BS 4515-1:2009

BSI British Standards

Specification for welding of steel pipelines on land and offshore

Part 1: Carbon and carbon manganese steel pipelines

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Contents

List of tables

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 72, an inside back cover and a back cover.

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This part of BS 4515 supersedes BS 4515-1:2004, which is withdrawn.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- removal of references to BS EN 288-9 which has been withdrawn.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/mm^2 (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 **8.1**k)].

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 **8.1**i)].

h) Whether specimens are to be allowed to cool for a duration other than 24 h before testing [see **8.1**g)].

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 **8.5.1**b)].

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 **9.5**i)].

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 **8.1**b)].

e) Use of roll welding [see **8.1**d)].

f) Use of a test weld for destructive testing or rewelding to the same procedure following NDT failure [see **8.1**h)].

g) The type and number of re-tests of a welding procedure when they are permitted [see **8.1**k)].

h) Welding procedure qualification test details and welding procedure specification for production welding [see **8.1**l)].

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 **9.4.1**b)].

k) Alternative methods of NDT for welder test pieces [see **9.6**c)].

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 **10.2**a)].

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 **11.7**a)].

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 **4.2**a)]. When specified by the employer [see **4.1**a)], 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 **4.2**b)].

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 **4.1**b)].

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 **4.2**c)], 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 **4.1**c)].

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 **4.1**d)], 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 **4.2**d)]. 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 **4.2**e)] 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 **4.1**h)]. 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 **4.2**f)]

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 **4.1**g).

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 over/under 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 **4.1**e) and **4.2**g)].

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 **4.2**h)]. 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 **4.2**i)]
Diameter	c	Nominal outside diameter, *D*, of pipe	A change outside the range 0.5*D* to 2*D*
Thickness	d	Nominal wall thickness, *t*, of pipe	A change outside the range 0.75*t* to 1.5*t*
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 ±10% of the nominal addition in a mixture
	h3	Gas flow rate [B)]	Any change exceeding ±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 ±10%
	j3	Wire feed speed (SAW, MAG, FCAW) [B] or welding current [B]	Any change exceeding ±10% (±15% for cellulosic electrodes)
	j4	Travel speed [B]	Any change exceeding ±10%
	j5	Calculated value of heat input [B]	No separate restriction
Welding position	k	Angle of pipe axis to the horizontal	Any change exceeding ±25°
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 ± 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 ±0.04%
Manganese	Any	Value tested ±0.25%
Silicon	Any	Value tested ±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 ±0.030% but shall be between 0.016% and 0.060%
Vanadium	Any	Value tested ±0.03%
Nickel	Any	Value tested ±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 ±0.005%
Nitrogen	Any	Value tested ±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

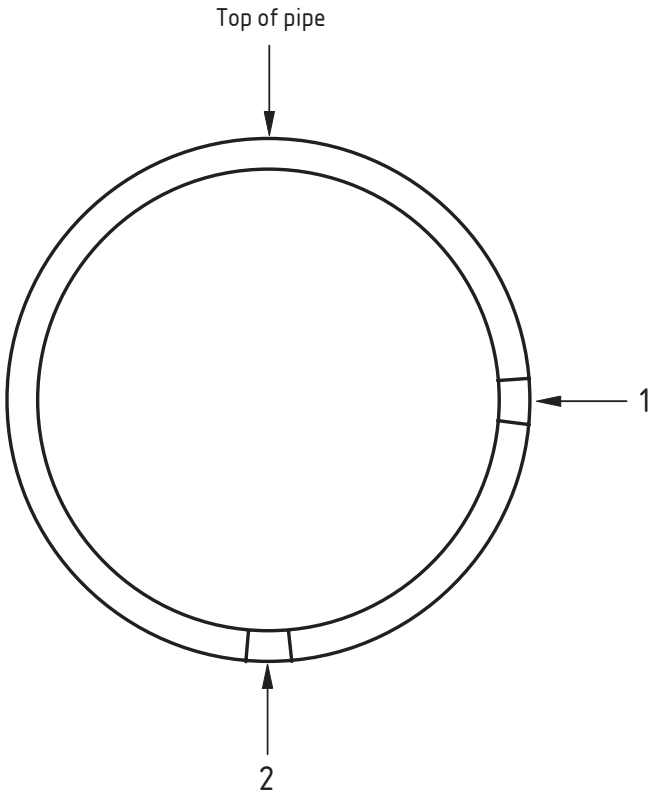
Test specimens shall be cut from the test joint at the locations shown in Figure 1. The minimum number of specimens and the tests to which they shall be subjected shall be as given in Table 3. For outside diameters of pipe up to and including 114.3 mm, the number and location of transverse tensile test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

When required by the employer, Charpy impact testing shall be carried out in accordance with **8.3.2.6** [see **4.1**k)]. 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 **4.1**l)].

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.

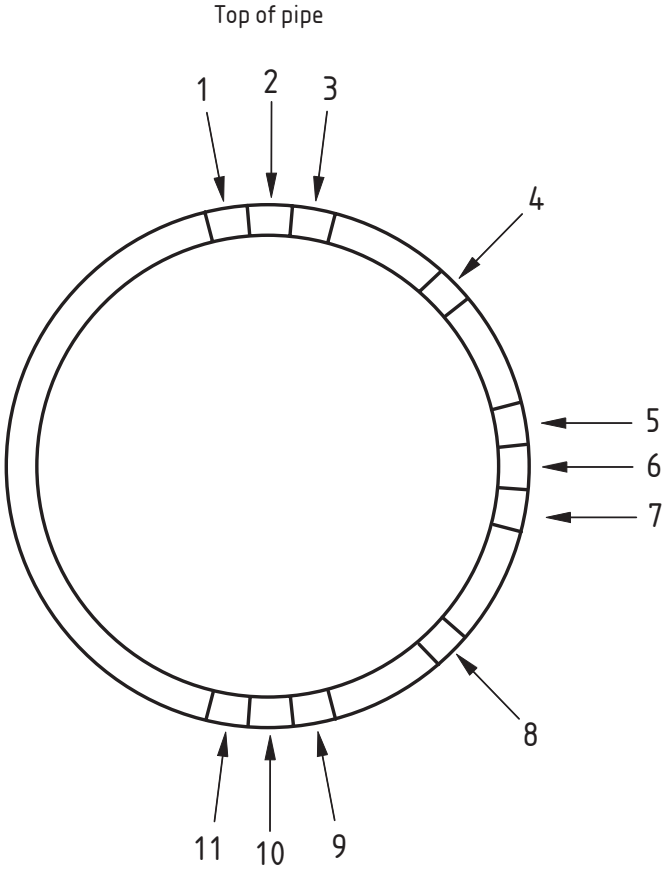
Figure 1 **Location of test specimens**



Specimen types	Location
Macro (see **8.3.2.4** and Table 3)	1
Macro (see **8.3.2.4** and Table 3)	2

a) Location of test specimens for diameters up to and including 114.3 mm

Figure 1 **Location of test specimens** *(continued)*



Specimen types	Location
Macro[A)]	1
Set of Charpy tests, weld metal centre-line [B)]	2
Set of Charpy tests, fusion line [B)]	3
Tensile	4
Set of Charpy tests, weld metal centre-line [B) C) D)]	5
Macro[A)]	6
Set of Charpy tests, fusion line [B) C) D)]	7
Tensile	8
Set of Charpy tests, weld metal centre-line [B) C) D)]	9
Macro[A)]	10
Set of Charpy tests, fusion line [B) C) D)]	11

[A)] Hardness specimen locations vary with weld direction and service condition (see **8.3.2.5** and Table 3).
[B)] When required by the employer [see **4.1**k)].
[C)] The Charpy impact locations are dependent upon welding direction (see **8.3.2.6**)
[D)] Additional sets for pipe thickness of >20 mm to be located within 2 mm of the outside surface of the weld next to the inside surface Charpy circumferential locations (see **8.3.2.6** and Figure 3).

b) Location of test specimens for diameters over 114.3 mm

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 **4.1**i)].

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

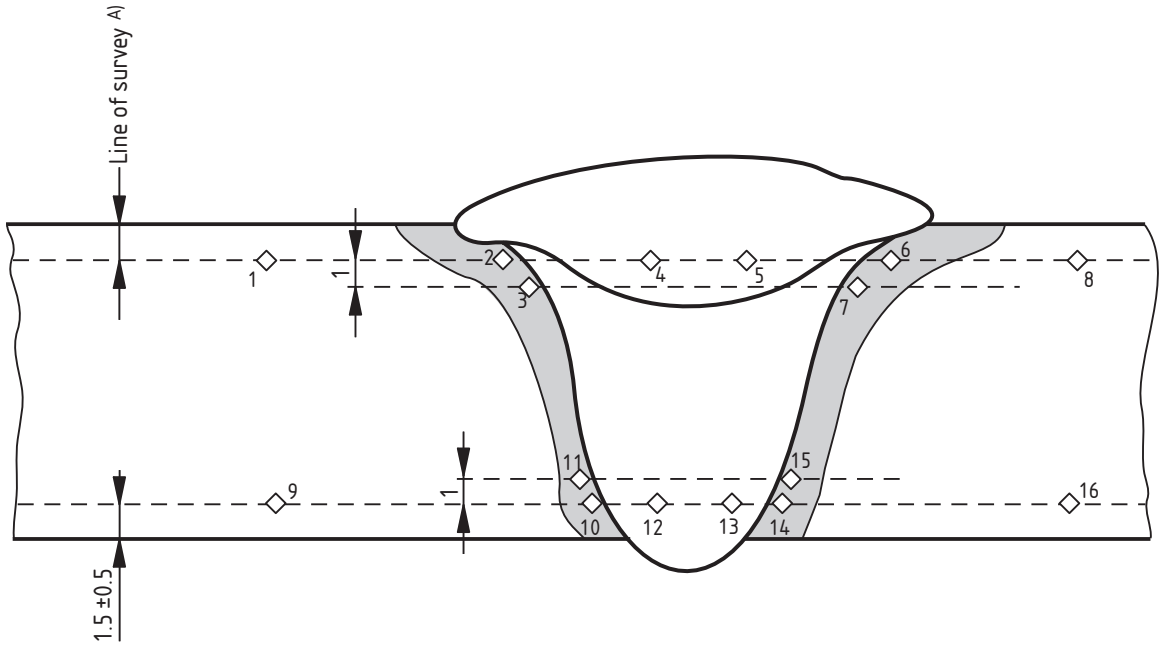
Hardness testing shall be in accordance with BS EN ISO 6507, preferably with a 10 kg load, although a 5 kg load will often be necessary for the narrow heat-affected zones in some welds made by mechanized processes. The indentations shall be made in the weld, the HAZs and the parent material with the 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**

Dimensions in millimetres



Key

Weld heat-affected zone (visible after etching)

NOTE Hardness indentations 2, 3, 6, 7, 10, 11, 14 and 15 should be entirely within the heat-affected zone and located as close as possible to the fusion boundary (between the weld metal and the heat-affected zone).

A) The line of survey should be positioned so that indentations 2 and 6 coincide with the heat-affected zone of the final run or change of profile of the fusion line associated with the final run.

Table 4 **Permitted maximum hardness values HV10**

Hardness location	Weld metal		Heat-affected zone	
	Root	Cap	Root	Cap
Sour service, any process				
$t < 9.5$ mm	250	275	250	275
$t \geqslant 9.5$ mm	250	275	250	300
Non-sour service				
– manual welding with cellulosic electrodes	275	275	275	325
– other welding processes [A)]	275	275	350	350

[A)] For pipe grade L555 the maximum permitted weld hardness shall be 300 HV10.

8.3.2.6 Impact testing

When impact tests are required by the employer [see **4.1**k)], the test specimens shall be taken and prepared in accordance with BS EN 10045-1 in such a way that the axis of the notch is perpendicular to the pipe surface.

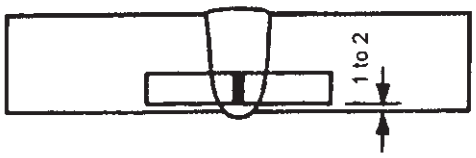
Test specimens and testing for impact tests shall be in accordance with this standard for position and temperature of testing, and with BS EN 875 for dimensions and testing.

For weld metal, test specimen type VWT0, and for fusion line, test specimen type VHT0, shall be used (see Figure 3). From each specified position, each set shall be comprised of three test specimens.

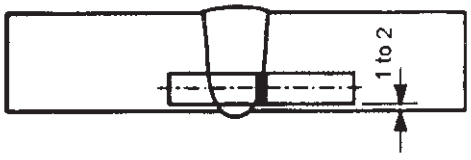
Test specimens with Charpy V-notch shall be used and sampled from 1 mm to 2 mm below the inner surface of the pipe and transverse to the weld.

Figure 3 **Position of Charpy V-notch test specimens**

Dimensions in millimetres

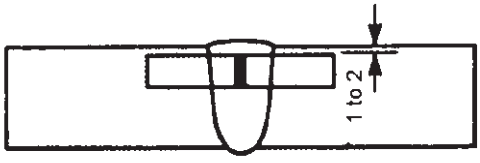


Notch location: Weld metal root (VWT0)

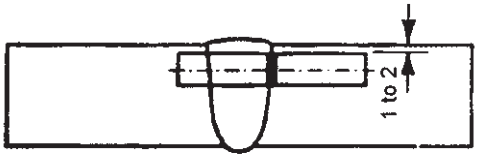


Notch location: Fusion line root (VHT0)

a) For all wall thicknesses



Notch location: Weld metal (VWT0)



Notch location: Fusion line (VHT0)

b) Additional for wall thicknesses >20 mm

Impact test specimens shall be taken from each of the locations in Figure 1. For vertical-down welding, specimens shall be taken from 12 o'clock and 6 o'clock positions and for vertical-up welding, specimens shall be taken from 12 o'clock and 3 o'clock positions.

When the pipe wall thickness exceeds 20 mm, two more sets are required, at either the 3 o'clock or 6 o'clock position depending on the welding direction, but taken within 1 mm to 2 mm of the outside surface of the pipe.

When tested at the minimum design temperature, all Charpy impact test specimens shall have an average not less than 40 J and a minimum individual value of 30 J. The requirements for sub-size specimens shall be reduced pro rata with their dimensions.

The Charpy impact test requirements shall apply for pipe and wall thicknesses up to and including 25 mm, minimum design temperatures that are not lower than –10 °C and pipe material with a specified minimum yield strength not greater than 555 N/mm^2. Charpy toughness and test temperature for other conditions shall be specified by the employer [see **4.1**m)].

When these Charpy requirements are met, the flaw acceptance criteria in Table 9 may be used. Derivation of alternatives for criteria through an ECA approach shall be in accordance with **12.1.3**.

