Lloyd's Register

Rules for the Manufacture, Testing and Certification of Materials, July 2008

Notice No. 1

Effective Date of Latest Amendments:

See page 1

Issue date: August 2008

RULES FOR THE MANUFACTURE, TESTING AND CERTIFICATION OF MATERIALS, *July 2008*

Notice No. 1

This Notice contains amendments within the following Sections of the *Rules for the Manufacture, Testing and Certification of Materials, July 2008.* The amendments are effective on the dates shown:

Chapter	***Section***	***Effective date***
12	Whole Chapter	1 August 2008
13	Whole Chapter	1 August 2008

It will be noted that the amendments also include corrigenda, which are effective from the date of this Notice.

The *Rules for the Manufacture, Testing and Certification of Materials July 2008* are to be read in conjunction with this Notice No. 1. The status of the Rules is now:

Rules for Materials	Effective date:	July 2008
Notice No. 1	Effective date:	1 August 2008

~~Chapter 12~~

~~Fabricated Steel Sections~~

Existing Chapter 12 has been deleted and replace by a new Chapter 12.

Chapter 12
Welding Qualifications

Effective date 1 August 2008

■ *Section 1*
General qualification requirements

1.1 General

1.1.1 This Section applies to all welding qualifications and tests required to be performed in the course of new construction, conversions, modifications or repairs made on ships, other marine structures and their associated pressure vessels, machinery and equipment.

1.1.2 These Rules also apply to all welding work related to other applications for which Lloyd's Register (hereinafter referred to as LR) have issued Rules or have an interest.

1.1.3 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules. All deviations are to be recorded as non-compliances and brought to the attention of the Surveyor along with the corrective actions taken. Failure to do this is considered to render the welding tests as not complying with the Rules.

1.1.4 Welding tests are to be performed under survey at the manufacturer's works. Welding procedure qualification tests and welder qualifications tests are to be performed and approved prior to commencement of fabrication or construction.

1.1.5 Weld procedure tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to and meet the technical intent of these Rules to the satisfaction of the Surveyor.

1.1.6 Welding tests that have previously been carried out may be considered for acceptance, provided that they have been supervised by an independent body acceptable to LR and the Surveyor is satisfied with the authenticity of such tests.

1.1.7 The responsibility for the performance of the weld tests rests with the manufacturer. Aspects of the welding tests, such as mechanical testing, non-destructive testing and heat treatment, may be subcontracted by the manufacturer provided that the subcontractor performs the work under the technical control and direction of the manufacturer, and this is agreed with the Surveyor prior to commencing the work.

1.1.8 In these Rules, the term 'manufacturer' is considered to include any firm or organisation that performs welding and is considered to be the shipbuilder, or construction firm, or fabricator, or material manufacturer.

1.2 Design

1.2.1 Welding procedure qualification tests are required to give assurance that construction welds made in accordance with the approved plans or the approved design have acceptable properties. It is the manufacturer's responsibility to establish and document whether a procedure is suitable for a particular application.

1.2.2 The requirements relate to mechanical properties of the weld and heat affected zone, however, other tests may be required on certain materials, for example, corrosion or fatigue tests, in order to ensure suitability for the proposed application.

1.3 Materials

1.3.1 Materials used for testing are to be of the same grade, type and from the same manufacturing process as those to be used for construction, unless prior agreement is obtained from the Surveyor. Such agreements will only apply on a case-by-case basis.

1.3.2 All materials used for testing are to be suitably marked and identifiable to the original manufacturer's material certificate.

1.4 Performance of welding tests

1.4.1 All welding and subsequent testing is to be performed in accordance with the requirements of this Chapter.

1.4.2 The manufacturer is responsible for monitoring the tests and for recording all the welding variables as specified in 2.2 and for compiling all the non-destructive examination (NDE) reports and mechanical test records for submission to the Surveyor.

1.4.3 The laboratory or testing establishment used to perform the tests is to have the necessary equipment, maintained in good order and suitably calibrated. The Surveyor is to be satisfied that the laboratory personnel have the appropriate skills and are appropriately qualified in accordance with Ch 2,1.2.1.

Section 2
Welding Procedure Qualification Tests for Steels

2.1 General

2.1.1 The requirements of this Section relate to welding procedure test requirements of carbon, carbon-manganese steels and low alloys steels. Additional requirements for austenitic and austenitic/ferritic duplex stainless steels, aluminium and copper alloys are specified in Sections 3 and 4 respectively.

2.1.2 Prior to performing the welding procedure qualification test, the manufacturer is to present to the Surveyor a preliminary Welding Procedure Specification (pWPS) detailing the welding processes, positions, joint types, materials and heat treatments to be performed during the test. The pWPS is to be presented for information prior to commencing the test.

2.1.3 The type and extent of testing to be applied to each welding procedure test is to be in accordance with subsequent Sections of this Chapter.

2.1.4 For the welding procedure approval, the welding procedure qualification tests given in this Section are to be carried out with satisfactory results. Welding procedure specifications are to refer to the test results achieved during welding procedure qualification testing.

2.2 Welding variables

2.2.1 In order that the conditions of the qualification test may be applied to production welding operations, the appropriate variables are to be recorded by the manufacturer during welding and testing from the following list:

(a) The unique qualification reference number and the date of welding;
(b) The material type, grade, product form, dimensions and identification;
(c) Welding process(es), including tack welds;
(d) Joint type, dimensions and surface condition;
(e) Welding position(s);
(f) Welding technique(s), weaving, multiple electrodes, etc;
(g) Welding consumables including fluxes, shielding gases, etc;
(h) Control of consumables, baking or drying conditions, etc;
(j) Welding parameters, current, voltages, travel speeds, etc;
(k) Number and sequence of weld runs;
(l) Backing materials including any backing gas;
(m) Preheats and interpass temperatures;
(n) Methods used for cleaning and inspection of root deposits;
(o) Post-weld heat treatment, temperature and cycle times;
(p) Special weld profiling requirements.

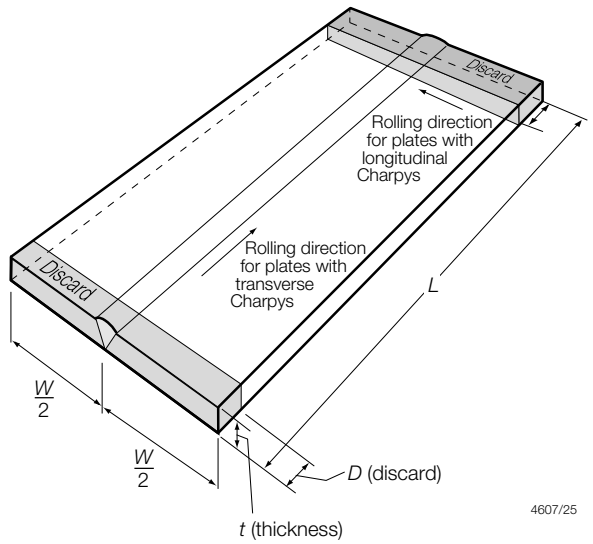
2.2.2 Other variables may need to be recorded depending on the particular welding process or application and are to be agreed with the Surveyor, for example the peak and base current and cycle times for pulse welding, electrode type and nozzle size for GTAW welding, etc.

2.3 Steel test assemblies

2.3.1 Tests are to be performed using the welding process and positions anticipated for actual construction. The weld test assemblies are to be representative of construction conditions and are to be welded in the same manner as intended for the actual production welds. Where pre-fabrication primers are used in the shipyard, these are to be included in the test assemblies.

2.3.2 For plate tests, the direction of plate rolling relative to the weld direction is to be considered. Where the material used for the test requires longitudinal impact tests, the plate rolling direction is to be perpendicular to the weld direction and for material which requires impact testing in the transverse direction, the rolling direction is to be parallel to the weld direction.

2.3.3 Typical test assemblies are shown in Fig. 12.2.1(a) to (c). These are a minimum requirement to permit the removal of all the necessary mechanical test specimens. Where impact tests or other toughness tests are required, the total width is not to be less than 8 times the material thickness of the thicker material being joined.

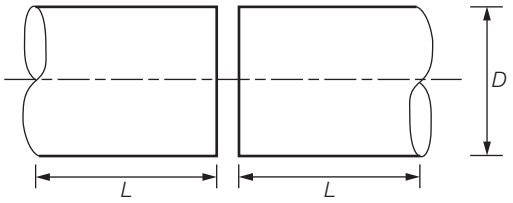


Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	400	75

Fig. 12.2.1(a) Butt weld test assembly in plate

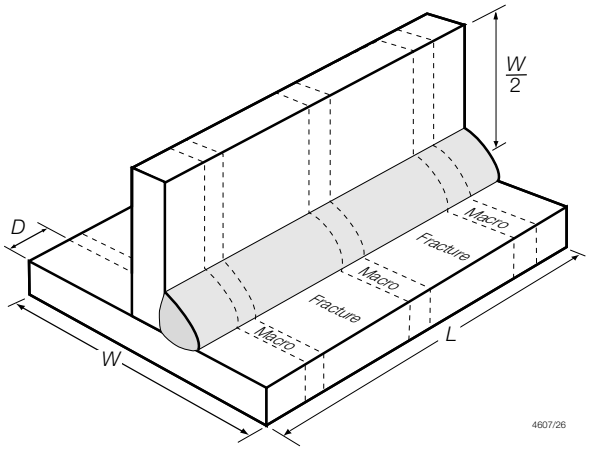
2.3.4 Welding procedure test assemblies are to be welded separately from production welds and are to be marked with the unique test identification number. The individual pieces of the test assembly may be held together to maintain their relative joint conditions by means of suitable tack welds, clamps or strongbacks.

2.3.5 Welding of the test assemblies and testing of test specimens is to be monitored by the Surveyor.



L = 150 mm minimum
D = Outside diameter

Fig. 12.2.1(b) Butt weld test assembly in pipe



Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	300	75

Fig. 12.2.1(c) Fillet weld test assembly in plate

2.3.6 The test assembly is to be placed in one of the welding positions shown in Fig. 12.2.2(a) to (d), as specified in the test Welding Procedure Specification (pWPS) and the specified level of preheat applied prior to the start of welding.

2.3.7 Designations for equivalent welding positions shown by different standards are shown in Table 12.2.1.

Table 12.2.1 Equivalent designations of welding positions

Weld position		Standard	
		ISO 6947	AWS
Plate butt welds			
Flat	D	PA	1G
Horizontal	X	PC	2G
Vertical, weld up	Vu	PF	3G
Vertical, weld down	Vd	PG	3G
Overhead	O	PE	4G
Pipe butt welds			
Pipe horizontal, rotated, weld horizontal	D	PA	1G
Pipe vertical, not rotated, weld horizontal	X	PC	2G
Pipe horizontal, not rotated, weld flat, vertical and overhead	D+Vu+O D+Vd+O	PF	5G
Pipe inclination fixed, not rotated	45°	H-L045 J-L045	6G
Plate fillet welds			
Flat	D	PA	1F
Horizontal	X	PB	2F
Vertical up	Vu	PF	3F
Vertical down	Vd	PG	3F
Overhead	O	PD	4F
Pipe fillet welds			
Flat, pipe rotated	D	PA	1FR
Horizontal, pipe fixed	X	PB	2F
Horizontal, pipe rotated	D	PB	2FR
Overhead, pipe fixed	O	PD	4F
Multiple, pipe fixed	D+Vu+O D+Vd+O	PF PG	5F

2.4 Welding of steel test assemblies

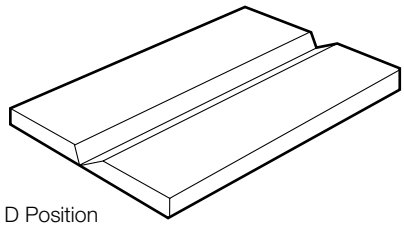
2.4.1 Welding of the test assembly is to be carried out in accordance with the agreed pWPS. Where, during the progress of the test, it is found necessary to change the conditions specified on the pWPS, this is to be brought to the attention of the Surveyor. If agreed, the test may be permitted to continue with the new conditions and these are to be recorded.

2.4.2 Where the production work requires welding over tack welds, the test is to simulate this condition and the tack welds are to be included in the inspection length of the test weld and their position recorded.

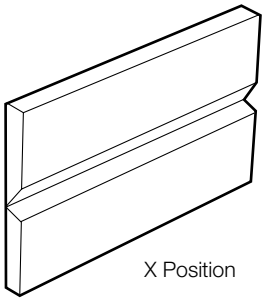
2.4.3 For manual and semi-automatic welding processes, weld stops and re-starts are to be included in the inspection length of the test weld.

2.4.4 Fillet weld test assemblies are welded on one side only.

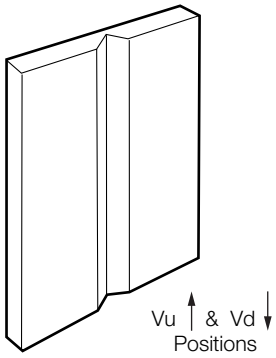
2.4.5 Where the construction welding is predominately fillet welding, in addition to the butt weld qualification test, a fillet weld qualification test is to be performed to confirm that acceptable weld quality is achieved.



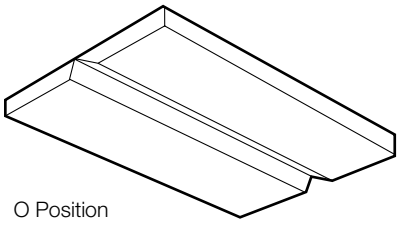
Flat
(Plates horizontal)



Horizontal
(Plates vertical)



Vertical
(Plates vertical)



Overhead
(Plates horizontal)

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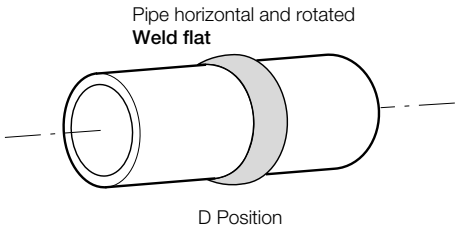
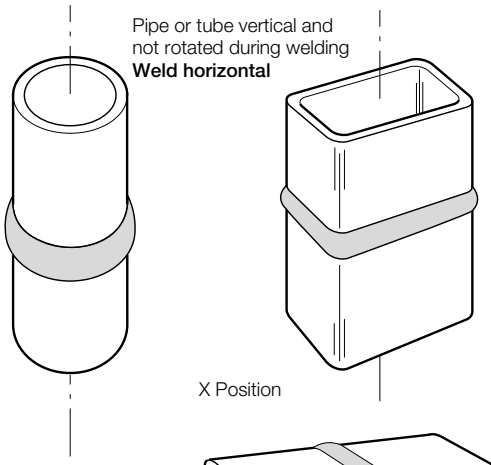
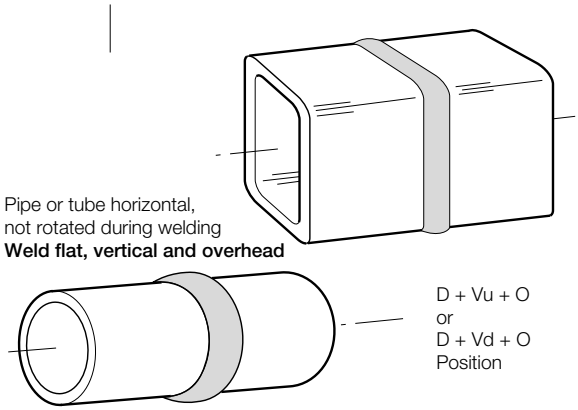
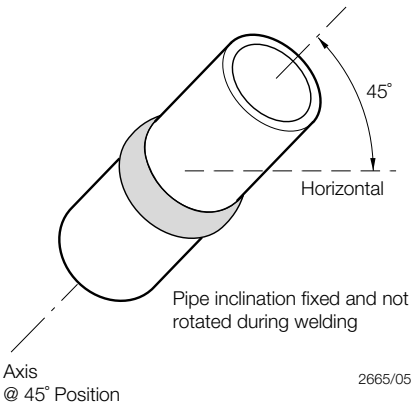
Position of test plates for plate assemblies

Fig. 12.2.2(a) Plate butt weld test positions









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Position of pipes and welds for qualification weld test assemblies

Fig. 12.2.2(b) Pipe butt weld test positions

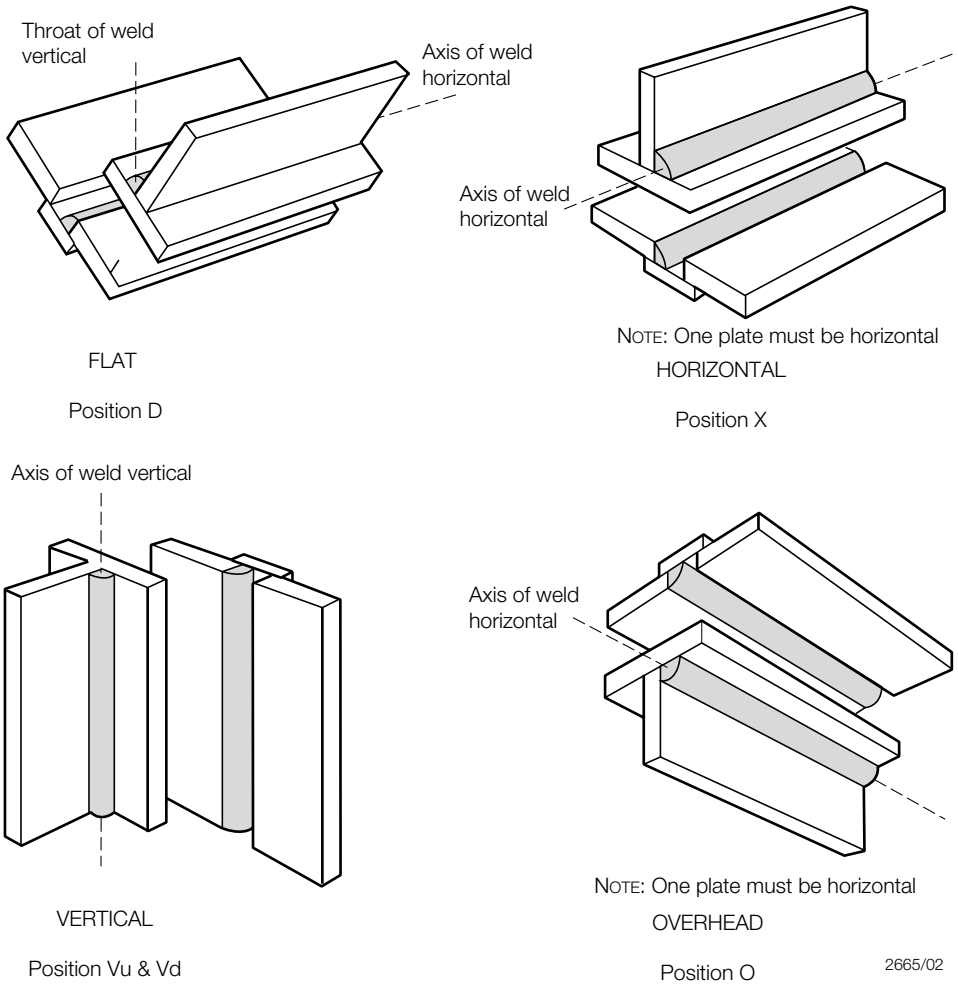


Fig. 12.2.2(c) Plate fillet weld test positions

2.5 Non-destructive examination (NDE)

2.5.1 On completion of welding, prior to sectioning for mechanical tests, the inspection length of the test assembly is to be subjected to both visual examination and surface crack detection.

2.5.2 Butt weld assemblies are also to be subjected to radiographic or ultrasonic examination over the whole inspection length of the weld.

2.5.3 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

2.5.4 Where post-weld heat treatment is required, NDE is to be performed after the heat treatment is complete.

2.5.5 NDE is to be performed in accordance with procedures acceptable to LR. Assessment of results is to be in accordance with ISO 5817 Level B except for excess convexity and excess throat thickness where Level C will apply.

2.5.6 As an alternative to radiography, ultrasonic examination may be carried out and acceptance criteria that are considered to result in equivalent weld quality are to be agreed, with the Surveyor, prior to the tests being carried out. Ultrasonic testing will be subject to the thickness limitation specified in Ch 13,2.12.5.

2.5.7 Where the test assembly does not satisfy the non-destructive examination acceptance criteria, the test is to be rejected. A duplicate test assembly may be welded using the original welding conditions. If this fails NDE, the welding procedure is to be considered as incapable of achieving the requirements without modification.

2.5.8 Subject to prior agreement with the Surveyor, where unacceptable imperfections are of a volumetric nature and are localised in one small area of the test assembly, the test may be permitted to continue and specimens for destructive testing may be removed, avoiding this area.

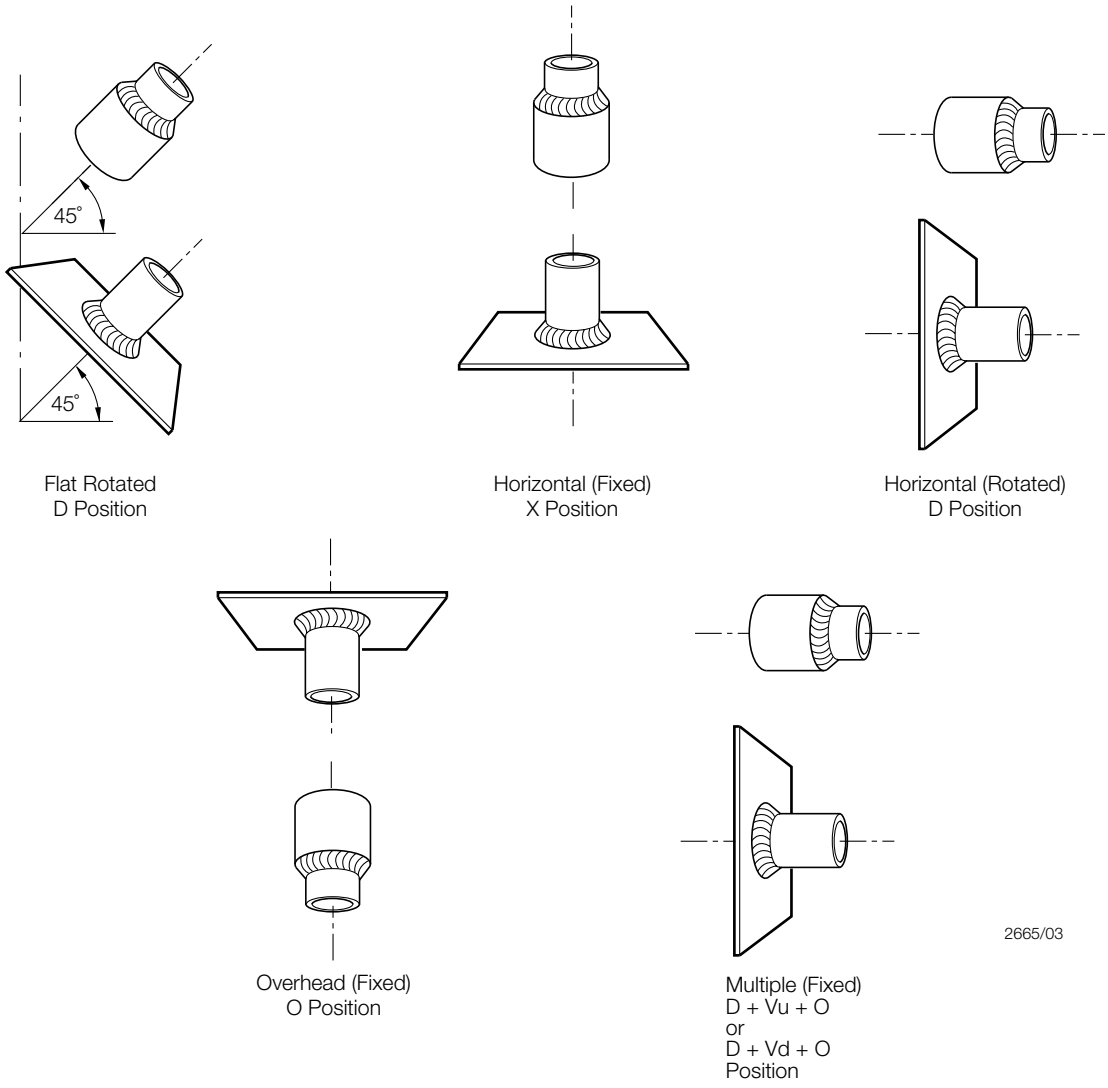


Fig. 12.2.2(d) Pipe fillet weld test positions

2.6 Destructive tests – General requirements

2.6.1 The weld test assembly may only be sectioned for destructive testing after any heat treatment and the required non-destructive examinations have been completed successfully.

