INTERNATIONAL STANDARD

ISO 13847

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Petroleum and natural gas industries — Pipeline transportation systems — Welding of pipelines

Industries du pétrole et du gaz naturel — Conduites pour systèmes de transport — Soudage des conduites

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 13847 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

Annexes A, B, C and D of this International Standard are for information only.

Introduction

Users of this International Standard should be aware that further or differing requirements may be needed for individual applications. This International Standard is not intended to inhibit a contractor from offering, or the company from accepting, alternative engineering solutions for the individual application. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the manufacturer should identify any variations from this International Standard and provide details.

Petroleum and natural gas industries — Pipeline transportation systems — Welding of pipelines

1 Scope

This International Standard specifies the requirements for producing and inspecting girth, branch and fillet welds in the pipeline part of pipeline transportation systems for the petroleum and natural gas industries meeting the requirements of ISO 13623.

This International Standard is applicable to the requirements for welding of carbon and low-alloy steel pipes. Application is restricted to pipes with a diameter of 20 mm and larger and wall thickness of 3 mm or more, and a specified minimum yield strength of 555 MPa or less. It is also applicable to welding into pipelines, items such as spools, risers, launchers/receivers, fittings, flanges and “pups” to pipeline valves.

The welding processes covered are shielded metal arc welding, gas tungsten arc welding, gas metal arc welding, flux-cored arc welding with and without shielding gas, and submerged arc welding.

This International Standard is not applicable to flash girth welding, resistance welding, solid-phase welding or other one-shot welding processes, nor to longitudinal welds in pipe or fittings, to “hot-tap” welding of pipelines in service or to the welding of process piping outside of the scope of ISO 13623.

NOTE Additional requirements may be necessary for welding of pipeline for particular pipeline operating conditions. These can include limitations on maximum hardness or strength, minimum impact toughness values, crack tip-opening displacement, all weld metal tensile testing or bend testing, thermal stress relief or others. Where appropriate, these additional requirements should be added to the requirements of this International Standard in a project-specific supplement.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 148:1983[1)], Steel — Charpy impact test (V-notch).

ISO 857-1:1998, *Welding and allied processes — Vocabulary — Part 1: Metal welding processes.*

ISO 1106-3:1984, *Recommended practice for radiographic examination of fusion welded joints — Part 3: Fusion welded circumferential joints in steel pipes of up to 50 mm wall thickness.*

ISO 3452:1984, *Non-destructive testing — Penetrant testing — General principles.*

ISO 3453:1984, *Non-destructive testing — Liquid penetrant inspection — Means of verification.*

ISO 4136:1989, *Fusion-welded butt joints in steel — Transverse tensile test.*

1) To be replaced by ISO 148-1:— (to be published), ISO 148-2:1998 and ISO 148-3:1998.

ISO 5173, *Destructive tests on welds in metallic materials — Bend test.*

ISO 6507-1:1997, *Metallic materials — Vickers hardness test — Part 1: Test method.*

ISO 6520-1:1998, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding.*

ISO 6947:1990, *Welds — Working positions — Definitions of angles of slope and rotation.*

ISO 7963:1985, *Welds in steel — Calibration block No. 2 for ultrasonic examination of welds*.

ISO 9712:1999, *Non-destructive testing — Qualification and certification of personnel.*

ISO 9935:1992, *Non-destructive testing — Penetrant flaw detectors — General technical requirements.*

ISO 9956-2:1995, *Specification and approval of welding procedures for metallic materials — Part 2: Welding procedure specification for arc welding.*

ISO 9956-3:1995, *Specification and approval of welding procedures for metallic materials — Part 3: Welding procedure tests for arc welding of steels.*

ISO 10474:1991, *Steel and steel products — Inspection documents.*

ISO 13623:2000, *Petroleum and natural gas industries — Pipeline transportation systems.*

ISO 14732:1998, *Welding personnel — Approval testing of welding operators for fusion welding and of resistance weld setters for fully mechanized and automatic welding of metallic materials.*

EN 876:1995[2)], *Destructive tests on welds in metallic materials — Longitudinal tensile test on weld metal in fusion welded joints.*

EN 1043-1:1995, *Destructive tests on welds in metallic materials — Hardness testing — Part 1: Hardness test on arc welded joints.*

EN 1321:1996, *Destructive tests on welds in metallic materials — Macroscopic and microscopic examination of welds.*

ASME[3)] *Boiler and Pressure Vessel Code Section V:1998, Nondestructive examination*.

AWS A5.01-93:1993[4)], *Filler metal procurement guidelines.*

AWS C5.3-91:1991, *Recommended practices for air carbon arc gouging and cutting.*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 857-1, ISO 6520-1 and the following apply.

3.1
approved welder
welder who has been approved in accordance with the requirements of this International Standard

2) CEN, European Committee for Standardization, Management Centre, Rue de Stassart 36, B-1050, Brussels, Belgium.

3) American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

4) The American Welding Society, 550 NW LeJeune Road, Miami, FL 33126, USA.

3.2
approved welding operator
welding operator who has been approved in accordance with the requirements of this International Standard

3.3
approved welding procedure specification
welding procedure specification which has been approved in accordance with the requirements of this International Standard

[ISO 9956-1:1995]

3.4
arc energy
product of welding voltage and current divided by travel speed of welding

NOTE The often-used term “heat input” is more correctly the arc energy modified by an arc efficiency factor.

3.5
by agreement
agreed between the company and the contractor

3.6
company
owner company or the engineering agency in charge of construction

NOTE The company may act through an inspector or other authorized representative. The company may also be the contractor in some instances.

3.7
contractor
entity that actually performs the work covered by this International Standard

3.8
girth weld
circumferential butt weld in pipe

3.9
internal repair
repair of the root pass from inside the pipe

3.10
mechanized welding
welding process in which the welding parameters and torch guidance are controlled mechanically or electronically but may be manually varied during welding to maintain the required welding conditions

3.11
one-shot welding process
process characterized by fusion or metallic bonding being induced around the entire circumference of the pipe simultaneously

EXAMPLES Flash welding, friction welding or pressure welding.

3.12
penumbra
shadow produced on a radiographic image when the incident radiation is partially, but not wholly, cut off by an intervening body

NOTE It is the region of geometric unsharpness around the image of an indication.

3.13
roll welding
welding process in which two pipes are abutted in a horizontal position and rotated while one or more welding passes are deposited between previously prepared bevels on the abutting ends

3.14
test piece
welded assembly prepared for the purpose of approving a welding procedure specification, welder or welding operator

3.15
welder
person who holds and manipulates the electrode holder, welding gun, torch or blowpipe by hand

[ISO 9606-1:1994/Amd.1:1998]

3.16
weld repair
process of correcting a defect that is discovered after the weld has been completed and submitted for inspection

NOTE The repair may involve complete removal of a cylinder of pipe or removal of a localized area by grinding or other means followed by additional welding.

3.17
welding operator
person who performs mechanized and/or automatic welding

[ISO 14732:1998]

3.18
welding procedure
specific course of action to be followed in making a weld, including reference to materials, preparation, preheating (if necessary), method and control of welding and post-weld heat treatment (if necessary) and equipment to be used

[ISO 9956-1:1995]

3.19
welding procedure specification
WPS
document providing the required variables for a specific welding procedure

4 Symbols and abbreviated terms

AWT	All-weld-metal tensile test
CE	Carbon equivalent
CRA	Corrosion-resistant alloy
CTOD	Crack tip opening displacement
DAC	Distance amplitude correction
ECA	Engineering critical assessment
GMAW	Gas metal arc welding (Process ISO 4063-13)

GSFCAW	Gas-shielded flux-cored arc welding (Processes ISO 4063-136, 137)
GTAW	Gas tungsten arc welding (Process ISO 4063-141)
HAZ	Heat-affected zone
HV	Vickers hardness
IQI	Image quality indicator
LPE	Liquid penetrant examination
MPE	Magnetic particle examination
NDE	Non-destructive examination
OD	Outside diameter of pipe
P_{cm}	Cracking compositional parameter
PWHT	Post-weld heat treatment
r	Nominal internal radius
SAW	Submerged arc welding (Process ISO 4063-12)
SMAW	Shielded metal arc welding (Process ISO 4063-111)
SMYS	Specified minimum yield strength
SSFCAW	Self-shielded flux-cored arc welding (Process ISO 4063-114)
t	Wall thickness
UE	Ultrasonic examination
VE	Visual examination
WPS	Welding procedure specification

5 Welding procedure specification testing and approval

5.1 General

For approval of a WPS, test pieces shall be welded, inspected and tested in accordance with ISO 9956-3 and 5.3 and 5.4 of this International Standard.

A WPS shall be deemed to be approved only if all the requirements for approval specified in this International Standard and the supplementary requirements specified by the company have been met.

An inspector accepted by the company shall witness the welding and testing of the test pieces for the approval of a WPS.

Prior to the start of production welding, the contractor shall submit to the company for agreement either the preliminary WPS(s) to be approved, or the WPS(s) already approved, in accordance with this International Standard. This process may be omitted when the company has supplied the contractor with an appropriately approved WPS.

Test pieces should be welded using project-specific materials.

5.2 Welding procedure specification

The WPS shall incorporate the technical contents specified in ISO 9956-2, in 5.6 of this International Standard and, when applicable, the following:

— steel grade and supply condition;

EXAMPLES Normalized, quenched and tempered, cold-formed and thermomechanically processed, normalizing formed.

— number and location of welders;

— time lapse between start of root pass and start of second (hot) pass;

— type of line-up clamp or tack welding;

— preheating procedure;

— extent of welding required before removal of line-up clamp or other line-up device;

— part of weld to be completed before joint is permitted to cool to ambient temperature;

— method for control of cooling;

— part of weld to be completed before lowering off, i.e. from side boom to pipe support, or barge move-up;

— action required for partially completed welds.

The company may require information on the method used for NDE of test welds to be documented.

Where the intended installation and/or service application of the welded pipeline involves significant plastic strain, such as during pipe-reeling or J-tube installation, the use of documented strain-ageing data and/or supplementary testing should be considered to demonstrate adequate evidence of strain-ageing resistance.