NOTE Attention is drawn to the publications by the European Pipeline Research Group [1] and [2].

8.4 Testing of repair welds for procedure qualification

8.4.1 General

Repair welds shall be made using a sample of the original weld excavated to a suitable profile and depth, with the excavation located as shown in Figure 4 or as specified by the employer [see **4.1**f)].

8.4.2 Non-destructive testing

All test welds shall be subjected to non-destructive testing in accordance with **8.3.1**.

8.4.3 Destructive testing

8.4.3.1 General

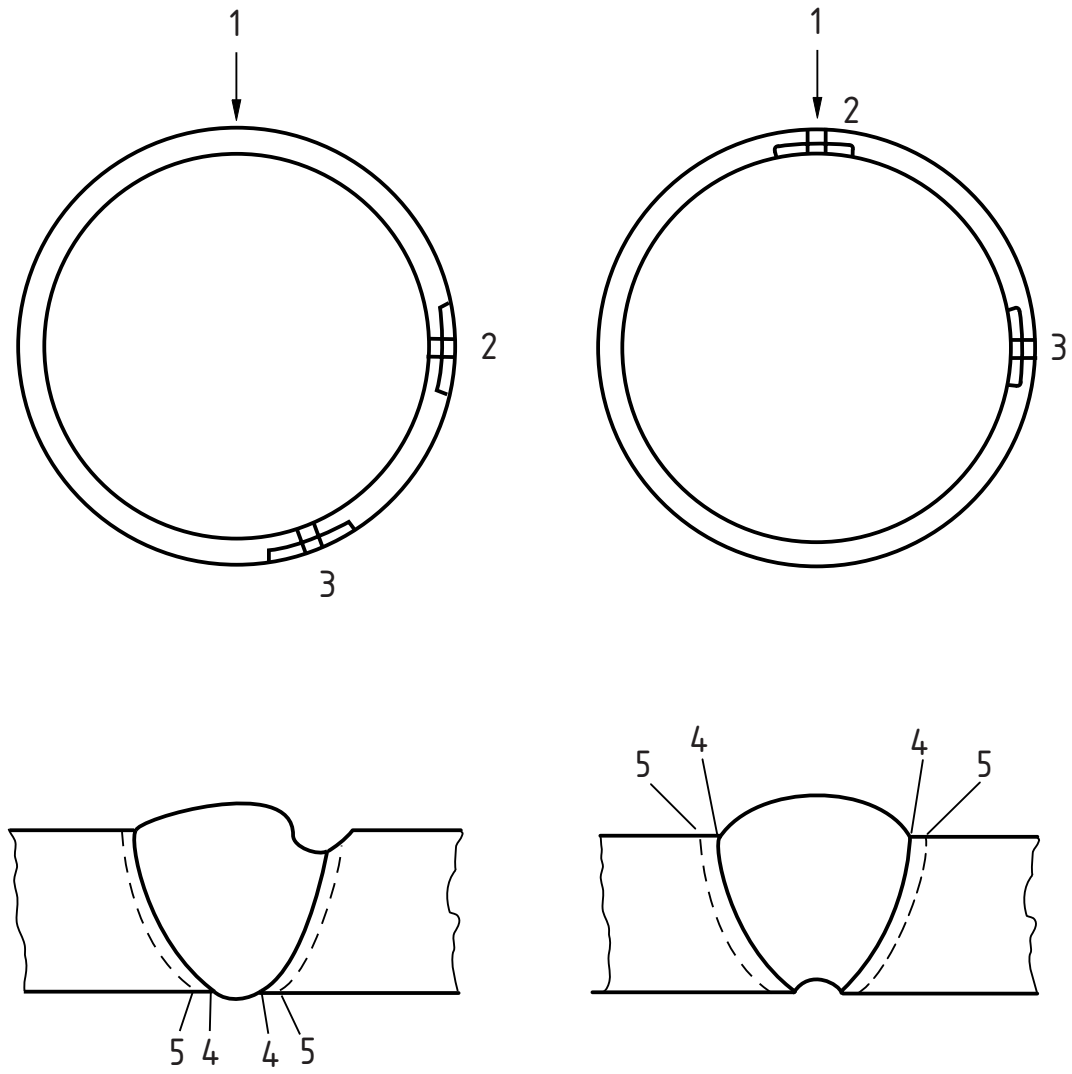
Test specimens for destructive testing shall be cut from the repair test weld at the locations shown in Figure 4a) to e). The minimum number of specimens and the tests to which they shall be subjected shall be as given in with Table 5.

When required by the employer for the qualification of the original welding procedure, Charpy impact testing shall also be carried out on repair procedures.

8.4.3.2 Transverse tensile testing

The requirements and method of testing shall be as specified in **8.3.2.2**.

Figure 4 **Location of repair excavations and destructive test specimens**



a) Cap repair

b) Single pass backweld repair

Key

1 Top of pipe
2 Vertical-down welding, macro/hardness
3 Vertical-up welding, macro/hardness
4 Original weld fusion line
5 Original weld heat-affected zone

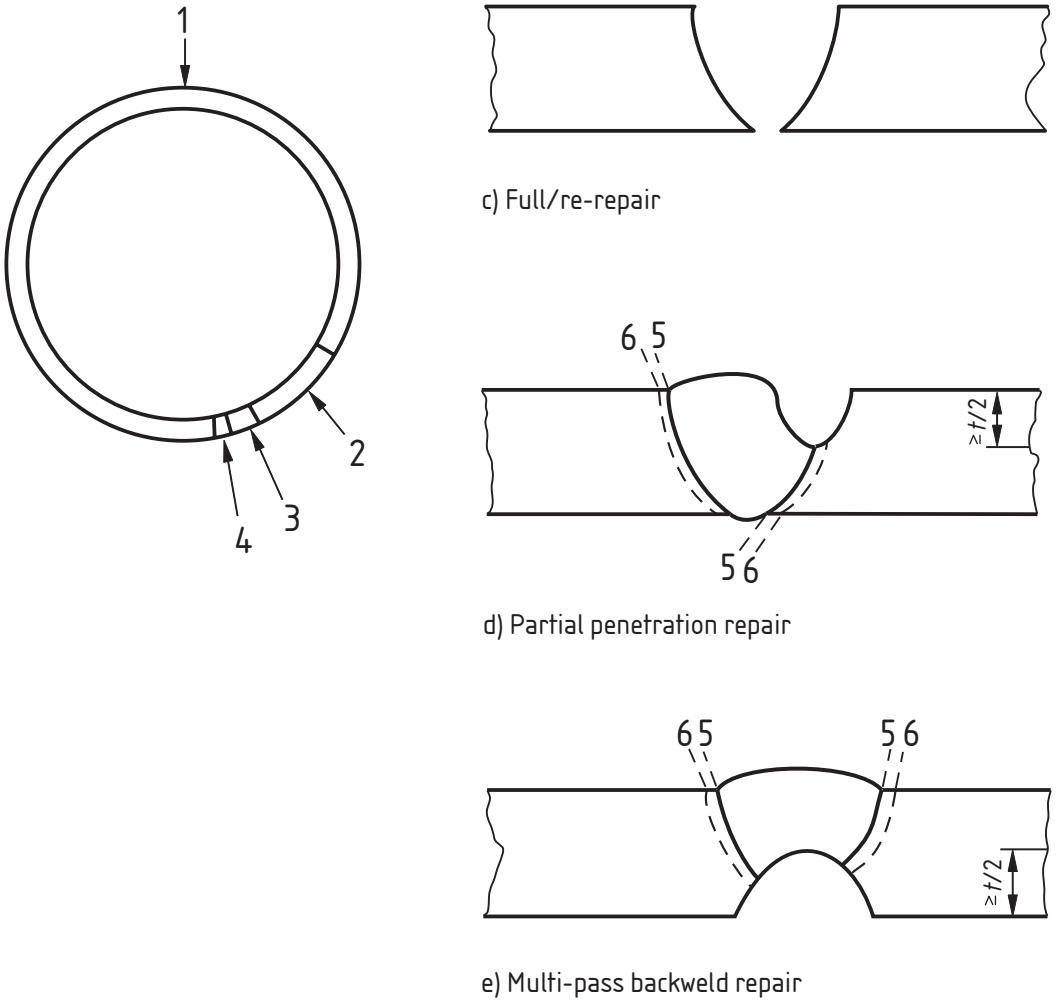
8.4.3.3 Macro-examination

The requirements and method of testing shall be as specified in **8.3.2.4**.

8.4.3.4 Hardness

The requirements and method of testing shall be as specified in **8.3.2.5**. The indentations for partial penetration and single run repair welds shall be located as shown in Figure 5a) to d). The indentations for full thickness repair welds shall be as shown in Figure 2.

Figure 4 **Location of repair excavations and destructive test specimens** *(continued)*



Key

1 Top of pipe
2 Charpy (optional)
3 Tensile
4 Macro/hardness
5 Original weld fusion line
6 Original weld heat-affected zone
t Wall thickness of test pipe

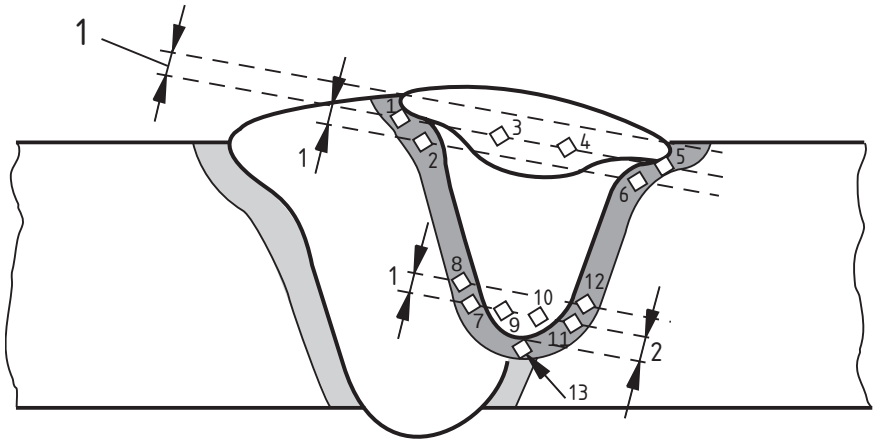
Table 5 **Number of test specimens to undergo destructive testing for weld repair procedure qualification**

Weld repair procedure	Number of specimens			
	Transverse tensile	Macro-examination	Hardness survey [A)]	Charpy test [B)]
Partial penetration repair and multi-pass backweld repair [D)]	1	1	1	3 sets of 3
Full penetration repair [D)]	1	1	1	2 sets of 3 [C)]
Re-repair [D)]	1	1	1	2 sets of 3 [C)]
Cap repair	N/A	1	1	N/A
Backweld repair	N/A	1	1	N/A

[A)] The hardness survey is carried out on the macro-examination test specimen.
[B)] When required by the employer for qualification of the original welding procedure.
[C)] For pipe thickness over 20 mm an additional set of Charpy specimens shall be tested at each of the positions shown in Figure 3b).
[D)] If all weld metal tensile testing was required for the original welding procedure (see **8.3.2.3**), then all weld metal tensile testing shall also be carried out on repair procedures.

Figure 5 **Recommended locations for hardness indentations for repair test welds**

Dimensions in millimetres



Key

Original weld heat-affected zone

Repair weld heat-affected zone

1 Line of survey

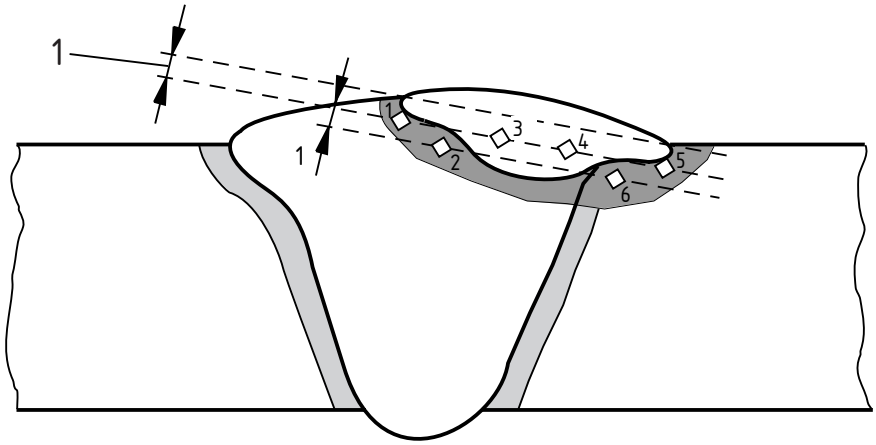
NOTE 1 Indentations in the heat-affected zone should be located as close to the fusion boundary as possible.

NOTE 2 The line of survey should be positioned so that heat-affected zone indentations coincide with the heat-affected zone of the final run or change in profile of the cap of fusion line associated with the final run.

a) Partial penetration repair

Figure 5 **Recommended locations for hardness indentations for repair welds** *(continued)*

Dimensions in millimetres



Key

Original weld heat-affected zone

Repair weld heat-affected zone

1 Line of survey

NOTE 1 Indentations in the heat-affected zone should be located as close to the fusion boundary as possible.

NOTE 2 The line of survey should be positioned so that indentations 1 and 5 coincide with the heat-affected zone of the final run or change in profile of the cap of fusion line associated with the final run.

b) Cap repair

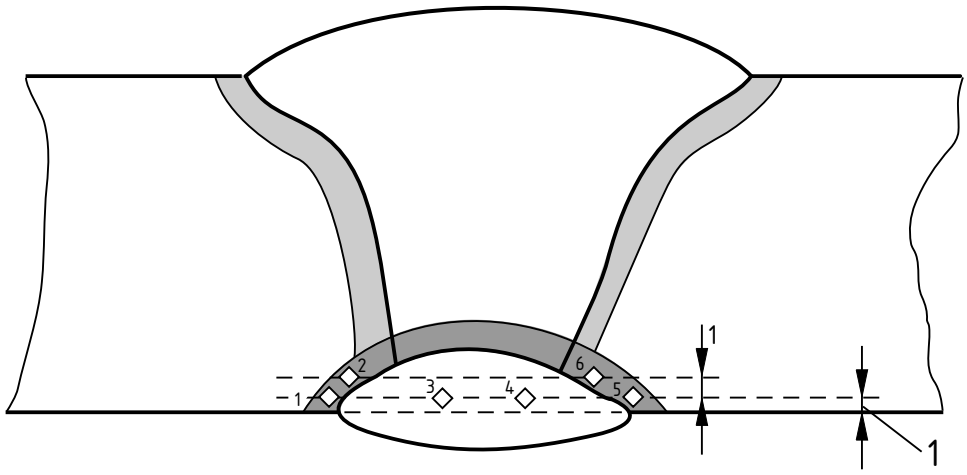
8.4.3.5 Impact testing

The requirements shall be as specified in **8.3.2.6**. The method for testing full penetration repair and re-repair welds shall be in accordance with **8.3.2.6** except that specimens are taken from the location shown in Figure 4.

