# British Standard

BRITISH STANDARD

BS 4515-1:2000

# Specification for welding of steel pipelines on land and offshore —

## Part 1: Carbon and carbon manganese steel pipelines

ICS 23.040.10; 25.160.01

# Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee WEE/21, Pipework welding, to Subcommittee WEE/21/7, Field welding of pipelines, upon which the following bodies were represented:

Association of Consulting Engineers
British Gas plc
British Institute of Non-destructive Testing
Electricity Association
Engineering Equipment and Materials Users' Association
Health and Safety Executive
International Marine Contractors Association
Offshore Contractors Association
Pipeline Industries Guild
The Welding Institute
UK Steel Association
Welding Manufacturers' Association (BEAMA Ltd.)



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# Contents

# Foreword

The revision of this British Standard has been prepared under the direction of the Subcommittee WEE/21/7. It is applicable to transmission pipelines for gases, liquids or slurries, both on land and offshore. It supersedes BS 4515:1996 which is withdrawn.

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 may 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 5, selecting the methods and frequency of non-destructive examination, 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.

This edition takes into account the publication of BS EN 288-9:1999 and gives additional national requirements for the testing, qualification and approval of butt welding procedures. It should be used in conjunction with BS EN 288-9:1999.

In reflecting current industry practice, this British Standard places duties on, and allocates powers of approval to, the employer. In this it differs from BS EN 288-9 (under which welding procedure approval is independent of 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.

It has been assumed, in the drafting of this British Standard, that the execution of its provisions will be entrusted to appropriately qualified and experienced personnel.

*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.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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

**Summary of pages**

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 31 and a back cover.

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## 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 500 N/mm$^2$ and designed in accordance with BS 8010-2 and -3.

The standard applies to pipes of outside diameter 21.0 mm and larger having a thickness of 3.0 mm or greater.

## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 499-1:1991, *Welding terms and symbols — Part 1: Glossary for welding, brazing and thermal cutting.*

BS 6072:1981, *Method for magnetic particle flaw detection.*

BS 8010-2, *Code of practice for pipelines — Part 2: Pipelines on land: design, construction and installation.*

BS 8010-3, *Code of practice for pipelines — Part 3: Pipelines subsea: design, construction and installation.*

BS EN 970:1997, *Non-destructive examination of fusion welds — Visual examination.*

BS EN 1321:1997, *Destructive test on welds in metallic material — Macroscopic and microscopic examination of welds.*

BS EN 1435:1997, *Non-destructive examination of welds — Radiographic examination of welded joints.*

BS EN 1714:1998, *Non-destructive examination of welded joints — Ultrasonic examination of welded joints.*

BS EN 10160:1999, *Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method).*

BS EN ISO 6507 (all parts), *Metallic materials — Vickers hardness test.*

PD 6493:1991, *Guidance on methods for assessing the acceptability of flaws in fusion welded structures.*

## 3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS 499-1:1991 apply together with the following.

**3.1**

**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.

**3.2**

**contractor**

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

**3.3**

**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.

[BS 8010-2 and -3]

**3.4**

**joint**

completed weld joining two sections of pipe, a section of pipe to a fitting, or two fittings

**3.5**

**welding procedure**[1)]

specific course of action followed in welding, including a list of materials and, where necessary, tools to be used

**3.6**

**welder**[1)]

operator who performs the welding

**3.7**

**approved welder**

welder who has demonstrated his ability to produce welds meeting the requirements of this standard

**3.8**

**root-run**[1)]

first run deposited in the root of a multi-run weld

**3.9**

**positional welding**

welding wherein the pipe or assembly is held stationary

**3.10**

**roll welding**[1)]

method of manipulation by rotating or rolling pipes or pipe assemblies so that all welding is carried out in or near the flat position

[1)] Definition taken from BS 499-1.

**3.11**
**semi-automatic welding**[1)]
welding in which some of the welding variables are automatically controlled, but manual guidance is necessary

**3.12**
**mechanized welding**[1)]
welding in which the welding parameters are controlled mechanically or electronically and may be manually varied during welding to maintain the required welding condition

**3.13**
**sour service**
pipeline design conditions in which a risk of sulfide stress cracking exists
NOTE This is normally assessed using NACE MR0175 [1].

**3.14**
**full penetration repair**
repair from the external surface of the original weld which penetrates to the bore of the pipe

**3.15**
**partial penetration repair**
multi-run repair from the external surface of the original weld which does not penetrate to the bore of the pipe

**3.16**
**cap repair**
single run repair to the external surface of the original weld

**3.17**
**internal (back-weld) repair**
repair from the internal surface of the original weld

**3.18**
**re-repair**
second attempt at repairing a defect in the same location. For qualification purposes this is a full penetration repair, testing a heat-affected zone which has received three full thermal cycles

**3.19**
**qualification**
series of actions necessary to demonstrate that a proposal meets the technical requirements of this British Standard

**3.20**
**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

**3.21**
**preliminary welding procedure specification (pWPS)**
tentative welding procedure specification, which is assumed to be adequate by the manufacturer, but which has not been approved.
NOTE Welding of test pieces needed for approval of a welding procedure specification has to be carried out on the basis of a preliminary welding procedure specification (pWPS).

## 4 Information to be specified and items to be approved

### 4.1 Information to be specified by the employer

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

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) whether different batches of electrodes and filler materials are to be individually identifiable and completely separated (see **7.2**);
d) whether an alternative location is specified for the excavation location for the repair weld test (see BS EN 288-9:1999, Figures A.1 and A.2);
e) whether specimens should be allowed to cool for a duration other than 24 h before testing (see **8.1**);
f) whether strain ageing data and/or additional tests are required as the basis for welding procedure approval for pipe-reeling (see **8.1**);
g) the type and number of re-tests required in the event of failure (see **8.1**);
h) whether additional NDT methods for fillet welds apply (see **9.1**);
i) whether a proposed change to a welding procedure will require requalification of the welders (see **10.5**);
j) whether prevailing weather conditions are such that quality of the completed weld would be impaired (see **11.9**)[2)];
k) the method(s) and frequency of visual inspection and non-destructive testing (see **12.1**);
l) whether completed welds are to be ground (see **12.1**);
m) whether alternative techniques are to be used for radiographic testing of welded butt joints (see **12.4.1**);
n) ultrasonic acceptance criteria (see **12.5.4**);
o) whether automatic ultrasonic testing is to be used (see **12.6**);

[1)] Definition taken from BS 499-1.
[2)] Information for this item may not be able to be supplied until the appropriate stage of the work is reached.

p) whether NDT acceptance criteria are to be based on quality control or engineering critical assessment (see **13.1.1**);

q) whether the maximum planar defect dimension is to be less than 25 mm (see **13.1.2**);

r) whether a more stringent limit for root penetration is required [see Table 4c)].