Weldability tests may be required to provide the necessary information for the selection of welding variables for a WPS.

All relevant welding parameters and variables shall be specified individually in accordance with ISO 9956-2 if a previously approved WPS is offered to the company for agreement.

NOTE For steel grades with increased susceptibility to delayed hydrogen cracking due to welding, such as with a SMYS of 555 MPa or higher, the WPS may be designed to prevent such cracking from occurring. The welding of these grades of pipe may also require the use of low hydrogen processes, PWHT, and a delay period prior to inspection.

5.3 Welding of test piece

5.3.1 Preliminary WPS

The preparation for and welding of test pieces shall be carried out in accordance with a documented preliminary WPS.

5.3.2 Test welding conditions

Test pieces should be welded under conditions that simulate those of the site production location (see 7.3 and 7.4).

5.3.3 Welding position

Welding positions and limitations for the angle of slope and rotation of the test piece shall be in accordance with ISO 6947.

5.3.4 Tack welds

Test pieces shall be tack-welded only if tack welding is necessary during production welding.

5.3.5 Shape and dimensions of test pieces

5.3.5.1 Girth welds

Test pieces for the approval of a WPS for girth welding shall be made by joining pipes with a minimum length of one diameter or 300 mm, whichever is greater. Certain situations may require the use of full pipelengths.

5.3.5.2 Branch connections and fillet welds

Test pieces for the approval of a WPS for welding branch connections or fillet welds shall be of the shape and dimensions specified in ISO 9956-3.

5.3.5.3 Welds between different materials

Test pieces may be welded for the approval of a WPS from two different materials, provided the test pieces can provide sufficient material for all the testing required for each material.

EXAMPLE A weld between pipe and a forged flange is subjected to appropriate mechanical testing on both sides of the weld.

5.4 Inspection and testing of test pieces

5.4.1 Scope of inspection and testing

The extent of inspection and testing of test pieces for the approval of a WPS for girth welding shall be in accordance with Table 1.

Table 1 — Inspection and testing of the test pieces for girth welding

Type of inspection/test	Extent of inspection/testing
Visual	100 %
Radiographic[a]	100 %
Transverse tensile test	2 specimens
Impact test[b]	2 sets for $t \leqslant 20$ mm 4 sets for $t > 20$ mm
Macro-examination and hardness test[c]	1 specimen
All-weld-metal tensile test[d]	by agreement

[a] This may be supplemented by UE by agreement.

[b] Tests may not be required for pipe with $t \leqslant 12$ mm or with SMYS < 360 MPa.

[c] The company may decide that, for material with SMYS < 420 MPa, hardness testing is not necessary.

[d] Optional requirement to confirm overmatching of the yield strength of the weld metal.

The extent of inspection and testing of test pieces for the approval of a WPS for fillet and branch welds shall be established by agreement.

5.4.2 Non-destructive examination

All test pieces shall be examined visually and non-destructively in accordance with clause 8 following any required PWHT and prior to cutting of the test specimens.

Test welds for the approval of a WPS for shop welding shall be subjected to NDE no sooner than 24 h after completion of welding.

The NDE shall be reported in accordance with clause 8 and the results shall meet the acceptance criteria in clause 9.

5.4.3 Destructive testing — Girth welding

5.4.3.1 Cutting of test specimens

Test specimens shall be taken from test pieces which have met the acceptance criteria for NDE. Test pieces which fail to meet these criteria shall be disregarded for destructive testing for WPS approval.

Test specimens may be taken from locations free of acceptable imperfections revealed by NDE.

Locations of test specimens for fixed horizontal-position welding and fixed vertical-position welding should be in accordance with Figures 1 and 2. Locations of test specimens for roll welding may be selected from Figure 1 or Figure 2.

Key:

1 Area 1 for:
— 1 tensile specimen

2 Area 2 for:
— Impact and additional test specimens if required

3 Area 3 for:
— 1 tensile specimen

4 Area 4 for:
— 1 macro test specimen
— 1 hardness test specimen

5 Area 5 for:
— AWT specimens

6 Top for fixed pipe

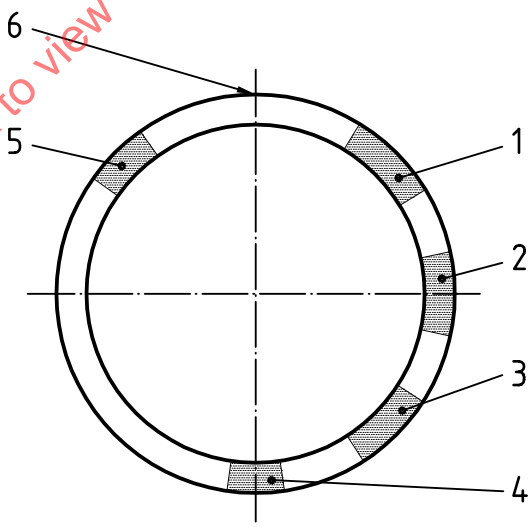
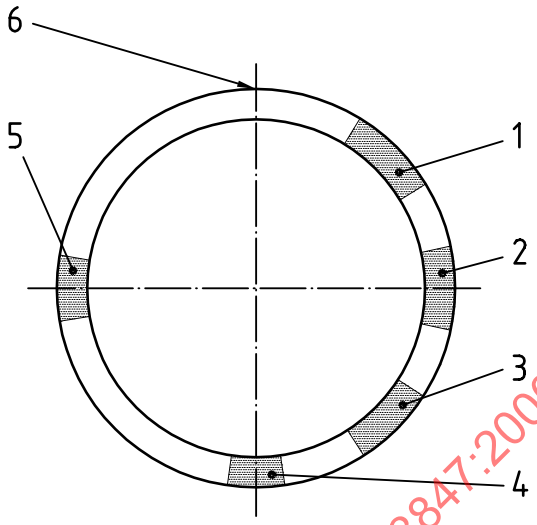


Figure 1 — Location of test specimens for a fixed-position girth weld in pipe for upwards welding



Key:

1 Area 1 for:
— 1 tensile specimen

2 Area 2 for:
— 1macro test specimen
— 1 hardness test specimen

3 Area 3 for:
— 1 tensile specimen

4 Area 4 for:
— Impact and additional test specimens if required

5 Area 5 for:
— AWT specimens

6 Top for fixed pipe

Figure 2 — Location of test specimens for a fixed-position girth weld in pipe for downwards welding

5.4.3.2 Degassing of test specimens

By agreement, and only for welds made using cellulosic-coated electrodes, test specimens may be degassed by heat treatment at 250 °C for a period not exceeding 10 h.

5.4.3.3 Test temperature

Destructive testing shall be performed at ambient temperature except for impact testing (see 5.4.3.5) or CTOD testing. For design-service temperatures greater than 75 °C, consideration should be given to performing elevated-temperature tensile tests.

5.4.3.4 Transverse tensile testing

Transverse tensile specimens shall be prepared and tested in accordance with ISO 4136.

For pipes greater than 50 mm OD, the weld reinforcement shall be removed on both faces of the specimen. Removal of the reinforcement is not required for specimens from pipe with an OD of 50 mm or less.

When testing full-section small-diameter pipes, the weld reinforcement may be left undressed on the inside surface of the pipe if removal of the reinforcement is not possible.

Specimens shall fail in the pipe or the weld metal at the specified minimum tensile strength or higher or in the pipe metal outside the weld or fusion zone at a stress of 95 % of the specified minimum tensile strength or higher.

Failure of specimens outside the weld or fusion zone at less than 95 % of the specified minimum tensile strength may be an indication of a base material deficiency, and an equal number of additional specimens shall be cut from the same test joint for tensile testing. These additional specimens shall fail at the specified minimum tensile strength or higher.

If any of the additional specimens break outside the weld or fusion zone below the tensile strength stated, the pipe shall be considered suspect, and its physical properties investigated and confirmed to meet specified values before continuing with test welding for WPS approval.

5.4.3.5 Impact testing

Charpy V-notch specimens shall be sampled from 1 mm to 2 mm below the surface of the parent metal and tranverse to the weld direction, as indicated in Figure 3. Full-size Charpy specimens shall be utilized where pipe wall thickness permits.

For each location indicated in Figure 3, a single impact test set shall comprise three test specimens.

For weld metal tests, the specimen notch shall be at the weld centreline. For HAZ tests the notch shall be located with the HAZ-weld fusion line through the centreline of the vertical V-notch.

Specimen dimensions and test procedure shall be in accordance with ISO 148. The test temperature shall be the minimum design temperature.

The results of full-size specimen impact testing for welds in pipe with a wall thickness of 25 mm or less shall meet the following requirements.

a) The average value for each set of Charpy V-notch specimens shall not be less than 40 J.

b) The minimum individual value for a maximum of one specimen of the three shall not be less than 30 J.

The above impact energy value requirements may be reduced *pro rata* for sub-size specimens.

By agreement, for welds in pipe with a wall thickness in excess of 25 mm, higher impact energy values or CTOD testing may be specified.

5.4.3.6 Macro-examination

Specimens and method of macro-examination for the approval of a WPS shall be in accordance with EN 1321.

For PG, PF, H-L045 and J-L045 welding positions (see Figure 4), one specimen shall be taken at a location corresponding approximately to the 3 o'clock position and one specimen corresponding approximately to the 6 o'clock position.

The specimens shall be free from cracks and lack of fusion. Any other imperfections shall be within the limits specified in clause 9.

5.4.3.7 Hardness testing

Hardness testing shall be in accordance with ISO 6507-1 using the Vickers method with a test force of 98,07 N.

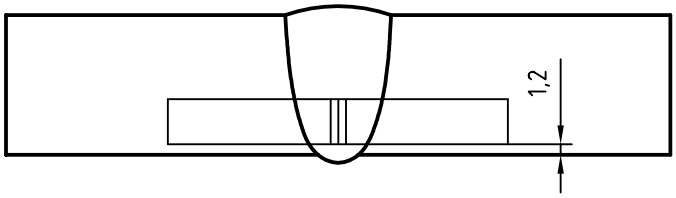
NOTE A test force of 49,03 N may be necessary for the narrow heat-affected zone in some welds made with mechanized or automatic processes.