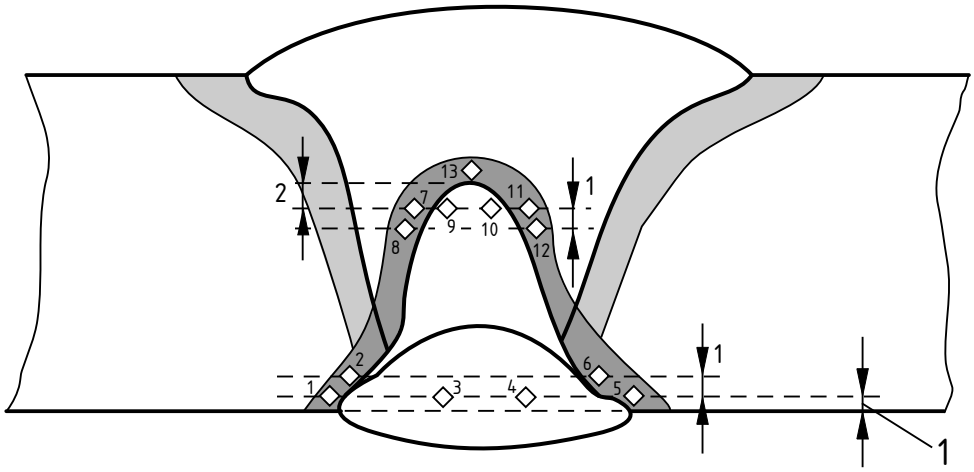
The method for testing partial penetration repair and multi-pass internal repair welds shall be in accordance with **8.3.2.6** except that specimens are taken from the location shown in Figure 4. Two sets of three heat-affected zone Charpy impact specimens (pipe side and original weld side notched as shown in Figure 6) shall be taken in addition to one set of three specimens at the repair weld centre-line. For pipe thickness over 20 mm, the repair weld fusion line shall pass through the centre of the notch in the heat-affected zone specimens (see Figure 6a). For pipe thickness up to and including 20 mm, the repair weld fusion line shall pass through the notch in the heat-affected zone test specimens at a depth of half the penetration of the repair weld (see Figure 6b).

Figure 5 **Recommended locations for hardness indentations for repair welds** *(continued)*

Dimensions in millimetres



c) Single pass backweld repair



d) Multi-pass backweld repairs

Key

Original weld heat-affected zone

Repair weld heat-affected zone

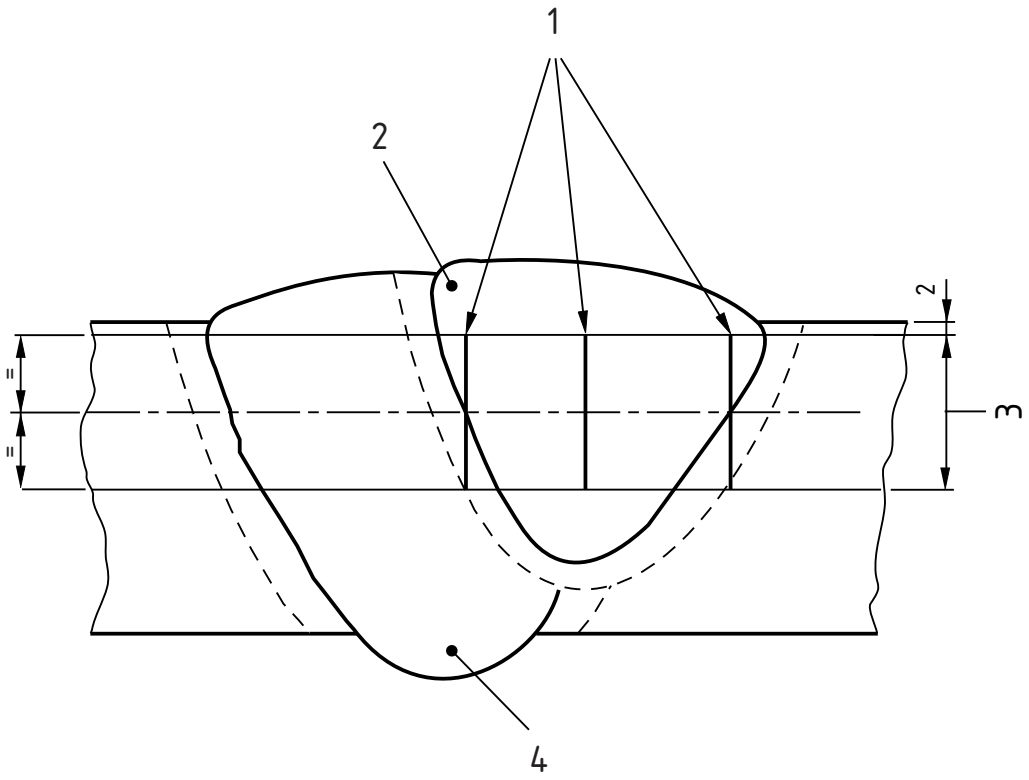
1 Line of survey

NOTE 1 Indentations in the heat-affected zone should be located as close to the fusion boundary as possible.

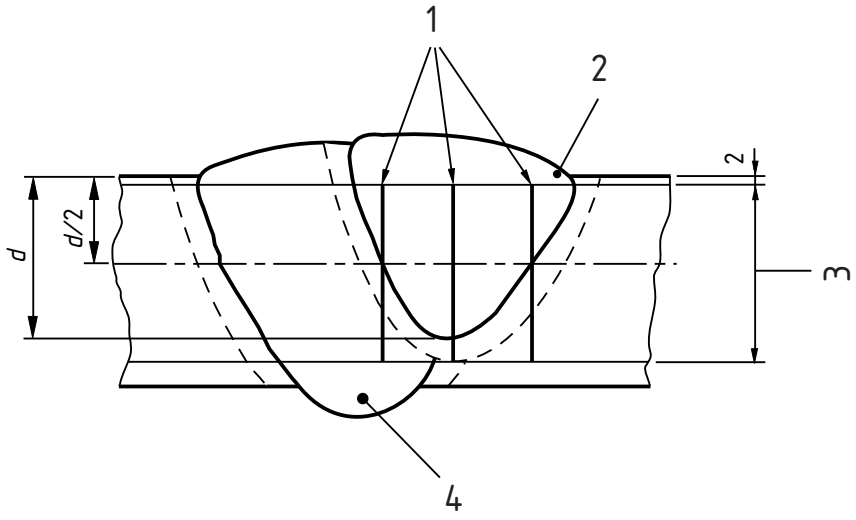
NOTE 2 The line of survey should be positioned so that indentations 1 and 5 coincide with the heat-affected zone of the final run or change in profile of the cap of fusion line associated with the final run.

Figure 6 **Positioning of Charpy V-notch impact specimens for procedure approval of partial penetration repair welds**

Dimensions in millimetres



a) Pipe thickness over 20 mm



b) Pipe thickness up to and including 20 mm

Key

1 Positions of V-notches
2 Repair weld
3 Charpy specimen thickness
4 Original weld

8.5 Testing of fillet welds for procedure qualification

8.5.1 Non-destructive testing

All fillet welds shall be examined visually in accordance with BS EN 970 followed by:

a) magnetic particle testing (see **11.7**); and

b) any additional NDT method specified by the employer [see **4.1**n)].

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

8.5.2 Destructive testing of fillet welds

8.5.2.1 Test specimens

The minimum number of test specimens and destructive testing carried out shall be in accordance with Table 6.

Table 6 **Number of test specimens for procedure approval tests on fillet welds**

Outside diameter of pipe	**Minimum number of specimens**		
mm	**Fracture test**	**Macro-examination**	**Hardness survey** [A)]
$\leqslant$114.3	2	2	1
$>$114.3	4	2	1

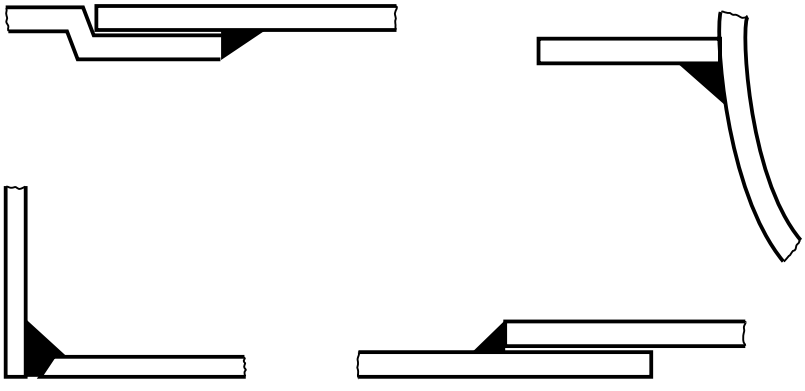
[A)] The hardness survey is carried out on a macro-examination test specimen.

Two of the fracture specimens shall be taken from those locations shown to have the greatest and least root gap.

The test specimens shall be prepared as shown in Figure 7 and shall be at least 25 mm wide and at least 50 mm long.

The test specimens shall be prepared by machine cutting or thermal cutting followed by grinding, but the sides of the specimens shall be smooth and parallel.

Figure 7 **Preparation of fillet weld specimens**



NOTE Specimens for fracture may be hacksaw notched in the weld.

8.5.2.2 Fracture test

8.5.2.2.1 The specimen shall be broken using one of the following methods in such a way that the root of the weld is in tension:

a) supporting both ends and striking the centre of the specimen;

b) gripping one end of the specimen and striking the other.

8.5.2.2.2 The exposed surface of each broken specimen shall be free from cracks, lack of fusion and lack of penetration. Other defects in the weld metal shall be within the following limits.

a) *Gas pores*. The greatest dimension of any gas pore shall not exceed 20% of the pipe thickness or 3 mm, whichever is the smaller. The combined areas of all pores shall not exceed 5% of the cross-sectional area.

b) *Inclusions*. Inclusions shall not exceed 1 mm in depth and 3 mm or 50% of the pipe thickness in length, whichever is the shorter. There shall be at least 12 mm of sound weld metal between adjacent inclusions.

8.5.2.3 Macro-examination

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

The profile, dimensions and number of runs of the fillet weld shall be as specified in the welding procedure. The specimen shall be free from cracks, lack of fusion and lack of penetration and the total area of any cavities or inclusions shall not exceed 5% of the fillet weld cross-sectional area.

8.5.2.4 Hardness

The hardness survey shall be undertaken on a macro-examination or fracture test specimen as appropriate. The specimens shall be tested in accordance with BS EN ISO 6507 using a 10 kg load. Make two weld zone traverses, one across the root and one near the weld cap (see Figure 8). The root traverse shall consist of at least five indentations: two in the heat-affected zone, one in the weld metal and one in the parent metal each side of the weld. The traverse near the cap shall consist of at least eight indentations: two in the heat-affected zone each side of the weld, two in the weld metal and one in the parent metal each side of the weld.

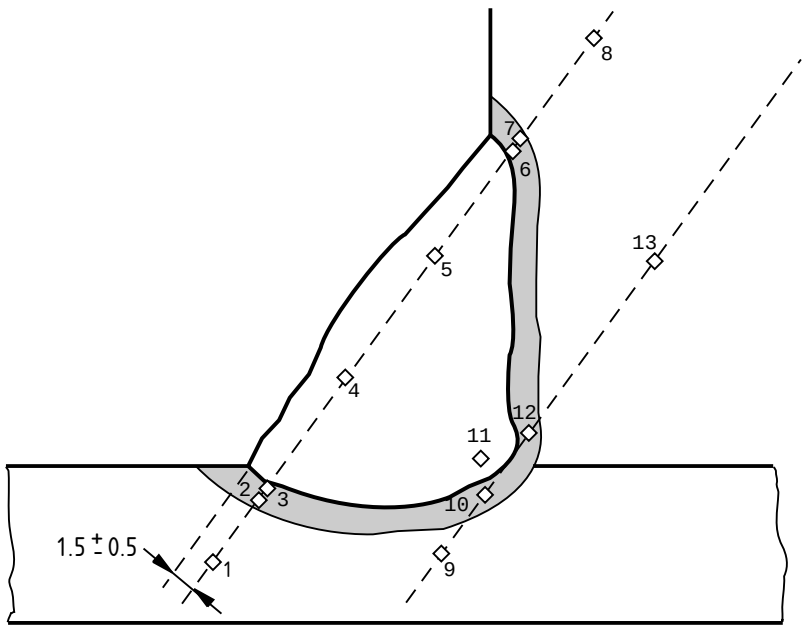
Unless otherwise specified by the employer [see **4.1**o)], the hardness values of the test specimen shall not exceed those given in Table 7. The root hardness values of internal fillet welds in contact with the pipe contents shall be in accordance with **8.3.2.5**.

Table 7 **Hardness values for fillet welds on the external surface of the pipe**

Hardness location	Sour service	Non-sour service	
	Any welding process	Manual metal-arc welding, cellulosic electrodes	Other processes
	HV10	HV10	HV10
Weld metal	275	275	275 [A)]
Heat-affected zone	275 [B)]	325	350

[A)] 300 HV10 for welds on pipe grade L555.
[B)] 300 HV10 for pipe 9.5 mm thick and above.

Figure 8 **Recommended locations for hardness indentations on a fillet weld**



Key

Weld heat-affected zone (visible after etching)

Dashed line on the right: Traverse line to be parallel to first traverse line and to pass through centre of heat-affected zone at the root.

NOTE Hardness indentations 3, 6, 10 and 12 should be entirely within the heat-affected zone and located as close as possible to the fusion boundary.

9 Testing, qualification and approval of welders

9.1 General

Each welder shall make a test weld or part of a weld using a qualified procedure to make the welds or parts of welds required on the pipelines. A welder who has satisfactorily completed a successful welding procedure qualification test shall automatically be qualified in that procedure.

Where more than one process or welder is utilized in producing a complete welded joint, the successful testing of the completed weld shall qualify each welder for his respective portion. Each welder's portion shall be clearly identified.

Each welder shall weld that portion of the weld which he will weld in construction in accordance with the qualified welding procedure.

A welder shall complete a separate qualification test for one or more of the following categories. A separate test is required for each category:

a) butt joint;

b) branch connections;

c) fillet welds for sleeves, sockets, slip-on flanges, other attachments and pipe supports.