### 4.2 Items subject to approval by the employer

The following items shall be subject to approval by the employer and fully documented:

a) the tensile strength of weld metal for joints between dissimilar materials if other than that of the higher strength parent metal (see **7.1**);

b) consumables to be used (see **7.1**);

c) the definition of a batch when batch testing of electrodes and filler materials is required (see **7.1**);

d) test weld production on pipes shorter than full length (see **8.1**);

e) explanation for NDT failure if a test weld is to be destructively tested or rewelded to the same procedure (see **8.1**);

f) the type and number of re-tests of a welding procedure when they are permitted (see **8.1**);

g) welding procedure qualification test details and welding procedure specification for production welding (see **8.1**);

h) use of roll welding (see **8.1**);

i) simulation of a fillet weld joint using flat plate fillet welds [see **10.4.1**b)];

j) alternative methods of NDT for welder test pieces [see **10.6**c)];

k) giving a welder a second opportunity to gain approval (see **10.8**);

l) all documentation relating to welder qualification tests (see **10.9**);

m) use of manual thermal cutting for pipe end bevelling and the ability of the operator (see **11.2**);

n) method of obtaining minimum misalignment other than rotation of the pipes (see **11.4**);

o) method of marking for ultrasonic testing (see **11.2**);

p) the blending out by grinding of minor imperfections within the joint preparation area [see **11.2**a)];

q) alternative alignment methods other than internal line-up clamps (see **11.5.1**);

r) the stage at which line-up clamps are removed (see **11.5.1**);

s) the stage at which the pipe is lowered onto skids, or support is removed from fittings (see **11.5.2**);

t) reduction of preheating requirements for tack welds [see **11.6**b)];

u) repair of places where stray arcs have occurred (see **11.8**);

v) means of applying preheat (see **11.10.2**);

w) methods of attaching and removing thermocouples (see **11.10.4**);

x) the welding procedure for branch connections where the angle between the main and branch is less than 60° (see **11.11.1**);

y) written ultrasonic examination procedure for pipe material around a planned cut-out (see **11.11.3**);

z) all non-destructive testing procedures to be used (see **12.1**);

aa) all inspection personnel (see **12.2**);

ab) the technique in BS EN 1435 to be used for radiographic examination (see **12.4.1**);

ac) any method for magnetic particle testing to be used at above ambient temperature (see **12.7.1**);

ad) any proposal to repair a weld (see **13.2.1**);

ae) any alternative limits on repair weld length (see **13.2.1**);

af) use of root sealing or single run repair deposits (see **13.2.4**);

ag) more than one attempt at a repair (see **13.2.4**);

ah) technique and equipment for brazing or aluminothermic welding of anode bonding leads (see annex B);

ai) proposed brazing or aluminothermic welding procedure specification (see annex B).

aj) the position of the longitudinal seam weld (if applicable) on the subsea pipeline at the hyperbaric weld location (see annex A).

## 5 Equipment

The contractor shall maintain all welding plant and ancillary equipment in good working order. Welding and cutting plant, instruments, cables and accessories shall conform with the requirements of the appropriate British Standard, e.g. BS 638. Pipe handling equipment, rollers and line-up clamps shall be such that they avoid damage or permanent deformation to the pipe, ensure that pipe axes are aligned as specified in **11.4** and allow the welding procedure to be used.

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 may 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 1b) to within the limits stated in that table.

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

## 6 Welding processes

The process used shall be a manual, semi-automatic or mechanized arc welding process or combination of processes.

## 7 Welding consumables

### 7.1 General

Electrodes, filler wires and shielding gases, and wire/flux combinations shall produce weld metal that has a tensile strength at least equal to the minimum specified for the parent metal. Moisture content of shielding gases shall correspond to a dewpoint of −30 °C or lower.

In the case of joints between dissimilar materials, the weld metal shall have a tensile strength at least equal to that specified for the higher strength parent metal unless an alternative value is approved by the employer.

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.

NOTE 1 Where high transverse strains are expected consideration should be given to requirements for weld metal yield strength.

Only consumables which have received the prior approval of the employer shall be used. When required by the employer, 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.

NOTE 2 Appropriate electrodes and filler materials conforming to the requirements of this subclause are specified in BS 639, BS 2493, BS 7084, BS 4165 and BS EN 1435. Carbon dioxide used as a shielding gas should conform to BS 4105.

### 7.2 Storage and handling

Different grades and, when specified by the employer, different batches of electrodes and filler materials shall be individually identifiable and be completely separated. When the electrode manufacturer recommends that electrodes are stored at a stated temperature, the contractor shall follow such 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. Electrodes, filler wires and fluxes that show signs of damage or deterioration 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.

Mixing of gases in the field shall be allowed provided 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 for butt welds

### 8.1 General

Testing, qualification and approval of welding procedures shall be in accordance with BS EN 288-9 except in the event of a failure, where the type and number of such re-tests shall be specified by the employer, and with the additional requirements **8.2** to **8.4**, which also apply to repair welds.

The quality of the test welds shall be determined by non-destructive and destructive testing after specimens have been allowed to cool to ambient temperatures in simulated site conditions for 24 h unless an alternative duration is specified by the employer.

When a welding procedure is to be qualified and approved for pipe-reeling, the proposed welding procedure shall include relevant previously-documented strain ageing data and/or any additional tests specified by the employer.

NOTE 1 These tests may include representative strain cycles and accelerated ageing typically for 1 h at 100 °C.

The test weld shall be produced in accordance with the proposed welding procedure specification under simulated site conditions on full pipe lengths unless otherwise approved by the employer.

If non-destructive testing indicates the presence of flaws exceeding the levels permitted in **13.1**, the reason for this shall be investigated and explained to the satisfaction of the employer before approval is given for the use of this test piece for the purposes of destructive testing or alternatively for re-welding the test piece to the same details.

Recorded details for each welding procedure qualification test shall be submitted by the contractor together with the welding procedure specification for production welding to the employer for approval (see **10.9**).

NOTE 2 Forms similar to those shown in annex C should be used.

NOTE 3 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**.

Roll welding shall only be used with the employer's approval and only when it can be demonstrated that the joint can be adequately supported to maintain its axial alignment.

### 8.2 Changes affecting qualification and approval (essential variables)

In addition to the requirement of BS EN 288-9:1999, clause **8**, the items specified in Table 1 shall apply. In addition, for repair welds in group 1 materials as specified in PD 6588, a repair procedure shall be qualified if it is outside the range of approval given in BS EN 288-9:1999, clause **8**.

**Table 1 — Welding procedure specification details and changes affecting approval**

| Item | | Welding procedure specification details | Changes affecting approval (essential variables) |
|---|---|---|---|
| Electrode or filler materials | a | Trade name | Any changes when Charpy testing is required |
| Welding parameters | b | The following information is needed for each wire size (different values[a] may be used for different runs): | |
| | b1 | Electrical stick-out (SAW, MAG, FCAW)[b] | Any change exceeding ±5 mm |
| | b2 | Arc voltage[b] | Any change exceeding ±10 % |
| | b3 | Wire feed speed (SAW, MAG, FCAW)[b] or welding current[a] | Any change exceeding ±10 % (±15 % for cellulosic electrodes) |
| | b4 | Travel speed[b] | Any change exceeding ±10 % |
| | b5 | Calculated value of heat input[a,b] | No separate restriction |
| Welding position | c | Angle of pipe axis to the horizontal | Any change exceeding ±25° |
| Direction of welding | d | Vertical up, vertical down or horizontal | Any change |

[a] These items shall be specified on the proposed 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 proposed 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.

