W28 Welding procedure qualification tests of steels for hull construction and marine structures

(June 2005) (Rev.1 Nov 2006) (Rev.2 Mar 2012)

1. Scope

1.1 This document gives requirements for qualification tests of welding procedures intended for the use of weldable steels as specified in UR W7, UR W8, UR W11 and UR W16 for hull construction and marine structures.

1.2 This document specifically excludes the welding procedure specified in UR W1.

1.3 All new welding procedure qualification tests are to be carried out in accordance with this document from 1 July 2007.

1.4 This document does not invalidate welding procedure qualification tests made and accepted by the Classification Society before 1 July 2007 provided the welding procedure qualification tests are considered by the Classification Society to meet the technical intent of this UR or have been qualified in accordance with the recognized standards such as ISO, EN, AWS, JIS or ASME.

2. General

2.1 Welding procedure qualification tests are intended to verify that a manufacturer is adequately qualified to perform welding operations using a particular procedure.

2.2 In general welding procedure tests are to reflect fabrication conditions in respect to welding equipment, inside or outside fabrication, weld preparation, preheating and any post-weld heat treatment. It is to be the manufacturer's responsibility to establish and document whether a procedure is suitable for the particular application.

2.3 For the welding procedure approval the welding procedure qualification test is to be carried out with satisfactory results. Welding procedure specifications are to refer to the test results achieved during welding procedure qualification testing.

2.4 Welding procedures qualified at a manufacturer are valid for welding in workshops under the same technical and quality management.

Note:

1. This UR is to be uniformly implemented by IACS Societies on ships contracted for construction from 1 January 2007 as well as the manufacturing of which is commenced on or after 1 January 2007.

2. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.

3. Rev.2 of this UR is to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 January 2013.

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3 Welding procedure specification

3.1 Preliminary welding procedure specification and welding procedure specification

3.1.1 A welding procedure specification (WPS) is to be prepared by the shipyard or manufacturer which intends to perform the welding procedure qualification test. This document is also referred to as a preliminary welding procedure specification (pWPS). The pWPS can be modified and amended during procedure tests as deemed necessary however it is to define all relevant variables as mentioned in the WPS (refer to ISO 15614 or other recognized standards).

3.1.2 The shipyard or manufacturer is to submit to the Society a pWPS for review prior to the tests. In case that the test pieces welded according to the pWPS show unacceptable results the pWPS is to be adjusted by the shipyard or manufacturer. The new pWPS is to be prepared and the test pieces welded in accordance with the new pWPS.

3.1.3 The WPS is to be used as a basis for the production welds, and upon satisfactory completion of the tests based on the pWPS, the Society may approve it as a WPS. In case that a WPS is approved by the Society the approval range is to be in compliance with section 5.

4. Qualification of welding procedures

4.1 General

4.1.1 Preparation and welding of test pieces are to be carried out in accordance with the pWPS and under the general condition of production welding which it represents.

4.1.2 Welding of the test assemblies and testing of test specimens are to be witnessed by the Surveyor.

4.1.3 If tack welds and/or start and stop points are a condition of the weld process they are to be fused into the joint and are to be included in the test assemblies.

4.2 Butt weld

4.2.1 Assembly of test pieces

The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and according to Fig. 1 with the minimum dimensions:

- manual or semi-automatic welding:

  width = 2a, a = 3 x t, min 150 mm
  length b = 6 x t, min 350 mm

- automatic welding:

  width = 2a, a = 4 x t, min 200 mm
  length b = 1000 mm

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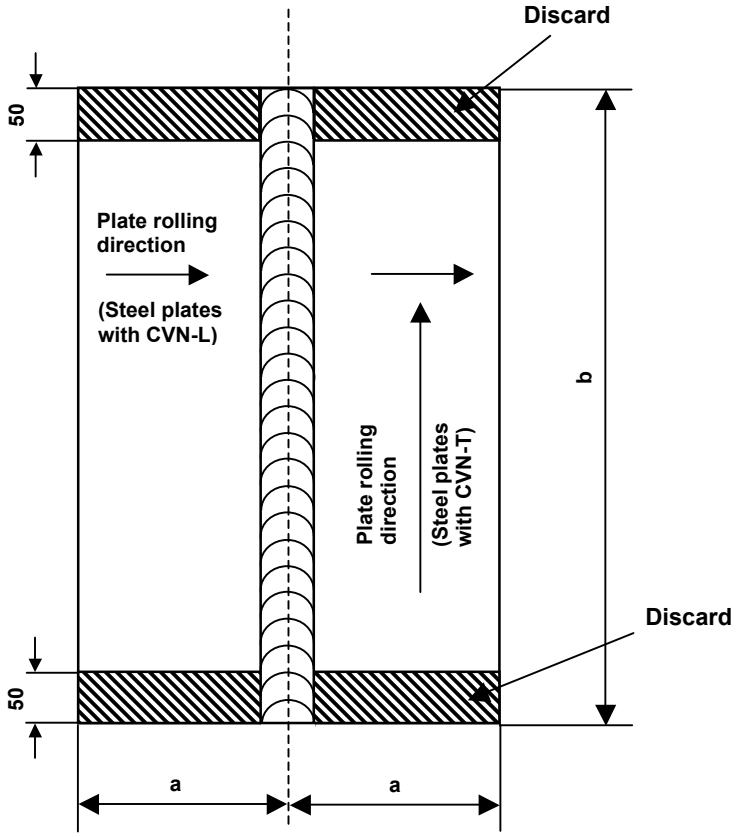

Fig.1 Test assembly for butt weld

For hull structural steel plates impact tested in the longitudinal direction (CVN-L) in UR W11, the butt weld of the test piece is perpendicular to the rolling direction of the two plates.

For high strength quenched and tempered steel plates impact tested in the transverse direction (CVN-T) in UR W16, the butt weld of the test piece is parallel to the rolling direction of the two plates.

4.2.2 Examinations and tests

Test assemblies are to be examined non-destructively and destructively in accordance with the following and Fig 2:

- Visual testing	100 %
- Surface crack detection	100 % (dye penetrant testing or magnetic particle testing)
- Radiographic or Ultrasonic testing	100 %
- Transverse tensile test	two specimens as per 4.2.2.2
- Longitudinal tensile test	required as per 4.2.2.3
- Transverse bend test	four specimens as per 4.2.2.4
- Charpy V-notch impact test	required as per 4.2.2.5
- Macro examination	one specimen as per 4.2.2.6
- Hardness test	required as per 4.2.2.7