2.6.2 The dimensions of the test specimens and testing conditions are to be in accordance with the requirements specified in Chapter 2.

2.6.3 The results of destructive tests are to be assessed in accordance with the acceptance criteria specified in 2.12, unless other, more stringent requirements are specified for the application.

2.6.4 Where a weld test is made between materials of different grades, the acceptance criteria that are to be applied are those applicable to the lower grade material.

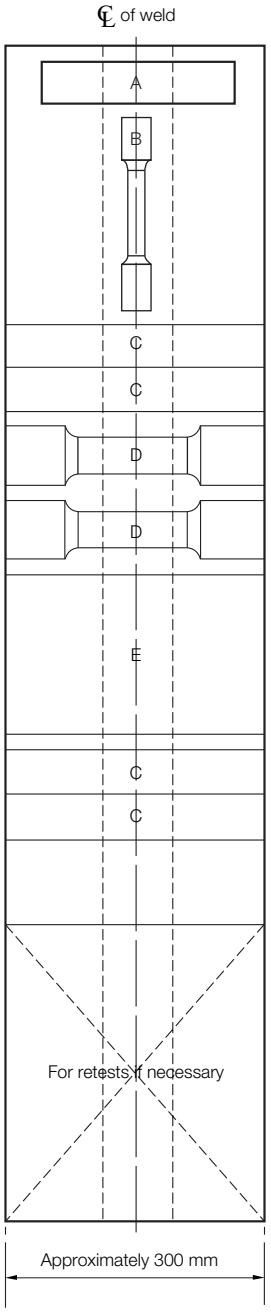
2.7 Destructive tests for steel butt welds

2.7.1 The test assembly is to be sectioned for mechanical testing in accordance with Figs. 12.2.3 or 12.2.4.

2.7.2 The longitudinal all weld metal tensile test specimen is to be of circular cross-section as detailed in Ch 11,2.1 and Fig. 11.2.1. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from each respective area of the weld. This does not apply to the process or consumables used to make the root or first weld run. During the test, the yield or proof stress, ultimate tensile strength, and elongation to failure are to be recorded.

2.7.3 Where approved welding consumables have been used, the longitudinal all weld metal tensile test may be omitted.

2.7.4 The transverse tensile test specimen is to be of full thickness with the dimensions shown in Fig. 11.2.2. The tensile strength and fracture locations are to be reported.



Test requirements
A One macro including hardness survey
B All weld metal tensile test
C Four bend tests.
Two root bends and two face bends for thickness up to 12 mm.
For thickness above 12 mm four side bends
D Two transverse tensiles
E Five sets of Charpy V-notch impact tests, notched at the following positions:
1 set at weld centre
1 set at fusion line (FL)
1 set at FL + 2 mm
1 set at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
1 set at FL + 10 mm (if required)

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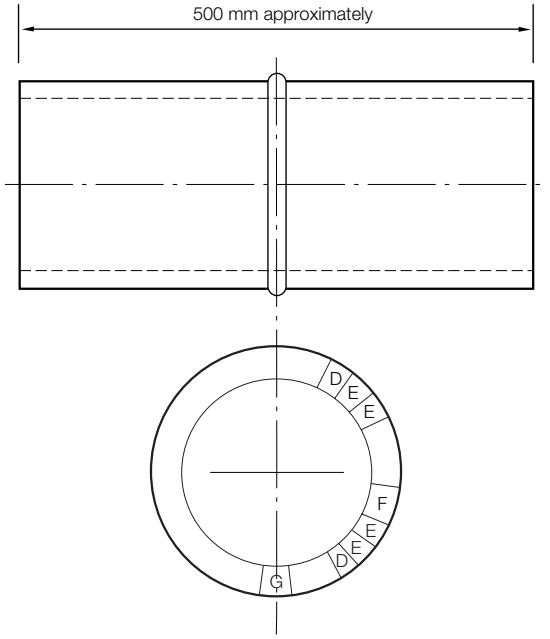
Fig. 12.2.3
Butt welds in plate and pipe over 750 mm diameter



The diameter of the test piece is to be a minimum of *D*/2
where
D is the maximum diameter of the pipe to be welded in construction

Test requirements
A Visual examination
B Surface crack detection
C 100% radiographic examination
D Two transverse tensile tests
E Four bend tests.
Four side bends for thickness greater than 12 mm.
In other cases, two face and two root bends
F Four sets Charpy V-notch impact tests
1 set notched at centre of weld
1 set notched at fusion line (FL)
1 set notched at FL + 2 mm
1 set notched at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
G One macro specimen including hardness survey

Fig. 12.2.4
Butt welds in pipe less than 750 mm diameter

2.7.5 Where the maximum load required to fracture the transverse tensile specimen is likely to exceed the capacity of the tensile testing equipment, several tensile specimens may be removed through the thickness and tested. Specimens are to be prepared such that they overlap in the thickness direction so that the full plate thickness is tested.

2.7.6 Transverse bend specimens of rectangular section are to be prepared with the weld centred in the middle of the specimen as shown in Fig. 12.2.5. For material of thickness 12 mm or greater, the face and root bends may be substituted by side bend tests. The weld reinforcement may be removed by grinding or machining prior to testing and the edges rounded to a radius not exceeding 10 per cent of the specimen thickness. Each specimen is to be bent through an angle of at least 180°. The bend test ratio is to be the lesser of the following:

(a) $D_f = (D/t) + 1$

or

(b) $D_f = 100/E_m$ (rounded up to the next whole number)

where

D_f = is the bend test ratio

(D/t) = is the value from Tables 11.3.3, 11.4.3 or 11.8.2, as appropriate

E_m = is the minimum specified percentage elongation for the test material (based on a proportional gauge length of $5{,}65\sqrt{S_0}$)

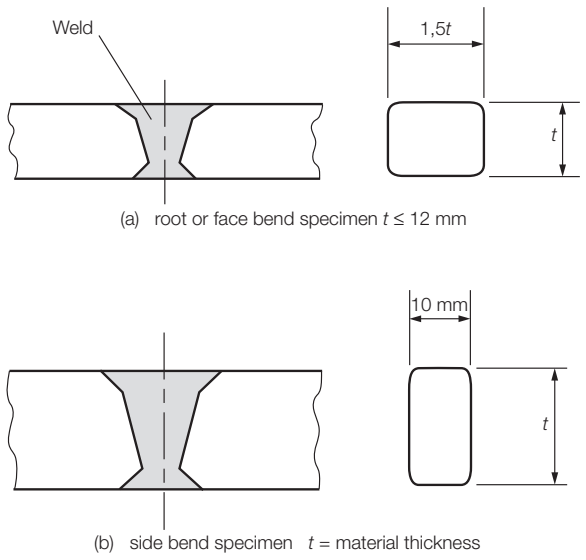


Fig. 12.2.5 Transverse bend test specimens

2.7.7 Where the weld test is made between different material types, the requirements of 2.7.8 are to be applied to the material with the lower toughness specification.

2.7.8 For hull structural steels, impact test specimens are to be prepared from the locations shown in Figs. 12.2.6 or 12.2.7, with the notch perpendicular to the plate surface and have the dimensions and proportions in accordance with Ch 2,3. Where more than one welding process or type of consumable has been used to make the weld, test specimens are also to be removed from these respective parts of the weld. Note that this does not apply to the welding process or consumables used solely to make the root or first weld run. Where the weld thickness exceeds 50 mm, an additional set of impact tests is required from the root area of the weld irrespective or whether different welding process or welding consumables are used as shown in Figs. 12.2.6 and 12.2.7.

2.7.9 For offshore structures and pressure vessels, impact test specimens are not required to be notched at the FL + 10 mm location. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from the respective areas of the weld. This does not apply to the process or consumables used solely to make the root or first weld run.

2.7.10 At least one macro examination specimen is to be removed from the test plate, near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone and be prepared and etched to clearly reveal the weld runs and the heat affected zone. Examination is to be performed under a magnification of between x5 and x10.

2.7.11 A chemical analysis of the weld metal is to be performed on the macro specimen where approved welding consumables have not been used. The results are to comply with the limits given in the welding consumable specification.

2.7.12 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.8, using a test load not in excess of 10 kg. For each row of indents, there are to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides). The recommended distance between indents is 1,0 mm, but the distance between indents should not be less than the minimum specified in ISO 6507/1.

2.8 Destructive tests for steel fillet welds

2.8.1 Fillet weld test assemblies are to be sectioned for destructive testing in accordance with Fig. 12.2.1(c) and as follows:

(a) two fracture tests;

(b) three macro-sections;

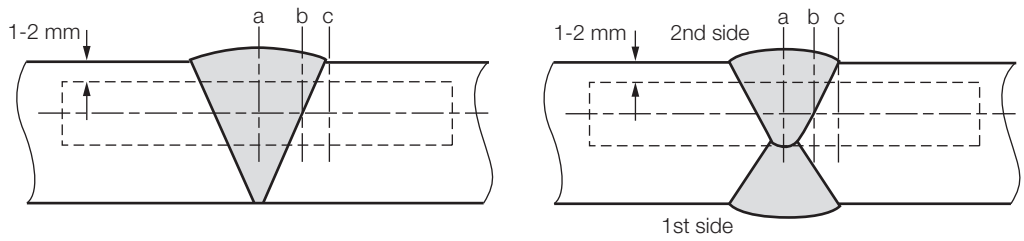
(c) one hardness survey.

2.8.2 Two fracture test specimens are to be removed from the test weld and are to be subjected to testing by bending the upright plate onto the through plate to produce fracture, as shown in Fig. 12.2.1(c).

2.8.3 At least three macro examination specimens are to be removed from the test plate. The specimens are to include the complete cross-section of the weld and the heat affected zone and is to be prepared to clearly reveal the weld runs and the heat affected zone. One of the specimens is to include a weld stop/start position. Examination is to be performed under a magnification of between x5 and x10.

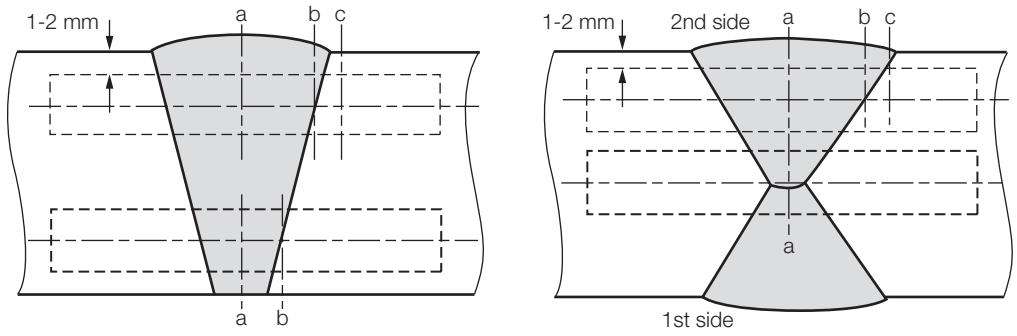
2.8.4 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.9, using a test load not exceeding 10 kg.

(a) $t \leq 50$ mm (1)



NOTE:
(1) For one side single run welding over 20 mm notch location 'a' is to be added on root side

(a) $t > 50$ mm



Notch locations:
a : centre of weld 'WM'
b : on fusion line 'FL'
c : in HAZ, 2mm from fusion line

Fig. 12.2.6 Locations of V-notch for butt weld of normal heat input (heat input ≤ 50 kJ/cm)

2.9 Destructive tests for T, K, Y steel nozzle welds

2.9.1 Full penetration 'T', 'K' and 'Y' joints for structural applications and nozzle welds for pressure vessels are to be sectioned for testing in accordance with Fig. 12.2.10 and tested as detailed below:

(a) three macro specimens;
(b) impact tests from the weld, fusion line and fusion line + 2 (where the material thickness permits);
(c) one hardness survey.

In addition, butt weld tests are to be performed in accordance with 2.7, using the same welding conditions, in order to verify acceptable weld and heat affected zone properties.

2.9.2 The impact tests are to be removed from the vertical (up) position 'B' in Fig. 12.2.10 and tested in accordance with 2.7.8.

2.9.3 A Vickers hardness survey is to be performed on the macro-section removed from position 'A' or 'C' in accordance with that shown in Fig. 12.2.11 using a test load not exceeding 10 kg.

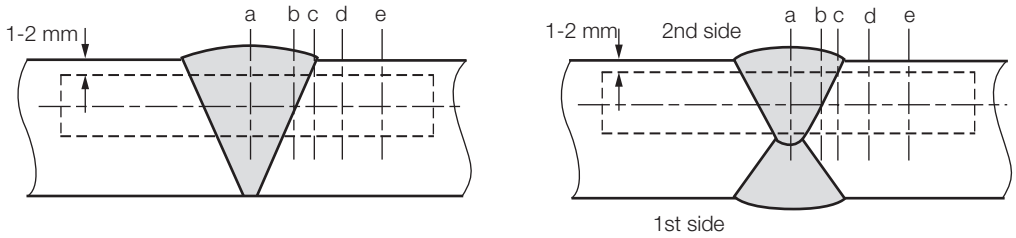
2.10 Destructive tests for steel pipe branch welds

2.10.1 Pipe branch welds may be by either full penetration, partial penetration or fillet welded, depending on the application and the approved plans. Where these types of welded joints are used, tests are to be performed which simulate the construction conditions.

2.10.2 The test weld assembly is to simulate the smallest angle between the branch and main pipe and is to be subjected to macro-examination and hardness testing, as follows:

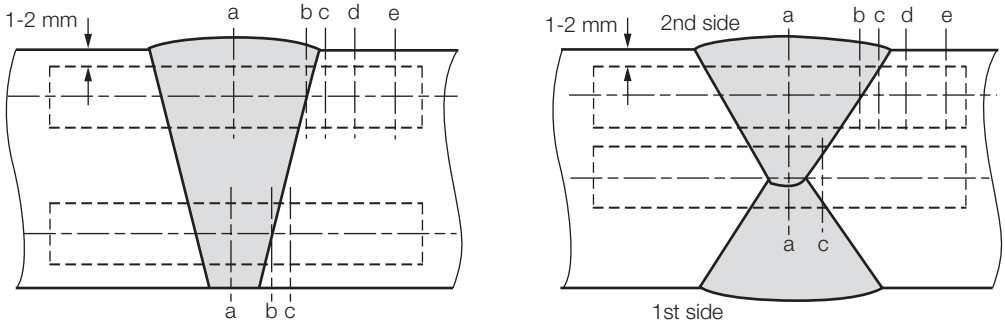
(a) For a branch weld that is full penetration, testing is to be performed in accordance with the requirements for 'T', 'K' and 'Y' joints in 2.9.
(b) For a branch weld that is either a partial penetration or fillet weld, testing is to be in accordance with the requirements for fillet welds in 2.8.

(a) $t \leq 50$ mm (1)



NOTE:
(1) For one side welding with thickness over 20 mm notch location 'a', 'b' and 'c' are to be added on root side

(a) $t > 50$ mm



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

Fig. 12.2.7 Locations of V-notch for butt weld of high heat input (heat input > 50 kJ/cm)

2.11 Destructive tests for weld cladding of steel

2.11.1 Where weld cladding or overlay is allowed by Chapter 13, and is considered as providing strength to the component to which it is welded, the type and location of test specimens are to be in accordance with Fig. 12.2.12, except that micro-sections are not required. Impact tests may be omitted where the base material does not have specified impact properties. The longitudinal tensile and bend tests are to be tested in a similar manner to transverse specimens specified in 2.7.2 and 2.7.6, respectively.

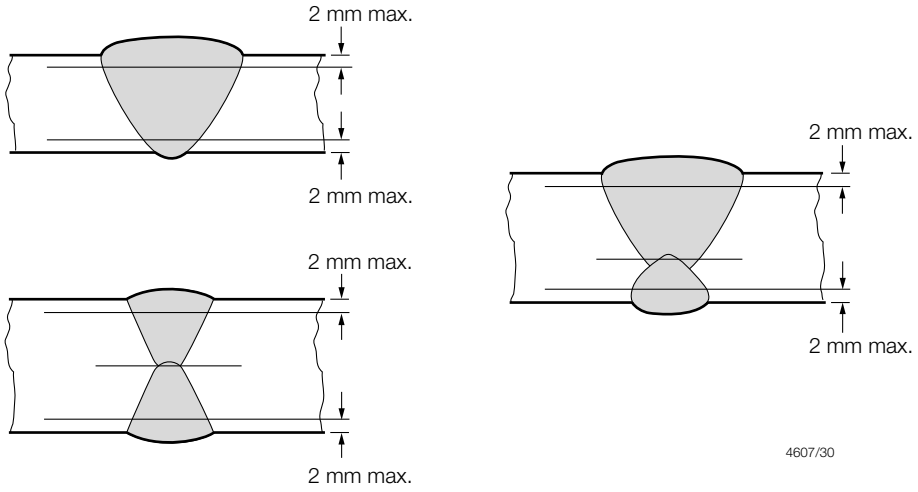
2.11.2 Where the weld cladding is not considered as contributing to the strength of the component, but is required for corrosion or wear resistance, the type and location of test specimens are to be in accordance with Fig. 12.2.12, except that tensile and impact tests are not required.

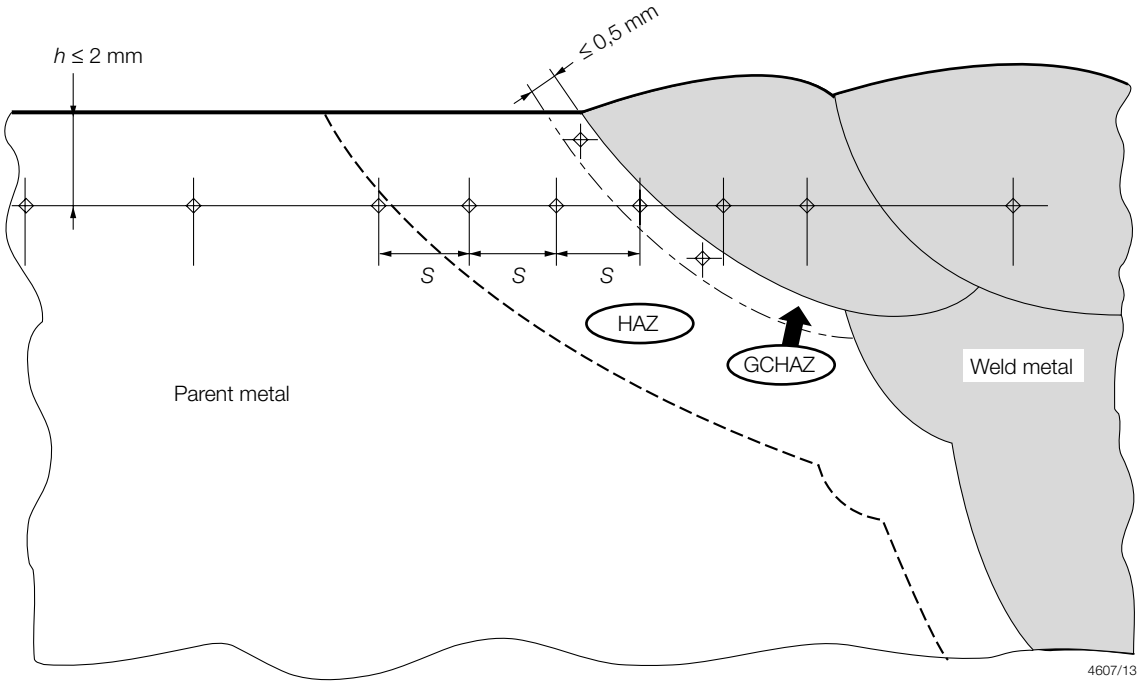
2.11.3 Where the weld cladding is applied for corrosion resistance, in addition to the above, weld metal analysis is to be performed on one of the micro-sections, on a surface parallel to the weld surface but 2 mm deep. The analysis is to be within the limits specified for the corrosion resistance required.

2.12 Mechanical test acceptance criteria for steels

2.12.1 **Longitudinal all weld metal tensile test**:
(a) In general, the longitudinal all weld tensile test is to meet the minimum properties specified in Tables 11.3.2 or 11.4.2, as appropriate to the grade of steel and welding process used in the test.
(b) Where the application is such that no consumable approvals are specified in Chapter 11, the longitudinal all weld tensile test tensile is to meet the minimum properties specified for the base materials used in the test.
(c) For pressure vessels manufactured from carbon or carbon/manganese steels, the tensile strength from the longitudinal all weld tensile test is not to be less than the minimum specified for the plate material and is not to be more than 145 N/mm^2 above this value (*see* Ch 13,4.8.3).

2.12.2 **Transverse tensile test**: The tensile strength measured from the transverse tensile test is not to be less than the minimum specified for the base material used in the test.





HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.8 Hardness testing locations for butt welds

2.12.3 **Bend tests**:

(a) In general, bend tests are to exhibit no defects exceeding 3,0 mm measured in any direction across the tension face of the specimen after being bent over the required diameter of former to the appropriate angle.

(b) Bend tests for pressure vessel applications are to exhibit no defects exceeding 3,0 mm measured along the specimen or 1,5 mm measured transverse to the specimen axis, after bending.

