. The indentations shall be as shown in Figure 2.

One of the sections for macro-examination shall be used for the hardness survey. For vertical-down welding, take the section from the 3 o'clock position and for vertical-up welding, take the section from the 6 o'clock position. For sour service surveys shall be carried out at the 3, 6 and 12 o'clock positions.

The hardness values shall not exceed those given in Table 4, except that for non-sour service, the maximum permitted weld metal hardness shall be 300 HV10 when welding pipe grade L555. This hardness limit shall not, however, apply to the root region of manual welds when cellulosic electrodes are employed.

Figure 2 Locations for hardness indentations

