BRITISH STANDARD

BS EN 10225:2009

Weldable structural steels for fixed offshore structures — Technical delivery conditions

ICS 77.140.10

BSI
British Standards

National foreword

This British Standard is the UK implementation of EN 10225:2009. It supersedes BS EN 10225:2001 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ISE/12, Structural steels.

A list of organizations represented on this committee can be obtained on request to its secretary.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2009

ISBN 978 0 580 64623 2

Amendments/corrigenda issued since publication

Date	Comments

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 10225

July 2009

ICS 77.140.10

Supersedes EN 10225:2001

English Version

Weldable structural steels for fixed offshore structures - Technical delivery conditions

Aciers de construction soudables destinés à la fabrication de structures marines fixes - Conditions techniques de livraison

Schweißgeeignete Baustähle für feststehende Offshore-Konstruktionen - Technische Lieferbedingungen

This European Standard was approved by CEN on 5 June 2009.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 10225:2009: E

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Foreword

This document (EN 10225:2009) has been prepared by Technical Committee ECISS/TC 10 “Structural steels - Grades and qualities”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2010, and conflicting national standards shall be withdrawn at the latest by January 2010.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 10225:2001.

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1 Scope

This European Standard specifies requirements for weldable structural steels to be used in the fabrication of fixed offshore structures in the form of plates up to and including 150 mm thick. It also specifies sections up to 63 mm thick except for sections delivered in the as-rolled condition which are permitted up to 25 mm thick only. Seamless hollow sections up to and including 40 mm thick and high frequency electric resistance welded hollow sections up to and including 20 mm thick are specified. Greater thicknesses for sections and hollow sections may be agreed, provided the technical requirements of this European Standard are maintained.

For plates the thickness limitations are:

S355G2+N, S355G5+M, - up to and including 20 mm

S355G3+N, S355G6+M - up to and including 40 mm

S355G7+N, S355G8+N, S355G9+N, S355G10+N - up to and including 150 mm

S355G7+M, S355G8+M, S355G9+M, S355G10+M - up to and including 100 mm

S420G1+QT, S420G1+M, S420G2+QT, S420G2+M - up to and including 100 mm

S460G1+QT, S460G1+M, S460G2+QT, S460G2+M - up to and including 100 mm

The standard is applicable to steels for offshore structures, designed to operate in the offshore sector but not to steels supplied for the fabrication of subsea pipelines, risers, process equipment, process piping, and other utilities. It is primarily applicable to the North Sea Sector, but may also be applicable in other areas provided that due consideration is given to local conditions e.g. temperature.

In the case of hollow sections formed from plate with the seam fusion welded, this European standard covers only the requirements of the plate material.

Minimum yield strengths up to 460 MPa are specified together with low temperature impact properties at temperatures down to –40 °C.

This European standard applies to material supplied ex-mill or from merchant's stock.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 473, *Non-destructive testing — Qualification and certification of NDT personnel — General principles*

EN 571-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

EN 895, *Destructive tests on welds in metallic materials — Transverse tensile tests*

EN 1011-1, *Welding — Recommendations for welding of metallic materials — Part 1: General guidance for arc welding*

EN 10002-1, *Metallic materials — Tensile testing — Part 1: Method of test at ambient temperature*

EN 10020:2000, *Definition and classification of grades of steels*

EN 10021:2006, *General technical delivery conditions for steel products*

EN 10024, *Hot rolled taper flange I sections — Tolerances on shape and dimensions*

EN 10025-1, *Hot rolled products of structural steels — Part 1: General technical delivery conditions*

EN 10025-3, *Hot rolled products of structural steels — Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels*

EN 10025-4, *Hot rolled products of structural steels — Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels*

EN 10025-6, *Hot rolled products of structural steels — Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition*

EN 10027-1, *Designation systems for steels — Part 1: Steel names*

EN 10027-2, *Designation systems for steels — Part 2: Numerical system*

EN 10029, *Hot rolled steel plates 3 mm thick or above — Tolerances on dimensions, shape and mass*

EN 10034, *Structural steel I and H sections — Tolerances on shape and dimensions*

EN 10045-1, *Metallic materials — Charpy impact test — Part 1: Test method*

EN 10052:1993, *Vocabulary of heat treatment terms for ferrous products*

EN 10055, *Hot rolled steel equal flange tees with radiused root and toes — Dimensions and tolerances on shape and dimensions*

EN 10056-2, *Structural steel equal and unequal leg angles — Part 2: Tolerances on shape and dimensions*

EN 10067, *Hot rolled bulb flats — Dimensions and tolerances on shape, dimensions and mass*

EN 10079:2007, *Definition of steel products*

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

EN 10163-2, *Delivery requirements for surface conditions of hot-rolled steel plates, wide flats and sections — Part 2: Plates and wide flats*

EN 10163-3, *Delivery requirements for surface conditions of hot-rolled steel plates, wide flats and sections — Part 3: Sections*

EN 10164, *Steel products with improved deformation properties perpendicular to the surface of the product — Technical delivery conditions*

EN 10204, *Metallic products — Types of inspection documents*

EN 10210-1, *Hot finished structural hollow sections of non-alloy and fine grain steels — Part 1: Technical delivery conditions*

EN 10210-2, *Hot finished structural hollow sections of non-alloy and fine grain steels — Part 2: Tolerances, dimensions and sectional properties*

EN 10246-3, *Non-destructive testing of steel tubes — Part 3: Automatic eddy current testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of imperfections*

EN 10246-5, *Non-destructive testing of steel tubes — Part 5: Automatic full peripheral magnetic transducer/flux leakage testing of seamless and welded (except submerged arc welded) ferromagnetic steel tubes for the detection of longitudinal imperfections*

EN 10246-7, *Non-destructive testing of steel tubes — Part 7: Automatic full peripheral ultrasonic testing of seamless and welded (except submerged arc welded) steel tubes for the detection of longitudinal imperfections*

EN 10246-8, *Non-destructive testing of steel tubes — Part 8: Automatic ultrasonic testing of the weld seam of electric welded steel tubes for the detection of longitudinal imperfections*

EN 10246-12, *Non-destructive testing of steel tubes — Part 12: Magnetic particle inspection of seamless and welded ferromagnetic steel tubes for the detection of surface imperfections*

EN 10246-14, *Non-destructive testing of steel tubes — Part 14: Automatic ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of laminar imperfections*

EN 10246-15, *Non-destructive testing of steel tubes — Part 15: Automatic ultrasonic testing of strip/plate used in the manufacture of welded steel tubes for the detection of laminar imperfections*

EN 10256, *Non-destructive testing of steel tubes — Qualification and competence of level 1 and 2 non-destructive testing personnel*

EN 10279, *Hot rolled steel channels — Tolerances on shape, dimensions and mass*

EN 10306, *Iron and steel — Ultrasonic testing of H beams with parallel flanges and IPE beams*

EN ISO 2566-1, *Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels (ISO 2566-1:1984)*

EN ISO 4063, *Welding and allied processes — Nomenclature of processes and reference numbers (ISO 4063:1998)*

EN ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method (ISO 6507-1:2005)*

EN ISO 6947, *Welds — Working positions — Definitions of angles of slope and rotation (ISO 6947:1993)*

EN ISO 8492*, Metallic materials — Tube — Flattening test (ISO 8492:1998)*

EN ISO 9934-1, *Non-destructive testing —- Magnetic particle testing — Part 1: General principles (ISO 9934-1:2001)*

EN ISO 12737, *Metallic materials — Determination of plane-strain fracture toughness (ISO 12737:2005)*

EN ISO 14284:2002, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition (ISO 14284:1996)*

EN ISO 15614-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (ISO 15614-1:2004+A1:2008)*

3 Terms and definitions

For the purposes of this standard, the following terms and definitions and those given in EN 10020:2000, EN 10021:2006, EN 10052:1993, EN 10079:2007 and EN ISO 14284:2002 apply:

3.1
parent product
product rolled from one piece of steel

3.2
manufacturer
manufacturer of the steel products

3.3
supplier
manufacturer of material supplied ex-mill or the merchant for material supplied from a merchant's stock (see Clause 1)

3.4
purchaser
purchaser or his representative

3.5
concast
material produced by a continuous casting process route

3.6
primary elements
elements that are essential to the overall integrity of the installation including critical load transfer points and stress concentrations such as nodes

NOTE This definition also includes bracing and piling.