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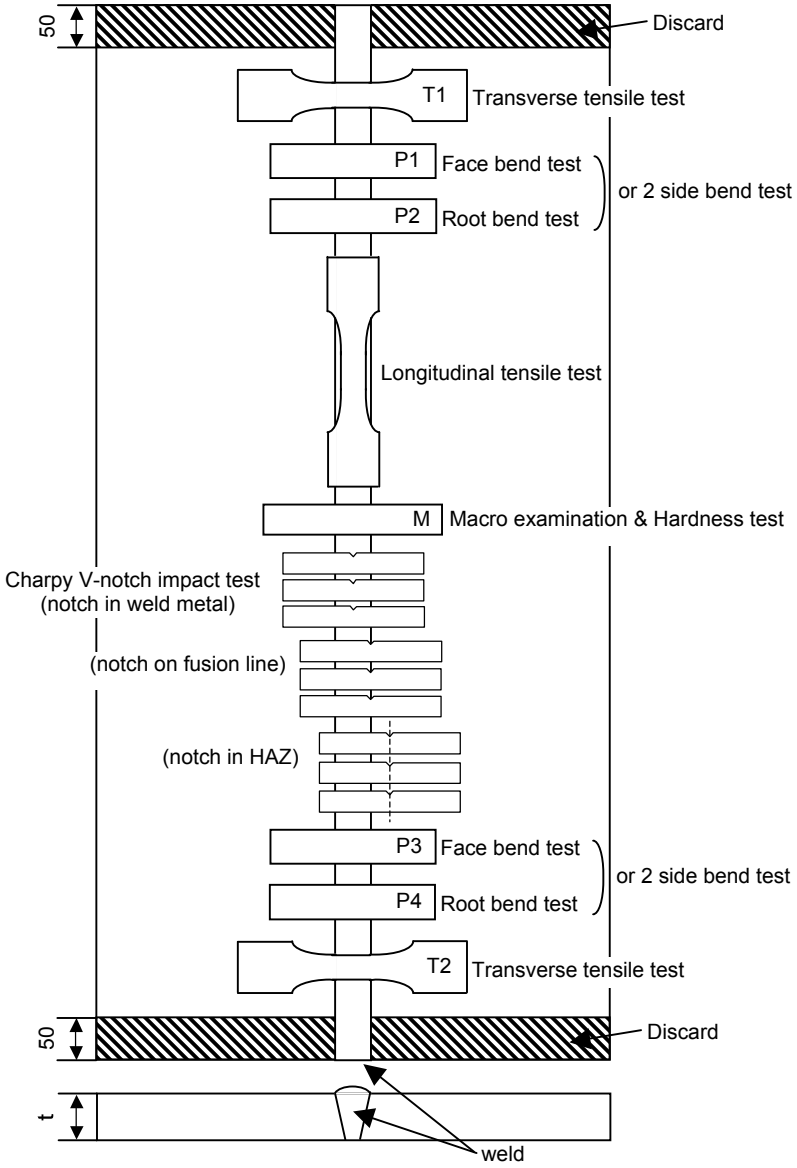

Fig.2 Test sampling

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4.2.2.1 Non-destructive testing

Test assemblies are to be examined by visual and by non-destructive testing prior to the cutting of test specimen. In case that any post-weld heat treatment is required or specified, non-destructive testing is to be performed after heat treatment. For steels according to UR W16 with specified minimum yield strength of 420 N/mm^2 and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless heat treatment has been carried out. NDT procedures are to be agreed with the Society.

Imperfections detected by visual or non-destructive testing are to be assessed in accordance with ISO 5817, class B, except for excess weld metal and excess of penetration for which the level C applies.

4.2.2.2 Transverse tensile test

The testing is to be carried out in accordance with UR W2.4. The tensile strength recorded for each specimen is not to be less than the minimum required for the base metal.

When butt welds are made between plates of different grades, the tensile strength to be obtained on the welded assembly is to be in accordance with the requirements relating to the steel grade having lower strength.

4.2.2.3 Longitudinal tensile test

Longitudinal tensile test of deposited weld metal taken lengthways from the weld is required for cases where the welding consumable is not approved by the Society.

The testing is to be carried out in accordance with UR W2.4. The tensile properties recorded for each specimen are not to be less than the minimum required for the approval of the appropriate grade of consumable.

Where more than one welding process or type of consumable has been used to make the test weld, test specimens are to be taken from the area of the weld where each was used with the exception of those processes or consumables used to make the first weld run or root deposit.

4.2.2.4 Bend test

Transverse bend tests for butt joints are to be in accordance with UR W2.6.

The mandrel diameter to thickness ratio (i.e. D/t) is to be that specified for the welding consumable (UR W17, UR W23) approvals + 1.

The bending angle is to be 180°. After testing, the test specimens are not to reveal any open defects in any direction greater than 3 mm. Defects appearing at the corners of a test specimen during testing are to be investigated case by case.

Two root and two face bend specimens are to be tested. For thickness 12 mm and over, four side bend specimens may alternatively be tested.

For butt joints in heterogeneous steel plates, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

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4.2.2.5 Impact test

a) Normal and higher strength hull structural steels according to UR W11

The positions of specimens are to be in accordance with these requirements. Dimensions and testing are to be in accordance with the requirements of UR W2.7.

Test specimen with Charpy-V-notch are to be used and sampled from 1 to 2 mm below the surface of the base metal, transverse to the weld and on the side containing the last weld run.

V-notch specimens are located in the butt-welded joint as indicated in Fig. 1 and 2 of Annex A and the V-notch is to be cut perpendicular to the surface of the weld.

Test temperature and absorbed energy are to be in accordance with Table 1.

Table 1 Impact test requirements for butt joints (t ≤ 50 mm)[(1),(2)]

Grade of steel	Testing Temperature (C^o)	Value of minimum average absorbed energy (J)		
		For manually or semi-automatically welded joints		For automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A[(3)]	20	47	34	34
B[(3)], D	0			
E	-20			
A32, A36	20			
D32, D36	0			
E32, E36	-20			
F32, F36	-40			
A40	20		39	39
D40	0			
E40	-20			
F40	-40			

Note:

(1) For thickness above 50 mm impact test requirements are to be agreed by the Society.

(2) These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.

(3) For Grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be minimum 27 J.

When butt welds are made between different steel grades/types, the test specimens are to be taken from the side of the joint with lower toughness of steel. Temperature and absorbed energy results are to be in accordance with the requirements for the lower toughness steel.

Where more than one welding process or consumable has been used to make the test weld, impact test specimens are to be taken from the respective areas where each was employed. This is not to apply to the process or consumables used solely to make the first weld run or root deposit.

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The testing of sub - size specimen is to be in accordance with UR W2.7.2

b) High strength quenched and tempered steels according to UR W16

Impact test is to be performed as described in the above a).

V-notch specimens are located in the butt welded joint as indicated in Fig. 1 and 2 of Annex A and the V-notch is to be cut perpendicular to the surface of the weld.

Test temperature and absorbed energy are to be in accordance with the requirements of base metal as specified in UR W16.

c) Weldable C and C-Mn hull steel castings and forgings according to UR W7 and UR W8

For base metal with specified impact values test temperature and absorbed energy are to be in accordance with the requirements of the base metal to be welded.

4.2.2.6 Macro examination

The test specimens are to be prepared and etched on one side to clearly reveal the weld metal, the fusion line and the heat affected zone.

Macro examination is to include about 10 mm unaffected base metal.

The examination is to reveal a regular weld profile, through fusion between adjacent layers of weld and base metal and the absence of defects such as cracks, lack of fusion etc.

4.2.2.7 Hardness test

Hardness test is required for steels with specified minimum yield strength of $R_{eH} \geq 355$ N/mm^2. The Vickers method HV 10 is normally to be used. The indentations are to be made in the weld metal, the heat affected zone and the base metal measuring and recording the hardness values. At least two rows of indentations are to be carried out in accordance with Fig. 1 and 2 of Annex B.