Hardness shall be measured and recorded in rows across the weld metal, the HAZ and the parent metal as indicated in EN 1043-1. For the HAZ, the first indentation shall be made as close as possible to the fusion line. The precise locations of each row shall be by agreement.

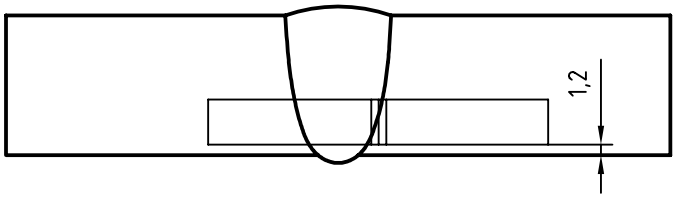
The results from hardness testing shall meet the requirements given in Table 2. By agreement, retesting is permitted only in the event that a single hardness value exceeds the maximum allowable values of Table 2.

Parent material hardness results shall be for information only.

Dimensions in millimetres

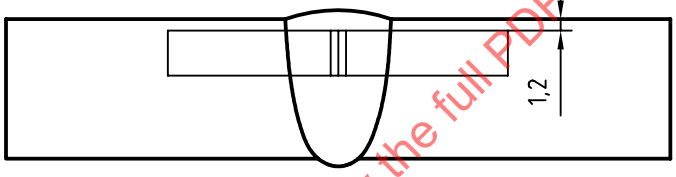


Notch location: Weld metal root

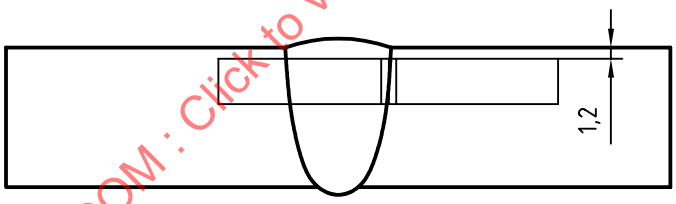


Notch location: HAZ root

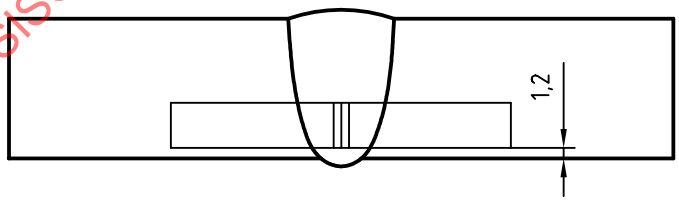
a) Wall thickness ⩽ 20 mm



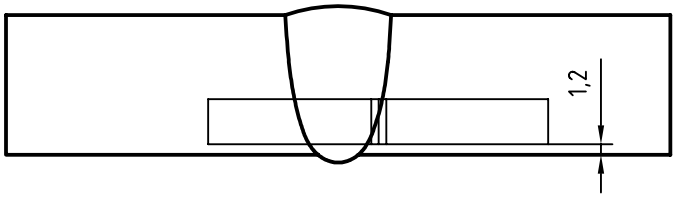
Notch location: Weld metal



Notch location: HAZ



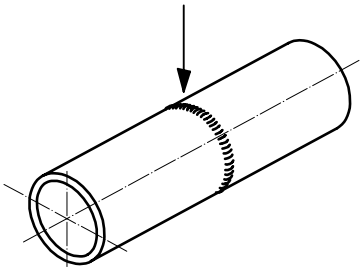
Notch location: Weld metal root



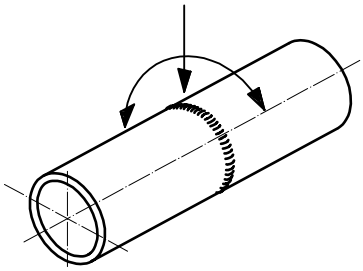
Notch location: HAZ root

b) Wall thickness > 20 mm

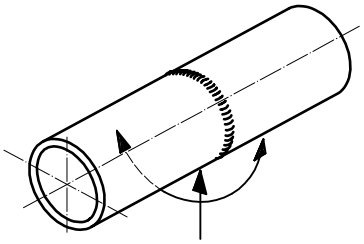
Figure 3 — Position of Charpy V-notch specimens



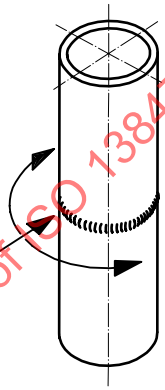
PA pipe: rotating
axis: horizontal
weld: flat



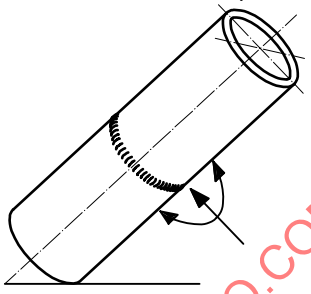
PG pipe: fixed
axis: horizontal
weld: vertical downward



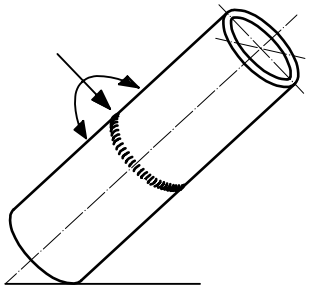
PF pipe: fixed
axis: horizontal
weld: vertical upward



PC pipe: fixed
axis: vertical
weld: horizontal



H-L045 pipe: fixed
axis: inclined
weld: upward



J-L045 pipe: fixed
axis: inclined
weld: downward

Figure 4 — Welding positions (ISO 6947)

Table 2 — Permissible maximum hardness values

Hardness location	Weld metal HV_{10}		HAZ HV_{10}	
	Root	Cover	Root	Cover
Sour service[a] and all welding processes:				
$t \leqslant 9{,}5$ mm	250	275	250	275
$t > 9{,}5$ mm	250	275	250	300
Non-sour service and all thicknesses:				
Manual welding cellulosic electrodes	275	275	275	325
Other welding processes	275	275	350	350

[a] The company shall specify when sour service requirements are to apply.

5.4.3.8 All-weld-metal tensile testing

When required by the company, test specimens for AWT shall be prepared and tested in accordance with EN 876.

The measured yield strength shall be greater than or equal to the SMYS of the parent pipe metal, or another value established by agreement.

5.4.4 Destructive testing — Branch and fillet welds

Test pieces for the approval of a WPS for fillet welding shall be tested as specified in Table 1 of ISO 9956-3:1995 and the additional fracture testing specified below.

For pipe with a diameter of 168,3 mm or less, two fracture test specimens shall be taken from the test piece. Four specimens shall be taken for pipe with a diameter above 168,3 mm.

The specimens shall be taken from diametrically opposed positions around the circumference.

Fracture tests shall be performed by breaking specimens with the root of the weld in tension, using one of the following methods:

— supporting both ends and striking the centre of the specimen; or

— gripping one end and striking the other.

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

a) Gas pores: the greatest dimension of any single pore shall not exceed 20 % of the wall thickness or 3 mm, whichever is smaller. The combined area of all pores shall not exceed 5 % of the affected area.

b) Inclusions: individual inclusions shall not be greater than 1 mm in depth and 3 mm or 50 % of the wall thickness in length, whichever is less. There shall be at least 12 mm of sound metal between adjacent inclusions.

5.5 Re-testing

5.5.1 General

A new preliminary WPS may be prepared for approval testing in case a test piece fails to comply with the requirements of this International Standard for WPS approval.

5.5.2 Re-testing for approval of WPS

In case of failure to meet the requirements for destructive testing in 5.4.3 resulting from the presence of weld imperfections, two further test specimens shall be obtained for each test specimen that failed. If either of these additional specimens does not comply with the requirements, the preliminary WPS shall be regarded as not complying with this International Standard, and shall be modified before continuing with test welding.

In case of failure to meet the requirements for destructive testing in 5.4.3 for other reasons, one additional test piece may be welded and subjected to the same inspection and testing.

5.6 Essential variables and range of approval

5.6.1 General

An approved WPS shall be applied during production welding within the ranges for the essential variables specified in this International Standard.

NOTE The specified variations relate to the materials properties and welding parameters for the welding of the test piece.

A change in one or more of the essential variables beyond the specified range requires the approval of another WPS in accordance with this International Standard.

5.6.2 Related to the contractor

An approval of a WPS obtained by a contractor is valid in workshops or sites of that contractor under identical or equivalent technical and quality control.

Transfer of an approved WPS between contractors should be treated with extreme caution, and requires the agreement of the company.

5.6.3 Related to the material

5.6.3.1 Steel grade

Except for pipes with a SMYS of 290 MPa or lower, the approved WPS should only be used for material of the same steel grade.

5.6.3.2 Chemical composition

Based on product analysis, the CE value may be increased by 0,030 max. or the P_{cm} value by 0,020 max. For sour service, consideration should be given to reducing these increases.

CE and P_{cm} shall be calculated as follows:

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

5.6.3.3 Supply condition

The WPS shall be approved only for welds in material of the same supply condition.

5.6.3.4 Thickness

For girth welding, the approved pipe thickness range shall be 0,75 to 1,5 times the wall thickness of the test piece.

For branch and fillet welding, the approved thickness range shall be as specified in ISO 9956-3.

5.6.3.5 Pipe diameter

The pipe diameter shall be as indicated in Table 3.

Table 3 — Range of approval for pipe diameter

Outside diameter of the test piece OD mm	Range of approval
⩽ 168,3	0,5 OD to 2 OD
>168,3	⩾ 0,5 OD

5.6.4 Related to all welding processes

5.6.4.1 Welding process

The WPS approval is valid only for the welding process(es) used for welding of the test piece. The sequence of welding processes, if more than one process is used, shall not be changed. These requirements shall also apply to the approval of a WPS for weld repair.

5.6.4.2 Welding positions

For the purpose of this International Standard, the welding positions in Figure 4 shall apply.

For girth, branch and fillet welding, an approved WPS may be used for the welding positions as specified in Table 4.

A variation in the pipe angle of up to 25° may be applied to each welding position.