3.7
secondary elements
elements of minor importance, failure of which would be unlikely to affect the overall integrity of the installation

3.8
seamless hollow section (S)
hollow long product, open at both ends, of circular, square or rectangular section, made by piercing a solid product to obtain a tube hollow which is further processed, hot or cold, into its final dimensions

3.9
high frequency welded hollow section (HFW)
hollow long product, open at both ends, of circular, square or rectangular section, made by pressure welding in a continuous or non-continuous process, in which strip is formed cold into a hollow profile and the seam weld made by heating the adjacent edges through the resistance to the passage of a high frequency current and pressing the edges together

NOTE The electric current may be applied by direct electrode contact or by induction. After welding, the tube hollow is further processed, hot or cold, into its final dimensions.

3.10
normalizing rolling
rolling process in which the final deformation is carried out in a particular temperature range leading to a material condition equivalent to that obtained after normalizing so that the specified values of the mechanical properties are retained even after normalizing

NOTE 1 For the purposes of this European standard, the designation of this delivery condition and of the normalized condition is +N.

NOTE 2 In international publications for both normalizing rolling and thermomechanical rolling, the expression "controlled rolling" may be found. However, in view of the different applicability of the products a distinction of the terms is necessary.

3.11
thermomechanical rolling
rolling process in which the final deformation is carried out in a certain temperature range leading to a material condition with certain properties which cannot be achieved or repeated by heat treatment alone

NOTE 1 For the purposes of this European standard, the designation of this delivery condition is +M.

NOTE 2 Thermomechanical rolling leading to the delivery condition +M can include processes with an increasing cooling rate with or without tempering including self-tempering but excluding direct quenching and quenching and tempering.

3.12
quenching and tempering

3.12.1
quenching
operation which consists of cooling a ferrous product more rapidly than in still air

NOTE Quenching also includes direct quenching.

3.12.2
tempering
heat treatment applied to a ferrous product generally after quench hardening or other heat treatment to bring the properties to the required level

NOTE 1 It consists of heating to specific temperatures ($< Ac_1$) and soaking one or more times followed by cooling at an appropriate rate.

NOTE 2 For the purposes of this European standard, the designation of delivery condition quenched and tempered is +QT.

4 Information to be supplied by the purchaser

4.1 General

The following information shall be supplied by the purchaser at the time of enquiry and order:

a) details of the product form;

b) number of this European standard i.e. EN 10225;

c) the steel grade (steel name or steel number);

d) the type of inspection documents required (see 9.1);

e) where applicable, the number of additional copies of inspection documents required and the forwarding address (see 9.2);

f) nominal dimensions and when necessary tolerances;

g) where applicable, that the material is required for the manufacture of piling;

h) purchaser's order number and item number if applicable;

i) quantity.

4.2 Options

A number of options are specified in Clause 13. In the event that the purchaser does not indicate a wish to implement any of these options, the supplier shall supply in accordance with the basic specification.

5 Dimensions, mass and tolerances

5.1 Dimensions and tolerances

5.1.1 The dimensions and tolerances of the product shall be in accordance with one of the following relevant European Standards and as further specified in 5.1.2 and 5.1.3:

EN 10024, EN 10029, EN 10034, EN 10055, EN 10056-2, EN 10067, EN 10210-2, EN 10279.

5.1.2 Unless otherwise agreed plate thickness tolerances shall be in accordance with EN 10029 Class A.

See option 1.

5.1.3 On plates, with ripples or corrugations less than 2 m apart (peak to peak) the following criteria shall apply.

a) The flatness tolerance shall, in all cases, be measured to the upper surface of the plate laid on a level surface;

b) The maximum depth of any ripple or corrugation under the 2 m straight edge shall be 5 mm. The average depth of all ripples on any one plate shall not exceed 4 mm;

c) The minimum depth to constitute a ripple or corrugation shall be 2 mm;

d) The maximum number of ripples or corrugations allowed in any one plate shall be as given in Tables 1 and 2, and shall apply to all plates 10 mm thick and over and for all plate widths.

Table 1 — Maximum number of ripples or corrugations in plate with thickness ≥ 12 mm

Length (*L*) m	**Maximum number of ripples or corrugations**
$L \leq 6$	2
$6 < L \leq 9$	3
$9 < L \leq 12$	4
$12 < L \leq 15$	5

Table 2 — Maximum number of ripples or corrugations inplate with thickness ≥ 10 mm < 12 mm

Length (*L*) m	**Maximum number of ripples or corrugations**
$L \leq 6$	4
$6 < L \leq 9$	5
$9 < L \leq 12$	6
$12 < L \leq 15$	8

5.2 Mass of steel

The calculated mass shall be determined using a density of 7,85 kg/dm^3.

6 Classification and designation

6.1 Classification

The steel grade S355 specified in this European Standard is classified as alloy quality steel and the steel grades S420 and S460 specified in this European Standard are classified as alloy special steels according to EN 10020.

This standard includes the following grades:

a) Group 1 grades with few changes from EN 10025 Parts 1, 3 and 4 and EN 10210-1: (minor changes to chemical analysis, CEV and impact requirements only);

b) Groups 2 and 3 grades substantially modified from EN 10025 Parts 1, 3 and 4 and EN 10210-1 including qualities with enhanced through-thickness ductility.

6.2 Designation

For the steel grades covered by this European Standard the steel names are based on EN 10027-1. The steel numbers are allocated in accordance with EN 10027-2.

The designation consists of:

a) the number of this European Standard i.e. EN 10225;

b) the symbol S;

c) the indication of the minimum specified yield strength for thicknesses ≤ 16 mm expressed in MPa;

d) the letter G, followed by the relevant digit(s) characterizing the steel grade;

e) where applicable, the letter indicating the delivery condition i.e. +N, +M or +QT (see 7.3).

7 Manufacturing process

7.1 Steel manufacturing process

The steels shall be made by the basic oxygen or basic electric arc furnace process. All steels shall be fully killed and made to fine grain practice.

In addition, steels of group 3 shall be vacuum degassed or ladle refined.

See option 2.

7.2 Thickness limits and segregation control

7.2.1 For concast steels of groups 2 and 3, provided that the resultant products comply with all the relevant requirements of this European Standard, the maximum thickness of product from the continuous casting process shall be at the manufacturer's discretion.