For each row of indentations there is to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides). A typical example is shown in Annex B.

The results from the hardness test are not to exceed the following:

- Steel with a specified minimum yield strength $R_{eH} \leq 420$ N/mm^2 ; 350 HV10
- Steel with a specified minimum yield strength 420 $N/mm^2 < R_{eH} \leq 690$ N/mm^2 ; 420 HV10

4.3 Fillet welds

4.3.1 Assembly of test pieces

The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and according to Fig. 3 with the minimum dimensions:

- manual and semi-automatic welding:

  width a = 3 x t, min. 150 mm
  length b = 6 x t, min. 350 mm

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- automatic welding:

  width a = 3 x t, min. 150 mm
  length b = 1000 mm

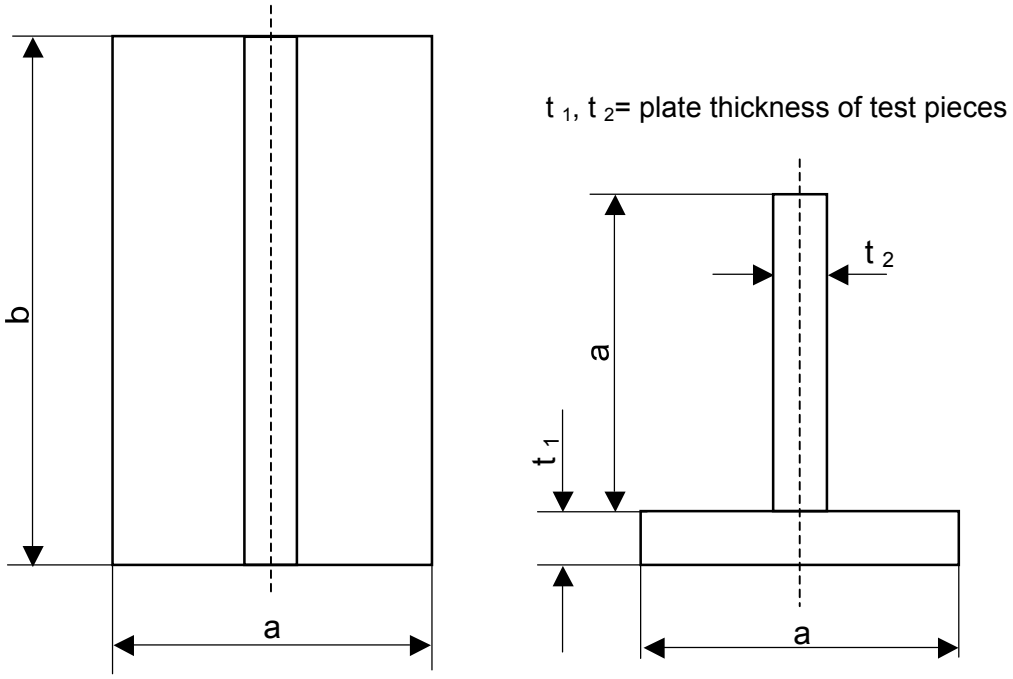

Fig.3 Test assembly for fillet weld

4.3.2 Welding of test pieces

The test assembly is welded on one side only. For single run manual and semi-automatic welding, a stop/restart is to be included in the test length and its position is to be clearly marked for subsequent examination.

4.3.3 Examinations and tests

Test assemblies are to be examined non-destructively and destructively in accordance with the following:

- Visual testing	100 %
- Surface crack detection	100 % (dye penetrant testing or magnetic particle testing)
- Macro examination	two specimen as per 4.3.3.2
- Hardness test	required as per 4.3.3.3
- Fracture test	required as per 4.3.3.4

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4.3.3.1 Non-destructive testing

Test assemblies are to be examined by visual and by non-destructive testing prior to the cutting of test specimen. In case that any post-weld heat treatment is required or specified non-destructive testing is to be performed after heat treatment. For steels according to UR W16 with specified minimum yield strength of 420 N/mm^2 and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless heat treatment has been carried out. NDT procedures are to be agreed with the Society.

Imperfections detected by visual or non-destructive testing are to be assessed in accordance with ISO 5817, class B except for excess convexity and excess throat thickness for which the level C applies.

4.3.3.2 Macro examination

The test specimens are to be prepared and etched on one side to clearly reveal the weld metal, fusion line, root penetration and the heat affected zone.

Macro examination is to include about 10 mm unaffected base metal.

The examination is to reveal a regular weld profile, through fusion between adjacent layers of weld and base metal, sufficient root penetration and the absence of defects such as cracks, lack of fusion etc.

4.3.3.3 Hardness test

Hardness test is required for steels with a specified minimum yield strength of $R_{eH} \geq 355$ N/mm^2. The Vickers method HV 10 is normally to be used. The indentations are to be made in the weld metal, the heat affected zone and the base metal measuring and recording the hardness values. At least two rows of indentations are to be carried out in accordance with Fig. 3, 4a and 4b of Annex B.

For each row of indentations there is to be a minimum of 3 individual indentations in the weld metal, the heat affected zone (both sides) and the base metal (both sides). A typical example is shown in Annex B.

The results from the hardness test are not to exceed the following:

- Steel with a specified minimum yield strength $R_{eH} \leq 420$ N/mm^2 ; 350 HV10
- Steel with a specified minimum yield strength 420 N/mm^2 < $R_{eH} \leq 690$ N/mm^2 ; 420 HV10

4.3.3.4 Fracture test

The fracture test is to be performed by folding the upright plate onto the through plate. Evaluation is to concentrate on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration. Imperfection that are detected is to be assessed in accordance with ISO 5817, class B.

4.4 Re-testing

4.4.1 If the test piece fails to comply with any of the requirements for visual or non-destructive testing one further test piece is to be welded and subjected to the same examination. If this additional test piece does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

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4.4.2 If any test specimens fail to comply with the relevant requirements for destructive testing due to weld imperfections only, two further test specimens are to be obtained for each one that failed. These specimens can be taken from the same test piece if there is sufficient material available or from a new test piece, and are to be subjected to the same test. If either of these additional test specimens does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

4.4.3 If a tensile test specimen fails to meet the requirements, the re-testing is to be in accordance with UR W 2.4.3.

4.4.4 If there is a single hardness value above the maximum values allowed, additional hardness tests are to be carried out (on the reverse of the specimen or after sufficient grinding of the tested surface). None of the additional hardness values is to exceed the maximum hardness values required.

4.4.5 The re-testing of Charpy impact specimens are to be carried out in accordance with UR W 2.7.4.

4.4.6 Where there is insufficient welded assembly remaining to provide additional test specimens, a further assembly is to be welded using the same procedure to provide the additional specimens.

4.5 Test record

4.5.1 Welding conditions for test assemblies and test results are to be recorded in welding procedure test record. Forms of welding procedure test records can be taken from the Society's rules or from relevant standards.

4.5.2 A statement of the results of assessing each test piece, including repeat tests, is to be made for each welding procedure test. The relevant items listed for the WPS of these requirements are to be included.

4.5.3 A statement that the test piece was made according to the particular welding procedure is to be signed by the Surveyor witnessing the test and is to include the Society´s identification.