Table 4 — Range of approval for welding positions

Position of test piece	Approved positions					
	PA	PG	PF	PC	H-L045	J-L045
PA	approved	not approved	not approved	not approved	not approved	not approved
PG	approved	approved	not approved	not approved	not approved	not approved
PF	approved	not approved	approved	not approved	not approved	not approved
PC	approved	not approved	not approved	approved	not approved	not approved
H-L045	approved	not approved	not approved	not approved	approved	not approved
J-L045	approved	not approved	not approved	not approved	not approved	approved

5.6.4.3 Weld preparation

The approved WPS shall be used within the tolerances for weld preparation specified in the WPS.

5.6.4.4 Type of joint

The approved WPS should be used for the types of joint indicated in Table 5.

Table 5 — Range of approval for type of joint

Type of joint in test piece	Approved types of joint		
	Girth weld		Fillet welds
	with backing	no backing	
Girth weld with backing	approved	not approved	approved
Girth weld without backing	approved	approved	approved
Fillet weld	not approved	not approved	approved

5.6.4.5 Filler metal

Except when impact testing and/or AWT is required, filler metal of the same consumable classification shall be used.

If impact testing and/or AWT are required for WPS approval, the range of approval only covers the specific make or brand used during the welding of the test piece except as otherwise stated below.

A change in the specific make or brand may be made when impact testing and/or AWT are required, provided a new test piece is prepared in accordance with the WPS for impact testing and/or AWT of the weld metal. The tested make or brand may be used, provided the results of the weld metal impact testing and/or AWT meet the requirements of 5.4.3.5 and/or 5.4.3.8.

5.6.4.6 Type of current

The approval applies to the same type of current (alternating current, direct current or pulsed current) and polarity as used for the welding of the test piece.

5.6.4.7 Arc energy

Arc energy is an essential variable when hardness and/or impact testing are required for WPS approval.

When impact testing is required, the approved range for the arc energy shall extend from the arc energy recorded during welding of the test piece to 15 % below this value.

When hardness testing is required, the approved range for arc energy shall extend from the arc energy recorded during welding of the test piece to 15 % above this value. For sour service, the arc energy should not fall below that recorded during approval testing.

5.6.4.8 Preheat temperature

The approved range of the preheat temperature shall extend from the preheat temperature recorded during the welding of the test piece and up to 50 °C higher.

5.6.4.9 Interpass temperature

The approved range for the interpass temperature shall extend from the preheat temperature up to the maximum interpass temperature recorded during the welding of the test piece.

5.6.4.10 Post-weld heating

When applied, the approved range for the time and duration of post-weld heating for hydrogen removal shall be the time and duration recorded during the welding of the test piece or above.

5.6.4.11 Post-weld heat treatment

The ranges of soaking temperature, soaking time and heating and cooling rates shall be those shown on the WPS.

5.6.4.12 Type of line-up clamp

The approved type of line-up clamp shall be limited to the clamp used for welding of the test piece.

5.6.4.13 Removal of line-up clamp

The line-up clamp shall not be removed before the weld has been completed to at least the same extent as at the time of clamp removal during welding of the test piece.

Weld completion can be expressed as a percentage of circumference of the weld, the number of passes or combination thereof.

5.6.4.14 Back-gouging, grinding and back-welding

Back-gouging, grinding and back-welding shall not deviate from the procedure followed for welding of the test piece.

5.6.4.15 Time interval

When welding with non-hydrogen-controlled consumables or processes, the time lapse between the start of the root and of the second pass shall not exceed the time lapse recorded during welding of the test piece.

EXAMPLE Cellulosic electrodes are an example of non-hydrogen-controlled consumables.

5.6.4.16 Root pass welders

The number of root pass welders shall be at least as many as during welding of the test piece.

5.6.5 Related to specific welding processes

5.6.5.1 Shielded metal arc welding and self-shielded flux-cored arc welding

A change in electrode diameter shall not be permitted in the first two layers on single-sided girth welds made without backing. For other welds, the approved diameter range of the electrode for each pass shall be from one size down to one size up from the electrode diameter used during the welding of the test piece.

NOTE Changing the electrode size may result in a change in arc energy to a value outside the approved range.

5.6.5.2 Submerged arc welding

The approved wire diameter and system shall be limited to the wire diameter and system, such as a single-wire or multiple-wire system, used in the welding of the test piece.

The approved flux shall be limited to the flux with the same make and classification as used during welding of the test piece.

The following welding parameter tolerances shall apply.

a) The approved range for the travel speed for any pass shall be the travel speed recorded during the welding of the test piece ± 10 %.

b) The approved range for the voltage for any pass shall be the voltage recorded during the welding of the test piece ± 10 %.

c) The approved range for wire feed speed or current setting for any part of the weld shall be the speed or current recorded during the welding of the test piece ± 10 %.

d) The approved range for the distance between contact tip and work piece for any pass shall be the distance recorded during the welding of the test piece ± 5 mm.

5.6.5.3 Gas metal arc welding and gas-shielded flux-cored arc welding

The approval given to the face and/or back-shielding gas shall be restricted to the type of gas and composition (see 7.11) used during the welding of the test piece.

The approval given to the wire diameter and system, such as single-wire or multiple-wire system, shall be restricted to the diameter and system used during the welding of the test piece.

The following welding parameter tolerances shall apply.

a) The approved range for the travel speed for any pass shall be the travel speed recorded during the welding of the test piece ± 10 %.

b) The approved range for wire feed speed or current setting for any part of the weld shall be the speed or current recorded during the welding of the test piece ± 10 %.

c) The approved range for the distance between contact tip and work piece for any pass shall be the distance recorded during the welding of the test piece ± 5 mm.

5.6.5.4 Gas tungsten arc welding

The approval given to the face- and/or back-shielding gas shall be restricted to the type of gas (nominal composition) used during the welding of the test piece.

The approved range for current setting is the setting used during the welding of the test piece ± 10 %.

5.6.5.5 Face-shielding gas flowrate

For processes GMAW, GSFCAW and GTAW, the approved range for the face-shielding gas flowrate is the flowrate recorded during the welding of the test piece ± 15 %.

5.7 Welding procedure specification for repair welding

The WPS used for the original weld may also be used for repair welding, provided the essential variables for the repair welding are within the ranges approved for the WPS except for the following repair types, which shall have a separate approval test:

— repair weld consisting of a single pass;

— internal repairs;

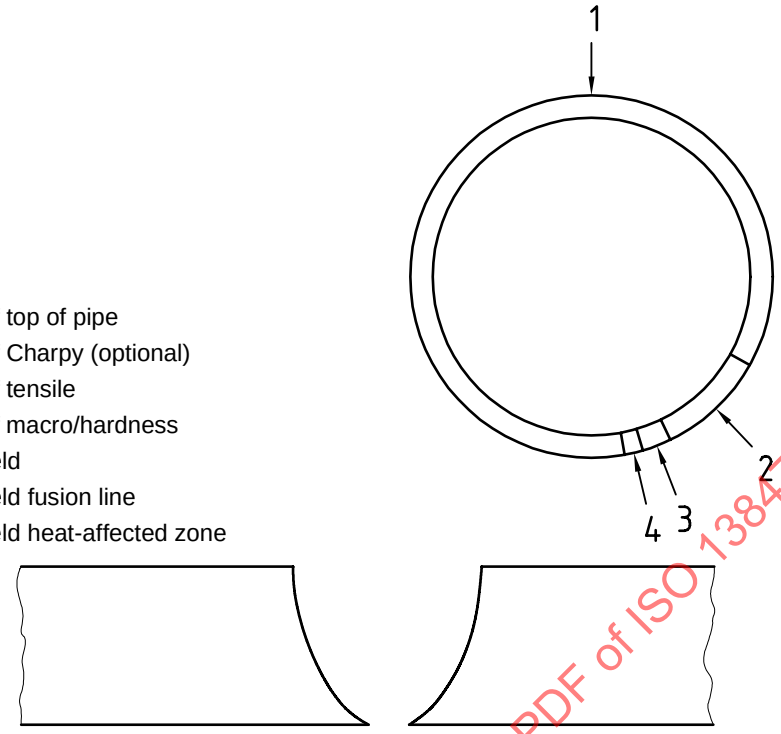
— repair of a weld joining materials with a SMYS exceeding 360 MPa.

The requirements for the approval of a WPS for repair welding shall be established by agreement.

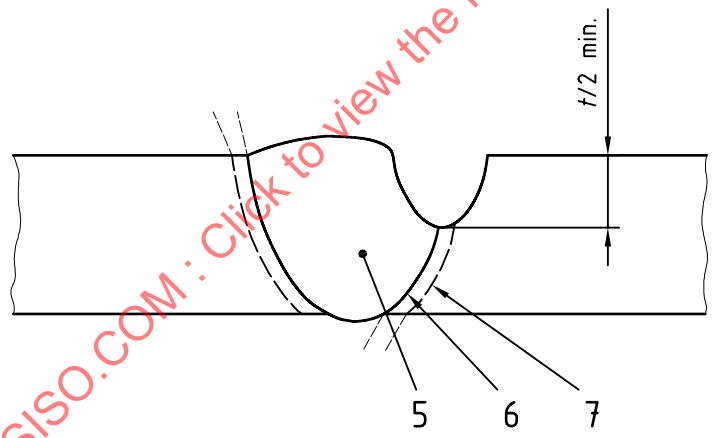
The groove for repair-welding tests shall be located typically as shown in Figure 5 and may include excavation of weld deposit or HAZ and parent metal. The extent of testing and examination, including the number and locations of test specimens, shall be established by agreement.