The validity of the welder's qualification shall commence from the date when all the required tests are successfully completed.

NOTE This date may be different to the date of issue marked on the certificate.

A welder's qualification shall remain valid for a period of 2 years from the date of completing a successful test, provided the relevant certificate is signed at 6 month intervals by the employer/co-ordinator and that the following conditions are fulfilled.

1) The welder is engaged with reasonable continuity on welding work within the current range of qualification. An interruption for a period no longer than 6 months is permitted.
2) The welder's work is in general accordance with the technical conditions under which the qualification test is carried out.

If any of these conditions are not fulfilled, the qualification shall be cancelled.

9.2 Butt joints

9.2.1 Roll welding

The butt test joint shall be made between two pieces of pipe rolled about the horizontal axis. The welder shall deposit metal at or near the position specified in the welding procedure until 200 mm (or longer in the case of mechanized welding) or slightly less than 25% of the joint has been completed, whichever is the greater.

NOTE After leaving a short distance unwelded another welder may weld a similar portion and so on, thus making it possible to test up to four welders on one joint.

When a welder does not complete the whole joint, the root run shall include a stop/start position.

9.2.2 Positional welding

The pipe containing the butt test joint shall be fixed as follows.

a) *For production welds positions within 25° of horizontal*. The pipe containing the test joint shall be fixed horizontally.
b) *For production welds positions within 25° of vertical*. The pipe containing the test joint shall be fixed vertically.
c) *For production welds positions between 25° to the vertical and 25° to the horizontal*. The pipe containing the test joint shall be fixed at 45° to the vertical.

9.3 Branch connections

Unless more than one process is used, each welder shall make all the runs on the full circumference of a branch to be qualified for welding branches.

A test weld shall be made with the branch and main pipe axes both horizontal or at the actual angle of production welding.

9.4 Fillet welds for sleeves, sockets, slip-on flanges or other attachments

9.4.1 General

A successful single qualification test on either of the following items shall qualify a welder for all the attachments given in a) within the limits specified in **9.5**:

a) sleeve, socket, slip-on flange or other type of attachment;

b) with prior approval of the employer, a simulation of the joint using flat plate material [see **4.2**j)].

NOTE The mechanical properties of the plate used may differ from the parent metal of the pipe specified in the welding procedure at the discretion of the employer.

9.4.2 Fillet welds in the flat or horizontal-vertical positions

The test weld shall be made between a sleeve, socket, flange or other attachment and a piece of pipe rolled about the horizontal axis or on a simulated joint in plate [see **9.4.1**b)]. The welder shall deposit metal at or near top centre until 200 mm or slightly less than 25% of the joint has been completed, whichever is the greater.

NOTE After leaving a short distance unwelded another welder may weld a similar portion and so on, thus making it possible to test up to four welders on one joint.

9.4.3 Fillet welds in all positions

The test weld shall be made between a sleeve, socket, flange or other attachment and a piece of pipe fixed with the axis horizontal or simulated joint in plate [see **9.4.1**b)]. When a simulated joint is used, the plates shall be positioned to cover all the welding positions for which approval is required.

9.5 Changes affecting qualification and approval (essential variables) of welders

A welder who has successfully completed a qualification test in accordance with **9.1** to **9.4** shall be qualified for the type and position of weld concerned within the limits of the following items. If any of the following changes occur, the welder using the new procedure shall be re-qualified.

a) A change from one welding process to another welding process or combination of welding processes.

b) A change in direction of welding from vertical-up to vertical-down or vice versa.

c) For butt joints and branch connections, a change in pipe diameter or thickness outside the ranges given in Table 8 (for branches, the diameter of the branch is the applicable dimension).

d) For a branch connection, a change in branch orientation exceeding 20° from that approved, except that approval on a connection with the branch and main pipe axes both horizontal gives approval for all welding positions.

e) A change in joint design, e.g. backing ring to no backing ring or single-U to single-V preparation.

Table 8 **Diameter and thickness ranges for butt joints and branch connections**

Diameter *D* of test pipe mm	**Diameter range approved**	**Thickness, *t*, of test pipe** mm	**Thickness range approved**
$D \leqslant 150$	$0.5D$ to $2D$	$t \leqslant 12$	$\leqslant 2t$
$D > 150$	$\geqslant D/2$	$t > 12$	$\geqslant 5$ mm

NOTE 1 The value of D is the nominal pipe size, and the approved range should also be quoted in nominal pipe sizes, e.g. a test on D = 114.3 mm qualifies from D = 60.3 mm to D = 219.1 mm.

NOTE 2 This table does not apply to pipe thicknesses less than 3 mm.

f) For manual metal-arc welding, a change from one electrode covering type to another.

g) For continuous tubular electrodes, a change from metal cored to flux-cored or vice versa; a change from one flux type to another; a change from gas shielded to non-shielded or vice versa.

h) A change from one shielding gas or gas mixture to another gas or gas mixture.

i) Any other change in the welding procedure or equipment which, in the opinion of the employer [see **4.1**p)], makes production of a sound weld more difficult for the welder.

9.6 Non-destructive testing

The test weld shall have a neat uniform appearance and shall be assessed by visual examination according to the appropriate acceptance criteria specified in **12.1**.

After visual examination (see **11.3**) NDT shall be carried out on each of the test welds using one of the following methods:

a) X-radiography in accordance with **11.4**;

b) automatic ultrasonic examination in accordance with **11.6**;

c) with the prior approval of the employer, alternative method(s) [see **4.2**k)].

The resultant film, ultrasonic read-out or other results shall be assessed in accordance with **12.1**.

9.7 Destructive testing

9.7.1 General

Destructive testing of butt joints shall only be used when required for adequate interpretation of the results of NDT. Fillet welds shall always be subjected to destructive testing.

9.7.2 Butt joints

When required, the destructive testing of butt joints for welder qualification shall conform to the requirements for macro-examination as used for procedure approval tests in **8.3.2**.

9.7.3 Fillet welds

The destructive testing of fillet welds for welder qualification shall conform to the procedure approval tests given in **8.5.2**, except that no hardness survey is required.

9.8 Re-tests

When failure of a welder to pass the test was because of conditions beyond their control, the welder shall, with the approval of the employer [see **4.2**l)], be given a second opportunity to gain approval. No further re-tests shall be given until the contractor has submitted proof of subsequent training of the welder acceptable to the employer.

If one of the destructive test specimens fails to meet the relevant test requirements, two additional specimens shall be taken from the positions immediately adjacent to, and on either side of, the failed specimen. The welder shall not be regarded as qualified if either additional specimen also fails to satisfy the test requirements.

9.9 Records

The details of each welder's qualification test and test results shall be recorded. All documentation relating to welder qualification tests shall be submitted to the employer for approval prior to the welders commencing production work [see **4.2**m)].

NOTE An example of a record form is shown in Annex D. The period for which records are kept should be specified by the employer.

9.10 Mechanized welding

For mechanized welding, each welder shall be qualified for a particular part or parts of the operation of making a welded joint.

Under no circumstances shall a welder be employed on operations other than those for which they have been tested, qualified and approved.

The inspection and testing of welds for qualification purposes and records shall be in accordance with **9.6**, **9.7**, **9.8** and **9.9**.

10 Production welding

10.1 Proximity of welds

Adjacent welds shall have a toe-to-toe distance not less than four times the pipe thickness.

NOTE Welds should be separated by the maximum possible distance.

10.2 Pipe end preparation

Bevelling of pipe ends shall be carried out by machining or by machine thermal cutting, which can be manually or mechanically operated.

Manual thermal cutting shall not be used for bevelling the ends of pipes for welding unless it is impractical to use machining or machine thermal cutting equipment, in which case prior approval to use

manual thermal cutting equipment shall be obtained from the employer [see **4.2**n)], who shall also be satisfied in regard to the ability of the operator.

When manual thermal cutting is used, the final dressing of the pipe ends shall be by filing, grinding or other mechanical means to obtain the dimensions given in the approved welding procedure.

If burns, small score marks, indentations or other minor imperfections occur within the joint preparation area, either of the following apply:

a) with the approval of the employer these imperfections shall be blended out by grinding [see **4.2**o)]; or

b) the joint shall be re-prepared.

Damage to pipes by bevelling machines shall be repaired in accordance with the pipe material specification.

On pipe which is cut back, the end zone shall be examined visually and by ultrasonic examination in accordance with the appropriate pipe material specification.

When a weld is intended to be examined by ultrasonic testing, before welding commences datum points shall be marked on both sides of the joint at a known distance from the root face on that component. The method of marking shall be subject to approval by the employer [see **4.2**p)].

NOTE The datum points enable the ultrasonic operator to locate reflectors in relation to the weld preparation. In the absence of a clear datum, root profile reflections could be incorrectly identified as volumetric defects.

10.3 Fusion faces

The fusion faces on pipes and the adjacent material shall be free from fins, planar flaws not conforming to **12.1**, tears, moisture, scale, rust, paint, grease or other foreign matter immediately prior to welding.

Cleaning to base metal shall extend for at least 25 mm from the edge of the fusion faces on both internal and external faces of the parts to be welded.

10.4 Alignment

The alignment of abutting pipe ends shall minimize the internal offset between surfaces. Any offset greater than 1.5 mm, provided it is caused by dimensional variations within specified tolerances, shall be equally distributed around the circumference of the pipe or fittings. Any misalignment shall be reduced to a minimum either by rotation of the pipes to obtain the best fit or by other methods approved by the employer [see **4.2**q)].

When a pipe with one longitudinal seam is used, this seam shall be located within the top half of the pipe circumference and the longitudinal seams of adjacent full pipe lengths shall be offset by an angle of approximately 90° or by a circumferential distance of approximately 250 mm, whichever is the smaller.

For pipes of different nominal thickness and the same outside diameter, alignment with a taper not steeper than 1 in 4 shall be achieved in accordance with either of the following:

a) provided that the material grade of the thicker pipe is equal to or greater than that of the thinner pipe, the smaller bore shall be machined, ground or filed; or

b) a transition piece shall be inserted.

NOTE It should be recognized that the ends of pipes and fittings are supplied to standard tolerances and might not match, especially if placed together at random. Additional workmanship might, therefore, be required to ensure that the required alignment is achieved.

10.5 Line-up clamps and pipe supports

10.5.1 Use of line-up clamps

Whenever practicable, internal line-up clamps shall be used to hold pipes firmly in position. Other alignment methods shall be subject to approval by the employer [see **4.2**r)].

Internal line-up clamps shall not be removed before the completion of the root run or at a later stage as qualified, the pipe remaining supported.

On no account shall straps, brackets, cleats or similar plate sections be attached to the pipe by welding for the purposes of alignment.

NOTE It is recommended that power-operated internal clamps are used to reduce ovality and improve line-up.

External line-up clamps shall not be removed until the completed part of the root run covers a minimum of 50% of the circumference of the joint uniformly spaced, the pipe remaining supported on each side of the joint.

The stage at which line-up clamps are removed shall be stated in the WPS and qualified subject to the approval of the employer [see **4.2**s)].

10.5.2 Removal of pipe supports

For landlines, the stage at which the pipe is lowered on to skids, or at which supports are removed in the case of fittings, shall be stated in the WPS and subject to the approval of the employer [see **4.2**t)].

10.6 Tack welds

Where tack welds are to be used, the work shall be set up in accordance with the approved WPS and supported.

On outside diameters up to and including 114.3 mm, a minimum of three tack welds each not less than 25 mm long shall be spaced equally around the joining circumference. On diameters over 114.3 mm at least four tack welds each not less than 25 mm long shall be used. If they are to be incorporated into the final weld, tack welds made in accordance with the welding procedure specified for the root run shall be ground to a suitable taper at each end to ensure fusion with the root run.

Preheating shall be in accordance with **10.10.2** from tack welding to completion of the joint.

10.7 Working clearance

The working clearance around the pipe at the weld shall be of sufficient size to provide access for welding and inspection of the joint.

When the pipe is welded in a trench, the bell hole shall be of sufficient size to provide the welder or welders access to the joint.

10.8 Stray arcs

Arcs shall be struck only on fusion faces of the pipe and contact of the electrode or of the non-insulated parts of the electrode holder with the outer surface of the pipe shall be avoided.

Places where any stray arcs have accidentally occurred shall either be repaired, subject to the approval of the employer [see **4.2**u)], or rejected.

Where permission to repair arc strikes has been given by the employer, the procedure shall include, but not necessarily be limited to, the mechanical removal of the defective material, blending of the excavation, checking by magnetic particle inspection and confirmation that the thickness of the pipe or fitting is within permitted tolerances.

NOTE Where the minimum thickness is below the tolerance for the pipe, repairs to an approved welding procedure may be carried out and subjected to further non-destructive testing.

10.9 Weather conditions

Welding shall not be undertaken when, in the opinion of the employer, the quality of the completed weld would be impaired by airborne moisture, blowing sands or high winds [see **4.1**q)].

NOTE Where protection from the weather can be provided to the satisfaction of the employer, welding may be continued.

10.10 Preheating and post-weld heat treatment

10.10.1 General

Preheating and post-weld heat treatment of the pipe shall be in accordance with the welding procedure. Post-weld heat treatment shall be applied by gas-fired muffle furnaces or electric methods of heating that have been approved by procedure test. Under no circumstances shall manually operated gas torches be used for the application of post-weld heat treatment.

*NOTE Guidance for establishing preheating temperatures to avoid hydrogen cracking is given in Annex E, but this might not be the temperature needed to meet the requirements specified in Clause **8**.*

10.10.2 Preheating

The area of pipe that is preheated shall extend around the entire periphery of the pipe or part being jointed. In each case the area extending to at least 75 mm on each side of the joint shall be maintained at the required temperature.

Preheating shall be applied by gas or electrical means in the manner used in the procedure qualification such that the equipment used maintains an even temperature distribution, does not interfere with the welding operation, and is approved by the employer relative to the particular application [see also **4.2**v)].

Care shall be taken to avoid damage to any coating on the pipe.

The temperature shall be measured in the manner used in the procedure qualification immediately prior to the commencement of welding and around the whole of the joint while welding is taking place. The preheating temperature actually attained shall reach the minimum required by the approved procedure but shall not exceed it by more than 50 °C.

NOTE Where practicable, the temperature should be measured on the face opposite to that on which the heat has been applied.

10.10.3 Post-weld heat treatment temperatures

Post-weld heat treatment temperatures shall be measured using thermocouples, so as to give a true reading of the joint temperature. When separate heating sources are used, thermocouples shall be placed so as to record the temperatures from each source.

10.10.4 Thermocouple attachment and junctions

Thermocouples shall be attached and removed after use by methods approved by the employer [see **4.2**w)].