5. Range of approval

5.1 General

5.1.1 All the conditions of validity stated below are to be met independently of each other.

5.1.2 Changes outside of the ranges specified are to require a new welding procedure test.

5.1.3 Shop primers may have an influence on the quality of fillet welds and is to be considered. Welding procedure qualification with shop primer will qualify those without but not vice versa.

5.2 Base metal

5.2.1 Normal and higher strength hull structural steels according to UR W11

a) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested.

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b) For each toughness grade, welding procedures are considered applicable to the same and two lower strength levels as that tested.

c) For applying the above a) and b) to high heat input processes above 50kJ/cm, e.g. the two-run technique with either submerged arc or gas shielded metal arc welding, electro slag and electro gas welding, welding procedure is applicable to that toughness grade tested and one strength level below.

Where steels used for construction are supplied from different delivery conditions from those tested the Society may require additional tests.

5.2.2 High strength quenched and tempered steels according to UR W16

a) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested.

b) For each toughness grade, welding procedures are considered applicable to the same and one lower strength level as that tested.

c) The approval of quenched and tempered steels does not quality thermo-mechanically rolled steels (TMCP steels) and vice versa.

5.2.3 Weldable C and C-Mn hull steel forgings according to UR W7

a) Welding procedures are considered applicable to the same and lower strength level as that tested.

b) The approval of quenched and tempered hull steel forgings does not quality other delivery conditions and vice versa.

5.2.4 Weldable C and C-Mn hull steel castings according to UR W8

a) Welding procedures are considered applicable to the same and lower strength level as that tested.

b) The approval of quenched and tempered hull steel castings does not quality other delivery conditions and vice versa.

5.3 Thickness

5.3.1 The qualification of a WPS carried out on a test assembly of thickness t is valid for the thickness range given in Table 2.

Table 2 Approval range of thickness for butt and T-joint welds and fillet welds

Thickness of test piece T[(1)] (mm)	Range of approval	
	Butt and T-joint welds with single run or single run from both sides	Butt and T-joint welds with multi-run and fillet welds[(2)]
$3 < t \leq 12$	0.7 x t to 1.1 x t	3 to 2 x t
$12 < t \leq 100$	0.7 x t to 1.1 x t[(3)]	0.5 x t to 2 x t (Max. 150)

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Note:

(1) For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval for the individual welding process.

(2) For fillet welds, the range of approval is to be applied to both base metals.

(3) For high heat input processes over 50kJ/cm, the upper limit of range of approval is to be 1.0 x t.

5.3.2 In addition to the requirements of Table 2, the range of approval of throat thickness “a” for fillet welds is to be as follows:

- Single run ; “0.75 x a” to “1.5 x a”

- Multi-run ; as for butt welds with multi-run (i.e. a=t)

5.3.3 For the vertical-down welding, the test piece thickness “t” is always taken as the upper limit of the range of application.

5.3.4 For unequal plate thickness of butt welds the lesser thickness is ruling dimension.

5.3.5 Notwithstanding the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of test assembly if three of the hardness values in the heat affected zone are found to be within 25 HV of the maximum permitted, as stated 4.2.2.7 and 4.3.3.3.

5.4 Welding position

Approval for a test made in any position is restricted to that position (see Annex C). To qualify a range of positions, test assemblies are to be welded for highest heat input position and lowest heat input position and all applicable tests are to be made on those assemblies.

5.5 Welding process

5.5.1 The approval is only valid for the welding process(es) used in the welding procedure test. It is not permitted to change from a multi-run to a single run.

5.5.2 For multi-process procedures the welding procedure approval may be carried out with separate welding procedure tests for each welding process. It is also possible to make the welding procedure test as a multi-process procedure test. The approval of such a test is only valid for the process sequence carried out during the multi-process procedure test.

5.6 Welding consumable

Except high heat input processes over 50kJ/cm, welding consumables cover other approved welding consumables having the same grade mark including all suffixes specified in UR W17 and UR W23 with the welding consumable tested.

5.7 Heat input

5.7.1 The upper limit of heat input approved is 25% greater than that used in welding the test piece or 55kJ/cm whichever is smaller, except that the upper limit is 10% greater than that for high heat input processes over 50kJ/cm.

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5.7.2 The lower limit of heat input approved is 25% lower than that used in welding the test piece.

5.8 Preheating and interpass temperature

5.8.1 The minimum preheating temperature is not to be less than that used in the qualification test.

5.8.2 The maximum interpass temperature is not to be higher than that used in the qualification test.

5.9 Post-weld heat treatment

The heat treatment used in the qualification test is to be maintained during manufacture. Holding time may be adjusted as a function of thickness.

5.10 Type of joint

5.10.1 Range of approval depending on type of welded joints for test assembly is to be specified in Table 3.

5.10.2 A qualification test performed on a butt weld will also qualify for fillet welding within the thickness ranges specified for fillet welds specified in 5.3 above.

Table 3 Range of approval for type of welded joint

Type of welded joint for test assembly			Range of approval	
Butt welding	One side	With backing	A	A, C~~, D~~
		Without backing	B	A, B, C, D
	Both side	With gouging	C	C
		Without gouging	D	C, D

5.11 Other variables

The range of approval relating to other variables may be taken according to the Society requirements.

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Annex A

Location of Charpy V-notch impact test

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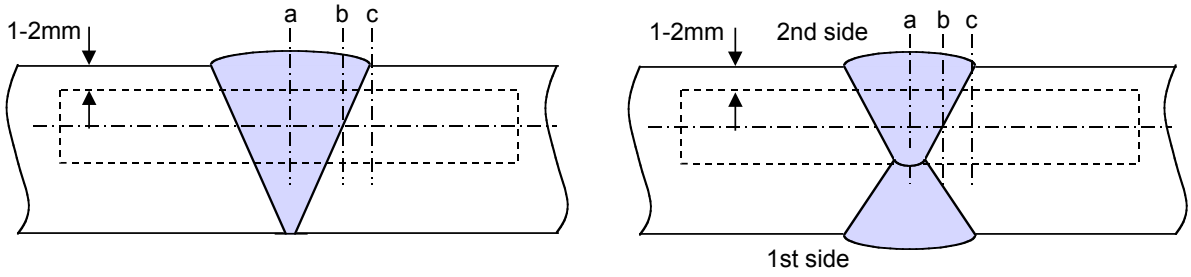
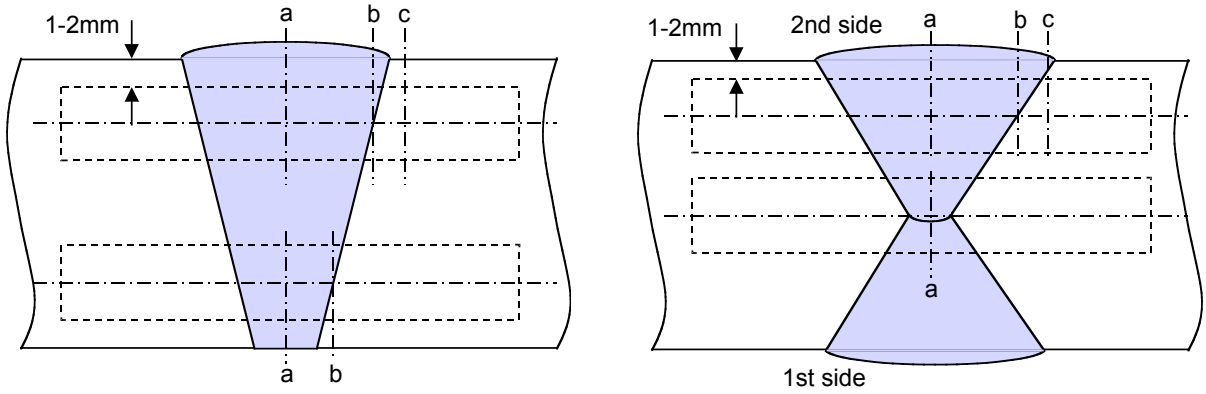
a) t≤50mm(1)