(c) In all cases, premature failure of the bend tests at the edges of the specimen is to not be cause for rejection unless these are associated with a weld defect.

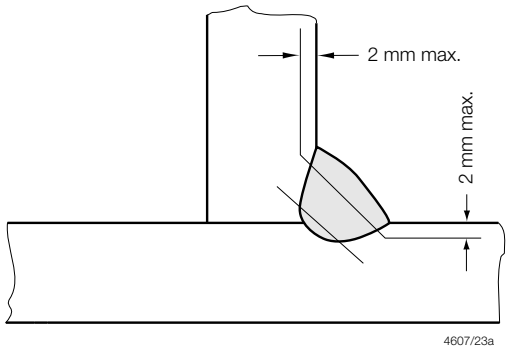
2.12.4 **Impact toughness tests**:

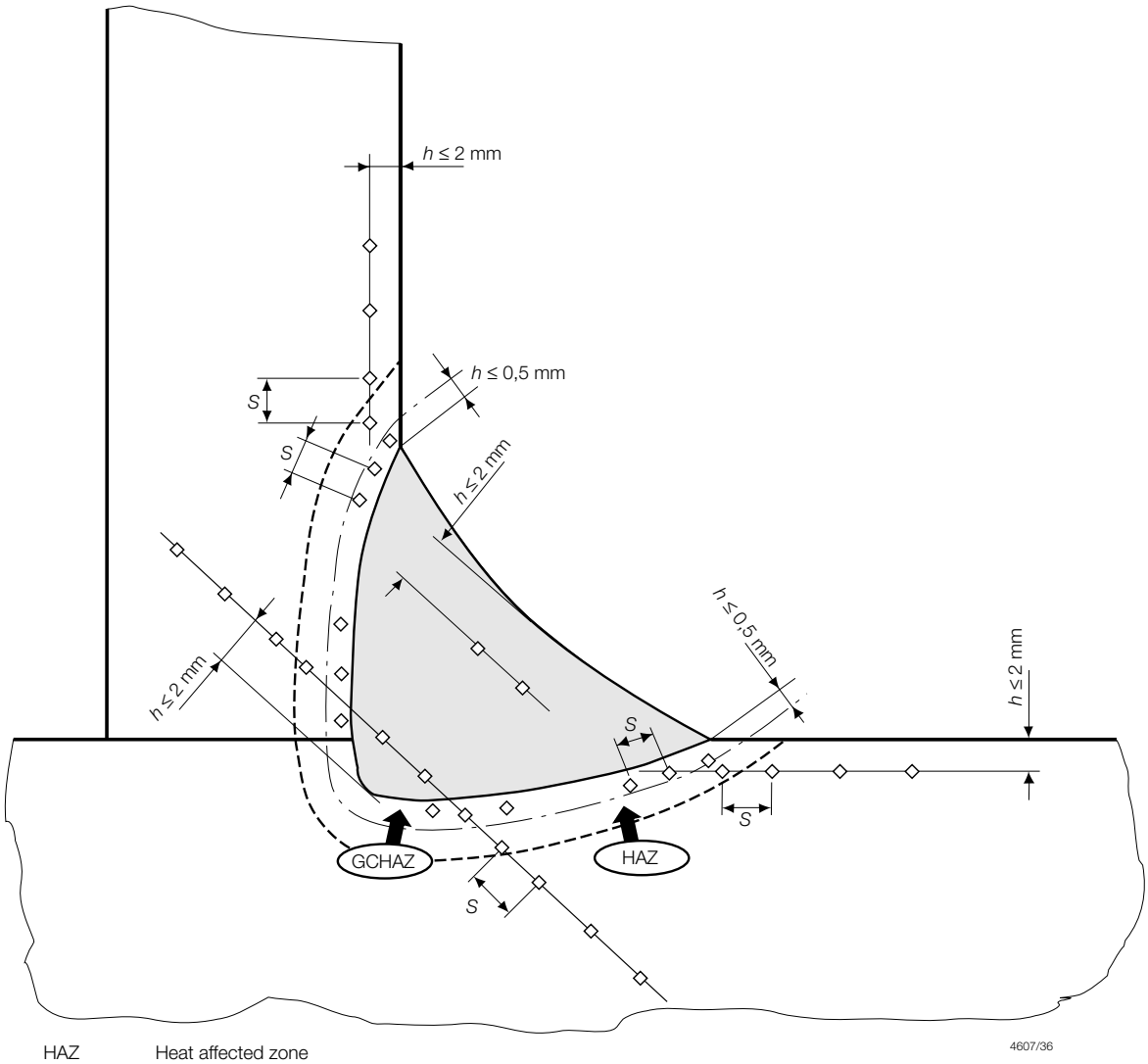
(a) Impact test specimens for hull construction are to be tested at the temperature, and are to achieve the minimum impact energy, as specified in Table 12.2.2.

(b) Impact test specimens for applications other than hull construction are to be tested at the same temperature and achieve the same minimum energy values, as specified for the base materials used in the test.

(c) Impact test acceptance criteria are to be in accordance with the above unless the Rules applicable to the particular construction specify more stringent requirements.

(d) For quench and tempered steels, the required test temperature and absorbed energy are to be in accordance with that specified for the parent materials.





HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.9 Hardness test locations for fillet welds

2.12.5 **Macro-examination**: The macro-section is to reveal an even weld profile blending smoothly with the base material. The weld dimensions are to be in accordance with the requirements of the pWPS and any defects present are to be assessed against the non-destructive examination acceptance criteria given in 2.5.5.

2.12.6 **Hardness surveys**: The maximum hardness value reported is not to exceed 350 Hv for steels with a specified minimum yield strength up to ≤420 N/mm^2, nor exceed 420 Hv for steels with a specified minimum yield strength in the range 420 N/mm^2 to 690 N/mm^2. For example, impact tests would be taken from the highest heat input position and hardness tests would be taken from the lowest heat input position.

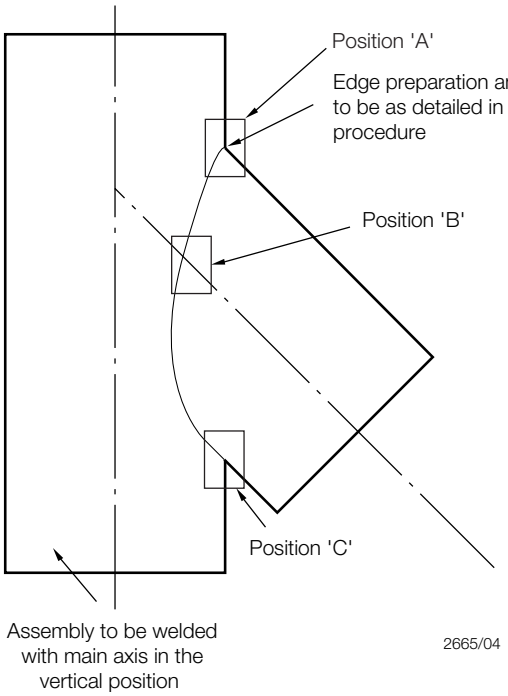


Fig. 12.2.10
Location of macro-examination test specimens for T, K and Y joints

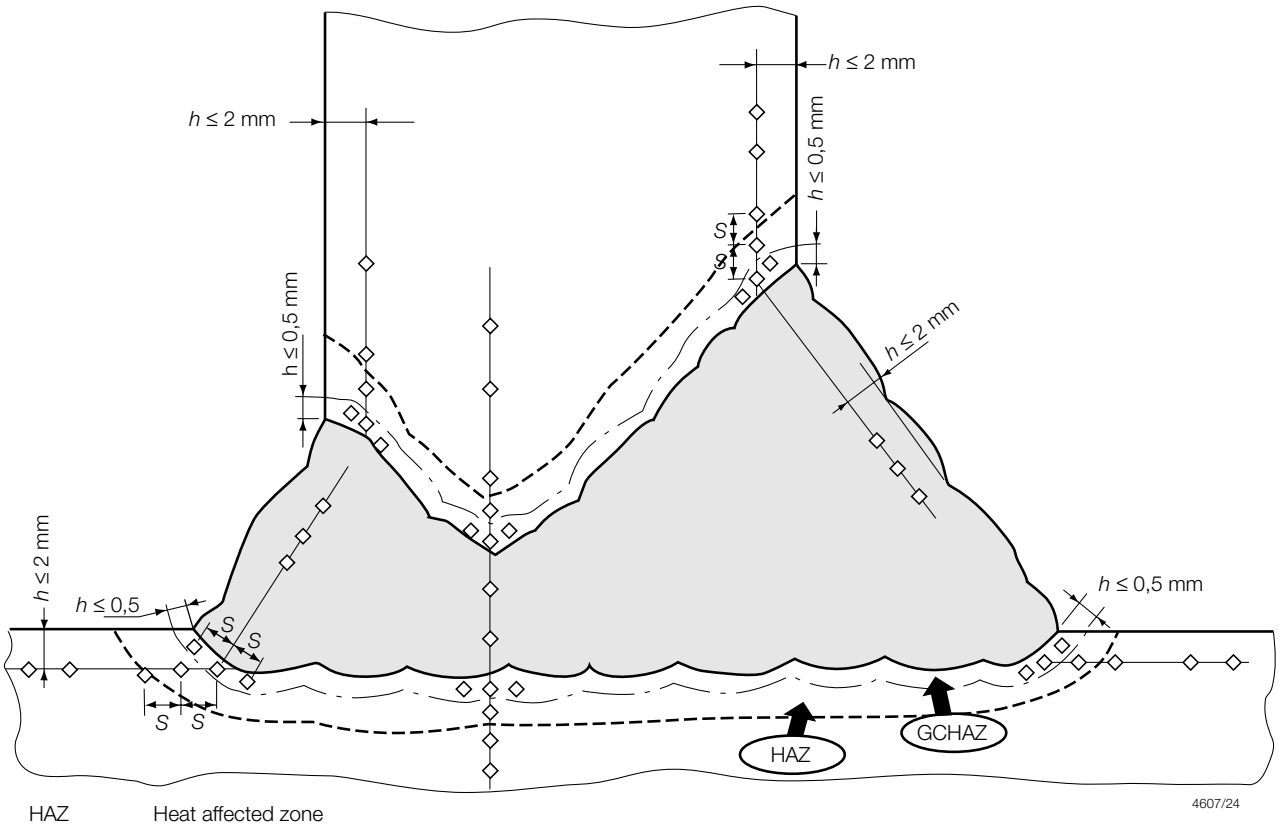
2.12.7 **Weld fracture or break tests (for pressure vessel test welds)**: The faces of the broken fillet weld fracture or weld break test are to be examined for defects and assessed in accordance with the non-destructive acceptance criteria given in ISO 5817 Level B, except for excess convexity and excess throat thickness where Level C will apply.

2.13 Failure to meet requirements

2.13.1 Where a tensile, bend or hardness specimen fails to meet requirements, further test specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.1.

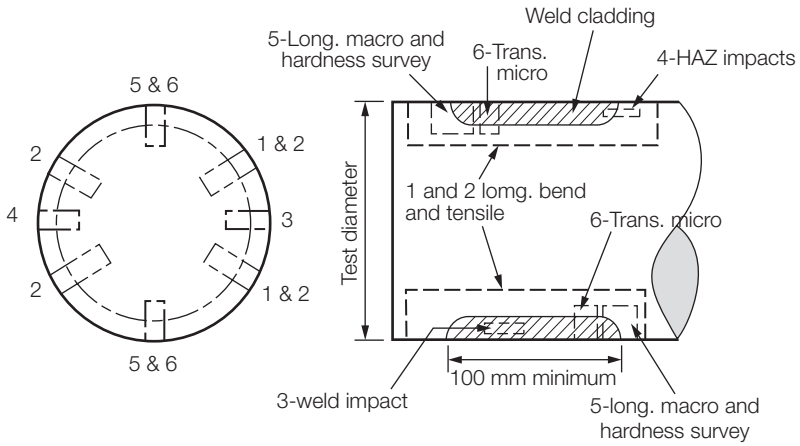
2.13.2 Where an impact specimen fails to meet requirements, a further set of three specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.2.

2.13.3 Where a macro specimen reveals a defect that is planar in nature, the welding procedure test is to be considered as not satisfying the requirements and a new test assembly is required.



HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.11 Hardness test locations for T, K and Y joints



Test specimens
1 Longitudinaltensile test to include the weld metal, heat affected zone (HAZ) and base metal.
2 Longitudinal side bend test to include the weld metal, heat affected zone (HAZ) and base metal.
3 Weld metal Charpy V notch impact test.
4 HAZ Charpy impact test from Fusion Line and Fusion Line + 2 mm.
5 Longitudinal macro-section and hardness survey.
6 Transverse micro-section.
NOTE
In the case of shafts and pipes of circular section, the longitudinal direction is parallel to the centreline of the shaft or pipe axis.

Fig. 12.2.12 Type and location of test specimens for weld cladding

2.13.4 Where a macro specimen does not meet requirements as a result of a volumetric imperfection exceeding the permitted size, two additional specimens may be removed from the same test weld and examined. If either of these macro-sections also fails to satisfy the requirements, the welding procedure is to be considered as not having met the requirements.

2.13.5 If there is a single hardness value above the maximum values specified, additional hardness tests are to be carried out, either 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 specified, otherwise the welding procedure is to be considered as not having met the requirements.

2.13.6 Where there is insufficient material available in the welded test assembly to provide re-test specimens, subject to prior agreement with the Surveyor, a second assembly may be welded using the same conditions as the original test weld.

Table 12.2.2 Impact test requirements for butt joints ($t \leq 50$ mm) *see* Notes 1 and 2

Grade of steel	Test temperature (°C)	Value of minimum energy absorbed (J)		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A, *see* Note 3 B, *see* Note 3, D E A32, A36 D32, D36 E32, E36 F32, F36	20 0 –20 20 0 –20 –40	47	34	34
A40 D40 E40 F40	20 0 –20 –40		39	39
> 40	As specified for parent material	As specified in Ch 11,4.3		

NOTES
1. For thickness above 50 mm, impact test requirements are to be specially agreed.
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 a minimum of 27 J.

2.14 Test records

2.14.1 The procedure qualification record (PQR) is to be prepared by the manufacturer and is to include details of the welding conditions used in the test specified in 2.2 and the results of all the non-destructive examinations and destructive tests, including re-tests.

2.14.2 Provided that the PQR lists all the relevant variables and there are no inconsistent features and the results satisfy the requirements, the PQR may be endorsed by the Surveyor as satisfying the requirement of the Rules (*see also* 1.1.4).

2.15 Range of approval

2.15.1 A welding procedure qualification test that has successfully met the requirements may be used for a wider range of applications than those used during the test.

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

2.15.3 Other ranges of approval from those specified in this Section may be agreed with the Surveyor, provided that they are in accordance with recognised National or International Standards.

2.15.4 **Manufacturer**. A welding procedure qualified by a manufacturer is valid for welding in workshops under the same technical and quality management.

2.15.5 **Welding process and technique**. The welding process and welding techniques approved are to be those employed during the welding procedure qualification test. Where multiple welding processes are used, these are to be employed in the same order as that used in the welding procedure qualification test. However, it may be acceptable to delete or add a welding process where it has been used solely to make the first weld run in the root of the joint, provided back gouging or grinding of the root weld is specified on the WPS. For multi-process procedures, the welding procedure approval may be carried out with separate welding procedure tests for each welding process.

2.15.6 **Welding positions**. Approval for a test made in any position is restricted to that position. To qualify a range of positions, test assemblies are to be welded for the highest heat input position, and the lowest heat input position, and all applicable tests are to be made on those assemblies. The above excludes welding in the vertical position with travel in the downward direction which will always require separate qualification testing and only be acceptable for that position.

2.15.7 **Joint types**. A qualification test performed on a butt weld may be considered acceptable for fillet and partial penetration welds, provided the same welding conditions are used. The range of approval depending on the type of joint for butt welds is given in Table 12.2.3.

Table 12.2.3 Range of approval for different types of butt joints

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 sides	With gouging	C	C
		Without gouging	D	C,D

2.15.8 **Range of material types**:

(a) A qualification test performed on one strength level of steel may be used to weld all similar materials with the same or lower specified minimum yield stress with the exception of the two-run (T) or high welding heat input (A) techniques where acceptance is limited to the strength level used in the test. Similarly, a qualification test performed on a steel with one toughness level may be considered acceptable for welding all similar materials with the same or three toughness grades lower specified minimum toughness level.

(b) For high strength quenched and tempered steels, for each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested. For each toughness grade, welding procedures are considered applicable to the same and one lower strength level as that tested. The approval of quenched and tempered steels does not qualify thermo-mechanically rolled steels (TMCP steels) and vice versa.

(c) For weldable C and C-Mn steel forgings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel forgings does not qualify other delivery conditions and vice versa.

(d) For weldable C and C-Mn steel castings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel castings does not qualify other delivery conditions and vice versa.

Dissimilar materials. Where a qualification test has been performed using dissimilar materials, acceptance is to be limited to the materials used in the test.

2.15.9 **Thickness and diameter range**:

(a) For straight butt welds, the material thickness range to be approved is to be based on the thickness of the test piece and the type of weld as shown in Table 12.2.4.

(b) For butt welds between plates of unequal thickness, the lesser thickness is the ruling dimension.

(c) For fillet welds and 'T' butt welds, Table 12.2.4 is to be applicable to both the abutting and through member thicknesses. In addition to the requirements of Table 12.2.4, the range of approval of throat thickness '*a*' for fillet welds is to be as follows:
- single run: 0,75*a* to 1,5*a*
- multi-run: as for butt welds with multi-run (i.e. $a = t$)

(d) Notwithstanding any of the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of the test assembly if three of the hardness values in the heat affected zone are found to be within 25 Hv of the maximum permitted.

(e) The material diameter range to be approved is to be based on the diameter of the test piece and type of weld as shown in Table 12.2.5.

Table 12.2.4 Welding procedure thickness approval range – Butt welds

Test thickness, *see* Note 1 (*t* in mm)	Range approved	
	All multi-run butt welds and all fillet welds *see* Notes 3 and 4	All single-run or two-run two-run (T technique) butt welds
$t \le 3$	*t* to 2*t*	0,7*t* to 1,1*t*
$3 < t \le 12$	3 to 2*t*	0,7*t* to 1,1*t*
$12 < t \le 100$	0,5*t* to 2*t*, *see* Note 2	0,7*t* to 1,1*t* *see* Note 5
$t > 100$	0,5*t* to 1,5*t*	0,7*t* to 1,1*t* *see* Note 5

NOTES
1. Where the test plates have dissimilar thickness, the thickness, *t*, is to be based on the minimum thickness for butt welds and the maximum thickness for fillet welds.
2. Subject to a maximum limit of 150 mm.
3. For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval of the individual welding process.
4. For vertical down welding, the test piece thickness, *t*, is the upper limit of the range of application.
5. For processes with heat input over 5,0 kJ/mm, the upper limit of the range of approval is to be 1,0 *t*.

Table 12.2.5 Diameter range approved

Diameter used for test, *see* Note 1	Range of diameters approved
$D \le 25$ mm	0,5*D* to 2*D*
$D > 25$ mm	> 0,5*D*, *see* Note 2

NOTES
1. *D* is the outside diameter of the pipe or the smallest side dimension of rectangular hollow section.
2. Lower diameter range limited to 25Ø mm minimum.

2.15.10 **Welding consumables**:
(a) For manual and semi-automatic welding used for the fill and capping weld runs, it may be acceptable to change the brand or trade name of the welding electrode or wire from that used in the test, provided the proposed alternative has the same or higher approval grading and the same flux type (e.g. basic low hydrogen, rutile, etc.) as used in that test.
(b) For the consumable used to make the root weld of full penetration butt welds made from one side only, no change in the type or trade name of the consumable or backing material is permitted.
(c) For processes with heat input over 5 kJ/mm, no change in the type or trade name of the consumable is permitted.

2.15.11 **Shielding gas**. For gas shielded welding processes, a change in shielding gas composition from that used in the test will require a new qualification test.

2.15.12 **Heat Input**. The upper limit of heat input approved is 25 per cent greater than that used in the test, or 5,5 kJ/mm, whichever is the smaller. With heat input over 5,0 KJ/mm, the upper limit is 10 per cent above that used in the test. In all cases, the lower limit of heat input approved is 25 per cent lower than that used in the test.

2.15.13 **Current type**. The current type used during the qualification test is to be the only type approved. Additionally, changes from or to pulsed current require new qualification tests.

2.15.14 **Preheat temperature**. The temperature used during the test is to be the minimum approved. Higher temperatures may be specified for production welds up to the maximum interpass temperature. Where hardness tests have been performed that exhibit results near the maximum permitted, an increase in preheat temperature is required when welding material of greater thickness than that used in the test.

2.15.15 **Interpass temperature**. The maximum interpass temperature recorded during qualification testing is to be the maximum approved. Lower temperatures may be specified for production welding, but no lower than the minimum preheat temperature.

2.15.16 **Post-weld heat treatment**. A qualification test performed with no post weld heat treatment is only acceptable for production welding where no heat treatment is applied. Where the qualification test has included a post weld heat treatment, this is to be applied to all welds made with the welding procedure. The average specified soak temperature may vary by up to 25°C from that tested.

2.15.17 **Shop primers.** Welding procedure qualification with shop primers qualifies welds without primer, but not vice versa.

2.16 Welding procedure specification (WPS)

2.16.1 A welding procedure specification (WPS) is to be prepared by the manufacturer detailing the welding conditions and techniques to be employed for production welding. The WPS is to be based on the conditions and variables used during the qualification test, and is to include all the ranges of the essential variables specified in 2.2.1 and 2.15.

2.16.2 The WPS should reference the procedure qualification record upon which it is based and is to be approved by the Surveyor prior to commencing production welding.

Section 3
Specific requirements for stainless steels

3.1 Scope

3.1.1 The requirements of this Section relate to the group of steel materials classed as stainless steels and include austenitic and duplex grades and martensitic grades.

3.1.2 In all cases, welding procedure tests are to be performed generally in accordance with Section 2 with the specific requirements specified below.

3.2 Austenitic stainless steels

3.2.1 The requirements of this Section relate to the group of stainless steel materials that are austenitic at ambient and sub-zero temperatures, (e.g. 304L, 316L types), *see* Table 3.7.1 in Chapter 3.

3.2.2 Impact tests are to be performed from specimens removed from the weld metal. Tests in the heat affected zone are not required.

3.2.3 Hardness tests are generally not required.

3.2.4 For cryogenic or corrosion resistant applications, the ferrite content in the weld cap region is to be measured and is to be in the range 2 to 10 per cent, with the exception of grades S 31245 and N 08904 where the content is to be nominally zero.

3.2.5 A qualification test performed on an austenitic grade may be considered acceptable for welding other austenitic steels with the same or lower level of alloying elements and the same or lower tensile strength.