Thermocouples shall be in metallic contact with the parts being heated.

Thermocouple junctions and wires shall be protected from flame impingement. To prevent direct radiation from the heating elements on the hot junction when electrical resistance heating is used, thermocouples shall be covered with a protective wrapping.

10.11 Branches

10.11.1 Angle of branch

Where a sloping branch has to be connected directly to the main pipe, it is preferred that the angle between the centre-line of the main pipe and that of the branch pipe is not less than 60°, provided that special precautions are taken locally at the acute crotch to ensure a sound weld. In cases where the angle between the main and the branch is unavoidably less than 60°, the welding procedure shall be subject to approval by the employer [see **4.2**x)].

NOTE In view of the additional difficulty involved in making a joint at the intersection of two pipes not at right angles, for branch pipes sloping away from a main pipe consideration should be given to using a right angle branch and a bend to give the required slope. All branches should preferably be made with specialized fittings, e.g. forged or pressed tees, forged set-in or set-on components.

10.11.2 Spacing of branches

The spacing of branches on the main pipe and the lengths of flanged branches shall allow access for welding and subsequent NDT.

10.11.3 Joint preparation

Branch connections and branch openings in the main pipe shall be cut either by machining or by thermal cutting.

The cut edges of the pipe shall then be dressed by filing or grinding to obtain the dimensions given in the approved welding procedure (see also **10.2**).

The ultrasonic examination of pipe material around planned cut-outs for nozzles shall be in accordance with BS EN 10160. A written procedure shall be submitted to the employer for approval [see **4.2**y)]. The zone to be examined shall be at least 100 mm wide (see also **12.1.2**).

10.11.4 Welding

10.11.4.1 Root gap

A constant root gap between the main pipe and branch pipe shall be maintained during the deposition of the first run. Tack welds shall be used only in accordance with **10.6**.

10.11.4.2 Internal welds

Internal welding of branches shall only be carried out as specified in the approved welding procedure.

10.11.5 Branch reinforcement (compensation)

When a reinforcement is thermally cut to shape, the cut edges shall be dressed by filing, grinding or machining.

Welds connecting reinforcements shall be butt welds or fillet welds or a combination of these types, made in accordance with the appropriate welding procedure.

10.12 Inter-run cleaning

Surface slag likely to produce unacceptable weld flaws shall be removed, either by hand or power tools, before a further run is applied on the pipe.

Visible defects such as cracks, cavities and other deposition faults shall be removed, and particular attention paid to the cleanliness of the junctions between the weld metal and the fusion faces, before deposition of further weld metal.

Cluster or surface porosity, stops and starts and high points shall be removed from the pipe by grinding.

10.13 Partially completed joints

Whenever possible, joints shall not be left partially completed. The welding of fittings shall be completed in one cycle. Where production conditions are such that pipe to pipe joints have to be left partially completed the following conditions apply.

a) The minimum number of runs deposited before cooling shall be qualified in the approved welding procedure.

b) Upon discontinuation of welding the joint shall be wrapped in dry insulating, heat resisting material with a waterproof backing to allow the joint to cool in a slow and uniform manner.

c) Prior to recommencement of welding, the joint shall be reheated to within the specified interpass temperature range.

11 Inspection and testing of welds

11.1 General

The method or combination of methods and frequency of visual inspection and NDT of welds shall be as specified by the employer [see **4.1**r)].

Prior to the start of welding, detailed written NDT procedures to be used for inspection and testing shall be prepared and submitted to the employer for approval [see **4.2**z)].

If the employer requires completed welds to be ground, this shall be stated in the enquiry and order [see **4.1**s)] and grinding shall be performed in accordance with an approved procedure.

11.2 Personnel qualification

All inspection personnel shall be approved by the employer [see **4.2**aa)].

11.3 Visual inspection

All welds shall be visually examined in accordance with BS EN 970 on the outside surface and, where practicable, in the bore. Visually detectable flaws shall be assessed in accordance with **12.1**.

11.4 Radiographic testing

11.4.1 General

Unless otherwise specified by the employer [see **4.1**t)], the radiographic testing of fusion welded circumferential butt joints in steel pipes shall be carried out in accordance with technique numbers **6.1.4**, **6.1.8**, **6.1.3** or **6.1.6** of BS EN 1435:1997+A2, in order of preference.

X-ray exposure and the use of BS EN 1435:1997+A2, Class B techniques are preferred for the radiographic testing of welds.

Use of radiographic isotopes might be required in some situations, for example for reasons of access, and shall be subject to agreement by the employer.

Class A techniques, when approved by the employer [see **4.2**bb)], shall only be used where Class B techniques cannot be practically achieved.

NOTE There might be several reasons why Class B cannot be practically achieved when employing established pipeline radiographic inspection techniques. For example, it might not be possible to satisfy the required geometric relationship between the source, object and film or to achieve the short duration radiographic inspection cycle times commonly employed in pipeline construction i.e. typically less than 4 min.

11.4.2 Approved radiographic procedures

The radiographic procedure details shall include the exposure time in addition to the requirements of BS EN 1435:1997+A2.

The radiographs used to approve the procedure shall show image quality indicators placed on both the source side and the film side of the area being examined. The contractural sensitivity level shall be achieved using the source side image quality indicator and (for correlation with production welds) the corresponding sensitivity on the film side image quality indicator shall be recorded.

NOTE An example of a form which defines the radiographic procedure is given in Annex F.

11.4.3 Film storage

All unexposed films shall be stored in a clean, dry place where the surrounding conditions should not detrimentally affect the emulsion.

11.5 Manual ultrasonic testing

11.5.1 General

Where manual ultrasonic testing is applied, it shall be carried out in accordance with examination level Method 1 of BS EN 1714:1998+A2. All discontinuity indications greater than 20% DAC (Distance Amplitude Curve) shall be reported. Discontinuity indications greater than 50% DAC or 6 dB shall be reported and evaluated in accordance with BS EN 1714:1998+A2, Clause **12**.

NOTE Manual ultrasonic testing may be used in the following situations:

a) as a supplement to radiography to assist in the interpretation of radiographs or where there is particular concern over flaws which might be difficult to detect by radiography, e.g. transverse weld metal hydrogen cracks angled at approximately 45° to weld surface;

b) as a substitute for radiography where the total penetrated thickness of steel is such that radiography would be impractical.

11.5.2 Additional information

Immediately prior to examination for manual ultrasonic testing, the operator shall be informed of any local deviations from the joint preparation drawn in the welding procedure, and shall be given details of any repairs already made.

11.5.3 Reporting and evaluation

All discontinuity indications having an amplitude above the reference level established for scanning in accordance with **11.5.1** shall be recorded. They shall then be sized and characterized, and assessed against the acceptance criteria specified by the employer [see **4.1**u)].

11.6 Automatic ultrasonic testing

When automatic ultrasonic testing is to be used, specific procedures, acceptance criteria, report format, method of data storage and presentation shall be agreed with the employer in order to establish

suitable performance for the intended application. The proposed technique shall be demonstrated and validated before being applied to production welds.

NOTE The use of realistic flaw reference samples based on the actual joint geometry and welding procedure might be required for this purpose.

11.7 Magnetic particle testing

The extent of magnetic particle testing carried out shall cover the weld and weld toe regions. The magnetic particle testing shall be in accordance with BS EN ISO 9934 with the following variations.

a) Wet methods shall be used at ambient temperatures. For higher temperatures the method shall be subject to approval by the employer [see **4.2**cc)].

b) The surface being inspected shall be examined by passing the magnetic flux in two directions at right angles to each other in separate operations.

12 Acceptance and rectification of welds

12.1 Non-destructive testing acceptance criteria

12.1.1 General

The acceptance criteria for NDT shall either be in accordance with **12.1.2** or, if specified by the employer [see **4.1**v)], **12.1.3**.

12.1.2 Acceptance criteria based on quality control

In areas of a weld preparation such as pipe ends, fusion faces and branches (see **10.2**, **10.3** and **10.11**) no planar defects shall exceed in any dimension, either:

a) 25 mm; or

b) a smaller value specified by the employer [see **4.1**w)].

The acceptance criteria for welds shall be as specified in Table 9.

Any accumulation of flaws, except porosity, affecting a total length of 100 mm or more of a weld in any continuous weld length of 300 mm or a total length of 15% or more of the weld length, whichever is the greater, shall not be accepted.

*NOTE 1 The dimensional limitations of flaws subject to rejection specified in **12.1.2** are intended to ensure good quality welded joints. Installation and service conditions might exist, however, that require a higher standard and when such conditions apply the higher standard required should be clearly stated.*

NOTE 2 The acceptance criteria given in Table 9 assume that all NDT is by visual or radiographic examination. No equivalent table for ultrasonic testing acceptance criteria for welds has been derived and so the acceptance criteria for ultrasonic examination should be agreed between the employer and contractor before welding begins.

Table 9 **Acceptance criteria for welds**

Flaw type [A)]		**Acceptance criteria**
External profile	a	Excess weld metal (reinforcement) shall be uniform, merge smoothly with the parent metal and extend beyond the original joint preparation by not more than 3 mm on each side. In no area shall the weld face be lower than the adjacent pipe surface. Fillet welds shall be not less than the specified dimensions, regular in form and without undercut (see Table entry for cap undercut).
Internal profile	b	The root bead or any concavity shall merge smoothly into the adjacent surfaces.
Root penetration	c	Not to exceed 3 mm. If service conditions necessitate a more stringent limit, this shall be specified by the employer [see **4.1**x)].
Root concavity	d	Length not to exceed 25% of total length of weld. Depth not to exceed 10% of pipe thickness or 1.5 mm, whichever is the smaller, but at no point shall the weld, including cap reinforcement, be thinner than the pipe thickness.
Root undercut Shrinkage groove	e	Length not to exceed 25 mm in any continuous weld length of 300 mm or not to exceed 1/12 of the total length of the weld when this is less than 300 mm. Depth not to exceed 10% of pipe thickness or 1.5 mm, whichever is the smaller. For branch welds this flaw is not permitted.
Incomplete root penetration (single side welds only) Lack of root fusion (single side welds only)	f	Length not to exceed 25 mm in any continuous weld length of 300 mm or not to exceed 1/12 of the total length of the weld when this is less than 300 mm. For branch welds this flaw is not permitted.
Cracks	g	Not permitted.
Cap undercut	h	The toes of welds shall blend smoothly and gradually into the parent metal. Length not to exceed 50 mm in any continuous weld length of 300 mm or not to exceed 1/6 of the total length of the weld when this is less than 300 mm. Depth not to exceed 10% of pipe thickness or 1.5 mm, whichever is the smaller. For branch welds the length shall not exceed 25 mm in any continuous weld length of 300 mm or not to exceed 1/12 of the total length of the weld when this is less than 300 mm.

Table 9 **Acceptance criteria for welds** *(continued)*

Flaw type [A]		**Acceptance criteria**
Elongated linear porosity in root run (hollow bead) Shrinkage cavity Lack of inter-run fusion Lack of side fusion Elongated inclusions Parallel elongated inclusions (wagon tracks) Incomplete root penetration (double side welds only [B])	i	Length of weld affected by any of these flaws not to exceed 50 mm in any continuous weld length of 300 mm or not to exceed 1/6 of the total length of the weld when this is less than 300 mm. For branch welds the length of weld affected by any of these flaws not to exceed 25 mm in any continuous weld length of 300 mm or not to exceed 1/12 of the total length of the weld when this is less than 300 mm. Width of elongated inclusions not to exceed 1.5 mm.
Porosity (other than elongated porosity in root run)	j	Not to exceed a total area when projected radially through the weld of 2% of projected weld area in the radiograph consisting of the length of the weld affected by the porosity, with a minimum length of 150 mm, multiplied by the maximum width of the weld. An isolated pore greater than 25% of the pipe thickness or 3 mm, whichever is the smaller, in any direction shall be considered unacceptable.
Isolated inclusions (copper, tungsten or non-elongated slag)	k	Width of an inclusion not to exceed 3 mm or half pipe thickness, whichever is the smaller. Total length of inclusions not to exceed 12 mm in any continuous weld length of 300 mm and not more than four inclusions of maximum width in this 300 mm length. Adjacent inclusions shall be separated by a minimum distance of 50 mm.
Burn-through	l	Not to exceed 5 mm in any dimension and only one in any continuous weld length of 300 mm.
Wormhole	m	Not to exceed 6 mm in length or 1.5 mm in diameter for thicknesses not exceeding 25 mm, or a length of 25% of the thickness or 12 mm, whichever is the smaller, or 3 mm in diameter for thicknesses over 25 mm.

[A] For definitions see BS 499-1:1991+A1 and BS EN 13622:2002.
[B] Also known as "lack of cross penetration".

12.1.3 Acceptance criteria based on engineering critical assessment

When the employer specifies that engineering critical assessment (ECA) is to be used for establishing acceptance criteria [see **4.1**v)], it shall be applied in accordance with BS 7910:2005+A1 or an alternative standard as agreed with the employer [see **4.2**dd)].

When specified for installation methods involving plastic deformation, a Level 3 assessment in accordance with BS 7910:2005+A1 shall be carried out.

NOTE In the derivation of acceptance criteria from an ECA, consideration should be given to the suitability of the selected NDT method for detection of the anticipated flaw types and locations, and the associated flaw sizing accuracy.

12.2 Rectification of welds

12.2.1 Removal of flaws

When welds fail to conform wholly or in part to **12.1**, the weld shall either be repaired locally or the weld zone entirely removed. The excavated portion of the weld shall be sufficiently deep and long to remove the entire flaw. Weld repairs shall not begin before NDT and inspection have been completed.

No weld shall be repaired without the approval of the employer [see **4.2**ee)].

Flaws shall be removed by chipping, grinding, machining or air-arc gouging followed by grinding, or entire welds shall be removed by thermal cutting or machining.

When air-arc gouging or thermal cutting are used, preheating shall be applied as necessary. When air-arc gouging is used for full thickness repairs, the last 3 mm of the weld shall be removed by mechanical means, for example grinding.

Repairs shall either be limited to 30% of the weld length for a partial penetration repair or 20% of the weld length for a full penetration repair or, if alternative repair length limits are proposed, they shall be subject to approval by the employer [see **4.2**ff)].

NOTE Stresses imposed by construction techniques existing at the time of making a repair, e.g. at a laybarge repair station, might be such that to remove 20% of the weld length would be unsafe.

12.2.2 Preparation for re-welding

At the ends and sides of an excavation of a weld there shall be a gradual taper (e.g. one in one) from the base of the excavation to the surface of the weld metal. The width and profile of the excavation shall allow access for re-welding.