Key:

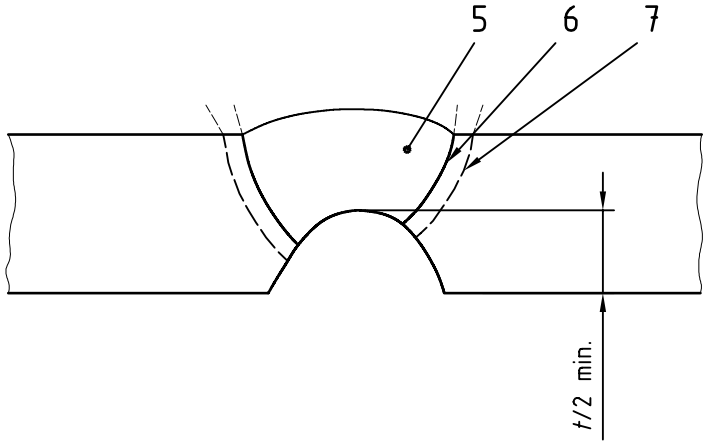
1 Location of top of pipe
2 Location of Charpy (optional)
3 Location of tensile
4 Location of macro/hardness
5 Original weld
6 Original weld fusion line
7 Original weld heat-affected zone



a) Full/re-repair



b) Partial penetration repair



c) Multi-pass back-weld repair

Figure 5 — Location of repair excavations and destructive test specimens

5.8 Period of validity

The period of validity of an approved WPS shall be established by agreement.

6 Approval and testing of welders and welding operators

6.1 Approval for manual and partly-mechanized welding

For approval of manual or partly-mechanized welding, welders shall make a test weld in accordance with the approved WPS for inspection and testing.

A welder shall be deemed to be approved for production welding only if all the requirements for inspection and testing of the test pieces specified in this clause have been met.

Except where stated otherwise in this clause, more than one welder may be employed in welding a test piece provided each welder completes at least 50 % of the circumference of a weld pass. The position of each welder shall be clearly identified when employing more than one welder.

Where more than one welding process or welder is employed in producing a test piece, the approval of the welders for production welding shall be limited to their part of the weld of the test piece.

Separate test welding shall be performed for the approval of a welder for girth, branch, and fillet welding, except that a branch welding approval shall also cover for fillet welding.

Welders who have completed the test piece for the successful approval of the WPS in accordance with clause 5 should be deemed approved for production welding.

6.2 Approval for mechanized welding

For mechanized welding, each welding operator shall be approved for a particular part or parts of the operation of making a welded joint. Under no circumstances shall welding operators be employed on operations other than those for which they have been approved.

6.3 Approval for automatic welding

Each welding operator shall be approved by a pre-production welding test in accordance with ISO 14732 and the requirements of this International Standard.

6.4 Test welding

6.4.1 Positional welding

6.4.1.1 Girth welds

The pipes for making the test weld shall be fixed as follows:

— horizontally for production welding on pipes positioned within 25° of the horizontal;

— vertically for production welding on pipes positioned within 25° of the vertical:

— at 4°, positions H-L045 or J-L045 as indicated in Figure 4, for production welding on pipes positioned between 25° to the vertical and 25° to the horizontal.

Approval for positional welding shall also approve the welder for roll welding.

6.4.1.2 Branch connections

Except where more than one welding process is used, a welder shall make all the passes on the full circumference of the test piece with a diameter of the branch less than 323,9 mm. More than one welder may be employed if the diameter of the branch is 323,9 mm or more, or when more than one welding process is used.

The position of the branch shall be

— at the top centre of a horizontal pipe (welding position PG as indicated in Figure 4) for the welding of branches positioned within 20° of the top centre of a horizontal pipe;

— at the bottom centre of a horizontal pipe (welding position PF as indicated in Figure 4) for all branches in all other positions.

6.4.1.3 Fillet welds

For approval for fillet welding, a welder shall weld a fillet weld between a sleeve, socket, slip-on-flange, weld-o-let or other type of attachment and a pipe positioned horizontally.

By agreement, simulated joints using flat plate material may be used provided the plate is positioned to cover all the welding positions for which welder approval is required. By agreement, the mechanical properties of the plate material may differ from the properties of the pipe specified in the WPS.

6.4.2 Roll welding

6.4.2.1 Girth welds

Test pieces shall be made between lengths of pipe rotating about a horizontal axis.

The root pass shall include a stop/start when more than one welder is employed during production welding.

More than one test weld may be made in one test piece, provided a short distance is left unwelded between test welds of the individual welders.

6.4.2.2 Fillet welds

Test pieces shall be made between a sleeve, socket, flange or other attachment and a piece of pipe rotating about a horizontal axis.

More than one test weld may be made on one test piece provided a short distance is left unwelded between test welds of individual welders.

6.5 Inspection and testing of test welds

6.5.1 Non-destructive examination

The weld of the test piece shall be examined visually in accordance with 8.4 and present a neat workmanlike appearance.

Non-destructive examination shall also include:

— radiography in accordance with 8.5; or

— ultrasonic examination in accordance with 8.6; or

— an alternative method by agreement.

The results of the non-destructive examination shall be assessed against the acceptance criteria specified in clause 9.

6.5.2 Destructive testing

The following destructive testing shall be carried out:

— macro-examination in accordance with 5.4.3.6 and, for girth welding using GMAW welding processes, bend testing in accordance with ISO 5173; and

— fracture testing in accordance with 5.4.4 for fillet welding.

Additional destructive testing may be specified.

6.6 Re-testing

A welder or welding operator may produce additional test pieces if it is agreed that failure of the test piece weld is due to metallurgical or other extraneous causes outside the control of the welder.

In case of failure resulting from lack of skill, a welder or welding operator shall receive further training before further test welding for approval is permitted. Further re-testing after a second failure shall be by agreement.

6.7 Range of approval

An approved welder or welding operator may be employed for production welding within the range of essential variables for welder approval specified in this International Standard. The specified ranges apply with respect to material properties and welding parameters applicable during test welding for welder approval.

Any variations beyond the specified ranges shall require a new welder or welding operator approval.

The essential variables for welder approval and applicable ranges shall be as follows:

a) welding process: same welding process(es);

b) direction of welding: same, upward or downward, direction;

c) pipe wall thickness for girth and branch welding only:

   1) all pipe wall thicknesses from 3 mm to twice the wall thickness of the pipe used for test welding, if the wall thickness for test welding is more than 3 mm and does not exceed 12 mm; or

   2) all wall thicknesses of 5 mm and more if the wall thickness for test welding exceeds 12 mm.

d) for girth and branch welding only: variations in pipe diameter in accordance with Table 3;

e) weld preparation: same weld preparation;

f) backing: use of same backing or addition of backing;

g) electrode coating for SMAW: same electrode coating type;

h) flux for continuous tubular wires, metal-cored to flux-cored or vice versa: same flux type;

i) shielding gas: same gas or gas mixture;

j) welding equipment or system: same welding equipment or system;

k) other variables: other variables by agreement.

6.8 Records

All relevant variables of the test welding and the inspection and testing results for the test weld shall be recorded on the welder approval documentation.

6.9 Period of validity

The period of validity of approval for a welder or welding operator shall commence on the date that all the required testing and inspection of the test welds has been satisfactorily completed. This date may be different from the date of issue of the approval documentation.

The approval of a welder or welding operator shall remain valid for a period of two years provided that

— the welder or welding operator is engaged with reasonable continuity in welding work for which the approval is applicable. A welder or welding operator approval shall be cancelled following an interruption of six months or more in the welding to which the approval relates,

— the welder or welding operator demonstrates adequate skill and knowledge, and

— compliance with the above requirements is confirmed at six-month intervals and recorded in the welder or welding approval documentation.

The approval shall be cancelled if any of the above conditions is not fulfilled or at any time by agreement.

7 Production welding

7.1 General

All welding, including tack welding for temporary support, shall be performed by approved welders or welding operators in accordance with an approved WPS.

The distance between girth welds, circumferential fillet welds and branch welds should not be less than the outside diameter of the pipe.

Guidance on other welding scenarios which may be encountered is given in annexes A, B and C.

7.2 Equipment

Welding equipment shall be of a capacity and type suitable for the work and shall be calibrated and maintained in a condition that allows production of acceptable welds, continuity of operation and safety of personnel. Equipment that does not meet these requirements shall be either repaired or replaced.

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

7.3 Working clearance

If welding aboveground or on a barge, the working clearance around the pipe at the weld should not be less than 0,4 m, unless using roll welding.

If welding in a trench, the bell hole shall be of sufficient size to provide the welders or welding operators access to the pipes and working clearance for welding. Standing water shall be removed from the bell hole before commencement of welding.

7.4 Weather conditions

Welding shall be suspended during weather conditions which, in the opinion of the contractor and/or the company, can adversely affect the weld quality. Protection from the weather may be provided to allow welding to continue.

Weld areas shall be preheated to 50 °C or higher when moisture is present on the pipe and when ambient temperatures are below 5 °C.

Continuation of welding at ambient temperatures below –20 °C shall be only by agreement.

7.5 Pipe end preparation

Pipe ends shall be bevelled to the dimensions specified in the WPS.

Bevelling shall be performed by machining, machine thermal cutting or grinding. Machine thermal cutting may be manually or mechanically operated.

Manual thermal cutting shall be used only by agreement and when machining or machine thermal cutting are not practicable. In case of manual thermal cutting, final dressing shall be by filing, grinding or other mechanical means.

The bevelled surface and adjacent material over a distance of at least 50 mm shall be free from scale, rust, paint, grease, moisture and other foreign matter that may adversely affect the weld quality before commencement of welding.

Examination of the pipe ends for the presence of laminations should be performed after a significant length of pipe has been removed.

7.6 Support

Pipes should not be moved during welding until both the root and second pass have been completed. Moving pipes after completion of the root pass shall be by agreement.

7.7 Line-up

Longitudinal and/or spiral welded seams of adjacent pipes shall be offset by at least 50 mm at the girth weld. Longitudinal weld seams shall be positioned in the top of the pipe between the 9 o'clock and 3 o'clock positions.

Radial offsets of pipe abutting ends shall be minimized, for example by rotating the pipe, until the best possible fit has been obtained. Hammering or heating of the pipes to correct misalignment shall not be performed.

Internal misalignment shall be uniformly distributed around the pipe and shall not exceed 3 mm or 1 % of the pipe internal diameter, whichever is less, at any location around the circumference. Larger misalignments may be accepted when the pipe ends are tapered by grinding or machining, with a slope not exceeding 1:4, provided the specified minimum wall thickness of the pipe is maintained.

Root gaps shall be measured and conform to the value specified in the WPS.