See option 3.

7.2.2 The minimum rolling reduction ratio of concast material for plate shall be 4:1 except for piling where it shall be 3:1.

See option 4.

7.2.3 Intermediate or finished products, produced by the continuous casting route shall be examined for centre line segregation in accordance with the manufacturer’s procedures and as agreed by the purchaser. This does not apply to seamless hollow sections.

See option 2.

7.3 Delivery condition

7.3.1 Plates of group 1

Plates shall be supplied in the furnace normalized/normalized rolled (+N) or thermomechanically rolled (+M) condition. The customer shall specify the appropriate grade at the time of enquiry and order.

Delivery conditions (+N) and (+M) are limited to a maximum thickness of 40 mm.

See option 5.

Examples:

a) Plate to grade S355G2+N

   Plate with few changes from EN 10025-3 and with minimum specified R_e = 355 MPa and impact values verified at –20 °C, supplied in the normalized or normalized rolled condition.

b) Plate to grade S355G6+M

   Plate with few changes from EN 10025-4 and with minimum specified R_e = 355 MPa and impact values verified at –40 °C, supplied in the thermomechanically rolled condition.

7.3.2 Plates of groups 2 and 3

Plates shall be supplied in the furnace normalized (+N), thermomechanically rolled (+M) or quenched and tempered (+QT) condition. The customer shall specify the appropriate grade at the time of enquiry and order.

Delivery condition (+N) is limited to a maximum thickness of 150 mm and delivery conditions (+M) and (+QT) to 100 mm.

See option 5.

EXAMPLE

a) Plate to grade S355G7+N (or S355G7+M)

Plate substantially modified from EN 10025-3 (or EN 10025-4) and with minimum specified R_e = 355 MPa and impact values verified at –40 °C, supplied in the normalized or normalized rolled (or thermomechanically rolled) condition.

NOTE The normalized rolled condition is only permitted when option 5 has been called up.

b) Plate to grade S460G2+QT (or S460G2+M)

Plate substantially modified from EN 10025-6 (or EN 10025-4), with controlled chemistry, particularly carbon, minimum specified R_e = 460 MPa and impact values verified at –40 °C with specified through-thickness properties, supplied in the quenched and tempered (or thermomechanically rolled) condition.

7.3.3 Sections

Sections shall be supplied in the as-rolled, normalized/normalized rolled (+N) or thermomechanically rolled (+M) condition as shown in Tables 11 and 12, at the manufacturer's discretion.

The as-rolled delivery condition is limited to a maximum thickness of 25 mm.

7.3.4 Hollow sections

Hollow sections shall be supplied in the normalized/normalized rolled (+N) or quenched and tempered (+QT) condition as shown in Tables 13 to 16 at the manufacturer's discretion.

NOTE S420 and S460 grades are normally only available in circular form.

8 Requirements

8.1 General

In addition to the requirements of this European Standard, the general technical delivery requirements specified in EN 10021 also apply.

8.2 Chemical composition

8.2.1 Cast analysis

a) The chemical composition for all qualities determined by cast analysis shall comply with the values in Tables 6, 11, 13 and 15.

b) For residual element control in steels of groups 2 and 3, boron (B) shall not be intentionally added to the steel. The deliberate addition of any elements other than those listed in Tables 6, 11, 13 and 15 shall not be permitted.

c) When a restricted cast analysis is agreed for steels of groups 2 and 3, the steel shall comply with the agreed analysis range.

See option 7.

8.2.2 Product analysis

8.2.2.1 Steels of group 1

Product analysis shall not be carried out except when option 8 is specified.

8.2.2.2 Steels of groups 2 and 3

a) The chemical composition determined by product analysis shall comply with the values given in Tables 6, 11, 13 and 15.

See option 6.

b) When restricted product analysis is agreed the steel shall comply with the agreed analysis range.

See option 7.

8.2.3 Carbon equivalent value (CEV) and P_{cm}

8.2.3.1 General

CEV[1)] and P_{cm} shall be calculated using the following equations where each element is expressed as a mass percentage:

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad (1)$$

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cu + Cr}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B \quad (2)$$

8.2.3.2 Plates

The maximum permissible CEV and P_{cm} values for plates are given in Table 3. These apply to product analysis except for grades S355G2+N, G3+N, G5+M and G6+M which shall be based on cast analysis.

The CEV value shall apply for all designations except S355G9+N, G9+M, G10+N and G10+M where the P_{cm} value shall apply.

See option 9.

1) IIW, International Institute of Welding formular

Table 3 — CEV and P_{cm} values for plates

Steel name[a]	CEV max.	P_{cm} max.
S355G2+N	0,43	Not specified
S355G3+N		
S355G5+M		
S355G6+M		
S355G7+N	0,43	0,24
S355G7+M		
S355G8+N		
S355G8+M		
S355G9+N	0,43	0,22
S355G10+N		
S355G9+M	0,41[b]/0,42[c]	0,21[b]/0,22[c]
S355G10+M		
S420G1+QT S420G1+M S420G2+QT S420G2+M	0,42	0,22[d]
S460G1+QT S460G1+M S460G2+QT S460G2+M	0,43	0,22[d]

[a] For steel numbers, see Tables 6 to 16.

[b] For $t \leq 75$ mm.

[c] For 75 mm $< t \leq 100$ mm.

[d] A P_{cm} value of 0,23 for $t \leq 15$ mm is permitted.

8.2.3.3 Sections

The CEV of all sections shall not exceed 0,43.

See option 9, where a P_{cm} value not exceeding 0,24 shall apply in lieu of CEV.

These values apply to the product analysis except for grades S355G1, G1+N, G4 and G4+M where cast analysis shall apply.

8.2.3.4 Hollow sections

The CEV of all hollow sections shall not exceed 0,43.

See option 9, where a P_{cm} value not exceeding 0,25 shall apply in lieu of a CEV.

These values apply to the product analysis except for the grade S355G1+N where cast analysis shall apply.

8.3 Mechanical properties

8.3.1 General

Under the inspection and testing conditions as specified in Clause 9 and in the heat treatment conditions given in 8.3.2 for plates and hollow sections, the tensile properties and the impact properties at the verification test temperature shall comply with the relevant requirements given in Tables 7 to 10 for plates, Table 12 for sections and Tables 14 and 16 for hollow sections.

8.3.2 Heat treatment condition of test pieces

For plates and hollow sections, samples (from which the test pieces are prepared and tested) shall be tested in the following conditions:

a) For nominal thicknesses up to and including 20 mm - as delivered condition only.

b) For nominal thicknesses over 20 mm up to and including 40 mm - as delivered condition. In addition, when required by the purchaser, the manufacturer shall provide supporting data illustrating the effect of simulated post weld heat treatment (PWHT) on the tensile and impact properties of the type of products involved.

c) For nominal thicknesses over 40 mm - as delivered condition. In addition, when required by the purchaser, the manufacturer shall provide supporting data illustrating the effect of simulated PWHT on the tensile and impact properties of the type of products involved. Alternatively, the purchaser may require the manufacturer to test the material in the simulated PWHT condition (see option 10).

d) For supply conditions +N and +M, the simulated PWHT shall be at 580 °C ± 20 °C (see option 11) for a minimum time of 1 h per 25 mm thickness of product, or 4 h, whichever is the greater.