12.2.3 Qualification

Repair welding procedures shall be qualified when required in accordance with **8.4**. The test weld to qualify a partial penetration repair weld procedure shall be made into an excavation to a depth of at least half the pipe thickness centred on the toe of the original weld.

One full penetration and one partial penetration repair test shall qualify all repair procedures except for root sealing or single run repairs.

Welders shall be re-qualified to use the repair procedure when required in accordance with **9.5**.

12.2.4 Re-welding

Root sealing or single run repair deposits shall only be undertaken if approved by the employer [see **4.2**gg)].

A repaired weld shall be subject to at least the same testing and inspection requirements as the original weld. Unless approved by the employer [see **4.2**hh)], repairs shall not be attempted more than once.

Full penetration repairs shall only be implemented under constant supervision.

If repairs cannot be implemented within the limitations specified in this subclause, or are not effected successfully, the weld shall be cut out.

Full records of all repairs shall be maintained.

Annex A (informative) Recommendations for hyperbaric arc welding

A.1 General

A.1.1 Hyperbaric welding may be defined as the process of welding in a dry underwater environment wherein the gaseous atmosphere acting upon the welding arc and weldpool is at an elevated pressure, the level of which is determined by the depth of water.

A.1.2 These recommendations relate to the hyperbaric arc welding of joints in steel pipelines as well as to weld repairs. All welding should be performed in accordance with Clause **4** to Clause **12**, except insofar as they are supplemented by this annex.

A.1.3 The recommendations are based on experience of welding in water depths down to 200 m and additional precautions and/or more extensive testing might be required for greater depths.

A.1.4 It is preferred that all welding is carried out with a hydrogen-controlled arc welding process and within a chamber or habitat from which the water has been displaced. Other methods should be subject to special approval and agreement between the contracting parties.

A.2 Diving regulations and safety

A.2.1 All diving operations on the UK continental shelf are subject to the Diving at Work Regulations 1997 [3].

A.2.2 The contractor should establish a well defined organization with clearly defined individual responsibilities, ensuring effective co-ordination of diving, welding and inspection activities.

A.2.3 The contractor should ensure that all personnel engaged in the work have received training and are familiar with the operations they are to perform. Guidance on topics such as training, qualifications and registration are given in the Diving at Work Regulations 1997 [3].

A.2.4 The diving phase of the work should take due account of interruptions due to team changes at the end of the permitted diver lock-out time, weather limitations on diving or other diving restrictions. The work should be planned to ensure that any interruptions in the process of welding do not influence the integrity of the weld. Details of the course of action to be followed in the event of interruptions should be included in the WPS. Due consideration should be paid to the removal of welding fume and smoke and the control of temperature caused by welding in confined spaces.

A.3 Equipment

A.3.1 The contractor should evaluate the type and characteristics of the equipment used for the tie-in or repair operation according to the particular environmental conditions, pipeline configuration and water depth.

A.3.2 All plant and equipment should be of proven design, fit for purpose and properly maintained. In particular, all electrical apparatus should be protected to reduce the risk of electric shock.

NOTE Guidance on electrical safety is provided in Code of practice for the safe use of electricity underwater *[4].*

A.3.3 The welding habitat should be of sufficient size to provide access to the joint to be welded and to accommodate all of the necessary welding, safety and life support equipment.

A.3.4 The habitat should be illuminated and the work area kept clear of excess fumes to enable remote video surveillance by supervisory personnel. Cameras should be provided for surveillance.

A.3.5 Equipment for the monitoring of the welding parameters and essential variables should be adequately maintained and accompanied by evidence of calibration as required.

A.4 Welding processes

A.4.1 All welding should be performed using hydrogen controlled processes.

A.4.2 When selecting the processes to be used for a particular application, consideration should be given to the following due to the possible influences of increasing ambient pressure:

a) deterioration in arc stability, metal transfer characteristics and operating tolerances;

b) reduction in weld metal toughness;

c) increased hydrogen partial pressure and risk of cold cracking.

A.5 Electrodes and filler materials

A.5.1 A detailed consumables handling and control procedure should be established for each type of consumable and each application containing at least the following information:

- preparation prior to transfer to the habitat;
- method of packaging;
- method of transfer to the habitat;
- storage prior to use in the habitat;
- method of controlling utilization and exposure to the hyperbaric environment;
- disposal of unused, exposed consumables.

A.5.2 The handling and control procedure should be designed to tolerate the maximum humidity anticipated in production welding. In the case of MMA (manual metallic arc welding) consumables, exposure limits should take into account the different re-absorption characteristics of the electrodes.

A.5.3 The consumables used for procedure qualification and production should be taken from the same batch.

A.5.4 Welding consumables for MMA and FCAW (flux-cored arc welding) should be selected on the basis of proven performance under hyperbaric conditions with particular respect to arc stability and metal transfer characteristics. In the case of consumables for which there is only limited experience, it should be established that satisfactory performance can be achieved over the required range of the procedure.

A.6 Shielding gases

A.6.1 All cylinders, supply lines and connections should be clearly marked.

A.6.2 Supply lines should be purged prior to the start of welding.

A.7 Testing, qualification and approval of welding procedures

A.7.1 A detailed WPS should be prepared. This should contain those items specified in BS EN ISO 15609-1, BS EN ISO 15614-10 and Table 1.

A.7.2 Items already listed in Table 1 for which additional information should be provided are as follows.

a) *Item o: Time lapse between runs*
The procedure should provide details of the method for closing the weld root and whether there are any restrictions on the time lapse between runs. When a time lapse is specified, then the definition of the start and completion of runs should be stated.

NOTE In order to overcome the effect of pressure fluctuations between the bore of the pipe and the habitat it is common practice to leave part of the root incomplete whilst further weld passes are deposited.

b) *Item p: Partially completed joints*
The procedure should provide details of the course of action to be taken due to scheduled and unscheduled interruptions in the diving operation. The diving work should be planned so that as far as practicable welding is performed in a continuous operation. When a prolonged interruption has occurred and the weld allowed to cool to ambient temperature during the initial passes of the weld, consideration should be given to the use of MPI (magnetic particle inspection) prior to resuming the welding.

A.7.3 The procedures should be qualified under either simulated or actual site conditions at the appropriate water depth.

A.7.4 When performed under simulated conditions, the equipment and operating procedures should be equivalent to those used in production.

NOTE The power source characteristics and electrical cable length can significantly influence the arc stability and operability of certain processes and consumables.

A.7.5 The test pieces should consist of two sections of pipe held in place by external line-up clamps assisted by strongbacks.

A.7.6 Changes affecting approval are given in BS EN ISO 15614-10 and Table 1, and additional items are as follows:

a) for TIG (tungsten inert gas) and MMA an increase in water depth of 10 m or 20% of the depth of qualification, whichever is the greater. For all other processes, the depth of qualification should be by agreement between the contracting parties;

b) any increase above the absolute humidity level for flux based welding processes as specified in BS EN ISO 15614-10:2005, **8.6**. Tests should be carried out at the maximum anticipated relative humidity.

A.7.7 Items already listed in BS EN ISO 15609-1, BS EN ISO 15614-10 and Table 1 for which alternative requirements might have to be specified are as follows:

- item j2: welding parameters, an increase in the tolerance on arc voltage;

  *NOTE The arc voltage gradient increases with pressure and consequently small changes in arc length or operating depth can result in substantially different monitored values of arc voltage. This factor is also relevant when calculating heat input values (see **A.7.1**).*

- item j5: the method of measuring heat input and deposition rate;
- item o: time lapse between runs (see **A.7.2**);
- item p: partially completed joints (see **A.7.2**).

A.7.8 All test butt joints should be subjected to NDT in accordance with **8.3.1**.

A.7.9 Destructive testing of butt welds in accordance with BS EN ISO 15614-10 should be performed in accordance with **8.3.2**.

A.7.10 The method and point of monitoring the electrical parameters should be established at the time of procedure qualification and maintained throughout the work.

A.8 Testing, qualification and approval of welders and welding operators

A.8.1 Prior to qualification testing, the welders should have received relevant training for welding under pressure.

A.8.2 Welders should be generally approved on pipe in accordance with BS EN ISO 15618-2 and Clause **9** at the maximum simulated or actual depth.

A.8.3 Approval should remain valid within the limits of the essential variables in accordance with **9.1**, **9.5** and **A.7.6**.

A.8.4 Operators of mechanized welding equipment should have received relevant training in the use of the specified equipment.

A.8.5 Operators of mechanized welding equipment should be generally qualified by either:

a) performing a qualification test weld on pipe in accordance with Clause **9** at the maximum simulated or actual depth;

b) an alternative method agreed between the contracting parties.

The degree of automation of the welding system should be considered when defining the scope of the qualification test.

A.9 Production welding

A.9.1 A function test should be performed prior to deployment of the welding habitat and associated equipment.

A.9.2 Alignment of the abutting pipe ends should be performed in accordance with **10.4**.

In the case of single butt welds it might not be possible to achieve the separation of the longitudinal seam welds in accordance with **10.4**. In such cases, the reduced separation of longitudinal seam welds should be restricted to two adjacent pipe lengths [see **4.2**ii)].

A.9.3 When preheating is not a requirement of the welding procedure, the contractor should have a means of ensuring that the weld area is dry prior to the commencement of welding. This is normally achieved by preheating.

A.9.4 External line-up clamps should be used as qualified by the procedure.

A.9.5 Partially completed joints should be treated in accordance with **A.7.2**b).

A.9.6 The removal of weld metal should be achieved by machining, grinding or chipping. For safety reasons arc or air-arc gouging using direct current, reverse polarity carbon electrodes should only be carried out by agreement between the contracting parties and might necessitate operators undergoing gouging tests.

A.10 Inspection and testing

A.10.1 The contractor should prepare detailed procedures describing the methods of inspection and the equipment to be used.

A.10.2 NDT should be performed in accordance with Clause **11** by appropriately qualified personnel and the following taken into consideration.

a) Welds should be visually inspected using a high definition video camera.

b) Radiography should involve the use of an external double wall technique using a specially housed gamma radiation source. Each source should be accompanied by a decay chart showing the capsule number, loading strength, the dated decay table and the source physical dimensions.

c) MPI should involve the use of water based inks owing to the possible toxic effects of other solvents.

d) Manual ultrasonic inspection should be performed by a suitably qualified diver using an encapsulated flaw detector linked to a surface read out unit.

e) Automatic ultrasonics (AUT) may be performed instead of radiography and manual ultrasonic inspection; interpretation should be performed by suitably qualified personnel and diver training might be required in equipment set up. Consideration should be given to development of AUT weld acceptance criteria also allowing for the accuracy of detection of the AUT equipment.

WARNING. During radiographic exposure, a dedicated camera should be focussed on the isotope container shutter to ensure the shutter has closed and the isotope is safe prior to allowing the diver to re-enter the habitat.

A.11 Documentation and records

Before commencement of the work the contractor should prepare documentation covering the operational and contingency procedures relating to welding, inspection and reporting.

Annex B (informative) Recommendations for brazing and aluminothermic welding of anode bonding leads

B.1 Joining technique

Full details of the joining technique and associated equipment for brazing and aluminothermic welding of anode bonding leads should be submitted to the employer for approval prior to use [see **4.2**jj)] and should conform to the manufacturer's recommendations.

B.2 Procedure qualification

Prior to starting, the contractor should submit a pWPS to the employer for approval [see **4.2**kk)]. The procedure should be qualified by making three consecutive test joints in the presence of the employer on material to be used in production. The test material should be selected by the employer to represent the upper quartile of the carbon equivalent range.

The electrical resistance to each joint should be measured and should not exceed 0.1 Ω. The mechanical strength of the joint should be tested by means of a sharp blow from a 1 kg hammer.

All three of the test joints should be sectioned and prepared for metallographic examination. The following tests should be performed on the sections.

a) *Copper penetration measurement*
The depth of copper penetration below the surface of the pipe material should be measured metallographically. The fusion line of the weld or braze should be not more than 1 mm below the pipe surface. Intergranular copper penetration of the pipe material should not exceed 0.5 mm beyond the fusion line when a micro-section is examined at a magnification not exceeding $\times$50.

b) *Hardness survey*
Each section should be tested in accordance with BS EN ISO 6507 using a 10 kg load. A traverse should be made across the weld zone as shown in Figure B.1 and should consist of at least six indentations; two in the heat-affected zone each side of the weld/braze and one in the parent metal each side of the weld/braze.

Unless specified by the employer [see **4.1**y)], the hardness values should not exceed 300 HV10 (275 HV10 for pipe less than 9.5 mm thick) for sour service and 325 HV10 for non-sour service.

B.3 Operator qualification

Prior to carrying out production work, each operator should complete three test joints which should pass the tests for electrical conductivity and mechanical strength (hammer tests) in accordance with **B.2**. All welding and tests should be witnessed by the employer.

B.4 Production joints

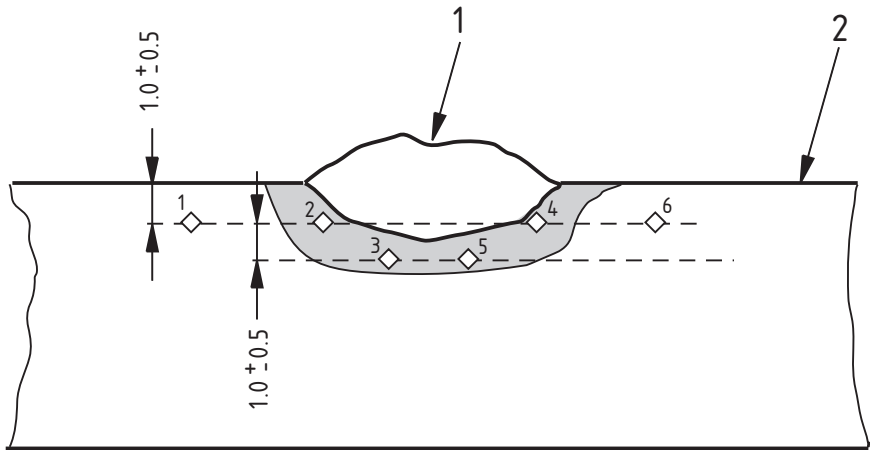
The attachments should be located at least 150 mm from any seam or circumferential weld. The weld area should be clean, dry and free from oil, grease, mill scale or other foreign matter. Preheating should be applied in accordance with the approved procedure.

All attachments should be tested for mechanical strength (hammer test) followed by an electrical continuity test in accordance with **B.2**.

If any attachment proves to be defective, it should be carefully removed, ensuring that the parent material thickness is not reduced below the specified tolerances. Rejoining should be carried out at a new location on the pipe.