### 8.3 Destructive testing

#### 8.3.1 *Transverse tensile testing requirements*

In addition to the requirements of BS EN 288-9:1999, **7.4.1**, the following shall apply.

If a specimen breaks outside the weld or fusion zone at a tensile strength of 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.

Any specimen that breaks outside the weld or fusion zone at a tensile strength less than 95 % of that of the specified minimum tensile strength of the pipe material shall be rejected and an equal number of additional specimens shall be cut from the same test joint and subjected to the tensile test.

NOTE If any of the additional specimens break outside the weld or fusion zone at a tensile strength below the minimum stated above, the pipe material should be considered to be suspect and its physical properties should be investigated before any additional joints are made.

#### 8.3.2 *Macro-examination requirements*

In addition to the requirements of BS EN 288-9:1999, **7.4.2**, the following specimens shall be tested.

For upwards welding, macro examination shall be at the 12 o'clock and 3 o'clock position.

For downwards welding, macro examination shall be at the 6 o'clock and 12 o'clock position.

#### 8.3.3 *Hardness requirements*

In addition to the requirements of BS EN 288-9:1999, **7.4.4**, for sour service, hardness testing shall be carried out at the 3, 6 and 12 o'clock position.

#### 8.3.4 *Impact testing requirement*

In addition to the requirements of BS EN 288-9:1999, **7.4.3**, Charpy tests are additionally required at the 12 o'clock position, notched at the weld centre line and the weld fusion line. When tested at the minimum design temperature, the requirements for all Charpy impact test specimens shall be not less than 40 J average and 30 J minimum individual value. The requirements for sub-size and specimens shall be reduced pro rata with their dimensions.

These Charpy 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 strength grades that are not greater than X 65 (minimum yield strength 448 N/mm$^{2)}$. Toughness requirements for other conditions shall be specified by the employer.

NOTE 1 Attention is drawn to the *European Pipeline Research Groups guidelines on acceptable girth weld defects in transmission pipelines*, by P. Hopkins and R. Denys [2].

NOTE 2 When it is not possible to meet the requirement of this subclause, the use of CTOD testing may also be considered for welding procedure approval subject to agreement between the contracting parties.

## 9 Testing, qualification and application of weld procedure for fillet welds

### 9.1 Non-destructive testing

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

a) magnetic particle testing (see **12.7**); and

b) any additional method specified by the employer.

The results from visual examination and non-destructive testing shall be assessed according to the appropriate acceptance criteria specified in **13.1**.

### 9.2 Destructive testing

#### 9.2.1 *Test specimens*

The minimum number of test specimens and the tests to which they shall be subjected shall be as given in Table 2.

Two of the fracture specimens shall be taken from those locations shown to have the greatest and least root gap. Macro-examination shall be carried out on one face of each of these two fracture specimens prior to being fractured.

The specimens shall be prepared as shown in Figure 1 and shall be at least 25 mm wide and at least 50 mm long.

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

**Table 2 — Test specimens for procedure approval tests on fillet welds**

| Outside diameter of pipe mm | Minimum number of specimens | | |
|---|---|---|---|
| | Fracture test | Macro-examination | Hardness survey[a] |
| ≤114.3 | 2 | 2 | 1 |
| >114.3 | 4 | 2 | 1 |

[a] The hardness survey is made on a macro-examination specimen.

#### 9.2.2 *Fracture test*

##### 9.2.2.1 *Requirements*

When tested as described in **9.2.2.2** 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 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.

##### 9.2.2.2 *Method*

Break the specimens by 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 and striking the other.

#### 9.2.3 *Macro-examination*

##### 9.2.3.1 *Requirements*

When tested as described in **9.2.3.2** the profile, dimensions and number of runs of the fillet weld shall be as specified in the welding procedure. The specimens 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.

##### 9.2.3.2 *Method*

Prepare and etch the specimens as described in BS EN 1321. Examine the polished and etched surfaces using a hand lens of ×5 magnification.

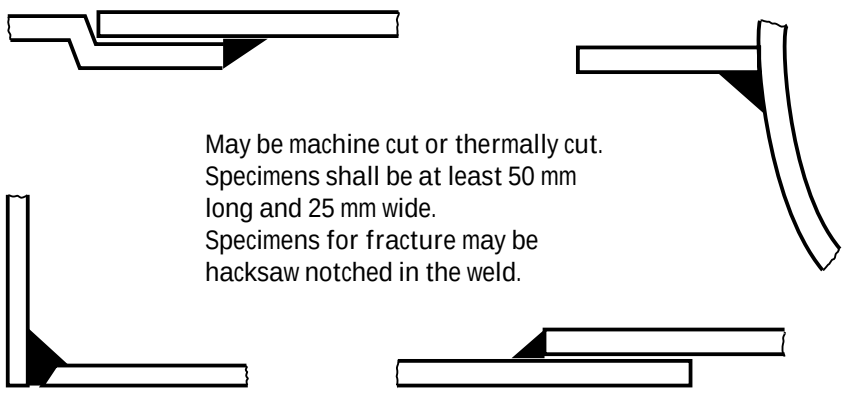



**Figure 1 — Preparation of fillet weld specimens**

#### 9.2.4 *Hardness survey*

**9.2.4.1** *Requirements*

When tested as described in **9.2.4.2** the hardness values shall not exceed those given in Table 3 unless otherwise specified by the employer.

**9.2.4.2** *Method*

Carry out the hardness survey on a macro-examination or fracture test specimen as appropriate. Test the specimens as described in BS EN ISO 6507 using a 10 kg load. Make two weld zone traverses, one across the root and one near the weld cap. The root traverse shall consist of at least five impressions: 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 impressions: two in the heat-affected zone each side of the weld, two in the weld metal and one in the parent metal side of the weld.

## 10 Testing, qualification and approval of welders

### 10.1 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 he will be required to make on the pipelines. A welder who has satisfactorily completed a welding procedure qualification test shall automatically be qualified in that procedure.

Where more than one process or welder is employed 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 pipe circumference which he will weld in construction in accordance with the qualified welding procedure.

A welder shall be given a single qualification for one or more of the following categories, a separate test being 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 begins from the date when all the required tests are satisfactorily completed. 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 two years providing that the relevant certificate is signed at six month intervals by the employer/coordinator and that all the following conditions are fulfilled.

1) The welder shall be engaged with reasonable continuity on welding work within the current range of qualification. An interruption for a period no longer than six months is permitted.

2) The welder's work shall be in general accordance with the technical conditions under which the qualification test is carried out.

NOTE There should be no specific reason to question the welder's skill and knowledge.