Note:

(1) For one side single run welding over 20mm notch location “a” is to be added on root side.

b) t>50mm



Notch locations:
a : center of weld “WM”
b : on fusion line “FL”
c : in HAZ, 2mm from fusion line

Fig. 1 Locations of V-notch for butt weld of normal heat input (heat input ≤ 50 kJ/cm)

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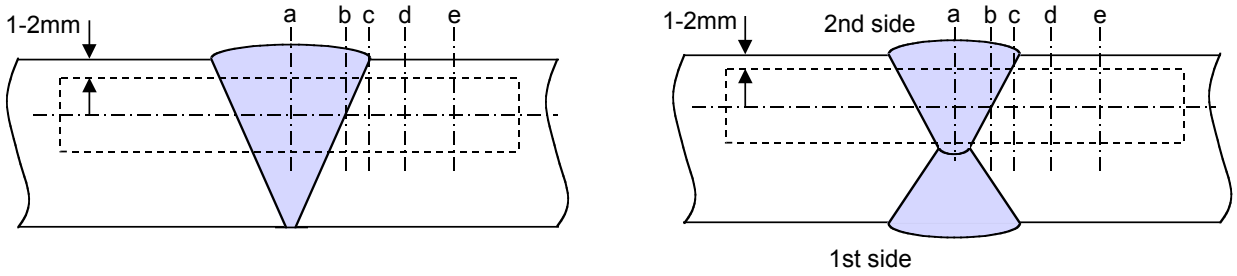
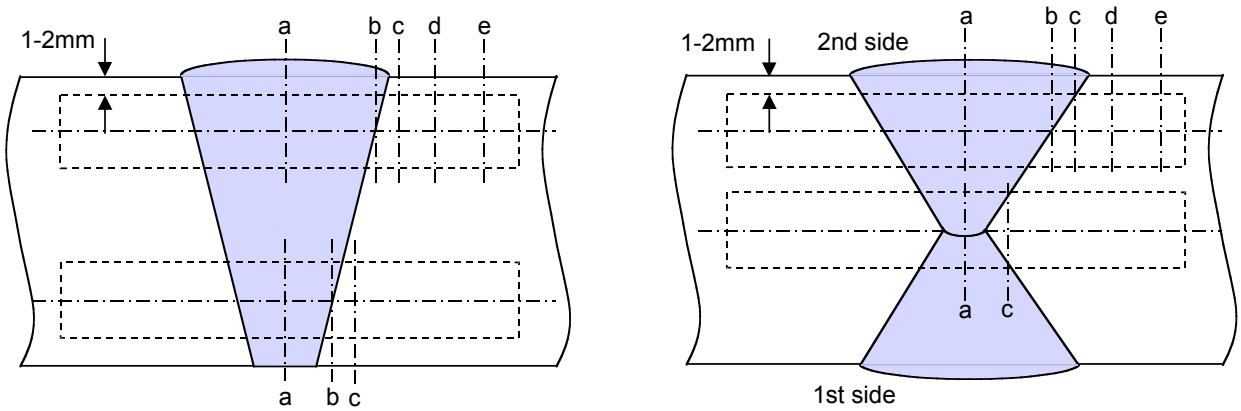
a) t≤50mm(1)



Note:

(1) For one side welding with thickness over 20mm notch locations “a”, “b” and “c” are to be added on root side.

b) t>50mm



Notch locations:
a : center of weld “WM”
b : on fusion line “FL”
c : in HAZ, 2mm from fusion line
d : in HAZ, 5mm from fusion line
e : in HAZ, 10mm from fusion line in case of heat input > 200kJ/cm

Fig. 2 Locations of V-notch for butt weld of high heat input (heat input > 50kJ/cm)

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Annex B

Hardness test

(Typical examples of hardness test)

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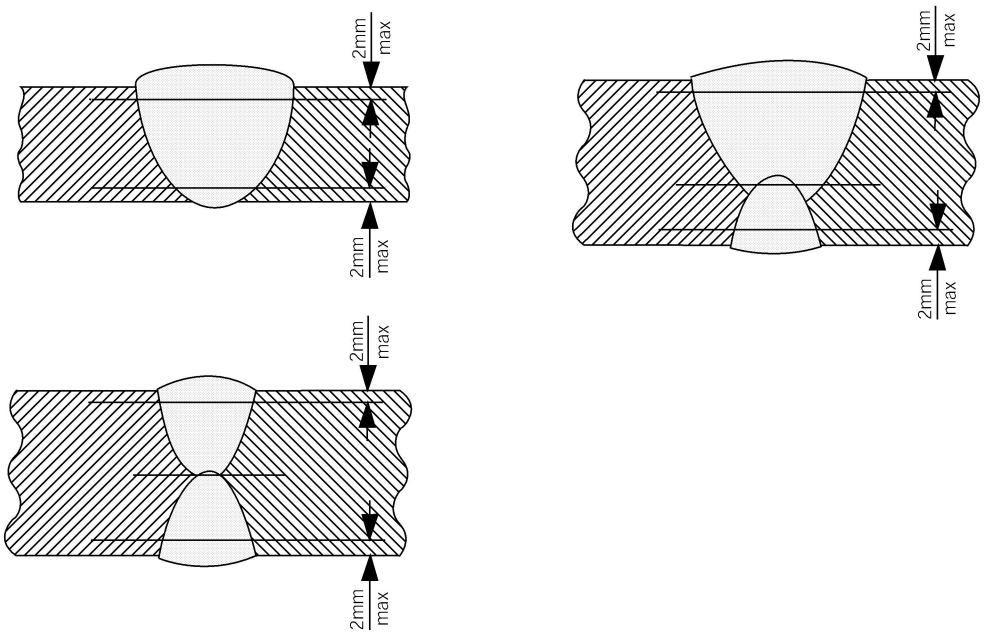

Fig. 1 Examples of hardness test with rows of indentations (R) in butt welds

Table 1 Recommended distances *l* between indentations for hardness test in the heat affected zone

Vickers hardness Symbol	Distance between indentations *l* (mm)
HV 10	1

The distance of any indentation from the previous indentation is not to be less than the value allowed for the previous indentation by ISO 6507/1.