3.2.6 A qualification test performed for cryogenic applications may be considered acceptable for chemical applications, but not vice versa.

3.3 Duplex stainless steels

3.3.1 The requirements of this Section relate to the group of stainless steel materials that have a ferritic-austenitic structure and are usually referred to as duplex or super duplex stainless steels (e.g. S 31803, S 32760).

3.3.2 Impact test specimens are to be removed from the weld and heat affected zone in accordance with Section 2 with the exception that impact test specimens notched at the FL + 10 mm location are not required. The specimens are to be tested at a temperature of –20°C or the minimum design temperature whichever is the lower and exhibit a minimum average energy of 40 J.

3.3.3 The corrosion resistance is to be maintained in the welded condition and the following tests are to be performed to demonstrate acceptable resistance, unless agreed otherwise.

(a) A sample is to be removed from the weld and heat affected zone for micro-structural examination and is to be suitably prepared and etched so that the micro-structures of the weld and heat affected zones can be examined at a magnification of x200 or higher. The micro-structure of the weld and heat affected zone is to be examined, the percentage grain boundary carbides and intermetallic precipitates is to be reported.

(b) The ferrite content in the un-reheated weld cap and cap HAZ along with the weld root and root HAZ are to be measured and reported. The ferrite content is to be in accordance with Table 12.3.1. Where the intended construction is such that the corrosion medium is only in contact with one surface of the weld (i.e. the weld root), the ferrite determination need only be reported in that surface area.

(c) Corrosion testing is to be performed on samples removed from the weld such that both the weld and HAZ are included in the test. The critical pitting temperature is to be determined in accordance with ASTM G48 Method C and meet the requirements specified in Table 12.3.1. The cap and root surfaces are to be inspected for evidence of pitting and may require probing the surface with a needle. Pitting found on the ends of the specimen in the weld cross-section may be ignored. The use of the weight loss method for corrosion testing may be accepted subject to special consideration.

Table 12.3.1 Requirements for ferrite content and corrosion tests for duplex stainless steel test welds

Duplex Stainless Steel Material Grade	Weld and HAZ Ferrite content	Minimum Critical Pitting Temperature (CPT)
S 31260	30 to 70%	20°C
S 31803	30 to 70%	20°C
S 32550	35 to 65%	25°C
S 32750	35 to 65%	25°C
S 32760	35 to 65%	25°C

3.3.4 Where the test weld is between a grade of carbon steel and duplex stainless steel, the test requirements of 3.3.3(a) and (c) are not required and the ferrite content of the weld and the duplex heat affected zone are to be reported for information.

3.3.5 A qualification test performed on a duplex stainless steel grade may be considered acceptable for welding other duplex grades which have the same or less stringent mechanical or corrosion properties.

3.3.6 The range of heat input is not to vary by more than +10 per cent or –25 per cent from that used during testing.

3.4 Martensitic stainless steels

3.4.1 The requirements of this Section relate to the group of stainless steel materials that have a martensitic structure at ambient temperatures, *see* Table 4.5.1 in Chapter 4.

3.4.2 The results of the hardness survey results are to be reported for information purposes only.

3.4.3 A qualification test is considered acceptable only for the grade of material used in the test.

■ *Section 4*
Welding procedure tests for non-ferrous alloys

4.1 Requirements for aluminium alloys

4.1.1 The requirements for welding procedure qualification tests for aluminium alloys are to be in accordance with the general requirements of Section 2 with the following exceptions and specific requirements.

4.1.2 Non-destructive examination is to be performed in accordance with 2.5 and the assessment of results is to be in accordance with Table 12.4.1.

4.1.3 Acceptance of the mechanical tests is to be in accordance with Ch 11,9. Welding of the strain hardened and heat treatable aluminium alloys will generally result in a loss of tensile strength in the heat affected zone below that specified for the base materials and the tensile strength acceptance criteria to be applied is that specified for the material in the annealed or "as fabricated" condition. Minimum values of tensile strength measured on the transverse tensile samples are given in Table 12.4.2.

Table 12.4.1 Non-destructive examination acceptance limits for aluminium alloys

Imperfection	Acceptance limits for aluminium alloys
Surface Profile	
Undercut	Slight intermittent, provided depth does not exceed 0,5 mm
Excess penetration and concavity	4,0 mm max.
Weld reinforcement height	7,0 mm max.
Asymmetry of fillet welds	Maximum difference between leg lengths = 20% of throat + 2 mm
Shrinkage groove or root concavity	Slight intermittent provided that it does not exceed 1,0 mm
Overlap	Not permitted
Reinforcement shape	The weld reinforcement is to blend smoothly with the parent material
Misalignment	t/10 but not greater than 2,5 mm
Cracking and lamellar tears	Not permitted
Lack of root fusion	Not permitted
Lack of side-wall fusion	Not permitted
Lack of inter-run fusion	Not permitted
Lack of penetration	Not permitted
Porosity	
Individual pores	d not greater than t/4 2,0 mm max.
Uniformly distributed	For t up to 6 mm d = 0,4 mm max. For t over 6 mm d = 0,8 mm max. pores between 0,8 < d < 1,6 limited to t/2 in number per 100 mm^2 of weld area
Solid inclusions	
Slag inclusions - linear *see* Note 1	Not permitted
Oxide inclusions - linear	Widely scattered and each not exceeding 1,5 max.
Slag inclusions - individual	Not permitted
Metallic inclusions	Tungsten – 0,8 mm max. Copper – not permitted
where t = material thickness d = diameter of circular shaped imperfection	
NOTES 1. Linear inclusions parallel to the weld may indicate lack of fusion or penetration and may require further investigation. 2. A planar defect is considered to have only two dimensions, i.e. no thickness. For example, cracks or lack of fusion. 3. A volumetric defect is one that is considered to have three dimensions, e.g. inclusions, porosity, etc.	

Table 12.4.2 Tensile strength requirements by grade for aluminium alloys

Parent material Grade (alloy designation)	Minimum tensile strength (N/mm^2)
5754	190
5086	240
5083	275
5383	290
5059	330
5456	290
6005A	170
6061	170
6082	170

4.1.4 Impact tests and hardness surveys are not required for aluminium alloys.

4.1.5 Four side bend tests may be used in place of root and face bends where the test thickness exceeds 12 mm, and longitudinal bend tests may be used instead of transverse tests where the test weld is between different grades of alloy. Bend specimens are to be bent round a former in accordance with Table 11.9.1, with the exception that the 6000 series alloys may be bent round a former with $D/t = 7$.

4.1.6 The ranges of approval to be applied to the WPS are to be as specified for steel in 2.15 with the following exceptions:

(a) The welding positions approved are as detailed in Table 12.4.3.

(b) The aluminium alloys are grouped into three groups as follows:
- Group A: aluminium-magnesium alloys, with Mg content ≤3,5 per cent (alloy 5754)
- Group B: aluminium-magnesium alloys with 4 per cent ≤ Mg ≤5,6 per cent (alloys 5059, 5083, 5086, 5383 and 5456)
- Group C: aluminium-magnesium-silicon alloys (alloys 6005A, 6061 and 6082)

For each group, the qualification made on one alloy qualifies the procedure also for the other alloys in the group, with equal or lower tensile strength after welding. The qualification made on group B alloys qualifies the procedure for Group A alloys also. Approval for the range of material grades is summarised in Table 12.4.4.

(c) The qualification of a procedure carried out on a test assembly of thickness t is valid for the thickness range given in Table 12.4.5. In the case of butt joints between dissimilar thicknesses, t is the thickness of the thinner material. In the case of fillet joints between dissimilar thicknesses, t is the thickness of the thicker material. In addition to the requirements of Table 12.4.5, the range of the qualification of throat thickness of fillet welds, a, is given in Table 12.4.6. Where a fillet weld is qualified by a butt weld test, the throat thickness range qualified is to be based on the thickness of the deposited weld metal.

(d) The range of shielding gas compositions approved is to be in accordance with Table 11.9.2 in Chapter 11.

(e) A change in the brand or trade name of the filler metal from that used in the test is acceptable, provided that the proposed consumable has the same or higher strength grading.

(f) A change in post-weld heat treatment or ageing is not permitted, except that for the heat treatable alloys, artificial ageing may give approval for prolonged natural ageing.

Table 12.4.3 Welding procedure approval, welding positions for aluminium alloys

Test Position		Positions Approved
Downhand	D	D
Horizontal-vertical	X	D, X, Vu
Vertical up	Vu	D, X, Vu
Overhead	O	D, X, Vu and O

NOTE
Welding in vertical down (Vd) position is not recommended.

Table 12.4.4 Welding procedure approval, aluminium material grades approved

Material used in qualification test	Material Grades approved				
5754	5754				
5086	5086	5754			
5083	5083	5086	5754		
5383	5383	5083	5086	5754	
5059	5059	5383	5083	5086	5754
5456	5456	5383	5083	5086	5754
6005A	6005A	6082	6061		
6082	6005A	6082	6061		
6061	6005A	6082	6061		

NOTE
Approval includes all the different strained and tempered conditions in each case.

Table 12.4.5 Range of qualification for parent material thickness

Thickness of test assembly, *t* (mm)	Range of qualification Multi pass welds	Range of qualification All single-run or two-run (T technique) butt welds
$t \leq 3$	0,5 to 2*t*	0,5*t* to 1,1*t*
$3 < t \leq 20$	3 to 2*t*	0,5*t* to 1,1*t*
$t > 20$	$\geq 0{,}8t$	0,5*t* to 1,1*t*

Table 12.4.6 Range of qualification of throat thickness for fillet welds

Throat thickness of test piece, *a* (mm)	Range of qualification
$a < 10$	0,75 *a* to 1,5 *a*
$a \geq 10$	≥ 7.5

4.2 Requirements for copper alloys

4.2.1 The requirements for welding procedure qualification tests for copper alloys are to be in accordance with the requirements for steel as given in Section 2 with the following exceptions and additions.

4.2.2 Impact tests on copper alloys are not required.

4.2.3 Hardness tests are not required for seawater service.

4.2.4 For the welding of cast copper alloys for propellers, the minimum tensile strength from the transverse tensile test is to be in accordance with Table 12.4.7.

Table 12.4.7 Minimum transverse tensile strengths for welded copper alloy propellers

Alloy designation	Minimum tensile strength (N/mm^2)
CU 1	370
CU 2	410
CU 3	500
CU 4	550

4.2.5 Bend tests are to be performed over a diameter of former as detailed in Table 12.4.8.

4.2.6 The range of approval to be applied to the WPS is to be as specified in 2.15 with the exception of the material grades which are detailed in Table 12.4.9.

Table 12.4.8 Former diameters for bend testing of copper alloy welds

Alloy designation (*see* Chapter 9)	Former diameter (*D*/*t*)
Cast propellers :	
CU1	4
CU2	4
CU3	6, *see* Note 1
CU4	6, *see* Note 1
Other short freezing range castings :	
Copper-Nickel 90/10	4
Copper-Nickel 70/30	4
Aluminium bronze	6
Wrought alloys (tubes and pipes) :	
Copper-phosphorus	3
Aluminium-brass	3
90/10 Copper-nickel-iron	3
70/30 Copper-nickel-iron	3

NOTE
Where the qualification tests for these alloys are subjected to post weld heat treatment the former diameter may be increased to $D/t = 10$.

Table 12.4.9 Range of approval for copper alloy material grades

Category	Alloy grade used in the qualification test	Alloy grades approved
Propellers	CU1 CU2 CU3 CU4	CU1 CU1 and CU2 CU1, CU2 and CU3 CU4 *see* Note 1
Tubes/pipes	90/10 Copper -Nickel-Iron	90/10 Copper -Nickel-Iron
	70/30 Copper -Nickel-Iron	70/30 Copper -Nickel-Iron and 90/10 Copper -Nickel-Iron
Tupes/pipes *see* Note 2	Copper-Phosphorus-non arsenical Copper-Phosphorus-non arsenical Aluminium brass	Copper-Phosphorus-non arsenical Copper-Phosphorus-non arsenical Aluminium brass

NOTES
1. Where a CU3 type welding consumable has been used for the qualification test, the range of approval may also include welding of CU3.
2. These grades have limited weldability and approval to weld is subject to the materials satisfying the requirements of Table 9.3.1 in Chapter 9.

■ *Section 5*
Welder qualification tests

5.1 Scope

5.1.1 The requirements of this Section relate to qualification of welders involved in welded construction associated with ships, or other marine structures, and products or components intended for use on or in these structures.

5.1.2 The requirements relate to fusion welding processes that are designated as manual, semi-automatic or partly mechanised. Special consideration will be given to other welding processes adapted from these requirements.

5.1.3 Prior to commencing production welding, the welder is to have performed a qualification test that satisfies these requirements. It is the responsibility of the manufacturer to ensure that the welder possesses the required level of skill for the work to be undertaken.

5.1.4 The qualification of welders is to be documented by the manufacturer and the records are to be available for review by the Surveyor.

5.1.5 Welder qualification tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to, and meet the technical intent of these Rules to the satisfaction of the Surveyor.

5.2 Welder qualification test assemblies

5.2.1 The welding of the welder qualification test assembly is to simulate, as far as practicable, the conditions to be experienced in production and be witnessed by the Surveyor. The test is to be carried out on a test assembly piece and not by way of production welding.

5.2.2 The test is to simulate, as far as practicable, the welding techniques and practices to be encountered during production welding. The test assembly is to be designed to test the skill of the welder and have the shape and dimensions appropriate to the range of approval required.

5.2.3 The inspection length of the test weld is to be such as to permit the removal of all the necessary test specimens and for plate tests, but in no case is to be less than 250 mm. The test assembly is to be set in one of the positions as shown in Fig. 12.2.2 appropriate to the welding positions to be approved.

5.2.4 A welding procedure specification (WPS) is required for the execution of the qualification test and is to include the information specified in 2.2.1, as a minimum.

5.2.5 The test assembly is to be marked with a unique identification and the inspection length is to be identified prior to commencing welding. For pipe welds, the whole circumference is to be considered as the inspection length.

5.2.6 During welding of the test assembly, the welding time is to be similar to that expected under production conditions. For manual or semi-automatic processes, at least one stop and re-start in the root and in the top surface layer is to be included in the inspection length and marked for future inspection.

5.2.7 During welding of the test assembly, minor imperfections may be removed by the welder by any method that is used in production, except on the surface layer.

5.2.8 The Surveyor may stop the test if the welding conditions are not correct or if there is any doubt about the competence of the welder to achieve the required standard.

5.3 Examination and testing

5.3.1 Each completed test weld is to be examined and tested in accordance with the requirements of Table 12.5.1.

5.3.2 Visual examination is to be performed in the as welded state prior to any other assessment.

Table 12.5.1 Welder qualification test requirements

Examination type	Butt welds	Fillet welds	Pipe branch welds
Visual	100%	100%	100%
Surface crack detection	*See* Note 1	100%	100%
Radiography	100% *See* Notes 2 and 6	Not required	Not required
Bend tests	4 required *See* Notes 3 and 6	Not required	Not required
Fracture tests	Not required	1 required *See* Note 4	Not required
Macro	Not required	1 required *See* Note 4	4 required *See* Note 5

NOTES
1. Surface crack detection examination may be required by the Surveyor in order to clarify the acceptability of any weld feature.
2. Radiography may be replaced by ultrasonic examination for carbon and low alloy steels where the thickness exceeds 12 mm.
3. Bend tests are required for gas metal arc welding with solid wire (GMAW) and oxy-acetylene welding.
4. The fracture test may be replaced with 4 macro sections equally spaced along the inspection length.
5. Macro-sections are to be separated by 90° measured around the abutting pipe member.
6. Radiography and bend tests are required for tests in aluminium alloys.

5.3.3 For plate butt welds, fracture testing may be used in place of radiography.

5.3.4 Where a backing strip has been used, it is to be retained for non-destructive examinations, but is to be removed prior to performing any bend or fracture tests.

5.3.5 Where fracture tests are required, they are to sample as much of the inspection length as practicable and the test assembly may be cut into several test specimens to achieve this. Testing is to be performed as shown in Figs. 12.5.1(a) or 12.5.1(b).

5.3.6 For butt weld tests in aluminium alloys both radiography and bend tests are required.

5.3.7 When bend tests are required, 2 root and 2 face bends are to be tested and where the test thickness exceeds 12 mm, these may be substituted by 4 side bends specimens. The diameter of former to be used is to be in accordance with that specified for welding procedure qualification testing given in 2.7.6(a).

5.3.8 Where macro examination is required, the specimen is to be polished and etched to reveal the weld runs and heat affected zones, and be examined at a magnification between x5 and x10.

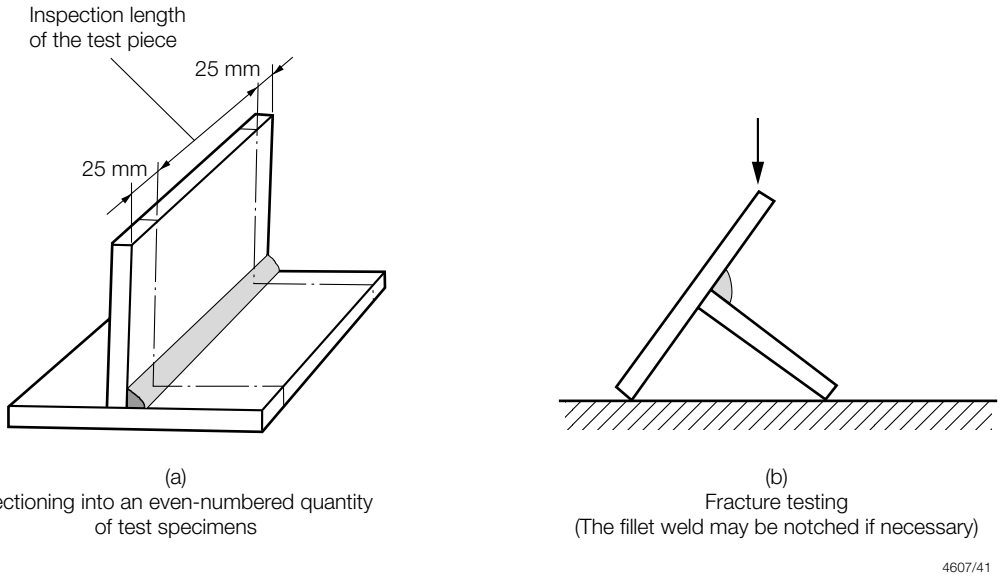
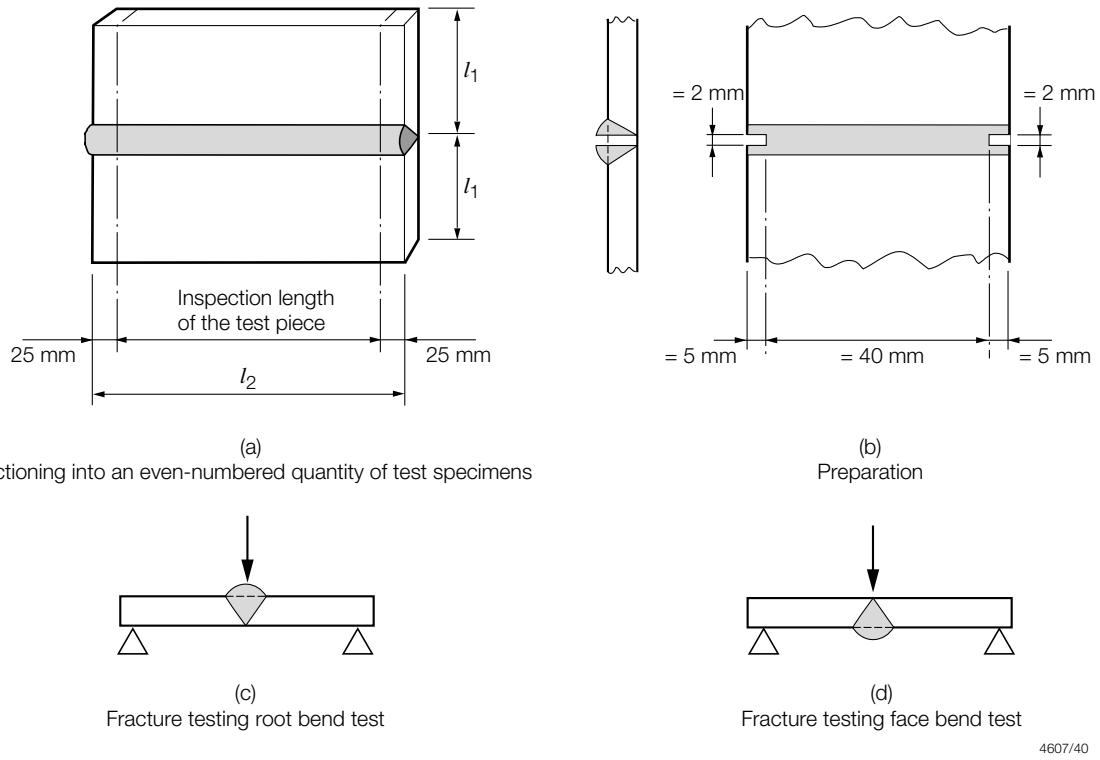


Fig. 12.5.1(a) Preparation and fracture testing of test specimens for a fillet weld in plate



(a)
Sectioning into an even-numbered quantity of test specimens

(b)
Preparation

(c)
Fracture testing root bend test

(d)
Fracture testing face bend test

Fig. 12.5.1(b) Preparation and fracture testing of test specimens for a butt weld in plate

5.4 Acceptance criteria

5.4.1 The acceptance criteria are to be in accordance with 2.5.5.

5.4.2 Fracture tests and macro-sections are to be assessed in accordance with the non-destructive examination acceptance criteria.

5.4.3 Bend tests are considered acceptable if after bending through an angle of at least 180°, there are no defects on the tension side of the specimen greater than 3 mm in any direction.

5.5 Failure to meet requirements

5.5.1 Where a macro-section fails to meet requirements, one additional specimen may be removed from the test assembly and examined.

5.5.2 Where a bend or fracture test specimen fails to meet requirements, two additional specimens may be prepared from the same test assembly. If there is insufficient material, the welder may be permitted to weld an additional assembly to the same WPS, at the discretion of the Surveyor.

5.5.3 Where any of the additional test specimens fails to satisfy the requirements, the test will be considered as not meeting the requirements.

5.5.4 Where a test fails to comply with the acceptance criteria, the welder may be permitted to weld a second test piece. If this does not meet requirements, the welder is to be considered as not being capable of achieving the requirements.

5.6 Range of approval

5.6.1 Upon successful completion of all the necessary examinations and tests, the welder is to be considered qualified. The essential variables and the range of welding conditions for which the welder is considered approved are specified in the following paragraphs.

5.6.2 Welding variables such as preheat, interpass temperature, heat input and current type are not considered welder qualification variables. However, if the WPS used for testing specify these, they are to be included in the test and the welder is expected to follow the specific instructions.