Internal line-up clamps shall be used for all mainline welding, whenever practicable, and shall not be released before the root pass has been completed.

External line-up clamps shall be used when the use of internal clamps is not practicable. External line-up clamps shall not be removed before at least 50 % of the root pass, uniformly spaced around the circumference, has been completed.

Before continuing welding after removal of external line-up clamps, weld beads shall be ground at the start and stop locations.

If necessary, tack welding shall be in accordance with 7.8.

Line-up clamps or other devices for maintaining line-up shall be of the same type as used during the welding of test pieces for WPS approval.

The line-up clamp shall be designed to prevent damage to the pipe and coatings.

7.8 Tack welding

Root gaps shall be maintained during the deposition of the first pass by tack welds if specified in the WPS.

Tack welding shall be carried out in accordance with the procedure specified in the WPS for welding of the root pass.

Tack welds which will be incorporated in the production weld shall be ground to a suitable taper at the start/stop locations to allow adequate fusion with the root pass.

End preparations specified in the WPS shall be maintained when removing temporary tack welds. Removal of tack welds shall be by grinding, followed by inspection of the ground area using MPE or LPE.

7.9 Earthing or grounding

Welding return cable connections shall be of sufficient cross-sectional area to prevent concentration of current and shall be securely attached to prevent arc burns. Attachment by welding shall not be performed.

Arc burns caused by a faulty attachment shall be removed in accordance with 7.13.

7.10 Electrodes and filler materials

The selection of electrodes and filler materials for production welding shall be by agreement when specified by the company.

When batch testing of filler materials is specified by the company, the company shall indicate the required lot classification from AWS A5.01 and the required tests. Inspection documents for the filler materials shall be in accordance with ISO 10474.

Electrodes, filler wires and wire/flux combinations shall be used which will produce weld metal with a tensile strength at least equal to the specified minimum tensile strength of the pipe metal. In the case of joints between dissimilar materials, the tensile strength of the weld metal shall not be less than the minimum tensile strength specified for the highest strength pipe metal, unless otherwise agreed.

Welding consumables shall be stored at a temperature and humidity recommended by the manufacturer. Baking of electrodes shall also be in accordance with the recommendations of the manufacturer of the electrode.

Different grades, different brands, and when agreed, different batches of electrodes and filler materials shall be individually identifiable and be completely segregated.

Electrodes and filler materials shall be stored and handled such that damage to these materials and their containers is avoided. Electrodes and filler materials in open containers shall be protected from excessive moisture changes. Electrodes, filler wires and fluxes that exhibit signs of damage or deterioration shall not be used.

7.11 Shielding gases

Gases or gas mixtures shall be used for shielding during welding where appropriate.

The moisture content of shielding gases shall correspond to a dewpoint of –30 °C or lower at atmosheric pressure.

For gas mixtures with specified additions, such as 2 % O_2 or 5 % O_2, the variation of such additions shall not exceed ± 10 % of that stated in the WPS.

Shielding gases shall be kept in the containers in which they are supplied and the containers shall be stored away from extremes of temperature. Gases shall not be field-intermixed in their containers.

Gases of questionable purity or in damaged containers shall not be used.

7.12 Preheating

Pipe shall be heated before welding if specified in the WPS and when required by 7.4, and this shall be carried out in accordance with a documented procedure.

Preheating shall be applied by gas or electrical means to achieve and maintain a satisfactory temperature distribution, to prevent interference with the welding operation and to avoid damage to coatings.

The preheating temperature shall not be less than the temperature specified in the WPS and shall not exceed this temperature by more than 50 °C.

The specified preheating temperature shall extend around the entire periphery of the pipe or the part being joined over a length of at least 75 mm on each side of the weld.

The preheating temperature shall be determined by temperature-indicating crayons which melt when the specified temperature is reached, or by thermocouples or pyrometers. Crayons or paints which indicate temperature by colour change should not be used.

If practicable, the temperature should be measured on the face opposite of that to which the heat is applied. When this is not practicable, the heat source shall be removed and the temperature determined on the heated face once the temperature has equalized. The time between removal of the heat source and measurement of temperature shall be approximately 2 min for thicknesses up to and including 25 mm, plus 1 min for each 12 mm thickness above 25 mm.

Temperatures shall be measured at a number of points around the joint immediately prior to commencement of welding.

7.13 Stray arcs

Arcs shall be struck only on fusion faces. Contact between electrodes or non-insulated parts of electrode holders and surfaces of the pipe shall be avoided.

Material affected by accidental stray arcs may be repaired only by agreement.

Arc burns shall be repaired in accordance with a documented procedure which shall define the methods for:

— mechanical removal of the affected pipe material;

— blending of the excavation;

— MPE or LPE;

— wall thickness measurement.

7.14 Backing

Permanent backing shall not be permitted. Temporary backing may be applied only if specified in the WPS.

7.15 Internal weld bead

The use of an internal weld bead shall be permitted only if it is specified in the WPS.

7.16 Weld metal deposition

7.16.1 Girth welding

The completed weld shall have a substantially uniform width around the entire circumference with a smooth transition to the base material. Internal and external reinforcements and concavity shall not exceed specified values.

At least two welders should work simultaneously, one on each side, during welding on pipe with a diameter larger than 325 mm.

The width of any weaving shall not exceed the weaving in the WPS if specified.

Interpass temperatures shall be measured and be within the range specified in the WPS. Interpass temperatures shall not exceed the maximum temperature recorded during welding of test pieces for WPS approval.

Weld stops and starts shall be staggered when manual or partly mechanized welding methods are used and, when feasible, with mechanized and automatic welding equipment. In the case of cables inside the pipeline during welding, such as for a buckle detector, stops and starts shall be shifted sideways from the six o'clock position to avoid masking of weld stop and start images on the radiograph.

7.16.2 Other welding

The configuration of branch welds shall be as specified.

The pipe material around planned cut-out areas for branches shall be examined with UE for the presence of pipe laminations when specified. The procedure for UE and the acceptance criteria shall be by agreement.

7.17 Weld cleaning and peening

Surface slag shall be removed using hand or power tools before deposition of the next weld pass. Clusters of surface porosity, stops and starts and high points shall be removed by grinding.

NOTE Surface slag is a possible source of unacceptable weld flaws and visible defects, such as cracks, cavities and other deposition faults.

The cleanliness of the junctions between the weld metal and the fusion faces shall be checked by visual examination before deposition of further weld metal.

After completion of the weld, the weld and the adjacent area shall be cleaned of spatter. Peening should not be performed.

7.18 Partially completed welds

Whenever possible, welds should not be left partially completed. The welding of fittings shall always be completed in one cycle.

Where necessary due to production conditions, interrupted welds may be completed provided that welding is not discontinued before deposition of the minimum number of passes specified in the WPS. If not specified in the WPS, the minimum number of passes to be completed before interrupting welding shall be by agreement.

Upon discontinuation of welding, the joint shall be wrapped in dry insulating and heat-resisting material with a waterproof backing for cooling in a slow and uniform manner.

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

Partially completed welds should be rejected when welding has been interrupted before the completion of three passes. Additional inspection may be specified in case completion of such welds is permitted.

7.19 Post-weld heat treatment

7.19.1 General

Welds shall be subject to PWHT if specified in the WPS.

The entire circumference of the joint shall be heated in a uniform manner, without overheating, in accordance with the procedure stated in the WPS.

7.19.2 Methods of heat treatment

Wherever possible, PWHT shall be carried out by placing the complete welded assembly in an enclosed furnace.

If this is not practicable, girth welds may be heat-treated locally by heating a band around the entire circumference, centred around the girth weld, using an electrical resistance mat, gas-fired muffles or other methods by agreement. The width of the band shall not be less than $5\sqrt{r \cdot t}$

where

r is the internal radius of the larger component;

t is the thickness of the thicker component.

Sufficient insulation shall be fitted to ensure that the temperature of the weld and its heat-affected zone is not less than specified in the WPS, and that the temperature at the edge of the heated band is not less than half the peak temperature. In addition, the adjacent portion of the assembly outside the heating zone shall be thermally insulated so that the temperature gradient is not harmful. To meet this requirement, the total insulated band width should be at least $10\sqrt{r \cdot t}$.

Branches may be locally heat-treated by heating a circumferential band around the entire assembly. The width of the heated band shall include the branch weld and at least $2{,}5\sqrt{r \cdot t}$ of the pipe in each direction from the edges of the branch weld.

Assemblies of different wall thicknesses may be placed in the same furnace charge for PWHT and treated in accordance with the requirements for PWHT of the thickest assembly in the charge, provided that the minimum thickness of the charge is not less than 50 % of the thickness of the thickest assembly.

7.19.3 Post-weld heat-treatment procedure

The PWHT holding time at temperature shall be a minimum of 2,5 min per millimetre of thickness. The holding temperature shall be (580 ± 20) °C. Other holding times and temperature ranges may be specified if warranted for the composition and condition of the material to be treated.

For furnace heat treatment, the temperature in the furnace at the time the assembly is placed in the furnace shall not exceed 400 °C, and the assembly shall not be removed from the furnace until the furnace temperature has fallen below 400 °C.

During heating and cooling above 400 °C, the temperature variation of the assembly shall not exceed 150 °C in any 4,5 m of assembly length.

For both furnace and local heat treatments, the rate of heating above 400 °C shall not exceed $5\,500/t$ °C · h^{-1}, and the rate of cooling while above 400 °C shall not exceed $6\,875/t$ °C · h^{-1} with t expressed in millimetres.

Below 400 °C the weld or assembly may be cooled in still air.

The maximum and minimum temperatures of any part of the assembly or weld zone at the holding temperature shall not exceed the PWHT temperature range specified above. Temperatures shall be measured, using thermocouples in effective contact with the steel, at sufficient locations on the assembly to monitor and assure that the whole assembly, or zone where applicable, is treated within the specified temperature range. Additional pyrometers should be used to confirm that undesirable thermal gradients do not occur.

7.20 Pipe and weld record

The weld numbering system shall be established by agreement before commencement of welding. The documentation addressed in clause 11 should be traceable back to individual weld numbers.