For the quenched and tempered supply condition, the simulated PWHT shall be within the range 550 °C to 620 °C with a maximum temperature of 25 °C below the tempering temperature on the test certificate, for a minimum time of 1 h per 25 mm thickness or 4 h, whichever is the greater.

8.3.3 Reduced section impact test pieces

If the nominal product thickness is not sufficient for the preparation of full size impact test pieces, test pieces of smaller width (see 10.3.5 b)) shall be taken, with a minimum width of 5 mm using the full thickness where necessary.

The average impact values obtained from three reduced section test pieces shall be as follows:

for 10 mm x 7,5 mm section, 75 % of specified value;

for 10 mm x 5 mm section, 50 % of specified value.

8.3.4 Strain age tests

Strain age tests shall not be carried out except when option 12 is specified.

See option 12.

8.3.5 Through-thickness testing

Through-thickness testing shall not be carried out, except for steels of group 3 in thickness ≥ 25 mm when option 13 is specified.

See option 13.

8.3.6 Flattening test

A flattening test shall not be carried out except when option 14 is specified for circular welded hollow sections.

See option 14.

8.3.7 Wide plate and CTOD data for parent plate steels of groups 2 and 3

Data is not required except when option 15 is specified.

See option 15.

8.4 Technological properties

8.4.1 Cold forming characteristics of steel plate of groups 2 and 3

When required by the purchaser, the supplier shall make available data which characterize the cold forming behaviour of these steels. If such data is not available or are deemed inadequate by the purchaser, additional testing may be specified (see Annex D).

See option 16.

8.4.2 Hot forming procedures for steel plate of groups 2 and 3

When required by the purchaser the steel supplier shall provide general information on the procedures and effects of hot forming on material properties.

See option 17.

NOTE Materials in delivery condition +M or +QT are generally unsuitable for subsequent normalizing or hot forming above 580 °C. Heating above 580 °C may lower the strength values. If temperatures above 580 °C are required, reference should be made to the supplier.

8.4.3 Weldability data for steels of groups 2 and 3

At the time of the enquiry and order for all products exceeding 40 mm in thickness the manufacturer shall have available data on the weldability of the material. Weldability data for other thicknesses may be agreed between supplier and customer. Any previously obtained data which the manufacturer proposes to submit shall have been verified by a competent third party, acceptable to the purchaser and who witnessed the tests. All previously obtained data presented shall bear the stamp or seal of the third party.

See option 18.

NOTE This data refers only to the weldability of the material being supplied and is intended for use in development and preparation of fabrication procedures.

8.5 Surface condition and internal defects

8.5.1 Plates

8.5.1.1 Surface condition

All surfaces shall be 100 % visually inspected. The surface condition shall comply with EN 10163-2, Class A, sub-class 3 except as otherwise specified in this clause. Plates shall be presented for inspection such that the steel surface can be readily examined.

Repair of defects such as cracks, shells or seams (in accordance with EN 10163-2) shall be followed by magnetic particle inspection or dye penetrant inspection.

8.5.1.2 Internal soundness for steels of group 1

The material shall be sound and free from such internal defects as might preclude its use for the purpose for which it is intended.

See option 19.

8.5.1.3 Internal soundness for steels of groups 2 and 3

All plates shall be ultrasonically tested in accordance with EN 10160.

Ultrasonic testing shall be carried out either prior to, or after the final heat treatment and shall meet the requirements of EN 10160, class S_1/E_2 for steels of group 3 and EN 10160, class S_0/E_1 for steels of group 2.

8.5.2 Sections

8.5.2.1 Surface condition

All surfaces shall be 100 % visually inspected for defects and the surface condition shall comply with EN 10163-3, Class C, sub-class 2.

See option 20.

8.5.2.2 Internal soundness for steels of group 1

The material shall be sound and free from such internal defects as might preclude its use for the purpose for which it is intended.

See option 21.

8.5.2.3 Internal soundness for steels of groups 2 and 3

The material shall be sound and free from such internal defects as might preclude its use for the purpose for which it is intended.

Internal soundness for rolled sections with web thickness greater than 12 mm shall be subject to ultrasonic examination of webs and flanges when specified by the purchaser and shall meet the requirements of EN 10306:2001, Class 2.1.

See option 21.

NOTE Testing of the region between the web and the flange should be subject to agreement between the supplier and the purchaser.

8.5.3 Hollow sections

8.5.3.1 Surface condition

Hollow sections shall be free from external and internal defects that can be detected by visual inspection in accordance with this European Standard as follows:

The outside surface condition and, where practical, the inside surface condition shall be such that surface discontinuities requiring dressing and/or surface defects can be identified.

It shall be permissible to rectify surface discontinuities by grinding or machining, provided that after so doing, the hollow section thickness in the dressed region is not less than the minimum permissible wall thickness. All dressed areas shall blend smoothly into the contour of the section.

Surface discontinuities which encroach on the minimum permissible wall thickness shall be considered as defects and the product shall be deemed not to comply with this European Standard.

Hollow sections shall contain no dents greater than 3 mm or 1 % of the specified outside diameter or largest outside dimensions respectively, whichever is the lesser. This shall be measured as the gap between the lowest point of the dent and a prolongation of the original contour of the hollow section. The length of the dent in any direction shall not exceed 25 % of the section's largest outside dimension.

Any sharp bottom gouge within a dent or otherwise shall be removed by grinding. The use of shot peening or welding is not permitted.

When the wall thickness has been reduced by more than 7,5 % of the nominal wall thickness during rectification, magnetic particle inspection shall be used to confirm removal of discontinuities (see 11.3.4).

8.5.3.2 Internal soundness (laminations)

Hollow sections shall comply with the requirements of EN 10246-14 acceptance level U3 or EN 10246-15 acceptance level U3.

When required, compliance with this requirement shall be demonstrated.

See option 22.

8.5.3.3 Non-destructive testing of the weld seam of welded hollow sections

The weld seam of welded hollow sections shall be tested full length for longitudinal defects in accordance with EN 10246-3, EN 10246-5 or EN 10246-8 to acceptance levels E4, F4 or U4 respectively.

NOTE For rectangular or square hollow sections this is normally carried out in the circular form before squaring.

The method of test shall be at the discretion of the manufacturer.

When EN 10246-5 or EN 10246-8 are used, calibration shall be carried out using an external reference notch.

When the purchaser has indicated that welded hollow sections are to be used in primary elements, the internal weld bead shall be removed and the weld seam tested full length for longitudinal defects in accordance with EN 10246-8 to acceptance level U3. Calibration shall be carried out using both internal and external reference notches.

See option 23.

8.5.3.4 Non-destructive testing of seamless hollow sections

All seamless hollow sections shall be ultrasonically tested for longitudinal defects in accordance with EN 10246-7 to acceptance level U3/C.

When the purchaser has indicated that the seamless hollow section is to be used in primary elements, they shall be tested in accordance with EN 10246-7 to acceptance level U2/C.

See option 23.

9 Inspection and testing

9.1 General

The products shall be subjected to specific inspection and testing in accordance with EN 10021 and supplied with an inspection document in accordance with EN 10204. The purchaser shall indicate on the enquiry and order the type of inspection document required and, where applicable, their nominated representative.