Figure B.1 **Recommended locations for hardness traverses and indentations for brazing and aluminothermic welding**

Dimensions in millimetres



Key

Weld heat-affected zone (visible after etching)

1 Weld/braze metal

2 Parent metal surface

NOTE Harness indentations 2, 3, 4 and 5 should be entirely within the heat-affected zone and located as close as possible to the fusion boundary.

Annex C (informative) Provisional welding procedure specification

Examples of welding procedure specification forms including a record form for the qualification test are shown in Figures C.1, C.2 and C.3.

Figure C.1 **Example of provisional welding procedure specification**

Provisional welding procedure specification									
Procedure no:		Revision no:		Outside diameter:		Wall thickness:			
Material specification 1: Composition:		Grade:			Heat treatment:				
% Al:	% V:	% Ni:		% Cu:	% Cr:	C.E.:			
% Ti:	% N:	% Ca:		% Nb:	% P:				
% C:	% Mn:	% Si:		% S:	% Mo:				
Material specification 2: Composition:		Grade:			Heat treatment:				
% Al:	% V:	% Ni:		% Cu:	% Cr:	C.E.:			
% Ti:	% N:	% Ca:		% Nb:	% P:				
% C:	% Mn:	% Si:		% S:	% Mo:				
Sketch of joint configuration		Groove shape Bevel angle: ± Root face: ± Root gap: ± Backing ring:				Number and sequence of runs			
Welding processes Manual: Semi-automatic: Mechanized: Number of filler wires for each pass:									
Type of line-up clamp used: Number of runs before removal of clamp: Number of runs and minimum and maximum pressure applied:									
Welding position: Angle of pipe axis from horizontal:									
Vertical welding direction:		Angle of torch, filler wire or electrode to weld line:							
Maximum width of any bead:									
Mechanized welding weave amplitude: Frequency: Dwell time:									
Shielding gas composition: Flow rate:									
Shielding flux Trade name: Type: Drying conditions: Holding conditions:									
Filler metal Trade name: Classification: Drying conditions: Holding conditions:									
Electrical characteristics Name of process to be entered in first column, appropriate parameters from heading in other columns									
MMA process **TIG process** **Cont. wire processes**	**Pass number**	**Electrode diameter** **Electrical stick-out**	**Trade name** **Filler wire diameter**	**Power and polarity**	**Current** (amps)	**Electrodes per pass** **Voltage** (volts)	**Run-out length** **Travel speed**	**Nominal heat input** (kJ/mm)	
Number of welders for root run:					Number of welders for second run:				
For MMA welding with cellulosic electrodes Maximum time lapse between start of root run and start of second run: Nominal time lapse between start of second run and start of next run:									
Minimum number of runs before lowering off/barge move-up: Minimum number of runs before cooling to ambient temperature:									
Method of powering cleaning tools:									
Preheating	Initial temperature of pipe before preheating/welding: Method of heating: Minimum temperature: Method of control: Method of measurement:								
Interpass temperature	Minimum: Maximum:								
Heat treatment required: Method:	Temperature: Time at temperature:								

Figure C.2 **Example of welding procedure specification for production welding**

Welding procedure specification for production welding

Procedure no.: Revision no.: Outside diameter: Wall thickness:

Sketch of joint configuration

Groove shape
Bevel angle: ±
Root face: ±
Root gap: ±
Backing ring:

Number and sequence of runs

Welding processes Manual: Semi-automatic: Mechanized:
Number of filler wires for each pass:

Type of line-up clamp used: Number of runs before removal of clamp:

Welding position: Angle of pipe axis from horizontal:
Vertical welding direction: Angle of torch, filler wire or electrode to weld line:

Maximum width of any bead:

Mechanized welding weave amplitude: Frequency: Dwell time:

Shielding gas composition: Flow rate:

Shielding flux Trade name: Type:
Drying conditions: Holding conditions:

Filler metal Trade name: Classification:
Drying conditions: Holding conditions:

Electrical characteristics
Name of process to be entered in first column, appropriate parameters from heading in other columns

MMA process	**Pass number**	**Electrode diameter**	**Trade name**	**Power and polarity**	**Current** (amps)	**Electrodes per pass**	**Run-out length**	**Nominal heat input** (kJ/mm)
TIG process			**Filler wire diameter**			**Voltage** (volts)	**Travel speed**	
Cont. wire processes		**Electrical stick-out**						

Number of welders for root run: Number of welders for second run:

For MMA welding with cellulosic electrodes
Maximum time lapse between start of root run and start of second run:
Nominal time lapse between start of second run and start of next run:

Minimum number of runs before lowering off/barge move-up:
Minimum number of runs before cooling to ambient temperature:

Preheating
Initial temperature of pipe before preheating/welding:
Method of heating: Minimum temperature:
Method of control: Method of measurement:

Interpass temperature Minimum: Maximum:

Intermediate heat treatment required:
Method: Temperature: Time at temperature:

Approvals:
Contractor: Client: Other authorities:

Figure C.3 **As-run record of welding procedure qualification test**

As-run record of welding procedure qualification test													
This weld was produced in accordance with provisional welding procedure specification no.: Rev:													
Welding was performed by the following welders:													
Cast numbers of base materials welded: Item 1: Item 2:													
Actual times: Finish of root run Start of second run Cooled to ambient temperature after pass no.													
Pass number	**Welding process**	**Interpass temp.** °C	**Electrode diameter**	**Filler wire diameter**	**Electrical stick-out**	**Power and polarity**	**Voltage** (volts)	**Current** (amps)	**Wire feed speed**	**Run-out length**	**Electrodes per pass**	**Travel speed**	**Heat input (calculated)** (kJ/mm)
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													

Annex D (informative) Example of a record form for an MMA welder qualification test

An example of a record form for an MMA welder qualification test is shown in Figure D.1.

Figure D.1 **Example of record form for an MMA welder qualification test**

Record of MMA welder qualification test							
Name of welder:							
Qualification category:							
Welding procedure specification no.:				Rev:			
Diameter welded:				Qualified range:			
Thickness welded:				Qualified range:			
Welding position:							
Date of test:				Place of test:			
Sketch of joint design:							
Welding parameters							
Pass number	**Preheat/ interpass temp.** °C	**Power and polarity** (a.c./d.c.) (+/-)	**Vertical direction (up/down)**	**Electrode covering type**	**Electrode diameter** mm	**Run-out length** mm	**Electrodes per pass (no.)**
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
Results of non-destructive testing assessments							
Visual examination:							
Radiography:							
Ultrasonic test:							
Alternative tests:							
Results of any destructive tests specified							
Macro-examination:							
Fillet weld fracture:							
Approvals:							
A copy of the welding procedure specification should accompany this record							

Annex E (informative)

Guidance for establishing preheating requirements

The following examples show how the nomogram given in Figure E.1 can be used as guidance for establishing preheating requirements to avoid HAZ hydrogen cracking when welding vertical-down. For other cases BS EN 1011-1 and BS EN 1011-2 should be used. However, for heavier wall pipe welded with higher strength cellulosic consumables, additional preheat might be necessary to avoid weld metal hydrogen cracking.

The following relationships have been used:

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

$$\text{Heat input (kJ/mm)} = \frac{VIk}{w}\times 10^{-3}$$

where

- V is the arc voltage in volts (V);
- I is the welding current in amperes (A);
- w is the welding speed in millimetres per second (mm/s);
- k is the thermal efficiency factor (e.g. 0.8 for manual metal arc welding; refer to BS EN 1011-1 for other processes).

EXAMPLE 1

Assume the following conditions:

- heat input for single run weld is 0.8 kJ/mm;
- pipe thickness is 12.5 mm;
- pipe material carbon equivalent is 0.39.

Using these values with Figure E.1, underbead cracking is avoided at a preheating temperature of –18 °C, i.e. no preheat is required at normal ambient temperature.

Alternatively, this can be expressed by stating that for the pipe material and thickness quoted, at an atmospheric temperature of –18 °C a heat input of 0.8 kJ/mm is necessary to avoid underbead cracking.

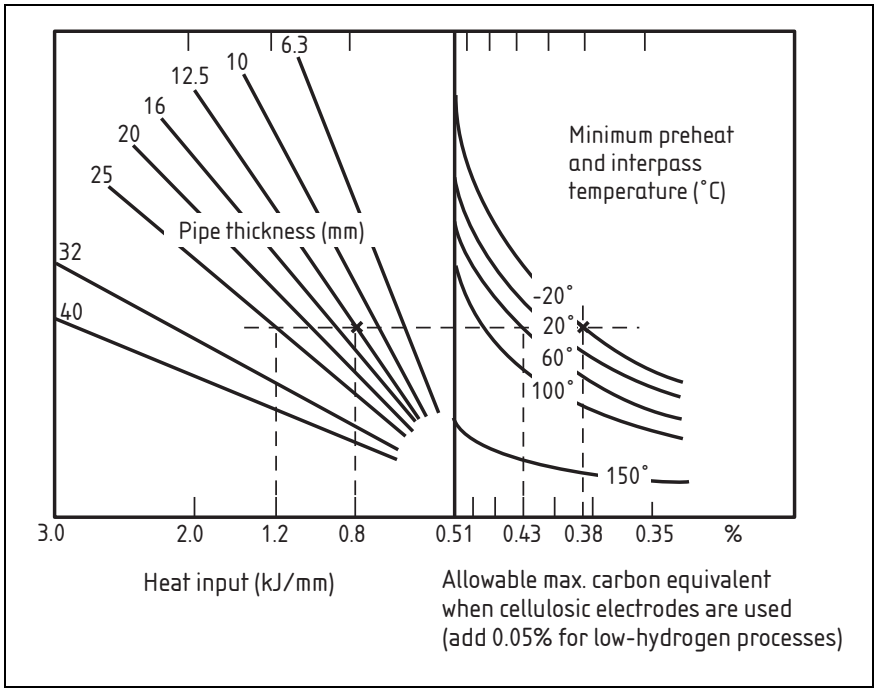
EXAMPLE 2

Assume the following conditions:

- heat input for single run weld is 1.2 kJ/mm
- pipe thickness is 25 mm
- pipe material carbon equivalent is 0.43

Using these values with Figure E.1, underbead cracking is avoided at a preheating temperature of 60 °C.

Figure E.1 **Nomogram for preheating requirements**



Annex F (informative) Example of a radiographic specification

Figure F.1 shows an example of a radiographic procedure specification.

Figure F.1 **Example of a radiographic procedure specification**

<table>
<tr><td colspan="9">Radiographic procedure specification</td></tr>
<tr><td colspan="5">Specification</td><td colspan="4">Procedure no.</td></tr>
<tr><td colspan="9">Project/contract</td></tr>
<tr><td colspan="9">Contractor</td></tr>
<tr><td colspan="9">Radiographic sub-contractor</td></tr>
<tr><td colspan="9">Pipe diameter</td></tr>
<tr><td colspan="9">Technique number (BS EN 1435) (Limitations of technique/procedure)</td></tr>
<tr><td colspan="9">Radiation source type</td></tr>
<tr><td colspan="5">Type of equipment
Tube voltage ... kilovolts
or
Source strength ... G. Becquerels</td><td colspan="4">External [A)]
Internal[A)]
Manually operated/cable[A)]
Battery crawler device[A)]</td></tr>
<tr><td colspan="5">Intensifying screen type
Thickness front
Thickness back</td><td colspan="4">Shielding

Beam collimation</td></tr>
<tr><td colspan="9">Filter type and placement</td></tr>
<tr><td colspan="5">Geometric relationship
Focus to film distance
Object to film distance
Focal spot size
Penumbra
Radiation angle (with respect to weld and film)</td><td colspan="4">Sketch</td></tr>
<tr><td colspan="5">Film type</td><td colspan="4">Cassette type or pre-packed[A)]</td></tr>
<tr><td>Processing chemicals</td><td colspan="2">Developer</td><td>Stop bath</td><td>Fixer</td><td>Wash</td><td colspan="3">Wash-additive</td></tr>
<tr><td>Make/type</td><td colspan="2"></td><td></td><td></td><td></td><td colspan="3"></td></tr>
<tr><td>Time/temperature</td><td colspan="2"></td><td></td><td></td><td></td><td colspan="3"></td></tr>
<tr><td colspan="4">Diagnostic film length</td><td colspan="5">Number of exposures</td></tr>
<tr><td>IQI type:</td><td colspan="3">Placement:</td><td colspan="3">Film/source side [A)]</td><td colspan="2">Position:</td></tr>
<tr><td colspan="9">Exposure conditions</td></tr>
<tr><td>Parameters</td><td colspan="8">Wall thickness (mm)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>kV</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>mA</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Exposure time</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="3">Radiographic sub-contractor</td><td colspan="3">Contractor</td><td colspan="2"></td></tr>
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Approved subject to qualification</td></tr>
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</table>

Annex G (informative) Recommendations for the welding of corrosion resistant alloy clad and lined pipelines

G.1 General

These recommendations relate to pipeline items where the mechanical design requirements of the pipeline are largely achieved by a carbon/carbon manganese steel layer and the main purpose of the corrosion resistant alloy (CRA) layer is to provide corrosion resistance. It is therefore expected that the CRA layer is of relatively low thickness when compared with the steel substrate. All welding should be performed in accordance with Clause **4** to Clause **12** and the additional recommendations of this annex.

The CRA materials considered are those commonly utilized for pipelines such as UNS S31603, UNS N08904, UNS N08825 and UNS N06625 [5]. However the recommendations may be applied to other materials.

This annex does not place restrictions on the pipeline item manufacturing method. However, contracting parties should be aware of the manufacturing method and the implications for pipeline welding and NDT.

The recommendations in this annex should not be applied to the welding of metal coated items, for example hot dipped or plated items.

G.2 Welding consumables

G.2.1 Consumable composition

The consumable used for the root of the weld should be selected to provide corrosion resistance at least equal to that of the clad or liner material. Account should be taken of the required strength of the final weld and the effects of dilution on weld microstructures. The manufacturing method and the composition and thickness of the CRA layer should be provided by the employer [see **4.1**z)]. Information on seal welds, longitudinal weld and buttering should also be provided where present [see **4.1**aa)].

Generally, a weld is completed either by welding the entire weld with the root consumable or switching to carbon steel at some stage through the weld. The latter technique might include a buffer layer.

G.2.2 Consumable toxicity

CRA consumables can generate high levels of hexavalent chromium depending on the CRA composition, the welding process and parameters. Adequate steps should be taken to protect the health of welders and other personnel in the vicinity of the welding from fume hazard.

G.3 Testing, qualification and approval of welding procedures for butt welds

G.3.1 General

The weld procedure qualification should accurately represent the welds to be made in the field. Therefore the pipe components used for qualification should feature any buttering or seal welds that will be present in the pipeline welds whether factory or field applied.