5.6.3 Where the WPS used for the welder qualification test specifies post weld heat treatment, this need not be applied to the test weld unless bend tests are required and the material exhibits low ductility in the as welded condition.

5.6.4 The qualification test performed by a manufacturer is only applicable to workshops under the same technical control and quality system as that used for the test.

5.6.5 The welding process used in the qualification test is the process approved. However, it is possible for the welder to use more than one process in the test and the range of approval that may be applied to each will be within the limits of the essential variables appropriate to the part of the test where each welding process was used.

5.6.6 Material types are to be grouped as shown in Table 12.5.2 for welder qualifications. A qualification test performed on one material from a group will permit welding of all other materials within the same group. In addition, qualification on one group of materials may confer approval to weld other groups as shown in Table 12.5.3.

5.6.7 A qualification test performed on one thickness will confer approval to weld other thicknesses as specified in Table 12.5.4. Where welding is required between materials of different thickness, the reference thickness for approval purposes is to be the lesser thickness.

5.6.8 A qualification test performed using a specific diameter of pipe will give approval to weld other diameters as shown in Table 12.5.5. For branch welds, the diameter upon which approval is based is to be the branch member.

5.6.9 A qualification test performed on a butt weld may be considered as giving approval for fillet welds.

Table 12.5.2 Welder qualification materials groupings

Material group	Material description	Typical LR Grades	Rules for Material references
WQ 01	Low carbon unalloyed, C/Mn, or Low alloyed steels (Re ≤ 360 N/mm^2)	A, B, D and E AH to FH32 and 36 Boiler 510FG and lower LT-AH to FH32 and 36 U1 and U2 Steel castings Steel pipes	Ch 3,2 Ch 3,3 Ch 3,4 Ch 3,6 Ch 3,9 and Ch 10 Ch 4,2, 3, 6 and 7 Ch 6,2, 3, 4 and 6
WQ 02	Cr-Mo, or Cr-Mo-V creep resisting steels	13CrMo45 and 11CrMo910 1Cr½Mo and 2¼Cr1Mo ½Cr½Mo¼V	Ch 3,4 Ch 4,6 and Ch 6,2, 3 and 6 Ch 4,6 and Ch 6,2
WQ 03	High strength fine grained, Normalised or quenched, or Tempered structural steels (2.0 – 5% Ni, with Re > 360 N/mm^2)	AH to FH40 to 69 LT-AH to LT-FH40 1½ , 3½ Ni steels and castings U3, R3, R3S and R4	Ch 3,3 and 10 Ch 3,6 Ch 3,6, Ch 4,7 and Ch 6,4 Ch 3,9 and Ch 10
WQ 04	Ferritic, or martensitic stainless steels (12 to 20% Cr)	13% Cr (martensitic)	Ch 4,5 (martensitic)
WQ 05	Ferritic low temperature steels	5Ni and 9Ni	Ch 3,6
WQ 011	Ferritic-austenitic stainless steels, Austenitic stainless steels, or Cr-Ni steels	304, 316, 317, 321 and 347 S31260, S31803, S32550 and S32750	Ch 3,7 and 8 Ch 4,8 and Ch 6,5
WQ 22a	Aluminium alloy – Non-heat treatable Mg < 3.5%	5754	Chapter 8
WQ 22b	Aluminium alloy – Non-heat treatable 3.5% < Mg < 5.6%	5083 and 5086	Chapter 8
WQ 23	Aluminium alloy – Heat treatable	6005-A, 6061 and 6082	Chapter 8
WQ 30	Copper alloys for propellers – Manganese bronze	Cu1	Ch 9,1
WQ 31	Copper alloys for propellers – Nickel-manganese bronze	Cu2	Ch 9,1
WQ 32	Copper alloys for propellers – Nickel-aluminium bronze	Cu3	Ch 9,1
WQ 33	Copper alloys for propellers – Manganese-aluminium bronze	Cu4	Ch 9,1
WQ 34	Copper alloys for tubes – Copper phosphorus	Deoxidised – non-arsenical and arsenical	Ch 9,3
WQ 35	Copper alloys for tubes – Aluminium brass	Aluminium brass	Ch 9,3
WQ 36	Copper alloys for tubes – Copper-nickel-iron	70/30 Cu/Ni and 90/10 Cu/Ni	Ch 9,3

Table 12.5.3 Welder qualification, range of approval for material groups

Material Group used for testing	Material Groups approved to weld			
WQ 01	WQ 01			
WQ 02	WQ 01	WQ 02		
WQ 03	WQ 01	WQ 02	WQ 03	
WQ 04	WQ 01	WQ 02	WQ 04	
WQ 05	WQ 05			
WQ 11	WQ 11	WQ 05, *see* Note 1	WQ 04, *see* Note 1	
WQ 22a	WQ 22a	WQ 22b		
WQ 22b	WQ 22a	WQ 22b		
WQ 23	WQ 22a	WQ 22b	WQ 23	
WQ 30	WQ 30	WQ 31	WQ 32	WQ 33
WQ 31	WQ 30	WQ 31	WQ 32	WQ 33
WQ 32	WQ 30	WQ 31	WQ 32	WQ 33
WQ 33	WQ 30	WQ 31	WQ 32	WQ 33
WQ 34	WQ 34	WQ 35		
WQ 35	WQ 34	WQ 35		
WQ 36	WQ 36			

NOTE
Provided an austenitic welding consumable compatible with material group WQ 11 is used.

Table 12.5.4 Welder qualification, range of approval for material thickness

Material type	Test piece thickness (mm)	Range approved, *see* Note (mm)
Steel and copper alloys	$t \leq 3$ $3 < t \leq 12$ $t > 12$	t to $2t$ 3,0 to t ≥ 5,0
Aluminium alloys	$t \leq 6$ $6 < t \leq 15$ $t > 40$ mm	0,7 to 2,5t $6,0 < t \leq 40,0$ 41 to 2t

NOTE
For oxy-acetylene welding the maximum thickness is limited to 1,5 t.

Table 12.5.5 Welder qualification, diameter range of approval for pipes and hollow sections

Material type	Test piece diameter (mm)	Range approved (mm)
Steel and copper alloys	$D \leq 25$ $25 < D \leq 150$ $D > 150$ Plate, *see* Note 2	D to $2D$ 0,5D to 2D, *see* Note 1 ≥ 0,5D ≥ 500
Aluminium alloys	$D \leq 125$ $D > 125$ Plate, *see* Note 2	0.25D to 2D ≥ 0,5D ≥ 500

NOTES
1. Subject to 25 mm minimum diameter.
2. Plate qualification will approve welding on pipes greater than 150 mm diameter when the pipe is rotated.

5.6.10 A butt qualification test welded from one side, with the root unsupported (i.e. no backing), will give approval for welds made from both sides with or without back gouging or grinding, but not vice versa.

5.6.11 A qualification test performed in one position will give approval to weld in other positions as shown in Table 12.5.6.

5.6.12 For manual metal arc welding with covered electrodes, a qualification test performed using an electrode with one type of coating will only be approved for welding with that type of coating. However, a qualification test performed using a basic low hydrogen type coating will confer approval to use electrodes with rutile coatings.

Table 12.5.6 Welding position ranges for welder qualification

Test weld conditions		Positions qualified			
Type of weld	Test position	Plate, *see* Note 2		Pipe	
		Butt weld	Fillet weld	Butt weld	Fillet weld
Plate butt	D	D	D	D, *see* Note 1	D, *see* Note 1
	X	D, X	D, X	D, *see* Note 1	D, *see* Note 1
	Vu	D, Vu	D, X, Vu	D, *see*Note 1, Vu, *see* Note 1	D, *see* Note 1, Vu, *see* Note 1, X
	Vd	Vd	Vd	*See* Note 2	*See* Note 2
	O	D, X, Vu, O	D, X, Vu, O	D, *see* Note 1	D, X, Vu, O
Plate Fillet	D	—	D	—	D, *see* Note 1
	X	—	D, X	—	D, *see* Note 1, X
	Vu	—	D, X, Vu	—	D, *see* Note 1, X, Vu, *see* Note 1
	Vd	—	Vd	—	*See* Note 2
	O	—	D, X, Vu, O	—	D1, X, Vu, O
Pipe butt	D, *see* Note 1	D	D, X	D, *see* Note 1	D, *see*Note 1, X
	X	D, X	D, X	D, *see* Note 1, X	D, *see* Note 1, X
	D+Vu+O, *see* Note 3	D, Vu, O	D, X, Vu, O	D, *see* Note 1	D, *see* Note 1, X, Vu, O
	D+Vd+O, *see* Note 3	Vd	Vd	D+Vu+O, *see* Note 3, Vd	Vd
	Axis at 45°, *see* Note 4,Travel Vu	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O
	Axis at 45°, *see* Note 4, Travel Vd	Vd	Vd	Vd	Vd
Pipe fillet	D, *see* Note 1	—	D	—	D, *see* Note 1
	X	—	D, X	—	D, *see* Note 1, X
	D+Vu+O, *see* Note 3	—	D, X, Vu, O	—	D, *see* Note 1, X, Vu, O
	D+Vd+O, *see* Note 3	—	Vd	D—	Vd

NOTES
1. Pipe rotate.
2. Vd position not usually recommended for pipe welds less than 500 mm diameter.
3. Pipe fixed with axis in the horizontal position (e.g. ASME 5G).
4. Pipe fixed with axis at 45° to the horizontal (e.g. ASME 6G).
5. Plate qualification tests may be considered acceptable for pipes with diameter over 500 mm.

5.6.13 For gas shielded welding processes that use a single component shielding gas, no change to the gas composition is permitted from that tested. Where the test has used a two component shielding gas, a change in the ratio of component gases is permitted, provided that one of the components is not reduced to zero. Where the test has used a three component shielding gas, changes are permitted in the ratio of component gases and the gas with the smallest ratio may be reduced to zero, provided this does not change the shielding gas from an active one to an inert one or vice versa. In addition, where a change in shielding gas composition requires a different welding method or technique to be employed, a new qualification test will be required.

5.6.14 A change of welding flux from that used for the test is permitted.

5.7 Welders qualification certification

5.7.1 All the relevant conditions used during the test are to be entered on the welder's qualification certificate along with the permitted range of approval.

5.7.2 If the Surveyor is satisfied that the welder has demonstrated the appropriate level of skill and all tests are satisfactory, the Surveyor will endorse the certificate verifying that the details contained on it are correct and that the test welds were prepared, welded and tested in accordance with the specified Rules, Codes or Standards.

5.7.3 The welder is considered to be approved for an initial validity period of 2 years. The welder is considered to have retained the qualification subject to the manufacturer confirming every 6 months that the welder has used the welding process with acceptable performance in the preceding 6 months.

5.7.4 After 2 years, the Surveyor may extend the validity of the approval for another period of two years provided that records or documented evidence is made available confirming acceptable welding performance, within the original range of approval, without a break exceeding 6 months. The Surveyor will signify acceptance of the extension to the validity by endorsing the certificate.

5.7.5 Where there is any reason to question the welder's ability, or there is a lack of continuity in the use of the welding process, or insufficient recorded evidence of acceptable weld performance, the welder is to perform a new qualification test.

5.7.6 Where the manufacturer has existing welders that have previously performed qualification tests, these may be considered for acceptance provided they satisfy the above requirements and the tests have been performed in the presence of an independent examiner that is acceptable to the Society.

5.7.7 Not withstanding the above, the Surveyor may at any time request a review of a welder's qualification records. If there is any reason for doubt concerning the skill of the welder, the Surveyor may withdraw the qualification and require a re-qualification test to be performed.

~~**Chapter 13**~~

~~**Welded Steel Machinery Structures**~~

Existing Chapter 13 has been deleted and replace by a new Chapter 13.

Chapter 13

Requirements for Welded Construction

Effective date 1 August 2008

■ *Section 1* General welding requirements

1.1 Scope

1.1.1 This Chapter specifies requirements for fabrication and welding during construction and repair of ships or other marine structures, and their associated pressure vessels, machinery, equipment, components and products intended for use in these structures.

1.1.2 The requirements relate to fusion welding. Special consideration will be given to the use of other welding processes based on these requirements.

1.1.3 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules and inform the Surveyor of any deviations that have occurred. All deviations are to be recorded as non-compliances along with the corrective actions taken and failure to do this is considered to render the fabrication to be in non-compliance with the Rules.

1.1.4 Welded constructions that comply with National or International specifications may be accepted to the satisfaction of the surveyor, provided that these specifications give reasonable equivalence to the requirements of this Chapter.

1.1.5 All welded construction is to be to the satisfaction of the Surveyor.

1.2 Design

1.2.1 Prior to commencing any work, the component to be manufactured is to be subjected to design review and approval in accordance with the Rule requirements.

1.2.2 The material characteristics that are affected by welding, particularly the loss of strength (e.g. in precipitation or strain hardened aluminium alloys) are to be considered in the design. The weld joints in such materials are to be arranged such that they are in areas of lower stress.

1.3 Materials

1.3.1 Materials used in welded construction are to be manufactured at works approved by LR. The use of materials from alternative sources will be subject to agreement of the Surveyor and satisfactory verification testing.

1.3.2 Materials are to be supplied and certified in accordance with the requirements of Chapters 1 to 10 of these Rules.

1.3.3 Materials used in welded construction are to be readily weldable and are to have proven weldability, unless requirements are agreed with LR in advance.

1.3.4 Where the construction details are such that materials are subject to through-thickness strains, consideration is to be given to using material with specified through-thickness properties as specified in Ch 3,8.

1.3.5 When ordering materials for construction, consideration is to be taken of the possible degradation of properties during fabrication or post-weld heat treatment. Where these materials are used, consideration is to be given to additional test requirements being specified to the supplier.

1.3.6 The identity of materials is to be established by way of markings etc, during fabrication, so that traceability to the original manufacturer's certificate is maintained.

1.3.7 Pre-fabrication shop primers may be applied prior to welding, provided that they are of an approved type and have been tested to demonstrate that they have no deleterious effects on the completed weld.

1.3.8 Where it is proposed to weld forgings and/or castings, full details of the joint details, welding procedures and post-weld heat treatments are to be submitted for consideration.

1.4 Requirements for manufacture and workmanship

1.4.1 The welding workshops are to be assessed by the Surveyor for their capability to produce work of the required quality in accordance with the requirements specified for the type of construction (*see* Sections 2 to 5).

1.4.2 Where structural components are to be assembled and welded in works sub-contracted by the builder, the Surveyor is to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter is achieved.

1.4.3 The manufacturer is to provide a system of regular supervision of all welding, by suitably qualified and experienced personnel.

1.4.4 Welding is to be performed in covered workshops as far as practicable. Where this is not possible, provision is to be made in the welding area to give adequate protection from wind, rain and cold, etc.

1.4.5 Where required, arrangements are to be such as to permit adequate ventilation and access for preheating, and for the satisfactory completion of all welding operations.

1.4.6 The location of welding connections and sequences of welding are to be arranged to minimise distortion and the build up of residual stresses. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

1.4.7 In the case of repairs to existing structures or components, care is to be exercised when attaching fit-up aids by welding to ensure that the base materials in way of the attachments are of weldable quality.

1.4.8 In order to prevent cross contamination of different material types, the welding of carbon steel materials is to be in areas segregated from that used for either austenitic or non-ferrous materials (*see* Section 7).

1.5 Cutting of materials

1.5.1 Materials may be cut to the required dimensions by thermal means, shearing or machining in accordance with the manufacturing drawings or specifications.

1.5.2 Cold shearing is not to be used on materials in excess of 25 mm thick. Where used, the cut edges that are to remain un-welded are to be cut back by machining or grinding for a minimum distance of 3 mm.

1.5.3 Material, which has been thermally cut, is to be free from excessive oxides, scale and notches.

1.5.4 All cut edges are to be examined to ensure freedom from material and/or cutting defects. Visual examination may be supplemented by other techniques.

1.5.5 Thermal cutting of alloy and high carbon steels may require the application of preheat, and special examination of these cut edges will be required to ensure no cracking. In these cases, the cut edge is to be machined or ground back a distance of at least 2 mm, unless it has been demonstrated that the cutting process has not damaged the material.

1.5.6 Any material damaged in the process of cutting is to be removed by machining, grinding or chipping back to sound metal. Weld repair may only be performed with the agreement of the Surveyor.

1.6 Forming and bending

1.6.1 Plates, pipes, etc., may be formed to the required shape by any process which does not impair the quality of the material.

1.6.2 Where hot forming is employed or during cold forming where the material is subjected to a permanent strain exceeding 10 per cent or formed to a diameter to thickness ratio less than 10, tests are required to be performed to demonstrate that the material properties remain acceptable.

1.6.3 As far as practicable, forming is to be performed by the application of steady continuous loading using a machine designed for that purpose. The use of hammering, in either the hot or cold condition is not to be employed.

1.6.4 Material may be welded prior to forming or bending, provided that it can be demonstrated that the weld mechanical properties are not impaired by the forming operation. All welds subjected to bending are to be inspected on completion to ensure freedom from surface breaking defects.

1.7 Assembly and preparation for welding

1.7.1 Excessive force is not to be used in fairing and closing the work. Where excessive root gaps exist between surfaces or edges to be joined, corrective measures are to be adopted.

1.7.2 Provision is to be made for retaining correct alignment during welding operations in accordance with the approved manufacturing specifications and welding procedures.

1.7.3 Tack welds are to be avoided as far as practicable. When used, tack welds are to be of the same quality as the finished welds, made in accordance with approved welding procedures, and where they are to be retained as part of the finished weld, they are to be clean and free from defects.

1.7.4 Generally, tack welds are not to be applied in lengths of less than 30 mm for mild steel grades and aluminium alloys, and 50 mm for higher tensile steel grades. Smaller tack welds may be accepted for steels, provided that the carbon equivalent of the materials being welded is not greater than 0,36 per cent.

1.7.5 Where deep penetration welding is used (*see* 2.4.6), welding procedure tests are to demonstrate that the specified degree of penetration is achieved in way of tack welds left in place.

1.7.6 Where temporary bridge pieces or strong-backs are used, they are to be of similar materials to the base materials and welded in accordance with approved welding procedures.

1.7.7 Any fit-up aids and tack welds, where welded to clad materials, are to be attached to the base material and not to the cladding.

1.7.8 Surfaces of all parts to be welded, are to be clean, dry and free from rust, grease, debris and other forms of contamination.

1.7.9 When misalignment of structural members either side of bulkheads, decks etc., exceeds the agreed tolerance, the misaligned item is to be released, realigned and re-welded in accordance with an approved procedure.

1.8 Welding equipment and welding consumables

1.8.1 Welding plant and equipment is to be suitable for the purpose intended and properly maintained, taking into account relevant safety precautions.

1.8.2 Suitable means of measuring the welding parameters (i.e. current, voltage and travel speed) are to be available. Electrical meters are to be properly maintained and have current calibrations.

1.8.3 Welding consumables are to be suitable for the type of joint and grade of material to be welded, and in general, are to be LR Approved in accordance with Chapter 11.

1.8.4 Special care is to be taken in the distribution, storage and handling of all welding consumables. They are to be kept in heated dry storage areas with a relatively uniform temperature in accordance with the consumable manufacturer's recommendations. Condensation on the metal surface (e.g. wire electrodes and studs) during storage and use is to be avoided.

1.8.5 Prior to use, welding consumables are to be dried and/or baked in accordance with the consumable manufacturer's recommendations.

1.8.6 Satisfactory storage and handling facilities for consumables are to be provided close to working areas and the condition of welding consumables are to be subject to regular inspections.

1.9 Welding procedure and welder qualifications

1.9.1 Welding procedures are to be developed by the manufacturer for all welding, include weld repairs, and are to be capable of achieving the mechanical property requirements and non-destructive examination quality appropriate to the work being undertaken.

1.9.2 Welding procedures are to be established for the welding of all joints and are to be qualified by testing in accordance with Chapter 12. The welding procedures are to give details of the welding process, type of consumable, joint preparation, welding position and filler metals to be used.

1.9.3 The proposed welding procedures are to be approved by the Surveyor prior to construction.

1.9.4 All welders and welding operators are to be qualified in accordance with the requirements of Chapter 12. Qualification records to demonstrate that welding personnel have the skills to achieve the required standard of workmanship are to be available to the Surveyor.

1.10 Welding during construction

1.10.1 Materials to be assembled for welding are to be retained in position by suitable means such that the root gaps and alignment are in accordance with the approved manufacturing specifications and welding procedures.

1.10.2 Surfaces of all parts to be welded, are to be clean, dry and reasonably free from rust, scale and grease.

1.10.3 Pre-heat is to be applied, as specified in the approved welding procedure, for a distance of at least 75 mm from the joint preparation edges. The method of application and temperature control are to be such as to maintain the required level throughout the welding operation.

1.10.4 When the ambient temperature is 0°C or less, or where moisture resides on the surfaces to be welded, due care is to be taken to pre-heat the joint to a minimum of 20°C, unless a higher pre-heat temperature is specified.

1.10.5 Where tack welds are to be removed from the root of the weld joint, this is to be carried out such that the surrounding material and joint preparation is not damaged.

1.10.6 The welding arc is to be struck on the parent metal which forms part of the weld joint or on previously deposited weld metal.

1.10.7 Where the welding process used is slag forming (e.g. manual metal arc, submerged arc, etc.) each run of deposit is to be cleaned and free from slag before the next run is applied.

1.10.8 Full penetration welds are to be made from both sides of the joint as far as practicable. Prior to welding the second side, the weld root is to be cleaned, in accordance with the requirements of the approved welding procedure, to ensure freedom from defects. When air-arc gouging is used, care is to be taken to ensure that the ensuing groove is slag and oxide free and has a profile suitable for welding.

1.10.9 Where welding from one side only, care is to be exercised to ensure the root gap is in accordance with the approved welding procedure and the root is properly fused.

1.10.10 Particular care is to be exercised in welding in the vertical position with direction of travel downward (Vd) to avoid welding defects. The use of solid wire gas metal arc (GMAW) process in the vertical down position is to be avoided.

1.10.11 Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption.

1.10.12 After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly cleaned of slag and debris, and preheat has been re-established.

1.10.13 Care is to be taken to avoid stress concentrations such as sharp corners or abrupt changes of section, and completed welds are to have an even contour, blending smoothly with the base materials. The weld shape and size is to be in accordance with that specified in the approved drawings or specifications.

1.10.14 Welded temporary attachments used to aid construction are to be removed carefully by grinding, cutting or chipping. The surface of the material is to be finished smooth by grinding followed by crack detection.

1.10.15 Where fabricated and welded components require to be machined, all major welding operations are to be completed prior to final machining.

1.10.16 Welding to parts which are subjected to rotating fatigue (e.g. shafts) is not generally permitted.

1.10.17 Welding onto parts that have been hardened for wear resistance or strength (e.g. gear teeth) is not permitted.

1.10.18 Where welding of clad ferritic steel plates is to be undertaken, the clad materials are to be ground back from the prepared edge by at least 10 mm. In general, the ferritic materials are to be welded prior to welding of the cladding material.