9.2 Ex-mill supply

The relevant inspection documents shall be issued to the purchaser at the time of dispatch. An additional number of copies as defined by the purchaser at the time of the order shall be sent to an address nominated by the purchaser (see 4.1 e)).

Inspection documentation of types 3.1 or 3.2 in accordance with EN 10204 shall contain at least the following information:

a) Identification

   1) product form;

   2) mill location;

   3) purchaser's order and item number where applicable;

   4) method of steel manufacture;

   5) heat or cast number and/or the product identification number(s) where available (see 9.4);

   6) dimensions;

   7) designation of steel (see 6.2).

b) Composition

   1) cast analysis;

   2) product analysis where applicable;

   3) carbon equivalent value where applicable (CEV);

   4) P_{cm} value where applicable.

c) Heat treatment

   1) details of heat treatment stating nominal temperature, nominal soaking times and cooling method;

d) Mechanical properties

   1) yield strength, tensile strength, elongation;

   2) yield strength/tensile strength ratio where applicable;

   3) Charpy V-notch impact test results;

   4) through-thickness properties (if required);

   5) strain age test results (if required).

e) Nominal or actual mass

f) Non-destructive test (NDT)

   1) confirmation that NDT has been satisfactorily carried out is to be included on the inspection document.

In addition to the above certification requirements, the analysis of residual elements and the results of any additional testing including details of segregation control monitoring requested by the purchaser at the time of enquiry and order shall be submitted.

Results of weldability testing in accordance with option 18 and Annexes E, F and G shall not form any part of the inspection document.

9.3 Merchant supply

If any steel is supplied from a merchant's stock, the merchant shall be responsible for:

a) supplying to the purchaser a copy of the original order requirements placed on the mill and the subsequent sales history of the product;

b) supplying to the purchaser all documentation required by this standard including a copy of the mill inspection document (see 9.2) verified by an independent inspection body;

c) satisfying the purchaser by means of numbers or identification marks on the steel (or tab when parcels of steel are bundled) that such steel has been tested and complies with all the requirements of this European Standard as applicable.

9.4 Identification of cast

The manufacturer shall identify the ingots, billets, slabs, plates, sections and hollow sections etc. in such a way as to enable the finished product to be traced to the cast from which it was made.

9.5 Delivery

Steel shall be delivered together with an accompanying advice note which shall contain the following minimum information:

a) mill location;

b) the purchaser's purchase order and item number if applicable (see 4.1);

c) cast number and/or the product identification number(s) (see 9.4);

d) the plate/section/hollow section sizes;

e) steel designation.

10 Sampling

10.1 General

The verification of the mechanical properties for plates, sections and hollow sections shall be by cast.

10.2 Frequency of testing

10.2.1 Tensile tests (General)

A sample product shall be taken for each 40 tonnes or part thereof, of the same thickness range as given in Tables 7 to 10, 12, 14 and 16 for the yield strengths, and for the same cast and in the same heat treatment condition but not showing a thickness variation of more than 5 mm above and below the thickness of the product sampled. Where ingot practice is used for plates, one sample product shall be taken from each parent plate.

10.2.2 Impact tests (General)

A sample product shall be taken for each 40 tonnes or part thereof, of the same thickness range as given in Tables 7 to 10, 12, 14 and 16 for the yield strengths, and for the same cast and in the same heat treatment condition.

10.2.3 Additional requirements for welded hollow sections

When required (see option 24) the weld of welded hollow sections shall be subjected to the following testing (see Table 4):

Table 4 — Test requirements for the weld of welded hollow sections

Test position	Group	Frequency	
		Tensile	Impact
Weld	1	1/test unit[a]	1/test unit[b]
Weld	2 and 3	1/test unit[a]	2/test unit[b]

[a] For HFW hollow sections with a nominal length of side greater than 150 mm or diameter greater than 219 mm.

[b] For HFW hollow sections with a nominal length of side greater than 150 mm or diameter greater than 168,3 mm.

10.3 Preparation of samples and test pieces

10.3.1 General

The manufacturer shall randomly select and identify samples in accordance with 10.3.2 and 10.3.3.

NOTE Weld samples for tensile or impact testing may not be available on square or rectangular hollow sections when the weld occurs in the corner region.

10.3.2 Location of samples and orientation of tensile test pieces

10.3.2.1 General

One sample product shall be taken from each test unit for tensile testing.

10.3.2.2 Plates

Samples shall be taken from one end of the plate at a position approximately ¼ of the plate width (see Figure A.1).

Tensile test pieces shall be prepared with their longitudinal axis transverse to the principal direction of rolling.

10.3.2.3 Sections

Samples from sections shall be taken from the relevant flange positions shown in Figure A.2. In the case of sections with tapered flanges, it is permissible, at the manufacturer's discretion, for the samples to be taken from the web at a quarter of the total height or from the flange.

Tensile test pieces shall be prepared with their longitudinal axis parallel to the principal direction of rolling.

10.3.2.4 Hollow sections

For hollow sections with an outside diameter equal to or less than 219,1 mm or a nominal length of side equal to or less than 150 mm, the test piece shall be either, at the manufacturer's discretion, a full tube section or a strip section and be taken in a direction longitudinal to the axis of the hollow section (see Figure A.3).

For hollow sections with an outside diameter greater than 219,1 mm or a nominal length of side greater than 150 mm, the test piece shall, at the manufacturer's discretion, be taken either longitudinal or transverse to the axis of the hollow section. Samples shall exclude any weld and, in the case of rectangular and square hollow sections, shall be taken from any side mid way between the corners as shown in Figure A.3.

For transverse testing of the weld of HFW hollow sections, with an outside diameter greater than 219,1 mm or nominal length of side greater than 150 mm, samples shall be taken with the weld positioned in the centre of the sample (see 10.3.1).

10.3.3 Location of samples and orientation of impact test pieces

10.3.3.1 General

One sample sufficient for 6 test pieces shall be taken from each test unit.

10.3.3.2 Plates

Samples shall be taken from the position shown in Figure A.1.

The test piece shall be taken from the following positions:

a) Sub-surface. One face of a Charpy specimen shall be located within 2 mm from a rolled surface except for materials less than 12 mm thick; and

b) Mid-thickness. For steels of groups 2 and 3 when the test thickness is above 40 mm, additional impact test pieces shall be taken from the mid-thickness position.

Charpy V-notch test pieces shall be machined parallel to the principal direction of rolling for steels of group 1 and transverse to the principal direction of rolling for steels of groups 2 and 3 (see Figure 1).

10.3.3.3 Sections

Samples shall be taken from within 25 mm of the centres of the positions shown in Figure A.2. For sections of non-uniform thickness, samples shall be taken from the thickest part of the section at the locations specified.

Test pieces shall be cut parallel to the principal direction of rolling.

See options 26 and 27.

10.3.3.4 Hollow sections

For hollow sections with an outside diameter equal to or less than 168,3 mm or a nominal length of side equal to or less than 150 mm the test piece shall be a longitudinal sample from a position as shown in Figure A.3 .

For hollow sections with an outside diameter greater than 168,3 mm or a nominal length of side greater than 150 mm the test piece shall, at the manufacturer's discretion, be taken either longitudinal or transverse to the axis of the hollow section. Samples shall exclude any weld and be taken from positions shown in Figure A.3.