Seal welds to be made in the field should be qualified in accordance with **G.4**.

NOTE Qualification of seal welds made in the factory is not covered in this annex.

G.3.2 Changes affecting qualification and approval (essential variables) of butt welds

A detailed WPS should be prepared for butt welds in CRA clad and lined pipelines. This WPS should contain those items listed in Table G.1.

Table G.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 and the order in which the processes are used
	a2	Whether manual, semi-automatic or mechanized	Any change between manual, semi-automatic and mechanized
	a3	Whether pulsed arc welding is used	Any change between pulsed and non-pulsed welding
Base material specification	b1	Specified standard and Unified Numbering System (UNS) number [5] for the CRA material	Any change
	b2	CRA [A)B)] composition	To be agreed between the contracting parties
	b3	Substrate material	In accordance with Table 1
	b4	Manufacturing method	Any change
Diameter	c	Nominal outside diameter, D, of the pipe	A change outside of the range 0.5D to 2D
Thickness	d1	Nominal wall thickness, t_c, of the CRA layer	Any change exceeding –0, +1.0 mm
	d2	Nominal wall thickness, t_s, of the substrate [C)]	A change outside of the range 0.75t to 1.5t

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

Item		Welding procedure specification details	Changes affecting approval (essential variables)
Joint configuration [D] (with a sketch including tolerances)	e1	Type of bevel	Any change
	e2	Angle(s) of bevel [E]	Any change exceeding ±2.5°
	e3	Size of root face [E]	Any change exceeding ±0.5 mm
	e4	Width of root gap [E]	Any change exceeding ±33% of the nominal gap tested
	e5	Any use of backing rings	Any addition or deletion, or change of material
	e6	Seal weld	Any addition or deletion
	e7	Seal weld WPS	Any change to: • position; • process; • consumable type; • weld size.
	e8	Internal mis-alignment	Any increase
Electrode or filler metal [F]	f1	Nominal diameter of filler/electrode core wire	Any change for the first three passes or lower 10 mm of the weld
			Any increase for the fourth pass onwards or outside of the lower 10 mm
	f2	Trade name	Any change
	f3	Classification	Any change
	f4	Any drying or pre-treatment for hydrogen controlled electrodes	Any change outside the manufacturer's recommendations
	f5	Number of wires for each run	Any change
Number of runs and number of sides welded	g1	The number of runs from each side	Any change from single to multi-run or vice versa
	g2	Sides welded first and last (double-sided welds only)	Any change
	g3	The thickness of CRA ligament prior to switching to non-CRA material [C]	Any change exceeding –0, +3 mm
	g4	The number of buffer material runs (if used)[C]	Any change

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

Item		Welding procedure specification details	Changes affecting approval (essential variables)
Shielding gas or flux or backing gas	h1	Shielding gas	Any change in the nominal composition
	h2	Backing gas	Any change in the nominal composition
	h3	Shielding gas flow rate	Any change exceeding ±10%
	h4	Trade name and type of flux	Any change
	h5	Method of monitoring the backing gas oxygen content in the pipe bore	Any change
	h6	Maximum oxygen content of the backing gas in the pipe [G)]	Any increase
	h7	Number of runs before cessation of backing gas supply	Any reduction
Electrical characteristics	i1	Current (a.c. or d.c.) and polarity	Any change
	i2	Pulse frequency in any pulsed welding	Any change exceeding ±10%
Welding parameters [E)]	j1	Electrical stick-out (SAW, MAG, FCAW)	Any change exceeding ±5 mm
	j2	Arc voltage	Any change exceeding ±10%
	j3	Welding current or wire feed speed (SAW, MAG, FCAW)	Any change exceeding ±10%
	j4	Background current in any pulsed welding	Any change exceeding ±10%
	j5	Peak current in any pulsed welding	Any change exceeding ±10%
	j6	Pulse duration	Any change exceeding ±10%
	j7	Travel speed	Any change exceeding ±10%
	j8	Calculated value of arc energy [A)]	To be agreed between the contracting parties
Welding position	k	Angle of pipe axis to the horizontal	Any change exceeding ±25° [H)], except that qualification in both the PC [I)] and PF [I)] positions covers all other welding positions
Direction of welding	l	Vertical up, vertical down, or horizontal	Any change
Welding technique [E)]	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

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

Item		**Welding procedure specification details**	**Changes affecting approval (essential variables)**
Line-up method	n1	Internal, external, or alternative method (give details)	Any change from internal to external, or from clamp to alternative
	n2	Number of runs before release of clamp	Any reduction
	n3	Use of root tacks	Any addition or deletion
Lowering-off (on land), or barge move-up (offshore)	o	Number of runs before this activity commences	Any reduction
Preheat and interpass temperature	p1	Preheat and minimum interpass temperature (°C)	Any reduction
	p2	Maximum interpass temperature (°C)	Any increase
	p3	Method of accelerating weld cooling	Any change
Repair welds	q1	Repair welding procedure details	Any of the items in this table affecting approval
	q2	Welding procedure details for the weld requiring repair	Any change affecting the approval of the procedure for the weld on which the repair welding procedure was qualified
	q3	Surface from which the repair takes place	Any change from external to internal, or vice versa
	q4	Number of attempts at a repair	Any increase
	q5	Number of runs in a repair	Any change from single run to multi-run or vice versa
	q6	Amount of original weld remaining	Any decrease in thickness
	q7	Type of repair weld	Any change from complete removal of the original weld to partial removal, or vice versa

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

Item		Welding procedure specification details	Changes affecting approval (essential variables)
Post weld heat treatment	r1	Post weld heat treatment	Addition or deletion
	r2	Holding temperature	Any change exceeding ±20 °C
	r3	Holding time	Any change exceeding 5%
	r4	Heating and cooling methods	Any change

A) These items should be specified on the pWPS, but are not mandatory for the production WPS if they are controlled through other procedures.
B) This requirement only applies when corrosion tests are specified.
C) When using a previously qualified procedure to weld a thinner item consideration should be given to the possibility of reduced strength in the joint due to the larger proportion of CRA material in the joint. This consideration applies to a weld made up of CRA and carbon steel passes.
D) Pipe end preparation should include items e1 to e8.
E) The information is needed for each wire size; different values may be used for different runs. These parameters should be specified as single nominal values on the pWPS but as qualified ranges (nominal values ± permitted variation) on the production WPS. In cases where the mean value measured in qualification differs from the nominal value, the qualified range should be calculated from the mean value measured in qualification.
F) The information is needed for each run.
G) This can be determined by corrosion testing or as specified by the employer [see **4.1**y].
H) For some CRA materials, because of micro-structural dependency on welding position, this range might need to be further restricted.
I) Welding positions PC and PF in accordance with BS EN ISO 6947.

G.3.3 Destructive testing of butt welds

G.3.3.1 Transverse weld tensile testing

The CRA layer of the pipeline should be removed from the specimens prior to carrying out transverse tensile testing of butt welds unless the strength of the CRA layer has been included in the design of the pipeline [see **4.1**cc)].

CRA clad and lined pipelines often operate at high temperatures. Additional tensile testing of butt welds at elevated temperatures should be considered in these instances.

G.3.3.2 Macro examination

For butt welds made from more than one consumable type the boundary regions between the different weld metals should be examined at a magnification of ×100 on all of the macro-sections. The areas examined should be free from cracks.

G.3.3.3 Hardness

A hardness traverse 1 mm above the pipe CRA layer and parallel to the pipe surface should be undertaken and included in the hardness surveys carried out in accordance with **8.3.2.5**.

If requested by the employer [see **4.1**dd)], additional hardness traverses along the fusion lines and up the weld centre-line should be undertaken.

Hardness limits for the CRA portions of the weld should be specified by the employer [see **4.1**ee)].

For non-sour service the hardness limits of the carbon steel portions of the weld should conform to the non-sour requirements of **8.3.2.5**. The non-sour requirements of **8.3.2.5** are also applicable for carbon steel portions of sour service pipelines where no corrosion of the CRA layer is expected.

G.3.3.4 Impact testing

The CRA layer in the pipeline should be removed from the specimens prior to carrying out impact testing.

G.3.3.5 Side bend testing

Four side bend specimens should be tested for butt welds from locations evenly distributed around the weld. Side bend testing should be conducted in accordance with BS EN 910 with the clad or liner intact. The width of the specimen should be the pipe thickness and the specimen thickness should be the greater of 10 mm or 0.67 times the pipe thickness. A former with a diameter not greater than 4 times the specimen thickness should be utilized. The specimens should be bent to 180°. If the pipe or fitting contains a longitudinal weld seam, then one of the four bend specimens should be located at the girth weld intersection with the longitudinal seam.

The test specimens should include the CRA layer.

The specimens should be visually examined after bending and should be free from cracks and tears greater than 3 mm in length.

G.3.3.6 Chemical analysis

A chemical analysis of the butt weld in CRA clad and lined pipelines should be carried out to establish the chemical composition of the weld region. The analysis sample should be taken at a point 1 mm below the internal surface of the butt weld using a method approved by the employer [see **4.2**ll)]. The analysis should record the proportions of the following elements: carbon, manganese, silicon, phosphorus, sulfur, chromium, nickel, molybdenum, copper, niobium, vanadium, titanium, nitrogen, aluminium and iron.

The chromium, nickel and molybdenum contents should be equal to or greater than the minimum specified for the CRA layer. The iron content and levels of other elements for particular alloy types should be specified by the employer [see **4.1**ff)].

G.3.4 Corrosion testing

When required by the employer, corrosion testing should be carried out on butt welds in CRA clad and lined pipelines. The extent and type of the corrosion testing should be determined by the employer.

G.4 Testing, qualification and approval of weld procedure for seal welds

G.4.1 General

Seal welds should be qualified in accordance with the following recommendations.

A seal weld should be considered as a fillet weld for the purposes of qualification.

G.4.2 Non-destructive testing

Seal welds should be inspected using dye penetrant testing (see **G.7.2**).

G.4.3 Hardness testing

Hardness limits for seal welds should be specified by the employer [see **4.1**ee)].

G.4.4 Chemical analysis

A chemical analysis of a seal weld in CRA lined pipelines should be carried out when required by the employer [see **4.1**gg)]. The location of the analysis sample is dependent upon the seal weld purpose. The location, elements to be analysed and acceptance criteria should be approved by the employer [see **4.2**mm)].

G.5 Testing, qualification and approval of welders and welding operators

G.5.1 Training

Each welder should receive instruction on the need to avoid contamination of the CRA layer and the techniques used to prevent such contamination.

G.5.2 Changes affecting qualification and approval (essential variables) of welders

The qualification and approval of welders who weld CRA clad and lined pipelines should be in accordance with **9.5**. If any of the following additional changes occur, the welder using the new procedure should be re-qualified:

a) any change in pipe CRA layer UNS number;

b) any change in type, brand, trade name or diameter of CRA welding consumable.

G.6 Production welding

G.6.1 Pipe end preparation

Bevelling of pipe ends should be carried out by machining or machine plasma cutting followed by filing or grinding. Flame cutting should not be used to bevel pipe ends.

Care should be taken to minimize internal spatter during production welding. The employer should specify whether adherent internal spatter is permissible or, if it is to be removed, the method of removal [see **4.1**hh)].

The use of files, grinding wheels or wire brushes on the internal surface should be minimized and is subject to employer approval [see **4.2**nn)].

G.6.2 Fusion face

Where seal welds are used they should be continuous around the full circumference of the pipe. Bevelling of pipe ends including removal of some seal weld material may be undertaken provided that the gap

between liner and pipe remains closed by a ligament of the seal weld. Welding without a seal weld is permitted where demonstrated by a successful weld procedure qualification.

G.6.3 Pipeline equipment

All pipeline equipment that comes into contact with pipe or fitting internal surfaces should be manufactured from non-ferrous materials. These components include:

- expansion shoes on bevelling machines and line-up clamps;
- support wheels and rubbing edges on bevelling machines and line-up clamps, radiography crawlers, back welding trolleys, buckle detectors and internal booms;
- earth clamps.

Umbilicals for internal pipeline equipment should be kept clean and free from ferrous particles.

Grinding disks, wire wheels, brushes and other hand tools should be suitable for stainless work, should be dedicated for use on the CRA layer and should not have been previously used on carbon steel. When not in use these tools should be stored so that the working surface is not contaminated by carbon steel, for example by suspension or by the use of wooden racks or boxes.

G.6.4 Backing gas

Where a maximum oxygen content is specified [see **4.1**bb)], the oxygen content of the backing gas should be continuously monitored during welding until purging is no longer required. Welding should not commence until the specified oxygen content has been achieved and should cease if the oxygen level rises above that specified.

Internal monitoring is preferred whenever practicable. The employer may approve the qualification of a procedure where external oxygen monitoring ceases immediately prior to completion of the root pass [see **4.2**oo)]. The method of sustaining the purge in these circumstances should be reliable.

G.7 Inspection and testing of welds

G.7.1 General

Welds made in accordance with this annex contain dissimilar materials. It is likely that the radiographic absorption and ultrasonic properties will vary across and through the weldments. The NDT techniques selected should take these factors into account and ensure that adequate inspection is achieved.

G.7.2 Dye penetrant testing

The extent of dye penetrant testing should cover the weld, HAZ and weld toe regions. Dye penetrant testing should be carried out in accordance with BS EN 571-1.

G.8 Acceptance and rectification of welds

G.8.1 Non-destructive testing acceptance criteria

Unless more onerous root acceptance criteria are required to preserve the corrosion resistance of the CRA layer the acceptance criteria for NDT should be in accordance with either **12.1.2** or **12.1.3**. If more onerous root acceptance criteria are required they should be specified by the employer [see **4.1**ii)].

Consideration should be given to the effects of lack of penetration [see item c) of Table 9], root porosity [see items j) and m) of Table 9] and burn-through [see item l) of Table 9] in reducing the CRA layer thickness.

G.8.2 Removal of flaws

The method of flaw removal from welds should be approved by the employer [see **4.2**pp)].

Arc-air gouging may only be used to remove carbon steel weld metals to within 3 mm of CRA material.

G.8.3 Repair weld qualification

The qualification of repair welds is required. The test weld to qualify a partial penetration repair weld procedure should be made into an excavation with a remaining ligament no**t** larger than that to be used in production.

Deeper excavations leading to oxidation of the root upon re-welding and full penetration repairs, when permitted by the employer [see **4.1**jj)], should either be made with backing gas or undergo corrosion testing to demonstrate that the level of oxidation is acceptable.

The destructive testing of the repair weld qualification coupons should be carried out in accordance with **G.3.3,** however the number of samples may be reduced with the approval of the employer [see **4.2**qq)].

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