8 Non-destructive examination

8.1 General

This clause specifies the requirements for performing manual and mechanized NDE.

The company shall specify the requirements for frequency, extent and method of NDE; otherwise the frequency and extent shall be as stated in 10.4.2 of ISO 13623:2000.

Specifications of all NDE procedures to be used shall be submitted to the company for agreement before commencement of welding.

Results of NDE shall meet the acceptance criteria specified in clause 9 for the NDE methods employed.

Consideration should be given to the possible need to delay NDE for a certain time after completion of welding, as any delayed hydrogen cracking may not occur immediately upon cooling.

NOTE The need for a delay period is generally greater for those welding situations which are likely to increase the risk of such cracking. In this regard, it should be noted that the cracking risk is potentially higher in welds made with cellulose-coated electrodes and also increases with increasing pipe strength or wall thickness.

8.2 Qualification of NDE personnel

NDE personnel shall be certified for the test method used in accordance with

a) ASME Section V for visual examination, and

b) ISO 9712 for other NDE.

The roles and responsibilities of NDE personnel shall be as defined in ISO 9712:1999, clause 5.

8.3 NDE procedure qualification

NDE procedures shall be qualified by practical demonstration on welds similar to the production welds for which the procedure will be used.

Practical demonstrations shall be conducted under anticipated field conditions and with weld temperatures as foreseen during the examination of production welds.

The make and type of NDE equipment for examination of production welds shall be the same as used for the qualification of NDE procedures.

8.4 Visual examination

Specifications for VE procedures shall define the following:

— use of direct or remote viewing;

— surface condition;

— method or tool for surface preparation;

— requirements for illumination, including instruments or equipment;

— checklist of features to be examined;

— sequence of examination, when applicable;

— data to be documented;

— format of report including report forms to be used.

VE shall be carried out in accordance with ASME Section V, article 9.

8.5 Radiographic examination

8.5.1 Technique

Examination shall be by X-ray in accordance with ISO 1106-3. The technique shall be Class B. Gamma-ray examination may only be used if agreed by the company.

8.5.2 Procedure specification

Specifications of radiographic procedures shall, where relevant, define the following:

— pipe diameter and wall thickness;

— radiation source;

— technique (equipment rating, in voltage, external or internal equipment);

— geometric relationships (source focal-spot size, film focus distance, object-film distance, radiation angle with respect to weld and film);

— penumbra or geometric unsharpness;

— film type (trade name, designation and dimensions);

— intensifying screens (front and/or back, material thickness, filters);

— exposure conditions (voltage, current and duration);

— processing (developing time/temperature, stop-bath, fixation, washing, drying, manual or automatic processing);

— IQI sensitivities, in percent of wall thickness, based on source- and film-side indicators, respectively;

— density;

— film overlap;

— reference to actual WPS;

— temperature of welds during inspection;

— archival life;

— initial source strength.

8.5.3 Procedure qualification

During radiographic procedure qualification, wire-type IQIs shall be placed both on the source side and on the film side. Only one IQI is required for each radiograph for short film lengths where the distance between IQIs would be less than 100 mm.

IQIs shall be wire type. IQI sensitivities for source-side penetrameters shall, for both single-side and double-side techniques, be in accordance with ISO 1106-3 Class B and Table 6 of this International Standard.

At least two radiographs shall be taken during the procedure qualification.

All relevant data on the qualification tests, including results, shall be documented.

Radiographs from the procedure qualification shall be kept available on site for reference throughout the period of production welding.

Table 6 — IQI sensitivity requirements for source-side penetrameter with single-side technique

Pipe wall thickness mm	**Penetrameter wire diameter** mm
< 6	0,10
6-8	0,125
8-10	0,16
10-16	0,20
16-25	0,25
25-32	0,32
32-40	0,40
40-50	0,50

8.5.4 Information on radiograph

The radiograph shall contain the following information:

— project name, project number and pipeline identification;

— weld number;

— whether the radiograph is of a repair weld, of a replacement weld or a re-shoot of radiograph;

— marker(s) indicating the position of the radiograph in relation to the weld.

8.5.5 Weld coverage

A sufficient number of film exposures shall be taken to give full circumferential coverage of the welds. Film overlaps shall not be less than 40 mm.

8.5.6 Screens

Front and back intensifying fluorometallic screens with a maximum thickness of 0,02 mm may be used by agreement.

8.5.7 Radiographic density

The density for isotopes shall not be less than 2,5.

Densities shall be measured at regular intervals.

All radiographs shall be viewed in dry condition.

8.5.8 Film storage

Radiographs shall be stored in suitable boxes in sequence with the weld numbering. Radiographs of rejected welds, repairs and re-shoots shall be stored together.

8.5.9 Buckle-detector cable

Welds shall be radiographed again if starts or stops of welds are obscured on the radiograph, for example by a buckle-detector cable.

8.6 Ultrasonic examination

8.6.1 Procedure specification

Specifications for UE procedures shall define the following:

— type of UE equipment;

— type and dimensions of transducers;

— range of frequencies;

— method of calibration;

— surface requirements;

— coupling medium;

— examination techniques;

— weld identification method;

— reporting requirements;

— reference to the applicable WPS;

— temperature range of welds during examination.

8.6.2 Equipment

UE equipment shall meet the requirements in ASME Section V, article 5.

For offshore applications, probes shall be suitable for use on surfaces with elevated temperatures.

The name of the manufacturer, the identification number, the transducer frequency, the refraction angle and the output point shall be clearly marked on each probe.

8.6.3 Calibration and construction of reference curve

Reference DAC curves shall be made in accordance with ASME Section V, article 5.

Calibration block No. 2 in accordance with ISO 7963 may be used for calibration of range. This block shall not be used for determining sensitivity.

Whenever material, bevel geometry, welding method or other factors call for additional considerations in flaw detection, preparation of special calibration test pieces is required.

The sound pathlength from the transducer to the reflector shall not be less than 0,6 N, where N is the near-field length of the probe.

For examination of welds with surfaces at elevated temperatures, calibrations shall be made at the same surface temperatures and with the same couplant as during the examination of production welds or by using a correction table constructed by practical experiments.

8.6.4 Manual ultrasonic examination

Examination shall not be performed on surfaces with roughness or irregularities which cause the transfer measurement to vary by more than 3 dB. The total value of transfer correction should not exceed 6 dB.

Tandem techniques shall be used for girth welds with a bevel angle between 0° and 10° if specified by the company.

When using straight-beam probes for weld examination, the DAC curve shall be drawn similarly to that for angle probes.

The length of indications shall be defined as the circumferential distance over which the echo height exceeds the reporting level.

8.6.5 Mechanized examination

UE examination shall be by mechanized UE equipment if specified by the company.

Mechanized equipment shall be capable of providing reproducible examinations and permanent records, and shall be capable of identifying defects in accordance with the categories specified in 9.5.

8.6.6 Evaluation of indications

All indications exceeding the DAC curve by more than 20 % shall be investigated and reported. Indications exceeding the DAC either by more than 50 % or 6 dB shall be reported and evaluated in accordance with clause 9. Length, position, amount by which the DAC is exceeded together with echo characteristics shall be documented for these indications.

If fitness-for-purpose criteria are used, the acceptance criteria shall be based on actual design criteria and actual specified material properties.

8.7 Magnetic particle examination

Specifications for MPE procedures shall define the following:

— quality and dimensions of material to be examined;

— welding process;

— type of magnetization;

— type of equipment;

— surface preparation;

— wet or dry examination;

— make and type of magnetic particle and contrast paint;

— method for determining the magnetic field strength in the material;

— method of demagnetization (if required);

— description of method of examination.

MPE should be carried out using either AC-yoke or DC-prods. DC-prods shall not be used unless specific company agreement has been obtained. If used, prods should be tipped with lead or soft prods should be used. Care shall be taken to avoid local heating of the surfaces to be examined. Arc strikes and burn marks shall be ground out and the area re-inspected.

Use of permanent magnets or DC-yokes may only be used if agreed by the company.

MPE shall be performed in accordance with the ASME Section V, article 7.

The method of determining magnetic field strengths in the material shall be subject to company agreement. The field strength shall be in accordance with ASME Section V, article 7.

MPE shall not be performed when surface temperatures exceed 300 °C. Only dry MPE shall be used for examinations with surface temperatures between 60 °C and 300 °C.

8.8 Liquid penetrant examination

LPE shall be performed in accordance with ISO 3452, ISO 3453 and ISO 9935 or equivalent.

Recommendations by the manufacturer of the penetrant shall be followed.

8.9 Examination report

All NDE examination shall be documented.

The documentation shall include the following information, where appropriate:

— contract number;

— applicable procedure specification;

— weld identification;

— examination reports presenting the results of examination;

— description and location (with sketch where appropriate) of all reportable indications;

— for shop welds, reference to the fabrication drawings;

— actions taken;

— date of examination;

— name and qualification level of inspector;

— approval signature of responsible inspector.

Examples of test reports as shown in annex D may be used.

9 Acceptance criteria for non-destructive examination

9.1 General

The acceptance criteria specified in this clause apply to imperfections detected by radiographic, ultrasonic, magnetic particle and liquid penetrant examinations. They may also be applied to imperfections revealed by visual examination.

Imperfections shall be classified in accordance with ISO 6520-1.

9.2 Right of rejection

The company can reject any weld that appears to meet the criteria of this International Standard if, in the company's opinion, the depth of the imperfection is detrimental to the weld.

9.3 Visual examination

9.3.1 Weld profile

Weld reinforcement shall be uniform and shall merge smoothly with the adjacent parent metal surfaces. Both external and internal reinforcement should not exceed a height of 3 mm.

9.3.2 Undercut

When visual and mechanical means are used to determine depth, undercut adjacent to the root and cover pass shall not exceed the lengths given in 9.4.8 and shall not be deeper than 1 mm or 10 % of the pipe wall thickness, whichever is smaller.