For transverse testing of the weld of the HFW hollow sections with an outside diameter greater than 168,3 mm or nominal length greater than 150 mm, samples shall be taken with the notch centred on the weld.

See option 24.

10.3.4 Preparation of tensile test pieces

10.3.4.1 Tensile test pieces shall be prepared in accordance with EN 10002-1 from samples obtained in accordance with Annex A so that, wherever practicable, the rolled surface of the steel is retained on two opposite sides of the test piece. Where this is not practicable, then:

a) for grades S355, rectangular test pieces having a thickness of not less than 12,5 mm shall be taken from the relevant position shown in Figure B.1;

b) for grades S420 and S460, rectangular test pieces having a thickness of approximately 1/2 of the product thickness and retaining one rolled surface shall be used;

c) alternatively, for all grades, round tensile test pieces having a diameter of not less than 12,5 mm shall be taken from the relevant position shown in Figure B.1.

10.3.4.2 Any straightening of test pieces which is required shall be done cold. Test pieces cut from circular hollow sections shall be tested in the curved condition, but it is permissible for the ends to be flattened cold for gripping.

10.3.5 Preparation of impact test pieces

Test pieces shall be prepared in accordance with EN 10045-1. The axis of the notch shall be perpendicular to the rolled surface of the product (see Figure 1). In addition the following shall apply:

a) for material equal to or greater than 12 mm thickness standard 10 mm x 10 mm test pieces shall be so machined that one side is not further than 2 mm from a rolled surface;

b) for material less than 12 mm thick, reduced width test pieces shall be used, with a minimum width of 5 mm, using the full thickness where necessary;

c) for plate material of groups 2 and 3 and thicknesses greater than 40 mm, additional standard 10 mm x 10 mm test pieces shall be machined from samples taken from the mid-thickness.

NOTE Impact tests for material less than 6 mm thick are not normally carried out but may be agreed between the purchaser and the manufacturer at the time of the enquiry and order.

10.4 Verification of chemical composition

10.4.1 For cast analysis determined for each cast, the values reported by the steel manufacturer shall apply.

10.4.2 Product analysis when required shall be determined twice per cast or once per 40 tonnes, or part thereof, whichever is the more stringent, on the test sample used for the verification of the mechanical properties (see 8.2).

11 Test methods

11.1 Chemical analysis

For the determination of the chemical composition the corresponding European Standards shall apply in cases of dispute.

11.2 Mechanical tests

Mechanical tests shall be carried out in the temperature range 10 °C to 35 °C, except where a temperature is specified for impact tests.

11.2.1 Tensile test

The tensile test shall be carried out in accordance with EN 10002-1. The tensile strength R_m, the yield strength R_e, and the elongation A, shall be determined. For transverse tensile testing of welds, only the tensile strength R_m shall be determined.

For the specified yield strength, the upper yield strength R_{eH} shall be determined.

If a yield phenomenon is not present, the 0,2 % proof strength ($R_{p0,2}$) or the 0,5 % proof strength for total elongation ($R_{t0,5}$) shall be determined; in cases of dispute the 0,2 % proof strength ($R_{p0,2}$) shall be determined.

The specified elongation values relate to a proportional gauge length of 5,65 $\sqrt{S_o}$ where S_o is the original cross-sectional area of the test pieces.

If other gauge lengths are used, the percentage value obtained shall be converted to the value for a gauge length of 5,65 $\sqrt{S_o}$ using the conversion tables in EN ISO 2566-1.

NOTE The scope of EN ISO 2566-1 precludes its use for quenched and tempered steels. However, it is technically acceptable to apply its provisions to the quenched and tempered steels in this standard.

11.2.2 Impact test

The impact test shall be carried out in accordance with EN 10045-1.

The average value of the three test results shall meet the specified requirement. One individual value may be below the minimum average value specified, provided that it is not less than 70 % of that value.

Three additional test pieces shall be taken from the same sample in accordance with 10.3.5 and tested in one of the following cases:

a) if the average of three impact values is lower than the minimum average value specified;

b) if the average value meets the specified requirement, but two individual values are lower than the minimum average value specified;

c) if any one value is lower than 70 % of the minimum average value specified.

The average value of the six tests shall be not less than the minimum average value specified. Not more than two of the individual values may be lower than the minimum average value specified and not more than one may be lower than 70 % of this value.

11.3 Non-destructive tests

11.3.1 Qualification of personnel

For implementation of the non-destructive testing procedures and evaluation, all NDT personnel shall be qualified in accordance with EN 473 or EN 10256 as appropriate.

11.3.2 Test methods for plates

a) Ultrasonic testing shall be carried out in accordance with EN 10160 (see 8.5.1.3);

b) Magnetic particle inspection shall be carried out in accordance with EN ISO 9934-1 (see 8.5.1.1);

c) Liquid penetrant inspection shall be carried out in accordance with EN 571-1 (see 8.5.1.1).

11.3.3 Test methods for sections

a) Ultrasonic testing shall be carried out in accordance with EN 10306 (see 8.5.2.3).

11.3.4 Test methods of structural hollow sections

a) Ultrasonic testing shall be carried out in accordance with EN 10246-7, EN 10246-8, EN 10246-14 or EN 10246-15 (see 8.5.3.2, 8.5.3.3 and 8.5.3.4);

b) Eddy current testing shall be in accordance with EN 10246-3 (8.5.3.3);

c) Flux leakage testing shall be carried out in accordance with EN 10246-5 (8.5.3.3);

d) Magnetic particle inspection shall be carried out in accordance with EN 10246-12 (see 8.5.3.1).

11.3.5 General

When specified at the time of enquiry and order, the manufacturer shall submit written ultrasonic, magnetic particle (MPI) and dye penetrant inspection procedures for approval prior to production of the order.

See option 2.

11.4 Re-tests and re-submission for testing

EN 10021 shall apply in respect of all re-tests and re-submission for testing.

In the case of strip, re-tests on a rejected coil shall be carried out after the cutting of an additional longitudinal section of sufficient length to remove the coil end effect, with a maximum of 20 m.

12 Marking, bundling and protective coating

12.1 Die stamp and paint marking

Die stamp letters and digits (see also 12.1.1 a)) shall be at least 8 mm high (see also 12.1.1 b)). Paint marking shall be in contrasting colours with letters and digits at least 40 mm high (see 12.1.1 b)).

All markings shall be located in accordance with Figures 2 to 4.

If die stamping on bundled sections is required this may be performed on the saw cut surface.

The following information shall be die-stamped except as provided in 12.2:

a) cast number and/or product identification number;

NOTE This may not be possible at some section mills, in which case it will be highlighted by the supplier at the time of the enquiry and order.

b) steel name;

c) manufacturer's name or trademark;

d) stamp of the inspection representative (where applicable);

For hollow sections, this information shall be stencilled onto the product for sizes greater than 193,7 mm diameter, 150 mm square and 200 x 100 mm rectangular.

See option 28.

The following information shall be paint marked except as provided in 12.2;

e) purchase order number if required;

f) item size (thickness, width, length, section identification, diameter and wall thickness etc.);

g) steel designation (see 6.2);

h) purchaser's item number (where applicable).

12.1.1 The following shall also apply:

a) Vibro-etching or laser marking may be used instead of die stamping;

b) For sections, die stamp letters and digits shall be at least 5 mm high and paint marked letters and digits shall be at least 25 mm high;

c) Where the manufacturer’s name or trademark is normally rolled onto the section, this shall be permitted.