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

### 10.2 Butt joints

#### 10.2.1 *Roll welding*

The 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 he has completed 200 mm or slightly less than 25 % of the joint, 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.

**Table 3 — Hardness values**

| Hardness location | Sour service | Non sour service | |
|---|---|---|---|
| | Any welding process | Manual metal-arc welding, cellulosic electrodes | Other processes |
| | HV10 | HV10 | HV10[a] |
| Weld metal: | | | |
| root and mid-thickness | 250 | 275 | 275 |
| cap | 275 | 275 | 275 |
| Heat-affected zone: | | | |
| root and mid-thickness | 250 | 275 | 350 |
| cap | 275[b] | 325 | 350 |

[a] See **9.2.4.2** regarding load for mechanized processes.
[b] 300 HV10 pipe 9.5 mm thick and above.

#### 10.2.2 *Positional welding*

The pipe containing the test joint shall be fixed as follows:

a) *within 20° of horizontal.* The pipe containing the test joint shall be fixed horizontally;

b) *within 20° of vertical.* The pipe containing the test joint shall be fixed vertically;

c) *between 20° to the vertical and 20° to the horizontal.* The pipe containing the test joint shall be fixed at 45° to the vertical.

### 10.3 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.

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

#### 10.4.1 *General*

A successful single qualification test on either one of the items listed in a) or b) shall qualify a welder for all the attachments given in a) within the limits specified in **10.5**:

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.

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.

#### 10.4.2 *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 **10.4.1**b)]. The welder shall deposit metal at or near top centre until he has completed 200 mm or slightly less than 25 % of joint, 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.

#### 10.4.3 *Fillet welds in all positions*

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

### 10.5 Changes affecting qualification and approval (essential variables)

A welder who has successfully completed a qualification test as detailed in **10.1** to **10.4** shall be qualified for the type and position of weld concerned within the limits of the following items. If any of changes a) to i) 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 4 (for branches, the diameter of the branch is the applicable dimension).

**Table 4 — 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 |
|---|---|---|---|
| $D \leq 150$ | $0{,}5D$ to $2D$ | $t \leq 12$ | $\leq 2t$ |
| $D > 150$ | $\geq D/2$ | $t > 12$ | $\geq 5$ 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 to $D$ = 219.1 mm.
NOTE 2 This table does not apply to pipe thicknesses less than 3 mm.

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;

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, will make production of a sound weld more difficult for the welder.

### 10.6 Non-destructive testing

The test weld shall present a neat workmanlike appearance and shall be assessed by visual examination according to the appropriate acceptance criteria specified in **13.1**.

After visual examination (see **12.3**) non-destructive testing shall be carried out on each of the test welds using one of the following methods:

a) X-radiography as specified in **12.4**;

b) automatic ultrasonic examination as specified in **12.6**;

c) with the prior approval of the employer, an alternative method(s).

The resultant film, ultrasonic read-out or other results shall be assessed in accordance with **13.1**.

### 10.7 Destructive testing

#### 10.7.1 *General*

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

#### 10.7.2 *Butt joints*

When required, the testing of butt joints for welder qualification shall conform to the requirements for macro-examination as used for procedure approval tests in **8.3.1.2**.

#### 10.7.3 *Fillet welds*

The testing of fillet welds for welder qualification shall conform to the requirements for procedure approval tests as given in **9.1.1**, except that no hardness survey is required.

### 10.8 Retests

When failure of a welder to pass the test was because of conditions beyond his control, such a welder shall, with the approval of the employer, be given a second opportunity to gain approval. No further retests shall be given until the contractor has submitted proof of subsequent training of the welder acceptable to the employer.

Should one of the destructive test specimens fail 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 is not regarded as qualified if either additional specimen also fails to satisfy the test requirements.

### 10.9 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.

NOTE Record forms similar to that shown in annex D should be used. The period for which records should be kept should be specified by the employer.

### 10.10 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 he has been tested, qualified and approved.

The inspection and testing of welds for qualification purposes and records shall be in accordance with the requirements of **10.6**, **10.7**, **10.8** and **10.9**.

## 11 Production welding

### 11.1 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.

### 11.2 Pipe end preparation

Bevelling shall be done by machining or by machine thermal cutting, manually or mechanically operated.

Manual thermal cutting shall not be used for bevelling the ends of pipe 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, who shall also be satisfied in regard to the ability of the operator. When manual thermal cutting is used, the final dressing shall be by filing, grinding or other mechanical means to 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:

a) with the approval of the employer these imperfections shall be blended out by grinding; or

b) the joint shall be re-prepared.

Damage to pipe 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 to the requirements of the appropriate pipe material specification.

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

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.

### 11.3 Fusion faces

The fusion faces and the adjacent material shall be free from fins, planar flaws not conforming to **13.1**, 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.

### 11.4 Alignment

The alignment of abutting pipe ends shall be such as to 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 by rotation of the pipes to obtain the best fit or by other methods approved by the employer.

When a pipe with one longitudinal seam is used, this seam shall be 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 as specified in a) or b):

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;

b) a transition piece shall be inserted.

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

### 11.5 Line-up clamps and pipe supports

#### 11.5.1 *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.

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

#### 11.5.2 *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.

### 11.6 Tack welds

Where tack welds are to be used, the work shall be set-up, properly spaced 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 adequate fusion with the root run.

Preheating requirements shall be maintained as specified in **11.10.2** from tack welding to completion of the joint.

NOTE With the approval of the employer, a lower preheat may be used for tack welding.

If preheating requirements are reduced, the tack welds shall be removed by careful grinding after at least 50 % of the root run has been applied.

### 11.7 Working clearance

The working clearance around the pipe at the weld shall be of sufficient size to provide adequate 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 with ready access to the joint.

### 11.8 Stray arcs

Arcs shall be struck only on fusion faces 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 or rejected as approved by the employer.

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, repairs to an approved welding procedure may be carried out and subjected to further non-destructive testing.

### 11.9 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.

NOTE Where adequate protection from the weather can be provided, welding may be continued.

## 11.10 Preheating and post-weld heat treatment

### 11.10.1 *General*

The preheating and post-weld heat treatment requirements shall be as specified in the welding procedure. Post-weld heat treatment shall be applied by gas-fired muffles 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 treatment.

NOTE 1 For post-weld heat treatment, reference should be made to an appropriate standard e.g. BS 2633.

NOTE 2 Guidance for establishing preheating temperatures to avoid hydrogen cracking is given in annex E, but this may not be the temperature needed to meet the requirements of BS EN 288-9:1999, Table 3.

### 11.10.2 *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 a satisfactory temperature distribution, does not interfere with the welding operation, and is approved by the employer relative to the particular application. Care shall be taken to avoid damage to any coating.

Temperatures 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.

### 11.10.3 *Post-weld heat treatment temperatures*

Post-weld heat treatment temperatures shall be measured using thermocouples, so disposed 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.

### 11.10.4 *Thermocouple attachment and junctions*

Thermocouples shall be attached and removed after use by methods approved by the employer. 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.