1.11 Non-destructive examination of welds

1.11.1 Non-destructive examinations are to be made in accordance with a definitive written procedure prepared and endorsed by a person qualified according to a Nationally Recognised Scheme with a grade equivalent to level III qualification of ISO 9712, SNT-TC-1A, EN473, or ASNT Central Certification Program (ACCP). As a minimum, the procedure will identify personnel qualification levels, NDE datum and identification system, extent of testing, methods to be applied with technique sheets, acceptance criteria and reporting requirements. These procedures are to be approved by the Surveyor.

1.11.2 Non-destructive examinations are to be undertaken by personnel qualified according to a Nationally Recognised Scheme with a grade equivalent to level II qualification of ISO 9712, SNT-TC-1A, EN473 or ASNT Central Certification Program (ACCP). Operators qualified to Level I of the above schemes (or equivalent recognised by LR) may be engaged in testing under the supervision of personnel qualified to Level II or III (or equivalent recognised by LR). Personnel qualifications are to be verified by certification.

1.11.3 Effective arrangements are to be provided by the manufacturer for the inspection of finished welds to ensure that all welding, and where necessary, all post-weld heat treatment, has been satisfactorily completed.

1.11.4 Welds are to be clean and free from paint at the time of visual inspection unless specified otherwise in the following Sections.

1.11.5 The weld surface finish is to ensure accurate and reliable detection of defects. Where the weld surface is irregular or has other features likely to interfere with the interpretation of non-destructive examination, the weld is to be ground or machined.

1.11.6 Prior to inspection, welded temporary attachments and lifting eyes used to aid construction are to be removed carefully by grinding, cutting or chipping or other approved means. The surface of the material is to be finished smooth by grinding followed by crack detection. Any defects caused in the removal process are to be repaired.

1.11.7 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0.41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

1.11.8 Non-destructive examinations are to be performed in accordance with the requirements of the Rules. Examinations are to be in accordance with agreed written procedures prepared by the manufacturer or ship builder.

1.11.9 The Surveyor may request additional inspections where there is reason to question the quality of workmanship, or where the weld is part of a complicated fabrication where there is high restraint or high residual stresses.

1.11.10 Welds are to be examined after completion of any post-weld heat treatment.

1.11.11 Where weld defects are discovered, the full extent is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and, where necessary, weld repaired in accordance with the relevant Sections of this Chapter.

1.11.12 Results of non-destructive examinations are to be recorded and evaluated by the constructor on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

1.11.13 The constructor is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued. Reports are to include the following information where appropriate:

(a) date of inspection;
(b) names, qualifications and signatures of operator and supervisor;
(c) component identification;
(d) weld identification, location and extent of testing;
(e) steel grade, type of joint, thickness of parent material, welding process;
(f) heat treatment status;
(g) test standard used;
(h) acceptance criteria;
(j) surface condition;
(k) inspection procedure reference;
(l) test equipment used;
(m) any test limitations, viewing conditions and temperature;
(n) statement of final acceptability to established criteria.

1.11.14 The extent of applied non-destructive examination is to be increased when warranted by the analysis of previous results.

1.12 Routine weld tests

1.12.1 Routine or production weld tests may be specified as a means of monitoring the quality of the welded joints. This type of quality control test is generally specified for pressure vessel and LNG construction but may be used for other types of welded fabrication.

1.12.2 Routine weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

1.12.3 Where routine test welds have been agreed, they are to be performed in accordance with the general requirements for the type of construction (*see* Sections 3 and 4).

1.13 Rectification of material defects

1.13.1 Repair of defects found in base materials is not to be carried out without the prior approval of the Surveyor.

1.13.2 In general, surface defects in the material may be removed by grinding, chipping, etc., provided the remaining material thickness is not reduced below the minimum thickness tolerance, and the area is ground to blend in smoothly with the surrounding material.

1.13.3 Confirmation that the defect has been removed is required by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.13.4 Surface defects, which cannot be repaired by the above method, may be repaired by welding where permitted by Chapters 3 to 9. Such repairs are to be performed in accordance with the requirements of this Section and those specified in Chapters 3 to 9.

1.13.5 Any defects in the structure resulting from the removal of temporary attachments are to be prepared, efficiently welded and ground smooth so as to achieve a defect free repair.

1.14 Rectification of distortion

1.14.1 Fairing, by linear or spot heating, to correct distortions due to welding, may be carried out. In order to ensure that the properties of the material are not adversely affected, approved procedures are to be utilised. On completion of such processes, visual examination of all heat affected areas in the vicinity is to be carried out to ensure freedom from cracking.

1.14.2 When misalignment of members exceeds the agreed tolerance, the misaligned item is to be cut apart, realigned and re-welded in accordance with an approved procedure.

1.15 Rectification of welds defects

1.15.1 Where repairs are extensive the manufacturer is to investigate the reason for the defects and take the necessary actions to prevent recurrence. In addition, consideration is to be given to the sequence of repairs and to providing temporary supports to prevent misalignment or collapse.

1.15.2 Cracks are to be reported to the Surveyor and the cause established prior to undertaking weld repairs.

1.15.3 Defects may be removed by grinding, chipping or thermal gouging. Where thermal gouging is used, the repair groove is to be subsequently ground clean to remove oxides and debris. The groove is to have a profile suitable for welding.

1.15.4 Prior to commencing repair welding, it is to be confirmed that no defect exists on the prepared surface by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.15.5 Repair welding is to be performed using approved welding procedures.

1.15.6 Completed repairs are to be re-examined by the non-destructive examination method(s) that detected the original defect and are to confirm that the original defect has been removed.

1.15.7 Where the component or structure has been subjected to post-weld heat treatment prior to weld repair, this is to be repeated after completion of all repair welding.

1.15.8 Where non-destructive examination reveals that the original defect has not been successfully removed, one more repair attempt may be performed.

1.15.9 The manufacturer is to monitor the quality of welding and maintain records of welding repairs and take the necessary corrective actions where repair rates are outside normal limits.

1.16 Post-weld heat treatment

1.16.1 On completion of welding, post-weld heat treatment may be required depending on the type of welded construction, the material type and thickness as specified by the relevant Parts or Sections of the Rules.

1.16.2 In general, heat treatment after welding is to be a stress relief treatment in order to reduce residual stresses introduced by welding and is generally applicable to ferritic steels. Where other types of heat treatment (e.g. normalising, solution annealing) are proposed, demonstration of acceptable mechanical properties of the weldment are to be confirmed by a welding procedure test which includes a simulated heat treatment.

1.16.3 Parts are to be properly prepared for heat treatment. Machined surfaces (e.g. flange faces, screw threads, etc.) are to be protected against scaling and sufficient temporary supports provided to prevent distortion or collapse of the structure.

1.16.4 Details of the heat treatment to be applied, soaking time and temperature, heating and cooling rates, etc., are to be submitted for review prior to commencing.

1.16.5 Post-weld heat treatment is to be carried out in a purpose built furnace which is efficiently maintained. In special cases, where the configuration of the component is such that thermal stresses during heating and cooling can be minimised, local post-weld heat treatment may be used. This would not normally apply to the complex geometry of cast materials during manufacture within the foundry environment.

1.16.6 In all cases, the heat treatment facilities and arrangements are to be capable of controlling the temperature throughout the heat treatment cycle and adequate means of measuring and recording the component temperature are to be provided. Thermocouples are to be attached so they are in contact with the component.

1.16.7 Unless specified otherwise, stress relief heat treatment is to be carried out by means of controlled heating from 300°C, to the soak temperature, holding within the prescribed soaking temperature range for the time specified (usually 1 hour per 25 mm of weld thickness) followed by controlled cooling to below 300°C.

1.16.8 Where post-weld stress relief is specified for welded constructions that contain joints between different materials (e.g. ferritic to austenitic steels), the details of the materials, welding procedures and heat treatment cycle to be applied are to be submitted for special consideration and approval.

1.16.9 Non-destructive examination of welds is to be performed after completion of any heat treatment.

1.17 Certification

1.17.1 Products or components are not to be considered complete until all the requirements of the construction specification have been met and all activities have been completed.

1.17.2 Upon completion of the works, the manufacturer is to provide documentation which indicates that:

(a) All welds are complete and there are no outstanding repairs.
(b) The appropriate post-weld heat treatments have been performed.
(c) Appropriate destructive tests have been performed.
(d) Proof testing of welds has been performed.

1.17.3 Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to provide a written declaration stating that the product is in accordance with the requirements of 1.17.2.

■ *Section 2*
Specific requirements for ship hull and machinery

2.1 Scope

2.1.1 The requirements of this Section apply to the construction of ships, including hull structure, superstructure and deckhouses, components forming part of the ship structure and its machinery (excluding pressure equipment and piping, *see* Section 4). These requirements are in addition to the general welding requirements specified in Section 1.

2.1.2 The shipyard and manufacturer's works are to be assessed to give assurance that they have the facilities, equipment, personnel and quality control procedures to produce work of the required quality.

2.2 Welding consumables

2.2.1 Welding consumables used for hull construction are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of material to be welded.

2.2.2 Steel welding consumable approvals, up to and including Grade Y40, are considered acceptable for hull construction in line with Table 11.1.1 in Chapter 11, Ch 12,2.2.2 and the following:

(a) Consumables are acceptable for welding steels up to 3 strength levels below that for which the approval applies, e.g. a consumable with approval grading 3Y is acceptable for welding EH36, EH32 and EH27S higher tensile ship steels and grade E normal strength ship steel.
(b) Consumables with an approved impact toughness grading are acceptable for welding steels with lower specified impact properties subject to (a) above, e.g. a consumable with approval grading 3Y is acceptable for welding EH, DH and AH materials.
(c) For welding steels of different grades or different strength levels, the welding consumables may be of a type suitable for the lesser grade or strength being connected. The use of a higher grade of welding consumable may be required at discontinuities or other points of stress concentration.

2.2.3 In general, the use of preheating and hydrogen controlled welding consumables for welding of ship steels up to strength grade H40 is to be in accordance with Table 13.2.1. The carbon equivalent is to be calculated from the ladle analysis using the formula given below:

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

Pre-heat and the use of low hydrogen controlled consumables will be required for welding of steel grades higher than Grade H40.

Table 13.2.1 Pre-heat and consumable requirements for welding of carbon and carbon manganese steels up to strength grade H40

Carbon equivalent C_{eq}	Preheat	Hydrogen controlled consumables
C_{eq} equal to or less than 0,41%	Not required	Not required, *see* Note 3
C_{eq} above 0,41 but not exceeding 0,45%	Not required, *see* Notes 1 and 2	Required
C_{eq} greater than 0,45%	Required	Required

NOTES
1. Preheat may need to be applied in order to meet the maximum hardness values specified in Ch 12,2.12.6.
2. Under conditions of high restraint or low ambient temperature preheat may need to be applied.
3. Hydrogen controlled consumables may need to be considered for welding of
   (a) Thicker materials (i.e. > 35 mm).
   (b) Higher strength materials.
   (c) Welds subject to high restraint.

2.2.4 All aluminium alloy welding consumables are to be approved in accordance with Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.2.

Table 13.2.2 Welding of aluminium alloys – Consumable requirements

Consumable approval grade	Base material alloy grade
RA or WA	5754
RB or WB	5086, 5754
RC or WC	5083, 5086, 5754
RD or WD	6005A, 6061, 6082

2.2.5 All austenitic stainless steel and duplex stainless steel welding consumables are to be approved in accordance with the Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.3.

2.3 Welding procedure and welder qualifications

2.3.1 Welding procedures and welder qualifications are to be tested and approved in accordance with the requirements of Chapter 12.

2.4 Construction and workmanship

2.4.1 Weld preparations and openings may be formed by thermal cutting, machining or chipping. Chipped surfaces that will not be subsequently covered by weld metal are to be ground smooth.

2.4.2 Prior to welding, the alignment of plates and stiffeners forming part of the hull structure is to be in accordance with the tolerances specified in the relevant part of the Rules.

Table 13.2.3 Welding of austenitic stainless and duplex stainless steels – Consumable requirements

Consumable approval grade	Suitable for welding material alloy grades
Austenitic stainless steels	
321 347	321 347 and 321
Austenitic stainless steel – Low carbon	
304L 304LN 316L 316LN 317L 317LN	304L 304LN and 304L 316L and 304L 316LN, 316L, 304LN and 304L 317L, 316LN, 316L, 304LN and 304L 317LN, 317L, 316LN, 316L, 304LN and 304L
Super austenitic stainless steels, *see* Note 2	
S31254 N08904	S31254 and N08904 N08904
Duplex stainless steels, *see* Note 1	
S31260 S31803 S32550 S32750 S32760	S31260 and S31803 S31803 S32550 S32750 and S32550 S32760, S32550, S31260 and S31803
Stainless steels welded to carbon steels	
SS/CMn Duplex/CMn	Carbon steel to all steels in Sections 1, 2 and 3 Carbon steel to all duplex stainless steel in Section 4

NOTES
1. The use of a different welding consumable grade from that of the base material may require demonstration of acceptable corrosion properties.
2. May be used for welding low carbon austenitic grades provided measures are taken to prevent solidification cracking from occurring.

2.4.3 When welding from one side only, care is to be exercised to ensure the root gap and fit up are in accordance with the approved welding procedure and the root is properly fused.

2.4.4 Where it is proposed to use permanent backing strips, the intended locations and welding procedures are to be submitted for consideration.

2.4.5 Temporary backing strips may be used provided they are in accordance with approved welding procedures and are subsequently removed on completion of welding.

2.4.6 The outer surfaces of completed welds are to blend smoothly with the base materials and provide a smooth transition and gradual change of section.

2.4.7 Weld joints in parts of oil engine structures that are stressed by the main gas or inertia loads are to be designed as continuous full penetration welds. They are to be arranged so that welds do not intersect, and that welding can be effected without difficulty.

2.4.8 When modifications or repairs have been made which result in openings having to be closed by welded inserts, particular care is to be given to the fit of the insert and the welding sequence. The welding is also to be subject to non-destructive examination.

2.4.9 Where welding of aluminium alloy is employed, the following additional requirements are to be complied with so far as they are applicable:

(a) Welding is to be performed by fusion welding using inert gas or tungsten inert gas process or by the friction stir welding process. Where it is proposed to use other welding processes, details are to be submitted for approval.

(b) The weld joint surfaces should be scratch brushed, preferably immediately before welding, in order to remove oxide or adhering films of dirt, filings, etc.

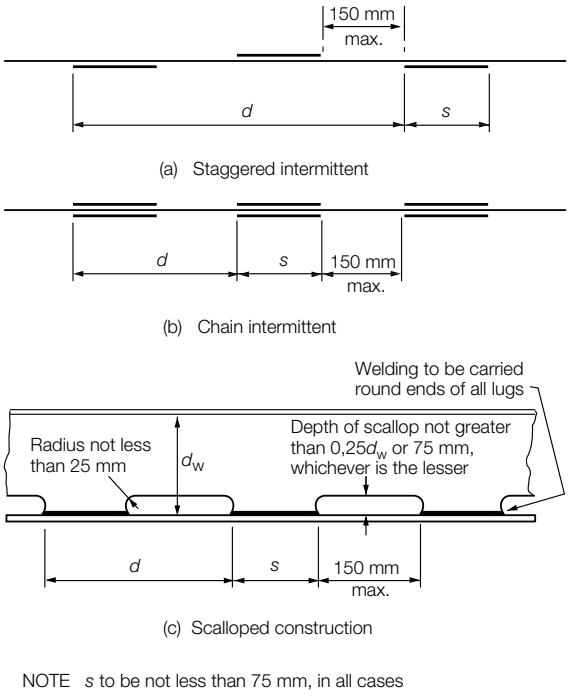
2.5 Butt welds

2.5.1 Where the ship hull is constructed of plates of different thicknesses, the thicker plates are to be chamfered in accordance with the approved plans. In all cases the chamfer is not to exceed a slope of 1 in 3 so that the plates are of equal thickness at the weld seam. Alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate provided the difference in thickness is not greater than 3 mm.

2.5.2 Where stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these are to be made flush in way of the fillet weld. Similarly for butt welds in webs of stiffening members, the butt weld is to be complete and generally made flush with the stiffening member before the fillet weld is made. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member (*see* Fig. 13.2.1). Scallops are to be of such a size and in such a position that a satisfactory weld can be made.

2.6 Lap connections

2.6.1 Overlaps are generally not to be used to connect plates which may be subjected to high tensile or compressive loading and alternative arrangements are to be considered. However, where plate overlaps are adopted, the width of the overlap is not to exceed four times, nor be less than three times the thickness of the thinner plate and the joints are to be positioned to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.



NOTE *s* to be not less than 75 mm, in all cases

Fig. 13.2.1 Weld types

2.7 Closing plates

2.7.1 For the connection of plating to internal webs, where access for welding is not practicable, the closing plating is to be attached by continuous full penetration welds or by slot fillet welds to face plates fitted to the webs. Slots are to have a minimum length of 90 mm and a minimum width of twice the plating thickness, with well rounded ends. Slots cut in plating are to be smooth and clean and are to be spaced not more than 230 mm apart, centre to centre. Slots are not to be filled with welding.

2.7.2 For the attachment of rudder shell plating to the internal stiffening of the rudder, slots are to have a minimum length of 75 mm and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded and the space between them is not to exceed 150 mm.

2.8 Stud welding

2.8.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs and the welding procedures adopted are to be approved.

2.9 Fillet welds

2.9.1 T-connections are generally to be made by fillet welds on both sides of the abutting plate, the dimensions and spacing of which are shown in Fig. 13.2.1. Where the connection is highly stressed, deep penetration or full penetration welding may be required. Where full penetration welding is required, the abutting plate may be required to be bevelled.

2.9.2 Where an approved deep penetration procedure is used, the fillet leg length calculated may be reduced by 15 per cent provided that the manufacturer is able to meet the following requirements:

(a) Use of a welding consumable approved for deep penetration welding in accordance with Chapter 11 for either the 'p' or 'T' techniques.
(b) Demonstrations by way of production weld testing that the minimum required penetration depths (i.e. throat thicknesses) are maintained. This is to be documented on a monthly basis by the manufacturer and be available to the Surveyor.

2.9.3 The calculated fillet leg length may be reduced by 20 per cent, provided that in addition to the requirements of 2.9.2(a) and (b), the manufacturer is able to consistently meet the following additional requirements:

(a) The documentation required in 2.9.2(b) is to be completed and made available to the Surveyor upon request on a weekly basis.
(b) Suitable process selection confirmed by satisfactory welding procedure tests covering both minimum and maximum root gaps.

2.9.4 Where intermittent welding is used, the welding is to be made continuous in way of brackets, lugs and scallops and at orthogonal connections with other members.

2.10 Post-weld heat treatment

2.10.1 Post-weld stress relief heat treatment is applied to improve the fatigue performance or to improve resistance to brittle fracture and is generally required for carbon and carbon-manganese and low alloy steels under any of the following conditions:

(a) Where the material thickness exceeds 65 mm.
(b) For complicated weld joints where there are high stress concentrations.
(c) Where fatigue loads are considered high.

2.10.2 Post-weld heat treatment is to be applied to the following types of welded construction:

(a) Welding of steel castings where the thickness of the casting at the weld exceeds 30 mm.
(b) Oil engine bedplates except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need to be stress relieved.
(c) Welding of gear wheels.
(d) Welding of gear cases associated with main or auxiliary engines (*see* Part 5).

2.10.3 Where required, heat treatment is to be performed in accordance with the requirements specified in 4.6 for pressure vessel construction.

2.10.4 Special consideration may be given to omit the required post-weld heat treatment. Evaluation is to be based on critical engineering assessment involving fracture mechanics testing and proposals are to be submitted which include full details of the application, materials, welding procedures, inspection procedures, design stresses, fatigue loads and cycles. Evidence will be required to demonstrate that the inspection techniques and procedures to be employed are able to detect flaws down to the sizes determined from the fracture mechanics (and or fatigue) calculations.

2.11 Tolerances

2.11.1 Tolerances after welding are to be in accordance with the relevant Part of the Rules.

2.11.2 Distortion which has resulted from welding may be corrected by spot heating in accordance with 1.14.

2.12 Non-destructive examination of welds

2.12.1 All finished welds are to be sound and free from cracks and lack of fusion and substantially free from incomplete penetration, porosity and slag. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and under-fill of welds is avoided.

2.12.2 Welds forming part of the hull and superstructure may be coated with a thin layer of protective primer prior to inspection provided it does not interfere with inspection and is removed, if required by the Surveyor, for closer interpretation of possible defective areas.

2.12.3 All welds are to be visually inspected by personnel designated by the builder. Visual inspection of all welds may be supplemented by other non-destructive examination techniques in cases of unclear interpretation, as considered necessary. The acceptance criteria for visual testing are given in Table 13.2.4.

2.12.4 In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld.

2.12.5 The method to be used for the volumetric examinations of welds is the responsibility of the builder. Radiography is generally preferred for the examination of butt welds of 10 mm thickness or less. Ultrasonic testing is acceptable for welds of 10 mm thickness or greater and is to be used for the examination of full penetration tee butt or cruciform welds or joints of similar configuration.

2.12.6 The acceptance criteria for radiographic testing are given in Table 13.2.5, and those for ultrasonic testing in Table 13.2.6. Alternative NDE acceptance criteria will be subject to special consideration provided that they are equivalent to these requirements.

Table 13.2.4 Acceptance criteria for visual testing, magnetic particle and liquid penetrant testing

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria for visual testing
Crack	100	Not accepted
Lack of fusion	401	Not accepted
Incomplete root penetration in butt joints welded from one side	4021	Not accepted
Surface pore	2017	Single pore diameter $d \leq 0{,}25t$, for butt welds, *see* Note 1 $d \leq 0{,}25a$, for fillet welds, with maximum diameter 3 mm, *see* Note 1 $2{,}5d$ as minimum distance to adjacent pore
Undercut in butt welds	501	Depth ≤ 0,5 mm, whatever the length Depth ≤ 0,8 mm, with a maximum continuous length of 90 mm, *see* Note 2
Undercut in fillet welds	501	Depth ≤ 0,8 mm, whatever the length

NOTES
1. *t* is the plate thickness of the thinnest plate, and *a* is the throat of the fillet weld.
2. Adjacent undercuts separated by a distance shorter than the shortest undercut are to be regarded as a single continuous undercut.