12.2 Bundling

Bundling is permitted for section sizes 450 mm and below, hollow sections 193,7 mm diameter and below, 150 mm square and below and 200 mm x 100 mm rectangular and below.

See option 29.

The information detailed in 12.1 a) to h) shall be shown on a label securely attached to the bundle.

Bundles shall be restricted to material from one cast. When a bundle is split for redistribution the information contained on the original label shall be transferred to the label on the new bundles or individual items as appropriate.

Additionally, when required for use in primary applications, at least one section or hollow section per bundle shall be stencilled with the size, thickness and steel designation. This requirement shall still be met if the bundle is split for redistribution.

12.3 Colour coding

Each plate shall be painted with either one or two 50 mm wide diagonal bands (depending on the grade) overlapping the edges in accordance with Figure 2.

Each section shall be painted with either one or two 50 mm wide bands (depending on the grade), along the longitudinal axis of the section and extending over the edges in accordance with Figure 3. In the case of bundled sections it is sufficient to add paint marking to the ends of the bundles only.

NOTE 1 The width of the painted bands may be reduced by agreement for smaller sections.

Each hollow section shall be painted with either one or two 50 mm wide bands (depending on the grade) longitudinally along the external surface and extending over the edges as shown in Figure 4. In the case of bundled hollow sections it is sufficient to add paint marking to the ends of the bundles only.

NOTE 2 The width of the painted bands may be reduced by agreement for smaller hollow sections.

Where two bands of the same colour are required they shall be separated by a minimum distance of 25 mm. The number and colour of bands shall be:

S355G1 and G1+N	Blue	Yellow
S355G2+N and G5+M	Blue	Yellow
S355G3+N and G6+M	Blue	White
S355G4 and G4+M	Blue	White
S355 steels of group 2	Blue	
S355 steels of group 3	Blue	Blue
S420 steels of group 2	Yellow	
S420 steels of group 3	Yellow	Yellow
S460 steels of group 2	Green	
S460 steels of group 3	Green	Green

All paint for colour coding and stencil marking shall be applied to a clean, dry, oil free surface and shall be able to resist weathering for at least six months.

12.4 Protective coating

Unless otherwise agreed all materials shall be supplied without the addition of protective surface coatings.

13 Options

Option 1. Tolerances other than those specified in EN 10029 Class A are required for plates (see 5.1.2).

Option 2. Details of manufacturing procedures for steels of groups 2 and 3 are required (see 7.1, 7.2.3, 11.3.5 and Annex C).

Option 3. Continuous casting process shall be limited to the production of material up to and including 50 mm thick except for piling where concast material up to and including 65 mm thick is permitted (see 7.2.1).

Option 4. Other reduction ratios shall be agreed for concast material (see 7.2.2).

Option 5. Normalizing rolling shall replace furnace normalizing (see 7.3.1 and 7.3.2). The designation +N shall apply.

Option 6. At the time of the enquiry and order the manufacturer shall advise the purchaser of the cast and product analyses ranges, for steels of groups 2 and 3 within the specified ranges in Tables 6, 11, 13 and 15, to which he proposes to work. This shall cover all elements listed in Tables 6, 11, 13 and 15 and also include residual elements required to be reported for each material type and manufacturing route (see 8.2.1 a) and 8.2.2.2 a)).

Option 7. A restricted cast and product analysis range shall be agreed between supplier and purchaser at the time of enquiry and order (see 8.2.1 c) and 8.2.2.2 b)). This option does not apply steels of group 1.

Option 8. Product analysis shall be carried out. This option applies to steels of group 1 only. Table 17 specifies the permissible deviations of the product analysis from the specified limits of the cast analysis (see 8.2.2.1).

Option 9. Maximum P_{cm} (based on product analysis) values shall be reported rather than CEV values (see 8.2.3.2, 8.2.3.3 and 8.2.3.4). This option does not apply to steels of group 1.

Option 10. For t greater than 40 mm in steels of groups 2 and 3 the material shall be tested in the PWHT condition and shall comply with the tensile and impact property requirements given in Tables 7 to 10, 12, 14 and 16 (see 8.3.2 c)).

Option 11. The purchaser shall specify a post weld heat treatment temperature other than 580 °C ± 20 °C (see 8.3.2 c)). In this case the properties to be obtained shall be agreed.

Option 12. Strain ageing testing shall be carried out for plates over 12,5 mm thickness in steels of groups 2 and 3 (see 8.3.4).

One plate from each cast to a maximum of three casts per grade, per process route and per manufacturing location shall be tested using Charpy V-notch impact test pieces from the sub-surface position (within 2 mm) cut transverse to the direction of rolling.

One sample of material shall be plastically strained 5 % and then aged for 1 h at 250 °C.

Charpy V-notch impact tests at –40 °C shall be performed on unstrained, strained and strain-aged samples. The following minimum values of the Charpy V-notch impact energy shall be attained in the strain-aged condition.

a) For grades S355G7+N, G7+M, G8+N, G8+M, G9+N, G9+M, G10+N and G10+M an average value of 36 J and an individual value of 26 J.

b) For all S420 grades an average value of 42 J and an individual value of 26 J.

c) For all S460 grades an average value of 46 J and an individual value of 29 J.

Option 13. Through-thickness testing shall be carried out in the final heat treatment condition. Testing is not required for thicknesses below 25 mm (see 8.3.5). Testing shall be in accordance with EN 10164, to meet the following:

a) EN 10164 Quality Class Z 35.

b) Through-thickness tensile strength shall be not less than 80 % of the specified minimum tensile strength.

Option 14. Flattening test

A flattening test (see 8.3.6) shall be carried out in accordance with EN ISO 8492 with the following acceptance criteria:

— flatten to 2/3 of the original outside diameter; no weld opening shall occur;

— flatten to 1/3 of the original outside diameter; no crack or break shall occur other than in the weld;

— flatten until opposite walls of the hollow section meet.

The presence of laminar imperfections or burnt metal shall not become apparent during the entire test.

Option 15. For steel plate of groups 2 and 3 (see 8.3.7) of thickness greater than 100 mm the steel manufacturer shall either:

a) provide wide plate data of parent plate applicable to the type of steel to be supplied; or

b) in the absence of relevant wide plate data, carry out CTOD tests on sample plates of thicknesses up to 150 mm preferably in accordance with EN ISO 12737 using displacement control. The subsidiary specimen geometry (B = W) is permitted. The tests shall be carried out after simulated post-weld treatment at 580 °C ± 20 °C. Three tests per plate thickness shall be performed at –10 °C. The CTOD specimens shall be taken transverse to the principal rolling direction of the plate and shall be through-thickness notched.

Option 16. Plate cold forming procedures for steels of groups 2 and 3 are required (see 8.4.1 and Annex D).

Option 17. Plate hot forming procedures for steels of groups 2 and 3 are required (see 8.4.2).

Option 18. Weldability tests shall be performed for steels of groups 2 and 3 (see 8.4.3) by means of any of the series of tests described in Annexes E, F and G. The purchaser shall specify which of the tests in Annexes E, F and G are to be carried out.

The necessity for weldability evaluation and the frequency of re-evaluation shall be determined by the steel type and supply circumstances at the time of enquiry and/or order.

Three steel types and supply circumstances are defined as follows.