9.4 Radiographic examination

9.4.1 Lack of penetration

Lack of penetration shall be unacceptable if any of the following conditions exist.

a) The length of an individual indication of lack of penetration exceeds 25 mm.

b) The aggregate length of indications of lack of penetration exceeds 25 mm in any continuous 300 mm length of weld.

c) The aggregate length of lack of penetration exceeds 8 % of the weld length in any weld less than 300 mm in length.

d) The aggregate length of lack of penetration in double-sided welds exceeds 50 mm in any continuous 300 mm of weld or 15 % of the weld length.

9.4.2 Lack of fusion

Lack of fusion at the root of single-sided welds shall be unacceptable if any of the following conditions exist.

a) The length of an individual indication exceeds 25 mm.

b) The aggregate length of indications exceeds 25 mm in any continuous 300 mm length of weld.

c) The aggregate length of indications exceeds 8 % of the weld length in any weld less than 300 mm in length.

Lack of side-wall fusion or lack of inter-run fusion shall be unacceptable if any of the following conditions exist.

— The length of an individual indication exceeds 50 mm.

— The aggregate length of indications exceeds 50 mm in any continuous 300 mm length of weld.

— The aggregate length of indications exceeds 15 % of the weld length.

9.4.3 Root concavity

Internal concavity up to 25 % of the total length of weld is acceptable provided the density of the radiographic image of the internal concavity does not exceed that of the thinnest adjacent base metal.

The criteria for burn-through in 9.4.4 shall be applied for root concavities with film densities exceeding the density of the thinnest base metal adjacent to the weld.

9.4.4 Burn-through

Burn-through shall be unacceptable if any of the following conditions exist.

a) The maximum dimension exceeds 6 mm and the density of the image of the burn-through exceeds that of the thinnest adjacent base metal.

b) The maximum dimension exceeds the thinner of the nominal wall thicknesses joined, and the density of the burn-through image exceeds that of the thinnest adjacent base metal.

c) More than one burn-through of any size is present and the density of more than one of the images exceeds that of the thinnest adjacent base metal.

9.4.5 Inclusions

The maximum dimension of an indication shall be considered to be its length when evaluating inclusions.

Parallel linear indications separated by approximately the width of the root bead (wagon tracks) shall be considered as single indications if the width of either of them is 0,8 mm or less and as separate indications if their widths exceed 0,8 mm.

Inclusions shall be unacceptable if any of the following conditions exist.

a) The length of a linear inclusion exceeds 50 mm.

b) The aggregate length of linear inclusions exceeds 50 mm in any continuous 300 mm length of weld.

c) The width of a linear inclusion exceeds 1,6 mm.

d) The aggregate length of isolated slag inclusions exceeds 50 mm in any continuous 300 mm length of weld.

e) The width of an isolated slag inclusion exceeds 3 mm or 50 % of the wall thickness whichever is less.

f) More than four isolated slag inclusions with the maximum width of 3 mm are present in any continuous 300 mm length of weld.

g) The aggregate length of linear and isolated slag inclusions exceeds 15 % of the weld length.

h) The width of a copper or tungsten inclusion exceeds 3 mm or 50 % of the wall thickness, whichever is less.

i) The aggregate length of copper or tungsten inclusions exceeds 12 mm in any continuous 300 mm length of weld or more than four such inclusions are present in any continuous 300 mm length of weld.

9.4.6 Porosity

The size of a pore shall be the maximum dimension of the indication seen on the radiograph.

a) **Individual gas pores or uniformly distributed porosity** shall be unacceptable if any of the following conditions exist.

   1) The size of an individual pore exceeds 3 mm.

   2) The size of an individual pore exceeds 25 % of the thinner of the nominal wall thicknesses joined.

   3) The total area, when projected radially through the weld, shall not exceed 2 % of the projected weld area in the radiograph. The area shall be the length of the weld affected by the porosity (with a minimum length of 150 mm) times the maximum width of the weld.

b) **Clustered porosity** present in any pass except the cover pass shall comply with the above criteria for individual gas pores or uniformly distributed porosity. Clustered porosity present in the finish pass shall be unacceptable if any of the following conditions exist.

   1) The size of the cluster exceeds 13 mm.

   2) The aggregate length of clustered porosity exceeds 13 mm in any continuous 300 mm of weld length.

   3) An individual pore within a cluster exceeds 2 mm in size.

c) **Hollow-bead porosity** is defined as elongated linear porosity that occurs in the root pass. Hollow bead shall be unacceptable if any of the following conditions exist.

   1) The length of an individual indication of hollow bead exceeds 50 mm.

   2) The aggregate length of hollow bead exceeds 50 mm in any continuous 300 mm of weld length.

   3) The aggregate length of hollow bead exceeds 15 % of the weld length.

9.4.7 Cracks

Cracks, other than crater and star cracks, shall not be permitted. For crater and star cracks, the maximum length shall be 4 mm.

9.4.8 Undercut

Undercutting shall be unacceptable if any of the following conditions exist.

a) The aggregate length of undercut, both external and internal, exceeds 50 mm in any continuous 300 mm of weld length.

b) The aggregate length of undercut, both external and internal, exceeds 15 % of the weld length.

9.4.9 Accumulation of discontinuities

Any accumulation of discontinuities shall be unacceptable if any of the following conditions exist.

a) The aggregate length of indications exceeds 50 mm in any continuous 300 mm of weld length.

b) The aggregate length of indications exceeds 15 % of the weld length.

9.5 Ultrasonic examination

9.5.1 General

Indications from UE examination shall be evaluated in accordance with the acceptance criteria in 9.4 for radiographic examination and 9.5.2 and 9.5.3.

9.5.2 Spherical porosity

Indications identified as porosity may be classified as non-planar indications.

Non-planar indications which cover a projected area of not more than 2 % on a radiograph shall be considered acceptable.

Spherical porosity may be classified as a planar indication with the area containing the porosity being evaluated as a single planar imperfection in accordance with 9.5.3.

9.5.3 Linear indications

All indications that produce a response greater than 20 % of the reference level shall, to the degree possible, be investigated to determine the location, shape, extent and type of reflector, and shall be evaluated according to the following criteria.

a) All cracks are unacceptable, regardless of size or location in the weld.

b) Linear indications (other than cracks) interpreted to be open to the surface are unacceptable if they exceed 25 mm in total length in a continuous 300 mm length of weld or 8 % of the weld length.

c) Linear indications interpreted to be buried within the weld are unacceptable if they exceed 50 mm in total length in a continuous 300 mm of weld or 15 % of the weld.

9.6 Surface testing

9.6.1 Classification of indications

Indications with a maximum dimension of 2 mm or less shall be classified as non-relevant. All larger indications, even if considered not to be detrimental, shall be regarded as relevant until re-examination following surface conditioning.

Indications with a length of more than three times the width shall be classified as linear indications. Indications with a length of less than three times the width shall be classified as rounded indications.

9.6.2 Acceptance criteria

The following acceptance criteria apply to surface examination using either magnetic particle or liquid penetrant.

Relevant indications shall be unacceptable if any of the following conditions exist:

a) linear indications evaluated as cracks;

b) linear indications evaluated as incomplete fusion exceeding 25 mm in aggregate length in a continuous 300 mm length of weld, or 8 % of the weld length.

Rounded indications shall be evaluated in accordance with the acceptance criteria in 9.4.6 for individual and clustered porosities. For evaluation purposes, the maximum dimension of a rounded indication shall be considered its size.

Verification may be obtained using other NDE methods in case of uncertainty of the type of discontinuity disclosed by an indication.

9.7 Discontinuities in pipe or fittings

Laminations, arc burns, long seam discontinuities and other discontinuities in the pipe or fittings detected during non-destructive testing or visual examination shall be reported to the company. Their disposition by repair or removal shall be as directed by the company.

9.8 Acceptance criteria — ECA

At the option of the company only, an ECA may be used to derive alternative acceptance criteria. An ECA should be performed in accordance with accepted industry practices such as BS PD 6493, API Std 1104, Appendix A , or EPRG.

ECAs shall be documented. All input data and assumptions made during the assessment shall be included in the documentation.

10 Repair and removal of defects

10.1 General

Weld repairs shall be made in accordance with the original WPS or a documented repair welding procedure specification.

A WPS for repair welding shall be approved in accordance with clause 5, except that the extent of testing shall be established by agreement.

10.2 Authorization for repair

Repair of defects in the root and filler passes and weld repairs made from inside the pipe shall be permissible only if agreed by the company.

10.3 Multiple repairs

A weld should be rejected and removed in case of failure to meet the acceptance criteria of clause 9 following one attempt to repair. Repairs not requiring welding shall not be counted as weld repairs.

If permitted, repair-on-repair welding shall be carried out in accordance with a WPS procedure approved following test welding on repaired weld metal.

10.4 Defect removal and preparation for repair

Welds not complying with the acceptance criteria of this International Standard shall be repaired or the weld removed completely.

Defects shall be removed by chipping, grinding, machining or air-arc gouging, followed by grinding. If air-arc gouging or thermal cutting is used, appropriate preheating shall be applied. If air-arc gouging is used, the last 3 mm through the root pass of the original weld shall be removed by mechanical means. Air-arc gouging shall be controlled by a procedure documenting the allowed variables as required by AWS C5.3-91.

Complete welds shall be removed by thermal cutting or machining.

Weld excavations shall be sufficiently deep and long to remove the defect. NDE of the excavated area, to confirm the complete removal of the defect shall be performed before commencement of repair welding.

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. More stringent limitations can be necessary for construction methods with significant loads or deformation at the location of the weld repair station, for example in case of installation from a barge.

Repaired areas shall be examined using the same examination method which located the defect. Should the examination reveal further imperfections, they shall be evaluated as new imperfections, i.e. remnants of the original defect may remain if within the acceptance criteria of this International Standard.

It is not necessary to perform NDE on the complete weld again. A sufficient length beyond the ends of the repair should be examined.

11 Documentation

Quality records should include the following:

— record of contract/design review;

— materials certificates;

— consumable certificates;

— WPSs;

— welding procedure approval test records;

— welder or welding operator approval certificates;

— non-destructive testing personnel certificates;

— heat treatment records;

— non-destructive testing and destructive testing procedures and reports;

— dimensional reports;

— records of repairs and other non-conformity reports.

The retention period and location of the records shall be decided by agreement.