Table 13.2.5 Acceptance criteria for radiographic testing

Discontinuity	Classification according to ISO 6520-1	Acceptance criteria for radiographic testing, *see* Note 1
Crack	100	Not accepted
Lack of fusion	401	Continuous maximum length *t*/2 or 25 mm, whichever is the less, *see* Note 2 Intermittent cumulative length maximum *t* or 50 mm, whichever is less, *see* Note 3
Incomplete root penetration	4021	Not accepted in butt joint welded from one side
		Continuous maximum length *t*/2 or 25 mm, whichever is lesser, *see* Note 2 Intermittent cumulative maximum length *t* or 50 mm, whichever is less, *see* Note 3
Slag inclusion	301	Continuous maximum length *t* or 50 mm, whichever is less, *see* Note 2 Intermittent cumulative length maximum 2*t* or 100 mm, whichever is less, *see* Notes 3 and 4

NOTES
1. *t* is the thickness of the thinnest plate.
2. Two adjacent individual discontinuities of length L1 and L2 situated on a line and where the distance L between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length L1+L+L2
3. Sum of the length of individual continuous discontinuities.
4. Parallel inclusions not separated by more than 3 times the width of the largest inclusion are to be regarded as one continuous discontinuity.

2.12.7 Checkpoints examined at the pre-assembly stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspection of weld ends.

2.12.8 Checkpoints examined at the assembly stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the builder. The locations and number of checkpoints are to be approved by the Surveyor.

2.12.9 Where components of the structure are subcontracted for fabrication, the same inspection regime is to be applied as if the item had been constructed within the main contractor's works. In these cases, particular attention is to be given to highly loaded fabrications (such as stabilizer fin boxes) forming an integral part of the hull envelope.

2.12.10 Particular attention is to be paid to highly stressed items. Magnetic particle inspection is to be used at ends of fillet welds, T-joints, joints or crossings in main structural members and at stern frame connections.

Table 13.2.6 Acceptance criteria for ultrasonic testing

Echo height	Acceptance criteria for ultrasonic testing, *see* Note
Greater than 100% of DAC curve	Maximum length *t*/2 or 25 mm, whichever is less
Greater than 50% of DAC curve, but less than 100% of DAC curve	Maximum length *t* or 50 mm, whichever is less
Indications evaluated to be cracks are unacceptable regardless of echo height; Indications evaluated to be lack of penetration in joints welded from one side are unacceptable regardless of echo height.	
NOTE Two adjacent individual discontinuities of length L1 and L2 situated on a line and where the distance L between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length L1 + L + L2.	

2.12.11 Special attention is to be given to the examination of plating in way of lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed, but includes the positions where lifting eye plates are permanent fixtures.

2.12.12 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

2.12.13 Typical locations for volumetric examination and number of checkpoints to be taken are given in the relevant Sections of the Rules. A list of the proposed items to be examined is to be submitted for approval.

2.12.14 For the hull structure of refrigerated spaces, and of ships designed to operate in low air temperatures, the extent of non-destructive examination will be specially considered. For non-destructive examination of gas ships see the *Rules for the carriage for Liquefied Gases*.

2.12.15 For all ship types, the builder is to carry out random non-destructive examination at the request of the Surveyor.

2.12.16 Results of non-destructive examinations made during construction are to be recorded and evaluated by the builder on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

2.12.17 The extent of applied non-destructive examinations is to be increased when warranted by the analysis of previous results.

2.13 Weld repairs

2.13.1 The full extent of any weld defect is to be ascertained by applying additional non-destructive examination where required. Unacceptable defects are to be completely removed and, where necessary, re-welded and re-examined in accordance with the requirements of 1.15.

2.13.2 During the assembly of large components, root gaps in excess of those specified in the approved welding procedure may be rectified by welding.

2.13.3 Rectification of wide root gaps in butt welds, up to a maximum gap of 16 mm, may be performed provided that the length of these areas is small in relation to the whole weld length. Repairs may be executed by applying weld buttering layers to one edge of the weld joint, followed by machining or grinding to return the root opening to the required dimensions. The weld buttering and filling of the joint are to be in accordance with welding procedures qualified in accordance with Chapter 12.

2.13.4 For sub-assemblies, rectification of wide root gaps may be performed using a backing strip, provided that it is removed on completion of the welding.

2.13.5 Rectification of wide root gaps in fillet welds may be carried out as follows:

(a) where the root gap, *g*, is in excess of 3 mm, but not greater than 5 mm, the fillet leg length, *z*, may be increased by *g* – 2,0 mm;

(b) where the root gap is in excess of 5 mm, the joint detail may be changed into a full penetration weld.

2.13.6 Where repair welds are made using small weld beads, suitable precautions (including preheat) are to be taken to avoid high hardness and possible cold cracking.

■ *Section 3*
Specific requirements for fabricated steel sections

3.1 Scope

3.1.1 Fabricated steel sections are items used in place of rolled sections and as such will not be regarded as sub-assemblies. Products regarded as sub-assemblies are subject to requirements of welded construction specified in Section 2.

3.1.2 The requirements for structural steel sections are based on these being manufactured from flat products by automatic welding and intended for use in the construction of ships and other marine structures.

3.1.3 Fabricated steel sections are to be manufactured in accordance with the requirements of this Section and the general requirements of Section 1.

3.1.4 In all cases, sections are to be manufactured at works, which have been assessed and approved in accordance with *Materials and Qualification Procedures for Ships, Book J, MQPS Procedure 12-1*.

3.2 Dimensions and tolerances

3.2.1 Products are to conform dimensionally to the provisions of an acceptable National or International Standard.

3.2.2 The minimum throat thickness of fillet welds is to be determined from:

Throat thickness = 0,34t but not to be taken as less than 3 mm

where

t = plate thickness of the thinner member to be joined (generally the web).

3.2.3 Where a welding procedure using deep penetration welding is used (*see* Chapter 11, 'p' and 'T' welding techniques) the minimum leg length required will be specially considered provided the requirements of 2.9.2 are complied with.

3.2.4 Unless agreed otherwise, the leg length of the weld is to be not less than 1,4 times the specified throat thickness.

3.3 Identification of products

3.3.1 Every finished item is to be clearly marked by the manufacturer in at least one place with the following particulars:

(a) The manufacturer's name or trade mark.
(b) Identification mark for the grade of steel.
(c) Identification number and/or initials which will enable the full history of the item to be traced.
(d) Where required by the purchaser, the order number or other identification mark.
(e) the letters 'LR'.
(f) the Surveyor's personal stamp.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

3.3.2 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be removed or unmistakably defaced, *see also* Ch 1,4.8.

3.4 Manufacture and workmanship

3.4.1 For cut edges that are to remain unwelded, it is to be demonstrated that the plate preparation procedures used are able to achieve edges that are free from cracks or other deleterious imperfections.

3.4.2 Where assembly jigs and devices are used to bring the web into contact with the flanges and hold these in place during welding, means are to be provided to ensure that the degree of contact is maintained until welding is complete.

3.4.3 Welding procedures are to be established for the welding of all joints including weld repairs and are to be approved in accordance with Chapter 12. Welders are to be approved in accordance with Chapter 12, and qualification records are to be available to the Surveyor.

3.4.4 The welding consumables used are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of steel as described in 2.2. For joining steel of different tensile strengths, the consumables are to be suitable for the tensile strength of the component considered in the determination of weld size.

3.4.5 The application of pre-heat and the use of low hydrogen welding consumables are to be in accordance with the requirements of 2.2.

3.4.6 Welding is to be double continuous fillet welding or full penetration welding as specified in the approved plans.

3.4.7 Where deep penetration welding is used, the requirements of 2.9.2 are to be complied with.

3.5 Non-destructive examination

3.5.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer and are to be carried out on all materials prior to despatch. Acceptance by the Surveyor of material later found to be defective does not absolve the manufacturer from this responsibility.

3.5.2 The Surveyor will carry out checks to ensure that the weld size and profile are in accordance with the manufacturing specification and the manufacturer's Quality Control Procedures.

3.5.3 The manufacturer is to examine the welds by magnetic particle or dye penetrant methods. The length examined is to be 200 mm at each end, for each length cut for delivery.

3.5.4 If cracks are revealed, these are to be reported to the Surveyor and the whole of the length is to be examined by magnetic particle or dye penetrant methods. Corrective action in respect of the manufacturing process, and repairs are to be as indicated in the manufacturers' Quality Control Manual.

3.5.5 The weld defect is not to exceed the acceptance levels given in Table 13.2.4.

3.6 Routine weld tests

3.6.1 One production batch test is required for every 500 m of fabricated section manufactured, or fraction thereof. From each batch test, two samples are to be removed, one from near the beginning of the production run and one from near the end. From each of these test samples one macro specimen and one fracture test specimens are to be taken.

3.6.2 The macro specimens are to be prepared and etched to demonstrate freedom from unacceptable defects and that the weld penetration is in accordance with the manufacturing specification. The fracture specimens are to be broken, one for each side of the fillet weld and the fractured surfaces examined for compliance with the requirements of Table 13.2.5.

3.6.3 Where the welding procedure used has employed the deep penetration technique, the amount of root penetration is to be measured on the macro specimen and is not to be less than that demonstrated during welding procedure approval testing.

3.6.4 For the purposes of this Section, a batch is to consist of products of only one size and grade of material.

3.7 Certification and records

3.7.1 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Where known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Description and dimensions of the product.
(e) Specification or grade of the steel.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples of constituent plates.
(h) Mechanical test results of constituent plates.
(j) Condition of supply when other than as-rolled.
(k) Make and brand of welding consumables.

3.7.2 Test certificates or shipping statements may be signed by the Surveyor, provided the documentation requirements of 1.17 are satisfied. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the works and signed by an authorised representative of the manufacturer: 'We hereby certify that the material has been made by an approved procedure in accordance with the Lloyd's Register's Rules for Materials'.

3.7.3 The manufacturer is to maintain records by which sources of material can be identified together with the results of all inspections and tests.

■ *Section 4*
Specific requirements for fusion welded pressure vessels

4.1 Scope

4.1.1 The requirements of this Section apply to fusion welded pressure vessels and process equipment, heating and steam raising boilers, and steam or gas turbine rotors and cylinders and are in addition to those requirements referred to in Section 1.

4.1.2 The allocation of pressure vessel Class is determined from the design criteria in Pt 5, Ch 10 and 11 of the Rules for Ships. Prior to commencing construction, the design of the vessel is to be approved. Construction requirements for turbine rotors and cylinders are to be in accordance with Class 2/1, unless a higher Class is specified in the approved plans.

4.1.3 Pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding work required for the Class of vessel proposed. The manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships, Book A, Procedure MQPS 0-4*.

4.1.4 The term 'fusion weld', for the purpose of these requirements, is applicable to welded joints made by manual, semi-automatic, or automatic electric arc welding processes. Special consideration will be given to the proposed use of other fusion welding processes.

4.2 Cutting and forming of shells and heads

4.2.1 Cut or chipped surfaces which will not be subsequently covered by weld metal are to be ground smooth.

4.2.2 Shell plates and heads are to be formed to the correct contour up to the extreme edge of the plate.

4.2.3 Vessels manufactured from carbon or carbon manganese steel plates (*see* Table 3.4.1 in Chapter 3, grades 360AR to 510FG), which have been hot formed or locally heated for forming, are to be re-heat treated in accordance with the original supplied condition on completion of this operation. Vessels formed from plates supplied in the as-rolled condition are to be heat treated in accordance with the material manufacturer's recommendations.

4.2.4 Subsequent heat treatment will not be required where steels are supplied in the as-rolled, normalised or normalised and controlled rolled condition, or hot forming is carried out entirely at a temperature within the normalising range.

4.2.5 For alloy steel vessels where hot forming is employed (*see* Table 3.4.1 in Chapter 3, 13Cr Mo 45 etc.), the plates are to be heat treated on completion in accordance with the material manufacturer's recommendations.

4.2.6 Where plates are cold formed, subsequent heat treatment is to be performed where the internal radius is less than 10 times the plate thickness. For carbon and carbon-manganese steels this heat treatment may be a stress relief heat treatment.

4.2.7 In all cases where hot forming is employed, and for cold forming to a radius less than 10 times the thickness, the manufacturer is required to demonstrate that the forming process and subsequent heat treatments result in acceptable properties.

4.3 Fitting of shell plates and attachments

4.3.1 The location of welded joints is to be such as to avoid intersecting butt welds in the vessel shell plates. The attachment of nozzles and openings in the vessels are to be arranged to avoid main shell weld seams.

4.3.2 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other, at any point, by more than 10 per cent of the plate thickness. In no case is the misalignment to exceed 3 mm for longitudinal seams, or 4 mm for circumferential seams.

4.3.3 Where a vessel is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be so arranged that their centrelines form a continuous circle.

4.3.4 For longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in thickness, so that the plates are of equal thickness at the longitudinal weld seam. For the circumferential seam, the thickest plate is to be similarly prepared over the same distance longitudinally.

4.3.5 For the circumferential seam, where the difference in the thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the weld joint. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate.

4.3.6 All attachments (lugs, brackets, reinforcing plates, etc.) are to conform to the shape of the surface to which they are attached.

4.4 Welding

4.4.1 Welding procedures are to be established for all welds joining pressure containing parts and for welds made directly onto pressure containing parts. Welding procedures are to be based on qualification tests performed in accordance with Chapter 12.

4.4.2 In all cases where tack welds, in the root of the weld seam, are used to retain plates or parts in position prior to welding, they are to be removed in the process of welding the seam.

4.4.3 Steel backing strips may be used for the circumferential seams of Class 2/1, Class 2/2 and Class 3 pressure vessels and are to be the same nominal composition as the plates to be welded.

4.4.4 Fillet welds are to be made to ensure proper fusion and penetration at the root of the fillet. At least two layers of weld metal are to be deposited at each weld affixing branch pipes, flanges and seatings.

4.4.5 The outer surface of completed welds is to be at least flush with the surface of the plates joined, and any weld reinforcement is to provide a smooth transition and gradual change of section with the plate surface.

4.4.6 Where attachment of lugs, brackets, branches, manhole frames, reinforcement plates and other members are to be made to the main pressure shell by welding, this is to be to the same standard as required for the main vessel shell construction.

4.4.7 The main weld seams and all welded attachments made to pressure containing parts are to be completed prior to post weld heat treatment.

4.4.8 The finish of welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to allow satisfactory examination of the welds. In the case of Class 1 and Class 2/1 pressure vessels, these welds are to be ground smooth, if necessary, to provide a suitable finish for examination.

4.5 General requirements for routine weld production tests

4.5.1 Routine weld production tests are specified as a means of monitoring the quality of the welded joints and are required for pressure vessel Classes 1, 2/1 and 2/2.

4.5.2 Routine production test plates are required during the manufacture of vessels and as part of the initial approval test programme for Class 1 vessel manufacturers, refer to *MQPS 0-4*.

4.5.3 Routine production weld tests are not required for Class 3 pressure vessels unless there are doubts about the weld quality where check tests may be requested by the Surveyor.

4.5.4 Routine production test plates are not required for circumferential seams of cylindrical pressure vessels. Spherical vessels are to have one test plate prepared having a welded joint which is a simulation of the circumferential seams.

4.5.5 Routine production weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

4.6 Production test plate assembly requirements

4.6.1 Two test plates and one complete test assembly, of sufficient dimensions to provide all the required mechanical test specimens is to be prepared for each vessel and is to be welded as a continuation and simulation of the longitudinal weld joint.

4.6.2 For Class 2/2 vessels, where a large number are made concurrently at the same works using the same welding procedure and the plate thicknesses do not vary by more than 5 mm, one test may be performed for each 37 m of longitudinal plus circumferential weld seam. In these cases the thickness of the test plate is to be equal to the thickest shell plate used in the construction.

4.6.3 Where the vessel size or design results in a small number of longitudinal weld seams, one test assembly may be prepared for testing provided that the welding details are the same for each seam.

4.6.4 Test plate materials are to be the same grade, thickness and supply condition and from the same cast as that of the vessel shell. The test assembly is to be welded at the same time as the vessel weld to which it relates and is to be supported so that distortion during welding is minimised.

4.6.5 As far as practicable, welding is to be performed by different welders where there is a requirement for several routine tests to be welded.

4.6.6 The test assembly may be detached from the vessel weld only after the Surveyor has performed a visual examination and has added his mark or stamp. Straightening of test welds prior to mechanical testing is not permitted.

4.6.7 Where the pressure vessel is required to be subjected to post weld heat treatment, the test weld is to be heat treated, after welding, in accordance with the same requirements. This may be performed separately from the vessel.

4.7 Inspection and testing

4.7.1 The test weld is to be subjected to the same type of non-destructive examination and acceptance criteria as specified for the weld seam to which the test relates. Non-destructive examination is to be performed prior to removing specimens for mechanical testing, but after any post weld heat treatment.

4.7.2 The test weld is to be sectioned to remove the number and type of test specimens for mechanical testing as given in 4.8.

4.8 Mechanical requirements

4.8.1 The routine production test assembly is to be machined to provide the following test specimens:

(a) Tensile.
(b) Bend.
(c) Hardness.
(d) Impact (*see* Table 13.4.1).
(e) Macrograph and hardness survey of full weld section.

4.8.2 One set of specimens for mechanical testing are to be removed, as shown in Figs. 13.4.1 or 13.4.2 as appropriate for the Class of approval. Impact tests are to be removed and tested where required by Table 13.4.1.

4.8.3 **Longitudinal tensile test for weld metal**. An all-weld metal longitudinal tensile test is required. For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, additional longitudinal tests are required from the respective area of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld. Specimens are to be tested in accordance with the following requirements:

(a) The diameter and gauge length of the test specimen is to be in accordance with Fig. 11.2.1 in Chapter 11.
(b) For carbon and carbon-manganese steels the tensile strength of the weld metal is to be not less than the minimum specified for the plate material and not more than 145 N/mm^2 above this value. The percentage elongation, A, is to be not less than that given by:

A = (980-R)/21,6 but not less than 80 per cent of the minimum elongation specified for the plate

where

R is the tensile strength, in N/mm^2, obtained from the all weld metal tensile tests.

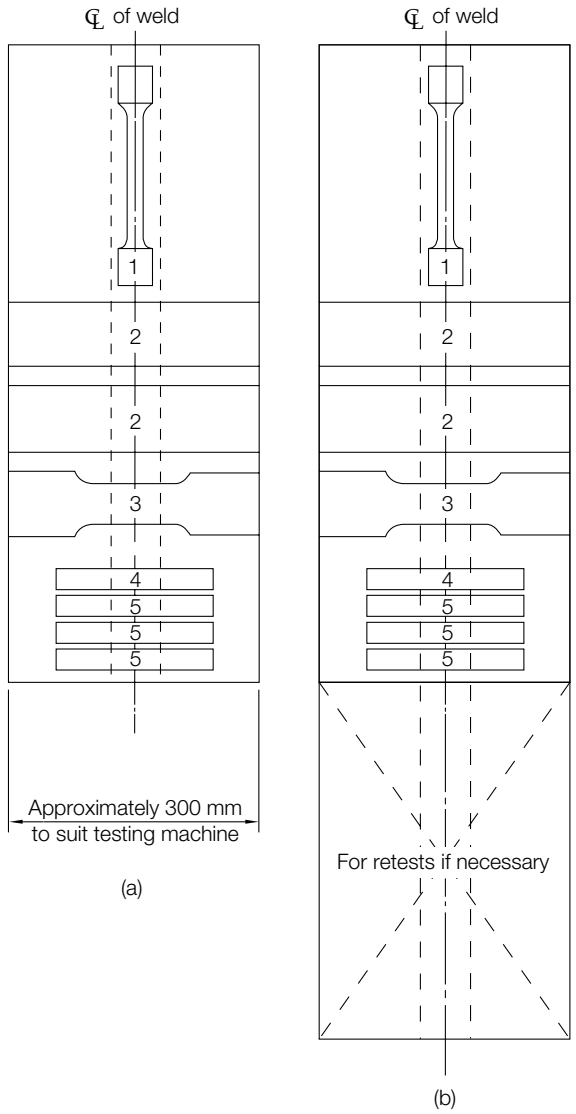
(c) For other materials the tensile strength and percentage elongation is not to be less than that specified for the base materials welded.

4.8.4 **Transverse tensile test for joint**. Transverse tensile test specimens are to be removed and tested in accordance with the following requirements:

(a) One reduced section tensile test specimen is to be cut transversely to the weld to the dimensions shown in Fig. 11.2.2 in Chapter 11 and the weld reinforcement is to be removed.
(b) In general, where the plate thickness exceeds 30 mm, or where the capacity of the tensile test machine prevents full thickness tests, each tensile test may be made up of several reduced section specimens, provided that the whole thickness of the weld is subjected to testing.
(c) The tensile strength obtained is to be not less than the minimum specified tensile strength for the plate material, and the location of the fracture is to be reported.

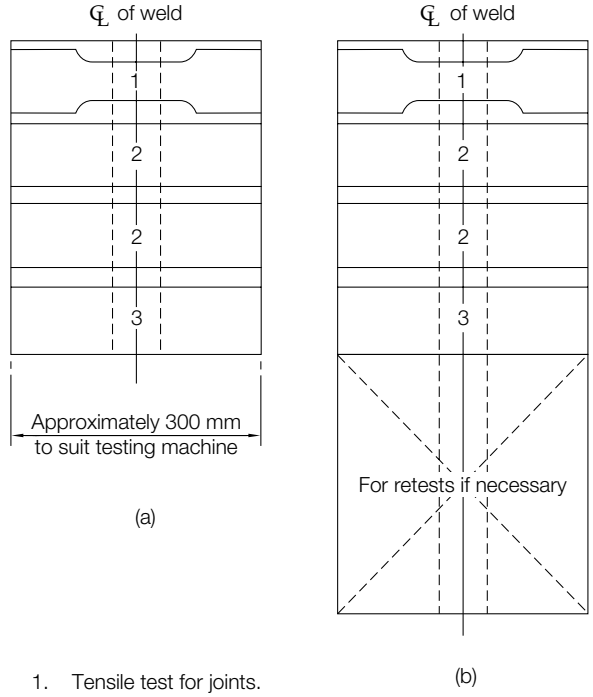
Table 13.4.1 Impact test requirements

Pressure vessel Class	Minimum design temperature	Plate material thickness t	Impact test temperature
Class 1	–10°C or above	All	5°C below the minimum design temperature or 20°C, whichever is the lower
All Classes	Below –10°C	$t \leq 20$ mm	5°C below the minimum design temperature
		20 mm $< t \leq 40$ mm	10°C below the minimum design temperature
		Over 40 mm	Subject to special consideration



1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joints.
4. Macro-test specimen and hardness test.
5. Charpy V-notch impact.
   (For all Class 1 pressure vessels and other Classes of pressure vessels where the minimum design temperature is below –10°C).

Fig. 13.4.1
Routine weld test – Test specimens for Class 1 and Class 2/1



1. Tensile test for joints.
2. Transverse bend test specimens.
3. Nicked bend test specimen.

Fig. 13.4.2
Routine weld tests – Test specimens for Class 2/2 and Class 3

4.8.5 **Transverse bend test**. The bend test specimens are to be removed and tested in accordance with the following requirements:

(a) Two bend test specimens of rectangular section are to be cut transversely to the weld, one bent with the outer surface of the weld in tension (face bend), and the other with the inner surface in tension (root bend).