## 11.11 Branches

### 11.11.1 *Angle of branch*

Where a sloping branch has to be connected directly to the main pipe, the angle between the centreline of the main and that of the branch pipe shall be not less than 60°, provided also 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.

NOTE In view of the additional difficulty involved in making a satisfactory 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.

### 11.11.2 *Spacing of branches*

The spacing of branches on the main pipe and the lengths of flanged branches shall be such that there is adequate access for satisfactory welding and subsequent NDE.

### 11.11.3 *Joint preparation*

Branch connections and branch openings in the main pipe shall be cut by machining or by thermal cutting. The cut edges shall then be dressed by filing or grinding to the dimensions given in the approved welding procedure (see also **11.2**).

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. The zone to be examined shall be at least 100 mm wide (see also **13.1.2**).

### 11.11.4 *Welding*

#### 11.11.4.1 *Gap*

The gap shall be maintained during the deposition of the first run. Tack welds shall be used only in accordance with the requirements of **11.6**.

#### 11.11.4.2 *Internal welds*

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

### 11.11.5 *Branch reinforcement (compensation)*

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

The reinforcement shall be securely held in position by tack welds which shall be of sound quality (see **11.6**).

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

### 11.12 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.

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 by grinding.

### 11.13 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 shall 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 and shall be cooled in a slow and uniform manner.

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

## 12 Inspection and testing of welds

### 12.1 General

The method or combination of methods and frequency of visual inspection and non-destructive testing shall be as specified by the employer.

Prior to the start of welding, all NDT procedures to be used shall be submitted to the employer for approval.

If the employer requires completed welds to be ground, this shall be stated in the enquiry and order. When a weld is to be ground, overheating due to the grinding action shall be avoided.

### 12.2 Personnel qualification

All inspection personnel shall have been approved by the employer.

### 12.3 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 **13.1**.

### 12.4 Radiographic testing

#### 12.4.1 *General*

The radiographic testing of fusion welded circumferential butt joints in steel pipes shall be carried out in accordance with BS EN 1435:1997. The minimum standard required shall be Class B (improved techniques) using one of the following techniques in order of preference, nos. 6.1.4, 6.1.8, 6.1.3 or 6.1.6 unless otherwise specified by the employer.

Class A techniques shall only be used where Class B cannot be practically achieved and only with the approval of the employer.

#### 12.4.2 *Approved radiographic procedures*

The procedure details shall include the exposure time in addition to the requirements of BS EN 1435.

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.

#### 12.4.3 *Film storage*

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

### 12.5 Manual ultrasonic testing

#### 12.5.1 *General*

Where ultrasonic testing is applied, it shall be carried out in accordance with BS EN 1714:1998, using examination level Method 1. All indications greater than 20 % DAC shall be reported. Indications greater than 50 % DAC or 6 dB shall be reported and evaluated in accordance with BS EN 1714:1998, clause **13**.

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 may be difficult to detect by radiography;

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

#### 12.5.2 *Additional information*

Immediately prior to examination, 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.

#### 12.5.3 *Reporting and evaluation*

All discontinuity indications having an amplitude above the reference level established for scanning in accordance with **12.5.1** shall be recorded. They shall then be sized and characterized, and assessed against the acceptance criteria specified by the employer.

### 12.6 Automatic ultrasonic testing

When specified by the employer, automatic ultrasonic testing shall be used for the initial detection and/or sizing of flaws.

Specific procedures, acceptance criteria, report format, method of data storage and presentation shall be agreed 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 may be required for this purpose.

### 12.7 Magnetic particle testing

The extent of the testing shall be to cover the weld and weld toe regions. The magnetic particle testing shall be in accordance with BS 6072 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.

b) Residual magnetism techniques shall not be used.

## 13 Acceptance and rectification of welds

### 13.1 Non-destructive testing acceptance criteria

#### 13.1.1 *General*

The acceptance criteria for non-destructive testing shall be in accordance with either **13.1.2** or, if specified by the employer, **13.1.3**.

#### 13.1.2 *Acceptance criteria based on quality control*

In areas of a weld preparation such as pipe ends, fusion faces and branches (see clauses **11.2**, **11.3** and **11.11**) no planar defects shall exceed in any dimension, either:

a) 25 mm; or

b) a smaller value specified by the employer.

The acceptance criteria for welds shall be as specified in Table 5.

Any accumulation of flaws, except porosity, affecting a total length of weld of 100 mm or more 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 this subclause are intended to ensure good quality welded joints. Service conditions may 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 5 assume that all non-destructive testing is by visual or radiographic examination. No "equivalent" ultrasonic testing table has been derived and so acceptance criteria for ultrasonic examination should be agreed between the employer and contractor before welding begins.

#### 13.1.3 *Acceptance criteria based on engineering critical assessment*

When the employer specifies that engineering critical assessment (ECA) is to be used for establishing acceptance criteria, it shall be applied in accordance with PD 6493.

### 13.2 Rectification of welds

#### 13.2.1 *Removal of flaws*

When the welds fail to conform wholly or in part to the requirements of **13.1**, either the weld shall be repaired locally or the weld zone shall be entirely removed. The excavated portion of the weld shall be sufficiently deep and long to remove the flaw. Weld repairs shall not begin before sufficient non-destructive testing and inspection has been completed.

No weld shall be repaired without the approval of the employer.

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, pre-heating shall be applied as necessary. When air-arc gouging is used, the last 3 mm through the root of the weld shall be removed by mechanical means.

Repairs shall be limited to 30 % of the weld length for a partial penetration repair, or 20 % of the weld length for a full penetration repair. If alternative repair length limits are proposed they shall be subject to approval by the employer.

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

#### 13.2.2 *Preparation for re-welding*

At the ends and sides of excavation there shall be a gradual taper from the base of the excavation to the surface of the weld metal. The width and profile of excavation shall be such as will give adequate access for re-welding.

#### 13.2.3 *Qualifications*

Repair welding procedures shall be qualified when required by **8.1**. 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 by **10.5**.

#### 13.2.4 *Re-welding*

Root sealing or single run repair deposits shall only be undertaken if approved by the employer.

A repaired weld shall be subject to at least the same testing and inspection requirements as the original weld. Repairs shall not be attempted more than once unless approved by the employer.

Full penetration repairs shall only be implemented under constant supervision. If repairs cannot be implemented within these limitations, or are not effected successfully, the weld shall be cut out.

Full records of all repairs shall be maintained.