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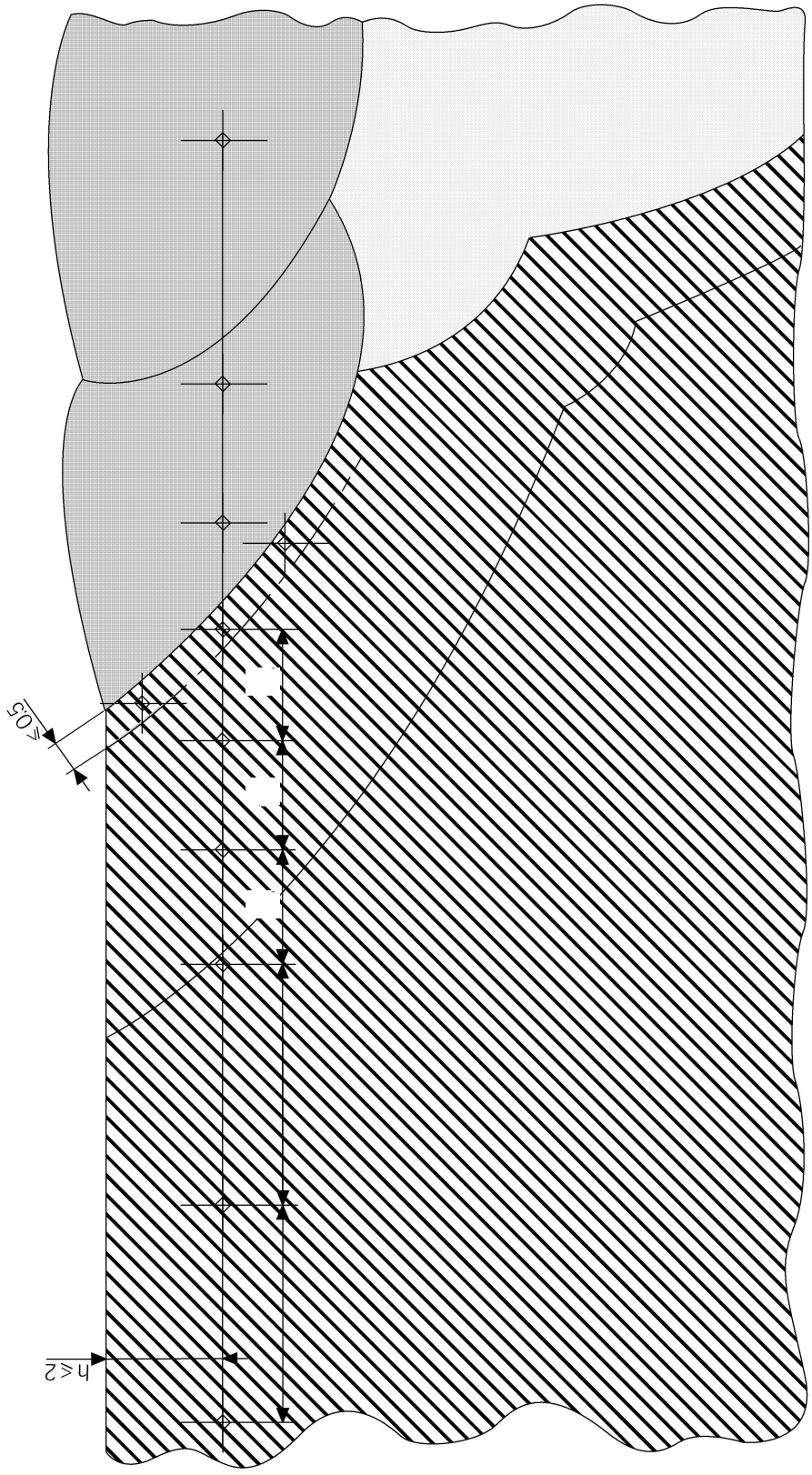

Fig. 2 Example showing the position of the indentations for hardness test in the weld metal, the heat affected zone and the base metal of a butt weld (dimensions in mm)

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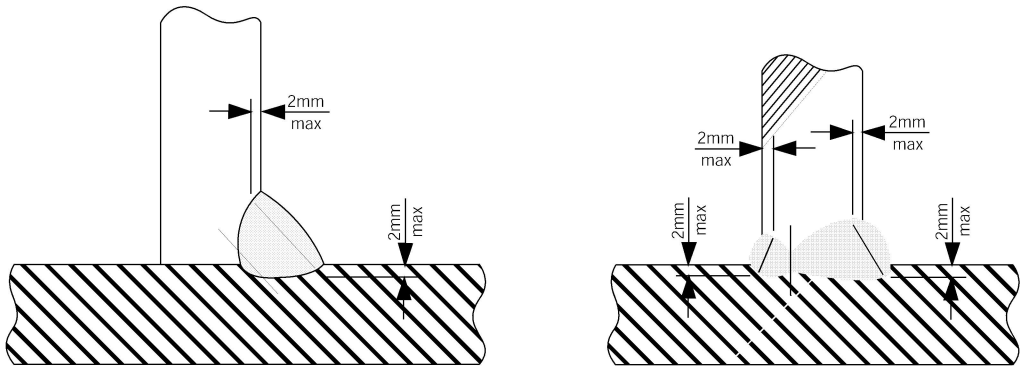


a) Fillet weld b) T-joint weld

Fig. 3 Examples of hardness test with row indentation (R) in fillet welds and in T-joint welds