(b) The specimen dimensions are to be in accordance with Chapter 11 and 2.1.3.

(c) Each specimen is to be mounted on roller supports with the centre of the weld midway between the supports. The former is to have a diameter specified in Ch 12,2.7.6 depending on the material being welded.

(d) After bending through an angle of at least 180° there is to be no crack or defect exceeding 1,5 mm measured across the specimen or 3 mm measured along the specimen. Premature failure at the edges of the specimen is not to be cause for rejection, unless this is associated with a weld defect.

4.8.6 **Macro-specimen and hardness survey**. A macro examination specimen is to be removed from the test assembly near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone. The specimen is to be prepared and examined in accordance with the following requirements:

(a) The cross-section of the specimen is to be ground, polished and etched to clearly reveal the weld runs, and the heat affected zones.
(b) The specimen is to show an even weld profile that blends smoothly with the base material and have satisfactory penetration and fusion, and an absence of significant inclusions or other defects.
(c) Where there is doubt in the condition of the weld as shown by macro-etching, the area concerned is to be microscopically examined.
(d) For carbon, carbon manganese and low alloy steels, a Vickers hardness survey is to be performed on the macro-specimen using either a 5 kg or 10 kg load. Testing is to include the base material, the weld and the heat affected zone. Hardness scans on the cross-section are to be performed as specified in Fig. 12.2.8. The maximum recorded hardness is to not exceed 350 Hv.

4.8.7 **Charpy V-notch impact test**. Charpy V notch impact test specimens are to be prepared and tested as required by Table 13.4.1 and in accordance with the following requirements:

(a) The dimensions and tolerances of the specimens are to be in accordance with Chapter 2.
(b) Charpy V-notch impact specimens and are to be removed with the notch perpendicular to the plate surface.
(c) Specimens are to be removed for testing from the weld centreline and the heat affected zone (fusion line and fusion line + 2 mm locations) detailed in Fig. 12.2.6 or Fig. 12.2.7, as appropriate. Heat affected zone impact tests may be omitted where the minimum design temperature is above +20°C.
(d) For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, impact tests are required from the respective areas of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld.
(e) The average energy of a set of three specimens is not to be less than 27 J or the minimum specified for the base material, whichever is the higher. The minimum energy for each individual specimen is to meet the requirements of Ch 1,4.5.2.

4.8.8 **Nick break bend tests**. A nick bend or fracture test specimen is to be a minimum of 100 mm long measured along the weld direction and is to be tested in accordance with and meet the requirements of the following:

(a) The specimen is to have a slot cut into each side along the centreline of the weld and perpendicular to the plate surface.
(b) The specimen is to be bent along the weld centreline until fracture occurs and the fracture faces are to be examined for defects. The weld is to be sound, with no evidence of cracking or lack of fusion or penetration and be substantially free from slag inclusions and porosity.

4.9 Failure to meet requirements

4.9.1 Where any test specimen fails to meet the requirements, additional specimens may be removed and re-tested in accordance with Ch 2,1.4.

4.9.2 Where a routine weld test fails to meet requirements, the welds to which it relates will be considered as not having met the requirements. The reason for the failure is to be established, and the manufacturer is to take such steps as necessary to either

(a) Remove the affected welds and have them re-welded, or
(b) Demonstrate that the affected production welds have acceptable properties.

4.10 Heat treatment

4.10.1 Fusion welded pressure vessels, where indicated in Table 13.4.2, are to be heat treated on completion of the welding of the seams and of all attachments to the shell and ends, and before the hydraulic test is carried out.

4.10.2 Tubes which have been expanded into headers or drums may be seal welded without further post-weld heat treatment.

4.10.3 Steam and gas turbine cylinders and rotors are to be subjected to post-weld heat treatment irrespective of thickness.

4.10.4 Where the weld attaches parts of different thicknesses, the thickness to be used when applying the requirements for post-weld heat treatment is to be either the thinner of the two plates for butt welded connections, or the thickness of the shell for welds to flanges, tubeplates and similar connections.

4.10.5 Care is to be exercised to provide drilled holes in double reinforcing plates and other closed spaces prior to heat treatment.

4.11 Basic requirements for heat treatment of fusion welded pressure vessels

4.11.1 Recommended soaking temperatures and soak durations for post-weld heat treatment are given in Table 13.4.3 for different materials. Where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

4.11.2 Where pressure vessels are of dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections, provided that sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.

4.11.3 Where materials other than those detailed in Table 13.4.3 are used or where it is proposed to adopt special methods of heat treatment, full particulars are to be submitted for consideration. In such cases, it may be necessary to carry out tests to show the effect of the proposed heat treatment.

Table 13.4.2 Post-weld heat treatment requirements

Type of steel	Plate thickness above which post-weld heat treatment (PWHT) is required	
	Steam raising plant	Other pressure vessels
Carbon and carbon/manganese steels without low temperature impact values	20 mm	30 mm
Carbon and carbon/manganese steels with low temperature impact values	20 mm	40 mm
1Cr ½Mo	All thicknesses	All thicknesses
2¼Cr 1Mo	All thicknesses	All thicknesses
½Cr ½Mo ¼V	All thicknesses	All thicknesses
Other alloy steels	Subject to special consideration	

Table 13.4.3 Post-weld soak temperatures and times

Material type	Soak temperature (°C)	Soak period
Carbon and carbon/manganese grades	580–620°	1 hour per 25 mm of thickness, minimum 1 hour
1Cr ½Mo	620–660°	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	650–690°	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	670–720°	1 hour per 25 mm of thickness, minimum of 1 hour
NOTE For materials supplied in the tempered condition, the post-weld heat treatment temperature is to be lower than the material tempering temperature.		

4.12 Non-Destructive Examination of welds

4.12.1 Non-Destructive Examinations (NDE) of pressure vessel welds are to be carried out in accordance with a nationally recognised code or standard.

4.12.2 NDE is not to be applied until an interval of at least 48 hours has elapsed since the completion of welding.

4.12.3 NDE Personnel are to be qualified to an appropriate level of a nationally recognised certification scheme.

4.12.4 Qualification schemes are to include assessments of practical ability for Levels I and II individuals. These examinations are to be made on representative test pieces containing relevant defects.

4.13 Extent of NDE for Class 1 pressure vessels

4.13.1 All butt welded seams in drums, shells, headers and test plates, together with tubes or nozzles with outside diameter greater than 170 mm, are subject to 100 per cent volumetric and surface crack detection inspections.

4.13.2 For circumferential butt welds in extruded connections, tubes, headers and other tubular parts with an outside diameter of 170 mm or less, at least 10 per cent of the total number of welds is to be subjected to volumetric examination and surface crack detection inspections.

4.14 Extent of NDE for Class 2/1 pressure vessels

4.14.1 For Class 2/1 pressure vessels, volumetric and surface crack detection inspections are to be applied at selected regions of each main seam. At least 10 per cent of each main seam is to be examined together with the full length of each welded test plate. When an unacceptable indication is detected, at least two additional check points in the seam are to be selected by the surveyor for examination using the same inspection method. Where further unacceptable defects are found either:

(a) the whole length of weld represented is to be cut out and re-welded and re-examined as if it was a new weld with the test plates being similarly treated, or

(b) the whole length of the weld represented is to be re-examined using the same inspection methods.

4.14.2 Butt welds in furnaces, combustion chambers and other pressure parts for fired pressure vessels under external pressure, are to be subject to spot volumetric examination. The minimum length for each check point is to be 300 mm.

4.14.3 The extent of NDE for turbine cylinders and rotors is to be agreed with the Surveyor.

4.15 NDE Method

4.15.1 Volumetric examinations may be made by radiography. For welds of nominal thickness greater or equal to 10 mm, the examinations may be by ultrasonic testing. The preferred method for surface crack detection in ferrous metals is magnetic particle inspection. The preferred method for non-magnetic materials is liquid penetrant inspection.

4.16 Evaluation and reports

4.16.1 The manufacturer is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance, or non-compliance, with the criteria established in the inspection procedure are to be issued. Reports are to include the following information where appropriate:

(a) Date of inspection.
(b) Names, qualifications and signatures of operator and supervisor.
(c) Component identification.
(d) Weld identification, location and extent of testing.
(e) Steel grade, type of joint, thickness of parent material and welding process.
(f) Heat treatment status.
(g) Test standard used.
(h) Acceptance criteria.
(j) Surface condition.
(k) Inspection procedure reference.
(l) Test equipment used.
(m) Any test limitations, viewing conditions and temperature.
(n) Results showing size, position and nature of any defects repaired.
(o) Statement of final acceptability to established criteria.

4.17 Repair to welds

4.17.1 Where non-destructive examinations reveal unacceptable defects in the welded seams, they are to be repaired in accordance with 1.15 and are to be shown by further non-destructive examinations to have been eliminated.

4.17.2 In the case where spot radiography has revealed unacceptable defects, the requirements of 4.14.1 apply.

4.17.3 Where post-weld heat treatment is required in accordance with 4.10, weld repairs to the vessel or cylindrical shell or parts attaching to the shell are to be subjected to a subsequent heat treatment in accordance with 4.10.

4.17.4 In the event of unsuccessful weld repair of a defect, only one more repair attempt may be made of the same defect. Any subsequent repairs may require the re-repair excavation to be enlarged to remove the original repair heat affected zone.

■ *Section 5*
Specific requirements for pressure pipework

5.1 Scope

5.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of this Section and the general requirements given in Section 1, unless more stringent requirements have been specified.

5.1.2 Piping systems are to be constructed in accordance with the approved plans and specifications.

5.1.3 Fabricated pipework will be accepted only if manufactured by firms that have demonstrated that they have the facilities and equipment and are competent to undertake the quality of welding required for the Class of pipework proposed.

5.2 Manufacture and workmanship

5.2.1 Pipe welding may be performed using manual, semi-automatic or fully automatic electric arc processes. The use of oxy-acetylene welding will be limited to Class 3 pipework in carbon steel or carbon/manganese material that is not for carrying flammable fluids and limited to butt joints in pipes not exceeding 100 mm diameter or 9,5 mm thickness.

5.2.2 Welding of pipework, including attachment welds directly to pressure retaining parts is to be performed in accordance with approved welding procedures that have been qualified in accordance with Chapter 12.

5.2.3 Where the work involves a significant number of branch connections, tests will be required to demonstrate that the type of joint(s) and welding techniques employed are capable of achieving the required quality.

5.2.4 Where pressure pipework is assembled and butt welded insitu, the piping is to be arranged well clear of adjacent structures to allow sufficient access for preheating, welding, heat-treatment and non-destructive examination of the joints.

5.2.5 Alignment of pipe butt welds is to be in accordance with Table 13.5.1 unless more stringent requirements have been agreed. Where fusible inserts are used, the alignment is to be within 0,5 mm in all cases.

5.2.6 The number of welds is to be kept to a minimum. The minimum separation between welds, measured toe-to-toe, is to be not be less than 75 mm. Where it is not possible to achieve this, adjacent welds are to be subjected to surface crack detection NDE.

5.2.7 Welding consumables and fusible root inserts, where used, are to be suitable for the materials being joined.

Table 13.5.1 Pipe butt weld alignment tolerances

Pipe size	Maximum permitted misalignment
D < 150 mm and $t \leq$ 6 mm	1,0 mm or 25% of t, whichever is the lesser
D < 300 mm and $t \leq$ 9,5 mm	1,5 mm or 25% of t, whichever is the lesser
$D \geq$ 300 and $t >$ 9,5 mm	2,0 mm or 25% of t, whichever is the lesser

where
D = pipe internal diameter
t = pipe wall thickness

5.2.8 Acceptable methods of flange attachment are to be used, *see* Fig. 12.2.2 in Pt 5, Ch 12 of the Rules for Ships. Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and be removed after welding. The rings are to be made of the same material as the pipes. The use of flange types (b) and (c) with alloy steel pipes is limited to pipes up to and including 168,3 mm outside diameter.

5.2.9 Where socket welded fittings are employed, the diametrical clearance between the outside diameter of the pipe and the base of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the internal step at the bottom of the socket.

5.2.10 For welding of carbon, carbon/manganese and low alloy steels, the preheat to be applied will be dependent on the material grade, thickness and hydrogen grading of the welding consumable in accordance with Table 13.5.2, unless welding procedure testing indicates that a higher level is required.

5.2.11 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

5.2.12 All welds in high pressure, high temperature pipelines are to have a smooth surface finish and even contour; and where necessary, made smooth by grinding.

5.2.13 Check tests of the quality of the welding are to be carried out periodically.

5.3 Heat treatment after bending of pipes

5.3.1 After forming or bending of pipes, the heat treatments specified in this Section are to be applied unless the pipe material manufacturer specifies or recommends other requirements.

5.3.2 Generally, hot forming is to be carried out within the normalising temperature range. When carried out within this temperature range, no subsequent heat treatment is required for carbon and carbon/manganese steels. For alloy steels, 1Cr ½Mo, 2¼Cr 1Mo and ½Cr ½Mo ¼V, a subsequent tempering heat treatment in accordance with the temperatures and times specified in Table 13.5.3 is required, irrespective of material thickness.

5.3.3 When hot forming is performed outside the normalising temperature range, a subsequent heat treatment in accordance with Table 13.5.3 is required.

5.3.4 After cold forming to a radius (measured at the centreline of the pipe) of less than four times the outside diameter, heat treatment in accordance with Table 13.5.3 is required.

5.3.5 Heat treatment should be carried out in accordance with 1.16.

Table 13.5.2 Welding preheat levels for pipework

Material Grade	Thickness, t (mm) *see* Note 4	Minimum preheat temperature (°C) *See* Note 1	
		Non-low H_2	Low H_2 *see* Note 2
Carbon and carbon/manganese grades: 320 and 360	$t \leq 15$ $t \geq 15$	50 100	10 50
Carbon and carbon/manganese grades: 410, 460 and 490	$t \leq 15$ $t \geq 15$	75 150	20 100
1Cr ½Mo	$t < 13$ $t \geq 13$	*See* Note 3	100 150
2¼Cr 1Mo	$t < 13$ $t \geq 13$	*See* Note 3	150 200
½Cr ½Mo ¼V	$t < 13$ $t \geq 13$	*See* Note 3	150 200

NOTES
1. Where the ambient temperature is 0°C or below, pre-warming of the weld joint is required in all cases.
2. Low hydrogen process or consumables are those that have been tested and have achieved a grading of H15 or better (*see* Chapter 11).
3. Low hydrogen welding process is required for these materials.
4. t = the thickness of the thinner member for butt welds, and the thicker member for fillet and branch welds.

Table 13.5.3 Heat treatment after bending of pipes

Type of steel	Heat treatment required
Carbon and carbon/manganese: Grades 320, 360, 410, 460 and 490	Normalise at 880 to 940°C
1Cr ½Mo	Normalise at 900 to 940°C, followed by tempering at 640 to 720°C
2¼Cr 1Mo	Normalise at 900 to 960°C, followed by tempering at 650 to 780°C
½Cr ½Mo ¼V	Normalise at 930 to 980°C, followed by tempering at 670 to 720°C
Other alloy steels	Subject to special consideration

5.3.6 Bending procedures and subsequent heat treatment for other alloy steels will be subject to special consideration.

5.4 Post-weld heat treatment

5.4.1 Post-weld heat treatment is to be carried out in accordance with the general requirements specified in 1.16 and 4.10.

5.4.2 The thickness limits, the recommended soaking temperatures and periods, for application of post-weld heat treatment are given in Table 13.5.4.

5.4.3 Where the use of oxy-acetylene welding is proposed, due consideration is to be given to the need for normalising and tempering after such welding.

5.5 Non-destructive examination

5.5.1 Non-destructive examination of pipe welds is to be carried out in accordance with the general requirements of 1.11 and the following.

5.5.2 Butt welds in Class 1 pipes with an outside diameter greater or equal to 75 mm are to be subject to 100 per cent volumetric and visual inspections. Consideration is to be given to the extent and method of testing applied to butt welds in Class 1 pipes with an outside diameter less than 75 mm.

5.5.3 The extent of testing to be applied to butt welds or fillet welds in Class II pipes with an outside diameter greater or equal to 100 mm is at the Surveyor's discretion.

5.5.4 NDE is not required for Class II pipes with a diameter less than 100 mm.

5.5.5 Non-destructive examination procedures, methods and the evaluation of reports are to be in accordance with 4.15 and 4.16.

5.6 Repairs to pipe welds

5.6.1 Where non-destructive examinations reveal unacceptable defects in a weld, the defects are to be removed and repaired in accordance with 1.15. Completed repairs are to be shown by further non-destructive examination to have eliminated the defects.

5.6.2 For pipes with diameter less than 88 mm and where unacceptable defects have been found during non-destructive examination, consideration is to be given to cutting the weld out completely, re-making the weld preparation and re-welding as a new joint (because of the difficulty of making small repairs).

Table 13.5.4 Post-weld heat treatment requirements for pipework

Material Grade	Thickness for which post-weld heat treatment is required	Soak temperature (°C) *see* Note 2	Soak period
Carbon and carbon/manganese grades : 320, 360, 410, 460, 490	Over 30 mm	580–620°C	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	Over 8 mm	620–660°C	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	All	650–690°C	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	All, *see* Note 1	670–720°C	1 hour per 25 mm of thickness, minimum of 1 hour

NOTES
1. Heat treatment may be omitted for thicknesses up to 8 mm and diameters not exceeding 100 mm provided welding procedure tests have demonstrated acceptable properties in the as welded condition.
2. For materials supplied in the tempered condition, the post weld heat treatment temperature is to be at least 20°C less than the material tempering temperature.

5.6.3 Where repeated weld repairs have to be made to a weld, only two such attempts are to be permitted, thereafter the weld is to be cut apart and removed, and re-welded as a new joint.

5.6.4 Where pipework requires post-weld heat treatment weld, repairs to the pressure retaining parts are to be subjected to a subsequent heat treatment. Similarly, where welding is conducted after pressure testing, a further pressure test is to be required unless specific exemption has been agreed.

■ *Section 6*
Repair of existing ships by welding

6.1 Scope

6.1.1 This Section specifies requirements for repairs made by welding after introduction into service. This Section includes defects to hull structures, machinery, equipment and components. It also includes replacement of structure due to damage or corrosion. These requirements are in addition to those specified in the preceding Sections of this Chapter.

6.1.2 These requirements apply unless the original builder or manufacturer has specified alternative requirements.

6.2 Materials used for repairs

6.2.1 Permanent materials used in the repair are to be in accordance with 1.3.

6.2.2 Prior to commencing any welding, the material grades present in the original structure in way of the repair are to be determined. Where the materials cannot be identified from the ship records, test samples may be removed for chemical analysis and mechanical testing in order to determine the material grades.

6.2.3 Temporary materials that are to be welded to the main structure to assist in executing the repairs, but removed on completion, are to be of weldable quality.

6.3 Workmanship

6.3.1 A repair method is to be established by the shipyard or repair yard and is to be agreed by the Surveyor prior to commencing any repair work.

6.3.2 The removal of crack-like defects is to be confirmed by visual examination and surface crack detection NDE. This may be augmented by ultrasonic examination where several defects are reported at different depths at the same location.

6.3.3 The weld joint or groove shape used for the repair is to have a profile suitable for welding.

6.3.4 The weld area is to be carefully cleaned, in particular, where the material surface has been painted or has been subjected to an oily or greasy environment.

6.4 Non-destructive examination

6.4.1 On completion of welding and any post-weld heat treatment, repair welds are to be subjected to the type and extent of NDE and assessed in accordance with the acceptance criteria specified for the original construction.

6.4.2 Where the original construction specification did not specify NDE, the completed welds are to be, as a minimum, subject to visual examination. Consideration of other NDE techniques is to take due cognizance of the location or the repair within the vessel.

6.4.3 Where spot NDE is applied and defects are found, the extent of NDE is to be increased to include an equal amount of weld length. Where this reveals unacceptable defects, either the whole weld will be rejected or the extent of inspection increased to 100 per cent examination.

6.4.4 The acceptance criteria to be applied are to generally be in accordance with the original build specification. Where conflict of requirements exist, the NDE acceptance limits for welding procedure tests specified in Ch 12,2.5.5 may be used as a minimum requirement.

6.5 Repairs to welds defects

6.5.1 Where NDE reveals unacceptable defects, these are to be repaired in accordance with 1.15.

■ *Section 7*
Austenitic and duplex stainless steel – Specific requirements

7.1 Scope

7.1.1 This Section specifies requirements for the fabrication and welding of austenitic and duplex stainless steels, and is in addition to those detailed above.

7.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

7.1.3 All tools and equipment used are to be suitable for use on stainless steel materials. The use of tools or equipment made of carbon steel materials is to be avoided. It is permissible to use carbon steel tools provided that the surfaces that come into contact with the austenitic and duplex stainless materials are protected with an austenitic or nickel base alloy.

7.2 Design

7.2.1 Care is to be exercised in the weld design to prevent crevice corrosion from occurring, particularly where austenitic materials are used. In this respect fillet welds and partial penetration welds are to be continuous and welded on both sides of the joint.

7.3 Forming and bending

7.3.1 Materials that are cold formed, such that the total strain exceeds 15 per cent (i.e. where the formed diameter to thickness ratio is less than 6:1) are to be subjected to a subsequent softening heat treatment in accordance with the material manufacturers recommendations, unless it is demonstrated by testing that the material properties are acceptable in the 'as formed' condition.

7.3.2 Materials may be hot formed provided that a subsequent softening heat treatment is carried out. The forming process and the subsequent heat treatment are to be in accordance with the material manufacturer's recommendations.

7.4 Fabrication and welding

7.4.1 Welding may be performed using shielded manual arc welding (SMAW), gas tungsten arc welding (GTAW), MIG/MAG welding (GMAW), flux cored arc welding (FCAW), plasma arc welding (PAW) and submerged arc welding (SAW). The use of other welding processes will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

7.4.2 Misalignment may be corrected by the application of steady even force (e.g. using hydraulic or screw-type clamps). Hammering or heating is not permitted.

7.4.3 For full penetration welds, a backing or shielding gas is to be provided to prevent oxidation of the root weld. The backing gas is to be maintained until completion of, at least, the root and first fill layer. The backing gas may be omitted where the weld is back gouged or ground to remove the root weld.

7.4.4 Shielding and backing gases are to be an inert type of high purity and oxygen free.

7.4.5 For welding of Duplex stainless, the use of backing gases that contain up to 2 per cent nitrogen is permitted.

7.4.6 Welding of duplex stainless steels without filler metal is generally not permitted.

7.4.7 Degreasing agents, acid solutions, washing water etc. used for cleaning and any marking crayons and paints used are to be free of chlorides.

7.5 Repairs

7.5.1 Correction of distortion by the application of heat is not permitted.

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