**Table 5 — Acceptance criteria for welds**

| Flaw type[a] | Acceptance criteria |
|---|---|
| a) External profile | Excess weld metal (reinforcement) shall be uniform and shall merge smoothly with the parent metal and shall 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 as given in h). |
| b) Internal profile | The root bead or any concavity shall merge smoothly into the adjacent surfaces. |
| c) Root penetration | Not to exceed 3 mm. If service conditions necessitate a more stringent limit, this shall be specified by the employer. |
| d) Root concavity | 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. |
| e) Root undercut<br>Shrinkage groove | 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. |
| f) Incomplete root penetration (single side welds only)<br>Lack of root fusion (single side welds only) | 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. |
| g) Cracks | Not permitted. |
| h) Cap undercut | 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 5 — Acceptance criteria for welds** *(continued)*

| Flaw type[a] | Acceptance criteria |
|---|---|
| i) Elongated linear porosity in root run (hollow bead)<br><br>Shrinkage cavity<br>Lack of inter-run fusion<br>Lack of side fusion<br>Elongated inclusions<br><br>Parallel elongated inclusions (wagon tracks)<br>Incomplete root penetration (double side welds only[b]) | Length of weld affected 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.<br><br>Width of elongated inclusions not to exceed 1.5 mm.<br><br>For branch welds the length of weld affected 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. |
| j) Porosity (other than elongated porosity in root run) | 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.<br>An isolated pore greater than 25 % of the pipe thickness or 3 mm, whichever is the smaller, in any direction shall be considered unacceptable. |
| k) Isolated inclusions (copper, tungsten or non-elongated slag) | 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. |
| l) Burn-through | Not to exceed 5 mm in any dimension and only one in any continuous weld length of 300 mm. |
| m) Wormhole | 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.
[b] Also known as "lack of cross penetration".

# 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 the requirements of sections 1 to 12 of this standard, 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 may be required for greater depths.

All welding should be 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 Operations at Work Regulations*, 1981 [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 suitable 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 Operations at Work Regulations*, 1981 [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 such an event should be included in the welding procedure specification. 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 to be 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 and adequately maintained. In particular, all electrical apparatus should be protected to avoid the risk of electrical shock.

NOTE Guidance on electrical safety is provided in *Code of Practice for the safe use of electricity underwater* issued by the Department of Energy [4].

**A.3.3** The welding habitat should be of sufficient size to provide adequate 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 adequately illuminated and the work area kept clear of excess fumes to enable remote video surveillance by the supervisory personnel. Cameras should be provided for surveillance.

**A.3.5** Equipment to be used for the monitoring of the welding parameters and essential variables should be adequately maintained and should be 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 to the following should be given 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 as a minimum 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.

NOTE The procedure should be designed to tolerate the maximum humidity anticipated in production welding. In the case of MMA consumables, exposure limits should take into account the different reabsorption characteristics of the electrodes.

**A.5.2** The consumables used for procedure qualification and production should be from the same batch.

**A.5.3** Welding consumables for MMA and FCAW should be selected on the basis of proven performance under hyperbaric conditions with particular respect to arc stability and metal transfer characteristics.

NOTE 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 adequately purged prior to the start of welding.

### A.7 Testing, qualification and approval of welding procedures

**A.7.1** A detailed welding procedure specification should be prepared. This should contain those items specified in Table A.1 together with the following additional information:

— water depth (simulated or actual);

— gas composition in the habitat;

— oxygen partial pressure;

— habitat temperature;

— the method of measuring heat input and deposition rate;

— relative humidity.

**A.7.2** Items already listed in Table A.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 1 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 welds.*

The procedure should provide details of the course of action to be taken due to scheduled and unscheduled interruptions in the diving operation.

NOTE 2 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 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 to be used in production.

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

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

**A.7.6** In addition to those items specified in Table A.1, the following items should be regarded as changes affecting approval:

a) for TIG 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) a change from an argonox or heliox environment to an air or nitrox environment. The converse should not require requalification;

c) any increase above the absolute humidity level for flux based welding processes. Tests should normally be carried out at the maximum anticipated relative humidity.

**A.7.7** Items already listed in Table A.1 for which alternative requirements may have to be specified are as follows:

— item o: time lapse between runs (see **A.7.2**);

— item p: partially completed joints (see **A.7.2**);

— item j: 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 will result in substantially different monitored values of arc voltage. This factor should also be taken into account if calculating heat input values (see **A.7.1**).

**A.7.8** All test butt joints should be subject to non-destructive testing in accordance with **9.1**.

**A.7.9** Destructive testing should be performed in accordance with **9.2**.

**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 the requirements of clause **10** of this standard at the maximum simulated or actual depth.

**Table A.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 standard and strength grade | Any change |
| | b2 | Heat treatment condition[a] | Any change |
| | b3 | Composition[a] | A change greater than that permitted by Table A.2 |
| Diameter | c | Nominal outside diameter $D$ of pipe | A change outside the range $0.75D$ to $1.5D$ |
| Thickness | d | Nominal wall thickness $t$ of pipe | A change outside the range $0.75t$ to $1.5t$ |
| Joint configuration (with a sketch, including tolerances) | e | Pipe end preparation including the following: | |
| | e1 | Type of bevel | Any change |
| | e2 | Angle(s) of bevel[b] | Any change outside (unspecified) approved tolerances |
| | e3 | Size of root face[b] | Any change outside (unspecified) approved tolerances |
| | e4 | Width of root gap[b] | Any change outside (unspecified) approved tolerances |
| | e5 | Any use of backing rings | Any addition or deletion, or change of material |
| | e6 | Dimensions[b] of fillet welds | Not restricted as an essential variable |
| Electrode or filler metal | f | The following information is needed for each run: | |
| | f1 | Nominal diameter of filler/electrode core wire | Any change for the capping layer or the first two layers |
| | | | Any increase for other runs |
| | f2 | Trade name | Any change when Charpy testing is required |
| | f3 | Classification | Any change |
| | f4 | Any drying or pretreatment 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 |
| 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[a, b] | No separate restriction |

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

| Item | | Welding procedure specification details | Changes affecting approval (essential variables) |
|---|---|---|---|
| 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 root run and of second run welders | 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 |
| | 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 proposed 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 proposed 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 A.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, c] | Any | Value tested −0.06 or +0.03 |
| 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 % |

[a] For example, for carbon, if value tested was 0.10 % then values qualified are 0.06 % to 0.14 %.

[b] Carbon equivalent = $C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$

[c] The employer may specify a lower maximum for sour service.

NOTE 1 Requalification is required for carbon manganese steels of the same specified minimum yield strength only if the ladle analysis differs from that tested by more than the amounts given in this table. Alternatively the tolerance may be applied to the differences in product analysis.

NOTE 2 The "values qualified" limits 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 be considered for pipeline steels with carbon equivalent values >0.4.

**A.8.3** Approval should remain valid within the limits of the essential variables as detailed in **10.1**, **10.5** and **A.7.6**a).

**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 **10** of this standard at the maximum simulated or actual depth;

b) an alternative method agreed between the contracting parties.

NOTE 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 **11.4**.

NOTE In the case of single butt welds it may not be possible to achieve the separation of the longitudinal seam welds as indicated in **11.4**. In such cases, the reduced separation of longitudinal seam welds should be restricted to two adjacent pipes lengths.

**A.9.3** When preheating is not a requirement of the welding procedure, the contractor should have suitable 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 the procedures established in **A.7.2**.

**A.9.6** The removal of weld metal should be by machining, grinding or chipping. For safety reasons the arc or air-arc gouging using direct current, reverse polarity carbon electrodes should only be by agreement between the contracting parties and may 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** Non-destructive testing should be performed in accordance with clause **12** of this standard by appropriately qualified personnel.