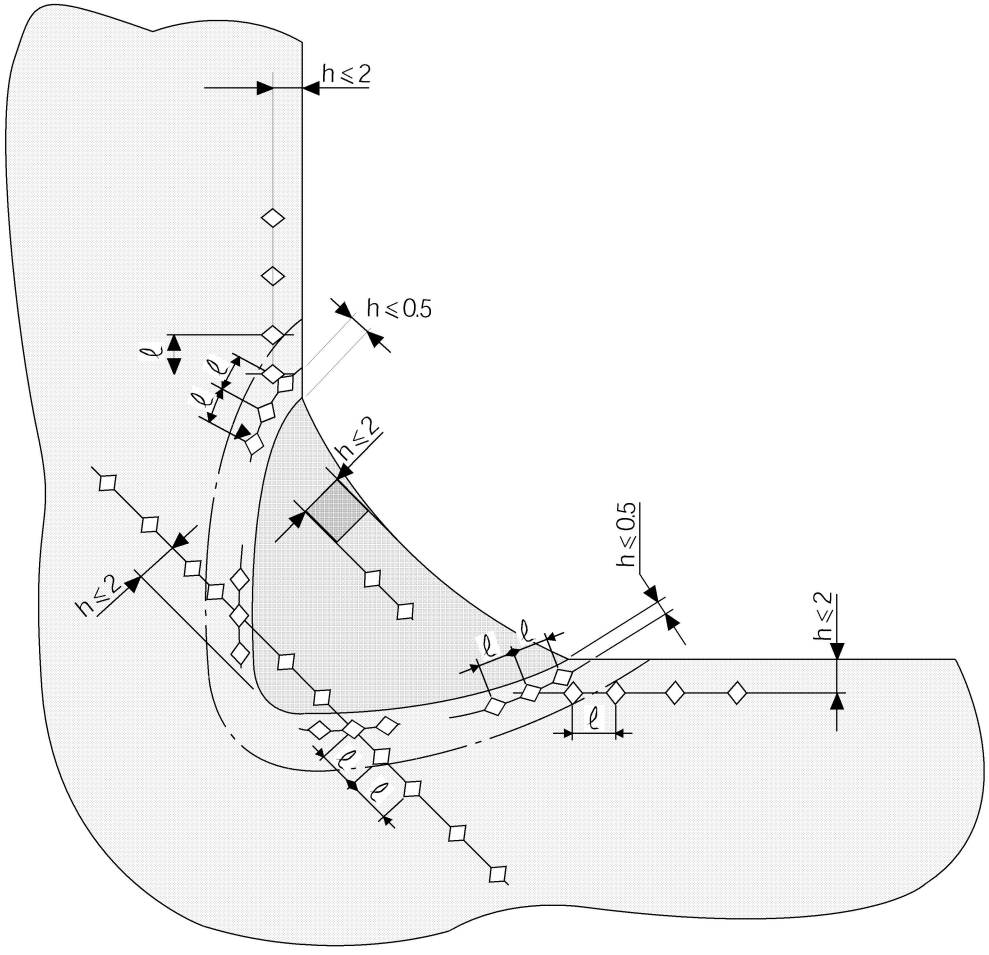


Fig. 4a Example showing the position of the indentations for hardness test in the weld metal, the heat affected zone and the base metal of a fillet weld (dimensions in mm)

W28
(cont)

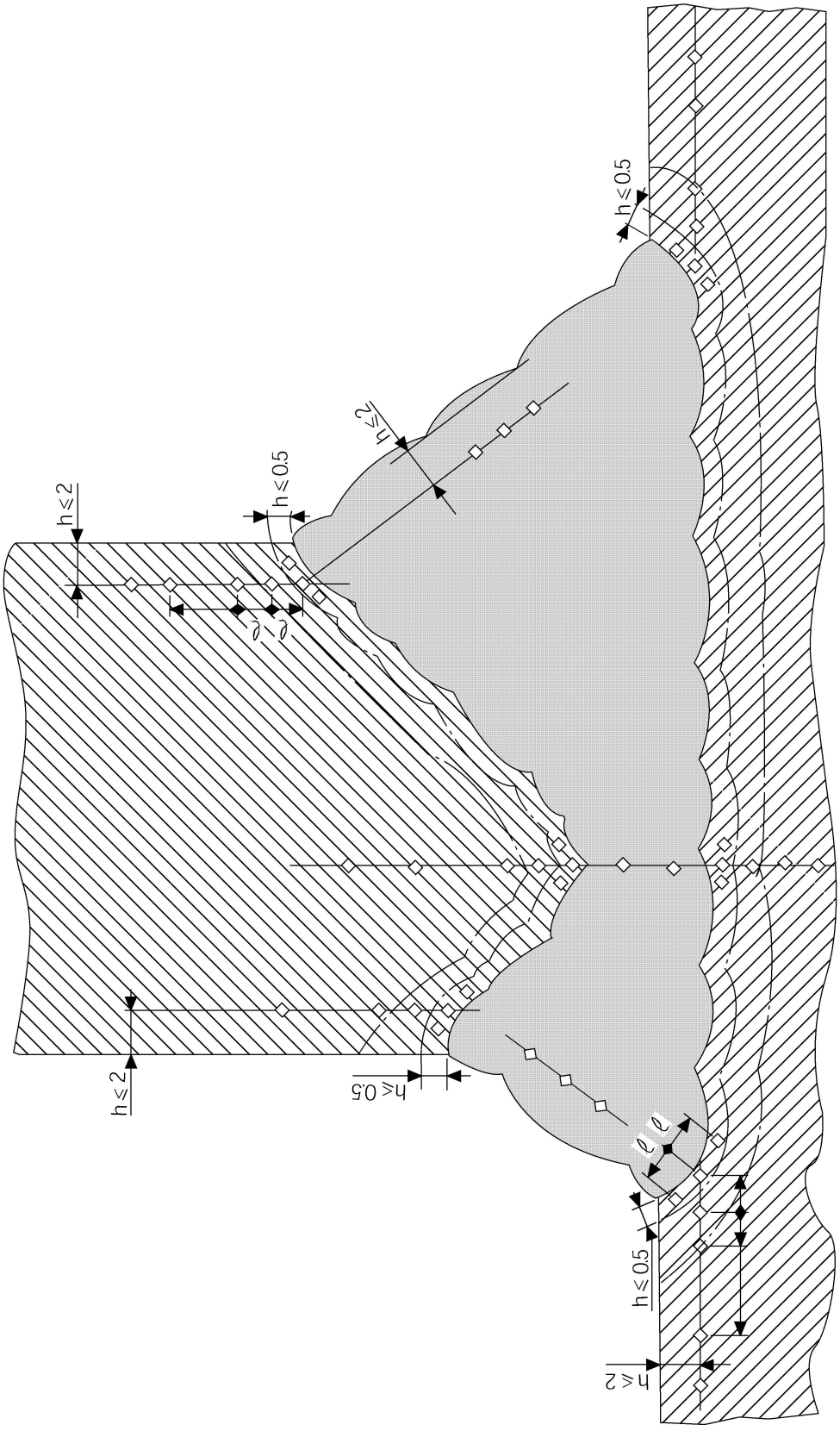


Fig. 4b Example showing the position of the indentations for hardness test on the weld metal, the heat affect zone and the base metal of a T-joint weld (dimensions in mm)

W28
(cont)