The following points should be considered.

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

b) Radiography will normally 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 will normally involve the use of water based inks due to the possible toxic effects of other solvents.

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

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

**A.11.1** 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 anodic bonding leads

### B.1 Joining technique

Full details of the joining technique and associated equipment should be submitted to the employer for approval prior to use and should conform to the manufacturer's recommendations.

### B.2 Procedure qualification

Prior to starting, the contractor should submit a preliminary weld procedure specification to the employer for approval. 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 not be 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 50.

b) *Hardness survey*

Each section should be tested as described in 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 impressions; two in the heat-affected zone each side of the weld/braze and one in the parent metal each side of the weld/braze.

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, unless otherwise specified by the employer.

### 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) required in **B.2** above. All welding and tests should be witnessed by the employer.

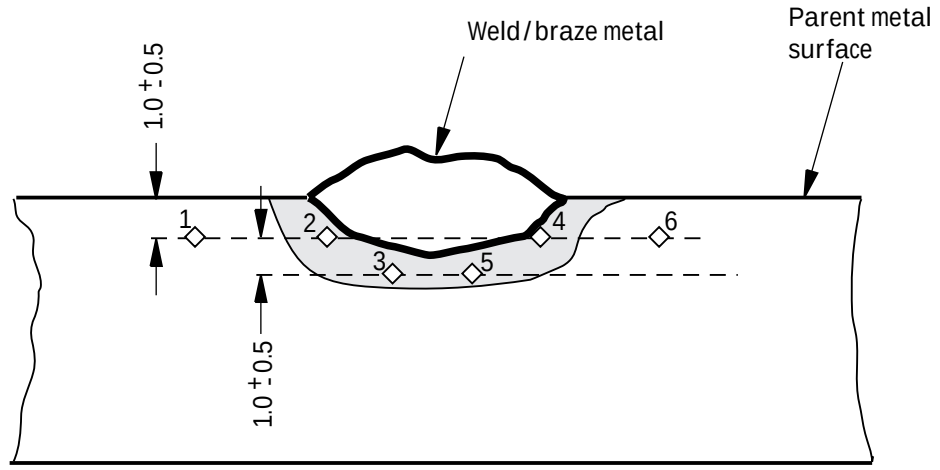
### B.4 Production joints

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 as specified in the approved procedure.

All attachments should be tested for mechanical strength (hammer test), followed by an electrical continuity test, both as recommended in **B.2**.

Should any attachment prove 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.

Dimensions in millimetres




Weld heat-affected zone (visible after etching)

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

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

## Annex C (informative)
## Proposed welding procedure specification

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

| **Proposed welding procedure specification** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Procedure no.: | | Revision no.: | | Outside diameter: | | Wall thickness: | | |
| **Material specification 1:** Composition: | | Grade: | | | Heat treatment: | | | |
| %A1: | %V: | %Ni: | | %Cu: | %Cr: | C.E.: | | |
| %Ti: | %N: | %Ca: | | %Nb: | %P: | | | |
| %C: | %Mn: | %Si: | | %S: | %Mo: | | | |
| **Material specification 2:** Composition: | | Grade: | | | Heat treatment: | | | |
| %A1: | %V: | %Ni: | | %Cu: | %Cr: | C.E.: | | |
| %Ti: | %N: | %Ca: | | %Nb: | %P: | | | |
| %C: | %Mn: | %Si: | | %S: | %Mo: | | | |
| Sketch of joint configuration | | Groove shape<br>Bevel angle: ±<br>Root face: ±<br>Root gap: ±<br>Backing ring: | | | Number and sequence of runs | | | |
| Welding processes<br>Number of filler wires for each pass: | | Manual: | | Semi-automatic: | | Mechanized: | | |
| Type of line-up clamp used:<br>Number of runs and minimum and maximum pressure applied: | | | | Number or 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:<br>Drying conditions: | | | Type:<br>Holding conditions: | | | |
| Filler metal | | Trade name:<br>Drying conditions: | | | Classification:<br>Holding conditions: | | | |
| Electrical characteristics<br>Name of process to be entered in first column, appropriate parameters from heading in other columns | | | | | | | | |
| MMA process<br>TIG process<br>Cont. wire processes | Pass number | Electrode diameter<br>Electrical stick-out | Trade name<br>Filler wire diameter | Power and polarity | Current (amps) | Electrodes per pass<br>Voltage (volts) | Run-out length<br>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<br>Maximum time lapse between start of root run and start of second run:<br>Nominal time lapse between start of second run and start of next run: | | | | | | | | |
| Minimum number of runs before lowering off/barge move-up:<br>Minimum number of runs before cooling to ambient temperature: | | | | | | | | |
| Method of powering cleaning tools: | | | | | | | | |
| Preheating | | Initial temperature of pipe before preheating/welding:<br>Method of heating:<br>Method of control: | | | Minimum temperature:<br>Method of measurement: | | | |
| Interpass temperature | | Minimum: | | | Maximum: | | | |
| Heat treatment required:<br>Method: | | Temperature: | | | Time at temperature: | | | |

**Figure C.1 — Example of proposed welding procedure specification**

<table>
<tr><td colspan="9">Welding procedure specification for production welding</td></tr>
<tr><td colspan="2">Procedure no.:</td><td colspan="2">Revision no.:</td><td colspan="2">Outside diameter:</td><td colspan="3">Wall thickness:</td></tr>
<tr><td colspan="3">Sketch of joint configuration</td><td colspan="2">Groove shape<br>Bevel angle: ±<br>Root face: ±<br>Root gap: ±<br>Backing ring:</td><td colspan="4">Number and sequence of runs</td></tr>
<tr><td colspan="2">Welding processes</td><td colspan="2">Manual:</td><td colspan="2">Semi-automatic:</td><td colspan="3">Mechanized:</td></tr>
<tr><td colspan="9">Number of filler wires for each pass:</td></tr>
<tr><td colspan="3">Type of line-up clamp used:</td><td colspan="6">Number or runs before removal of clamp:</td></tr>
<tr><td colspan="3">Welding position:</td><td colspan="6">Angle of pipe axis from horizontal:</td></tr>
<tr><td colspan="3">Vertical welding direction:</td><td colspan="6">Angle of torch, filler wire or electrode to weld line:</td></tr>
<tr><td colspan="9">Maximum width of any bead:</td></tr>
<tr><td colspan="3">Mechanized welding weave amplitude:</td><td colspan="3">Frequency:</td><td colspan="3">Dwell time:</td></tr>
<tr><td colspan="3">Shielding gas composition:</td><td colspan="6">Flow rate:</td></tr>
<tr><td colspan="2">Shielding flux</td><td colspan="3">Trade name:<br>Drying conditions:</td><td colspan="4">Type:<br>Holding conditions:</td></tr>
<tr><td colspan="2">Filler metal</td><td colspan="3">Trade name:<br>Drying conditions:</td><td colspan="4">Classification:<br>Holding conditions:</td></tr>
<tr><td colspan="9">Electrical characteristics<br>Name of process to be entered in first column, appropriate parameters from heading in other columns</td></tr>
<tr><td rowspan="3">MMA process<br>TIG process<br>Cont. wire processes</td><td rowspan="3">Pass number</td><td rowspan="2">Electrode diameter<br>Electrical stick-out</td><td>Trade name</td><td rowspan="3">Power and polarity</td><td rowspan="3">Current (amps)</td><td rowspan="2">Electrodes per pass<br>Voltage (volts)</td><td rowspan="2">Run-out length<br>Travel speed</td><td rowspan="3">Nominal heat input (kJ/mm)</td></tr>
<tr><td>Filler wire diameter</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Number of welders for root run:</td><td colspan="4">Number of welders for second run:</td></tr>
<tr><td colspan="9">For MMA welding with cellulosic electrodes<br>Maximum time lapse between start of root run and start of second run:</td></tr>
<tr><td colspan="9">Minimum number of runs before lowering off/barge move-up:<br>Minimum number of runs before cooling to ambient temperature:</td></tr>
<tr><td colspan="2">Preheating</td><td colspan="7">Initial temperature of pipe before preheating/welding:<br>Method of heating: Minimum temperature:<br>Method of control: Method of measurement:</td></tr>
<tr><td colspan="2">Interpass temperature</td><td colspan="7">Minimum: Maximum:</td></tr>
<tr><td colspan="9">Intermediate heat treatment required:<br>Method: Temperature: Time at temperature:</td></tr>
<tr><td colspan="9">Approvals:</td></tr>
<tr><td colspan="2">Contractor:</td><td colspan="3">Client:</td><td colspan="4">Other authorities:</td></tr>
</table>

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

| **As-run record of welding procedure qualification test** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| This weld was produced in accordance with proposed 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 | | | | | | | | | | | | | |

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

## Annex D (informative)
## Example of a 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*** | | | | | | | |

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

## Annex E (informative)
## Guidance for establishing preheating requirements

The following examples below show how the nomogram given in Figure E.1 can be used as guidance in establishing preheating requirements to avoid HAZ hydrogen cracking when welding vertical-down. For other cases BS 5135 may be used. However, for heavier wall pipe welded with higher strength cellulosic consumables, additional preheat may be necessary to avoid weld metal hydrogen cracking.

The following relationships have been used:

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

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

where

$V$ is the arc voltage (V);
$I$ is the welding current (A);
$w$ is the welding speed (mm/s);
$k$ is the thermal efficiency factor (0.8 for manual metal arc welding).

*Example 1*
Assume the following conditions:

| | |
|---|---|
| Heat input for single run weld: | 0.8 kJ/mm |
| Pipe thickness: | 12.5 mm |
| Pipe material carbon equivalent: | 0.39 |

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

Alternatively, this may 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: | 1.2 kJ/mm |
| Pipe thickness: | 25 mm |
| Pipe material carbon equivalent: | 0.43 |

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

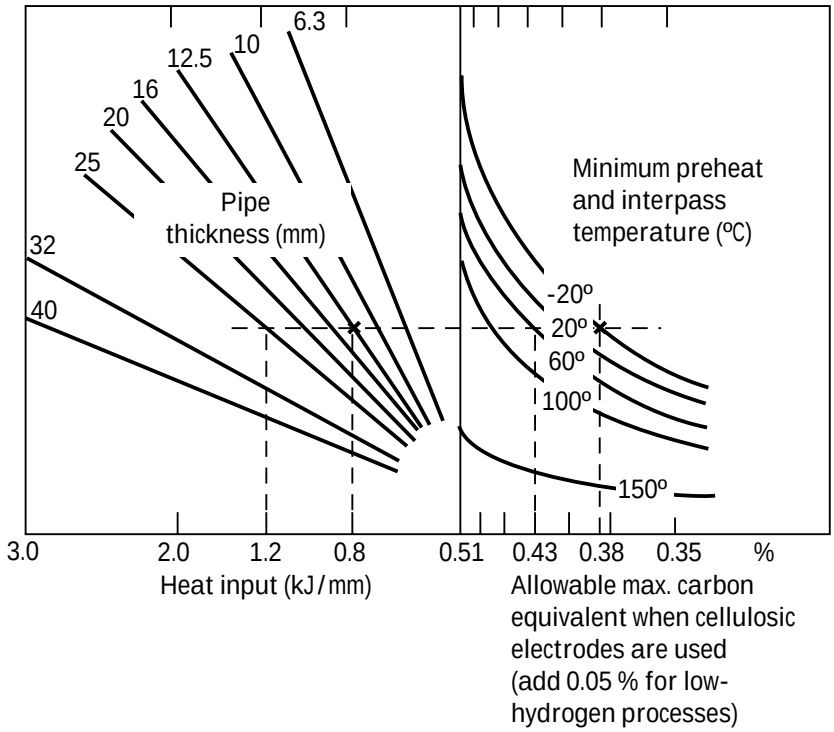


**Figure E.1 — Nomogram for preheating requirements**

## Annex F (informative)
## Example of a radiographic specification

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

| **Radiographic procedure specification** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Specification | | | | Procedure no. | | | |
| Project/contract | | | | | | | |
| Contractor | | | | | | | |
| Radiographic sub-contractor | | | | | | | |
| Pipe diameter | | | | | | | |
| Technique number (BS EN 1435) (Limitations of technique/procedure) | | | | | | | |
| Radiation source type | | | | | | | |
| Type of equipment<br>Tube voltage ... kilovolts<br>or<br>Source strength ... G. Becquerels | | | | External[a]<br>Internal[a]<br>Manually operated/cable[a]<br>Battery crawler device[a] | | | |
| Intensifying screen type<br>Thickness front<br>Thickness back | | | | Shielding<br><br>Beam collimation | | | |
| Filter type and placement | | | | | | | |
| Geometric relationship<br>Focus to film distance<br>Object to film distance<br>Focal spot size<br>Penumbra<br>Radiation angle (with respect to weld and film) | | | | Sketch | | | |
| Film type | | | | Cassette type or pre-packed[a] | | | |
| **Processing chemicals** | **Developer** | | **Stop bath** | **Fixer** | **Wash** | **Wash-additive** | |
| Make/type | | | | | | | |
| Time/temperature | | | | | | | |
| Diagnostic film length | | | | Number of exposures | | | |
| IQI type: | Placement: | | | Film/source side[a] | | Position: | |
| Exposure conditions | | | | | | | |
| **Parameters** | **Wall thickness** (mm) | | | | | | |
| kV | | | | | | | |
| mA | | | | | | | |
| Exposure time | | | | | | | |
| | Radiographic sub-contractor | | Contractor | | | | |
| | Signed<br>Name<br>Title<br>Date | | Signed<br>Name<br>Title<br>Date | | | Signed<br><br><br>Approved subject to qualification | |
| [a] Delete as appropriate. | | | | | | | |

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

*blank*

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