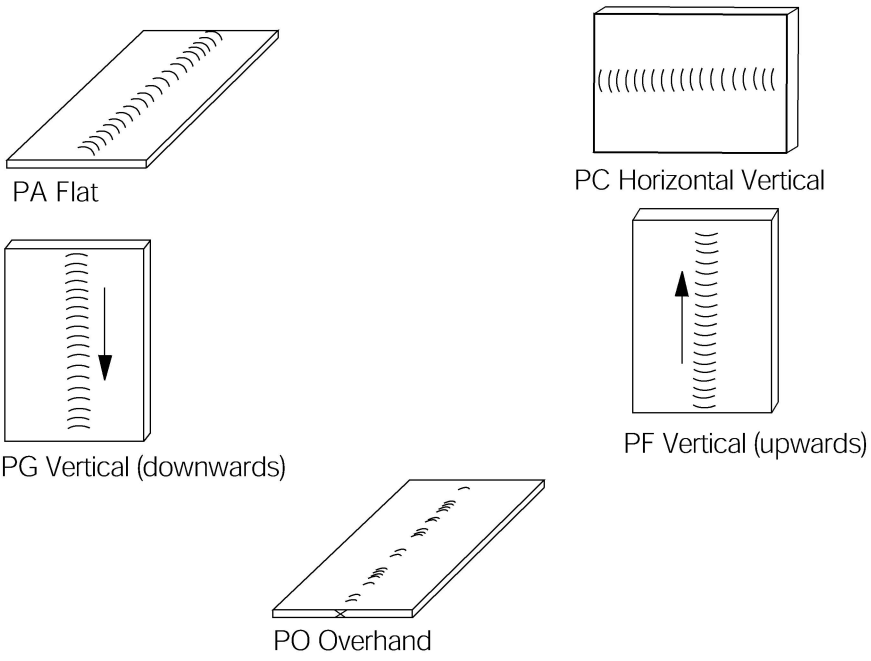
Annex C

Welding positions

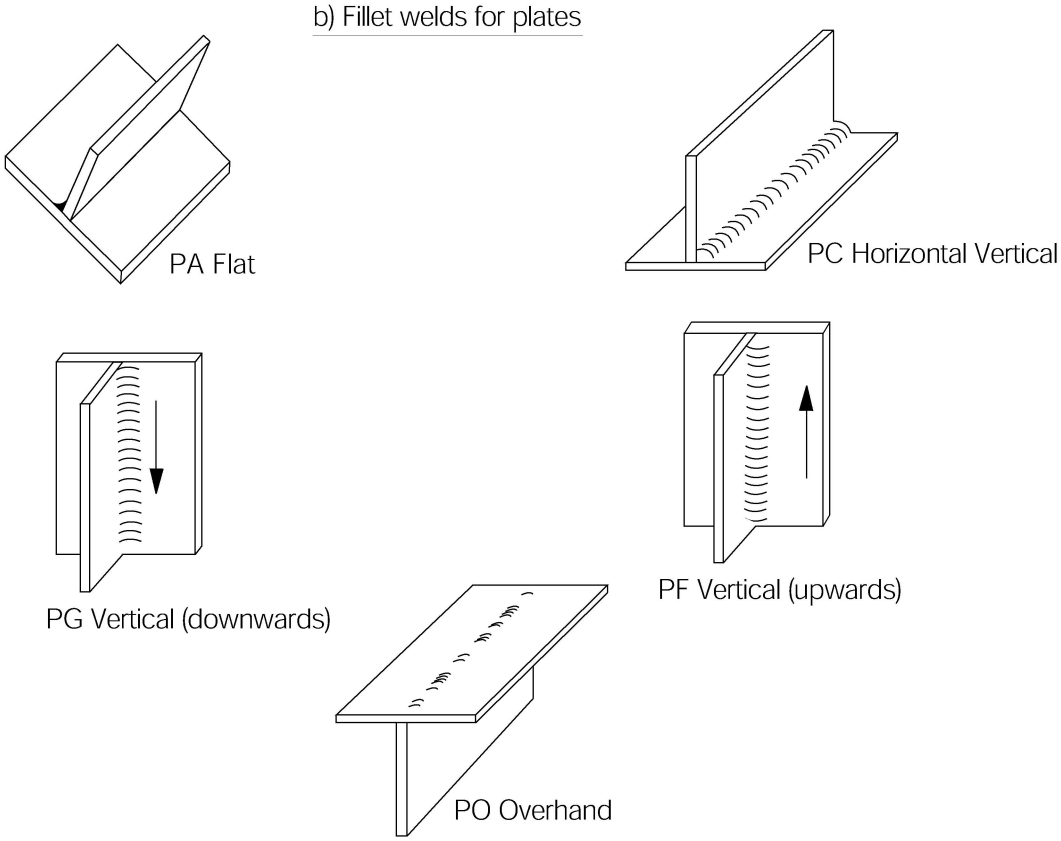
W28
(cont)

Annex C.1: Welding positions according to ISO Standard

a) Butt welds for plates



b) Fillet welds for plates

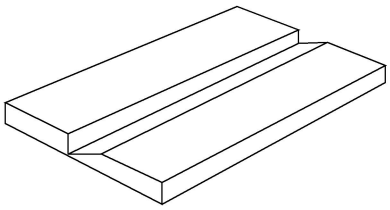


W28
(cont)

Annex C.2: Welding positions according to AWS-Code

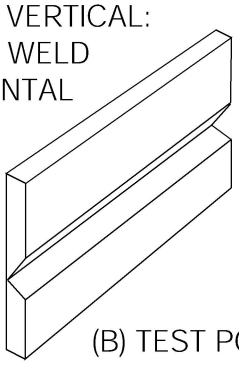
a) Butt weld for plates

PLATES HORIZONTAL

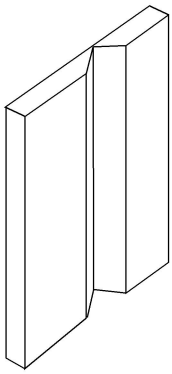


(A) TEST POSITION 1G

PLATES VERTICAL:
AXIS OF WELD
HORIZONTAL



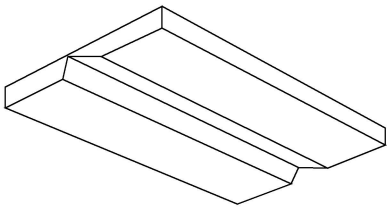
(B) TEST POSITION 2G



PLATES VERTICAL:
AXIS OF WELD
VERTICAL

(C) TEST POSITION 3G

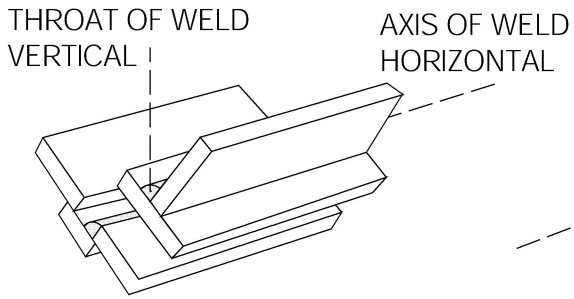
PLATES HORIZONTAL



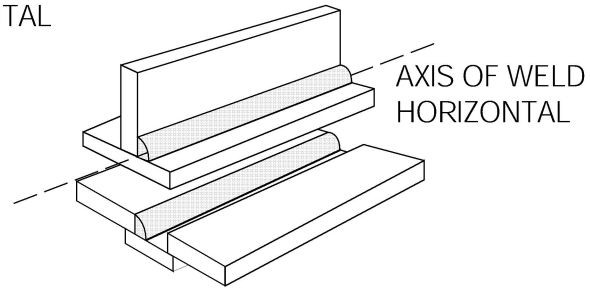
(D) TEST POSITION 4G

W28
(cont)

b) Fillet welds for plates

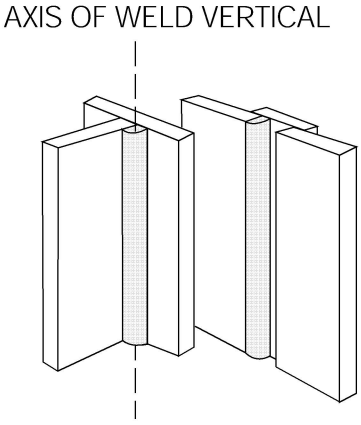


(A) FLAT POSITION 1F

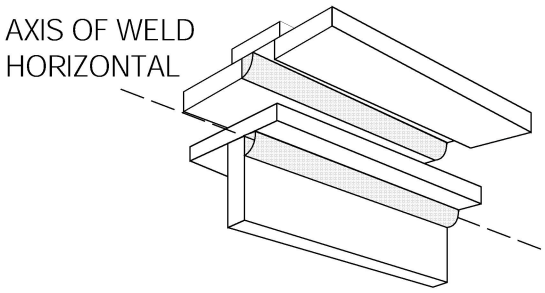


Note: One plate must be horizontal

(B) HORIZONTAL POSITION 2F



(C) VERTICAL POSITION 3F



Note: One plate must be horizontal

(D) OVERHEAD POSITION 4F

End of Document