Class A. Steel types, process routes and manufacturing plants from which steel weldability has been fully evaluated and for which there is extensive existing fabrication experience.

A steel shall be considered for the same type if it is within the range of the product analysis of this specification and manufactured using the same alloying system. The individual elements shall be within the ranges given in Table 5 with respect to the steel for which the data is being provided.

Table 5 — Tolerances of individual elements

Element	Tolerances	
C	+ 0,02	- 0,04
Si	+ 0,15	- 0,15
Mn	+ 0,20	- 0,30
S	+ 0,005	- 0,010
P	+ 0,010	- 0,015
Ni	+ 0,5	- 0,20
Cu	+ 0,15	- 0,20
N	+ 0,0025	- 0,0045
Al	+ 0,02	- 0,03
Nb	+ 0,010	- 0,015
V	+ 0,02	- 0,03
Ti	+ 0,008	- 0,008
Cr	+ 0,10	- 0,20
Mo	+ 0,04	- 0,06
CEV (IIW)	+ 0,02	- 0,06
P_{cm}	+ 0,02	- 0,04

Class B. Steel types already well recognised in terms of weldability and fabrication, but from a new supplier, location or process route.

Class C. Steel types which are newly developed or not previously supplied for offshore structures, or for which weldability data or extensive fabrication experience is not available.

Necessity/frequency of weldability testing:

Class A Steels. On purchaser's request and after contract, the supplier shall provide comprehensive weldability data from tests on previous production of plates, sections or hollow sections of similar thickness. Frequency of test shall be for the initial order only.

Class B Steels. On purchaser's request and where information has been supplied previously for Class A steels, and providing that the analysis of elements of the chemical composition of the steel falls within the range specified for Class A steels, a limited weldability programme may be agreed to qualify production at the new location or by a different process route. Frequency shall be for the initial order following any change of production location or process.

The weldability of steel from a new supplier shall be demonstrated by provision of data for a Class A steel and the effects of any variation in production location or process route demonstrated as for Class B above.

Class C Steels. A full weldability testing programme shall be carried out to a scope agreed between purchaser and supplier. Frequency shall be for the initial contract and for further contracts until the steel can be classified as Class A or B.

Weldability tests for class C steels are only required for plates, sections and hollow sections exceeding 40 mm in thickness (see 8.4.3 and Annexes E, F and G).

Test materials shall be selected from products whose mechanical and chemical properties and manufacturing routes are typical for the production materials which the manufacturer intends to supply.

Material for the weldability evaluation shall preferably be selected with chemical compositions corresponding to the top end of the production range, particularly in respect of carbon equivalent and shall be approved by the purchaser.

Representative test samples and significant sized pieces of untested material shall be uniquely identified and stored for a period of one year during which time they shall be available for additional testing or inspection if required by the purchaser.

On completion of each weld evaluation programme and verification of test results the steel manufacturer shall prepare a report.

Option 19. Steel plates of group 1 shall be ultrasonically tested to a class from EN 10160 as agreed by the manufacturer and purchaser (see 8.5.1.2).

Option 20. Other surface conditions in accordance with EN 10163-3 shall be agreed (see 8.5.2.1).

Option 21. Sections shall be ultrasonically tested to a class from EN 10306 as agreed between the supplier and purchaser (see 8.5.2.2 and 8.5.2.3).

Option 22. The internal soundness in accordance with EN 10246-14, to acceptance level U3 or EN 10246-15, to acceptance level U3, shall be demonstrated by test. The method to be applied and the point in the manufacturing process at which the test is carried out is at the discretion of the manufacturer (see 8.5.3.2).

NOTE Internal soundness tests are usually carried out in accordance with European Standards on strip/plate prior to tube making or in the circular form. Additional testing for the corner region if required may be agreed between supplier and purchaser.

Option 23. Hollow sections shall be suitable for use as primary components (see 8.5.3.3 and 8.5.3.4).

Option 24. Testing of the weld is required (see 10.2.3 and 10.3.3.4).

Option 25. Sections/hollow sections with thicknesses greater than specified shall be supplied. All the technical requirements of this European Standard shall be maintained (see Tables 12, 14 and 16).

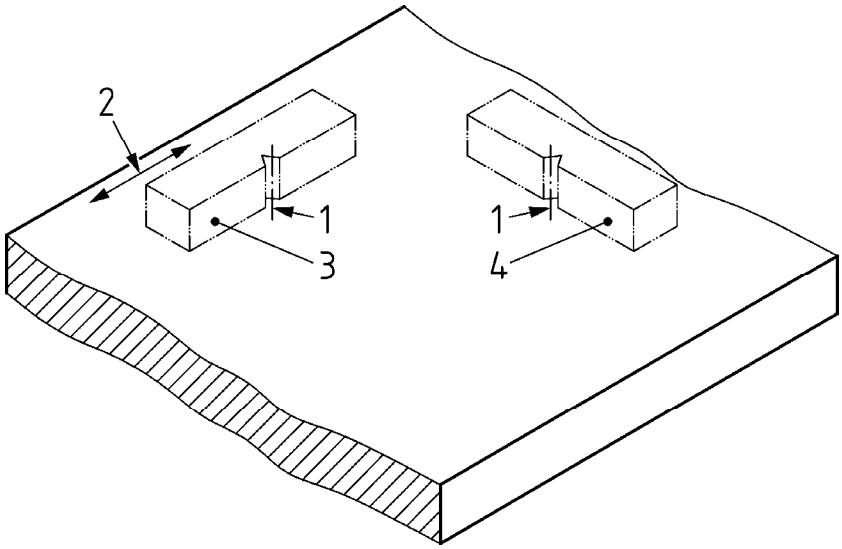
Option 26. For section grades S355G12, G12+N and G12+M transverse Charpy V-notch impact tests shall be carried out in lieu of longitudinal tests to meet 50 J minimum average at –40 °C (see 10.3.3.3 and footnote a in Table 12).

Option 27. For section grades S420G4 and G4+M and S460G4 and G4+M transverse Charpy V-Notch impact tests shall be carried out in addition to longitudinal tests. Energy values and test temperatures for the transverse tests to be agreed between manufacturer and purchaser at the time of enquiry and order (see 10.3.3.3 and footnote c in Table 12).

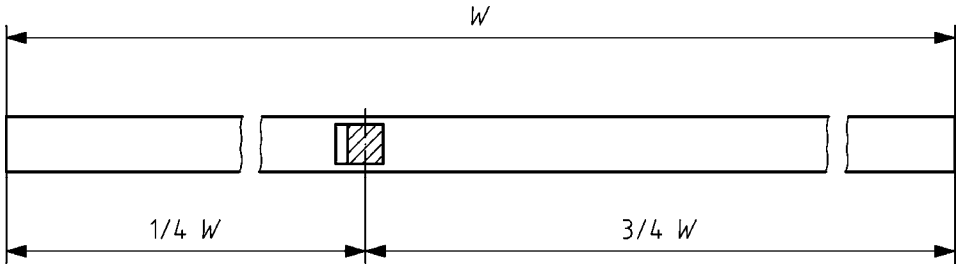
Option 28. For thicknesses greater than 12,7 mm the information shall be die stamped on the product (see 12.1).

Option 29. Sections and hollow sections shall be supplied individually (not bundled) (see 12.2).

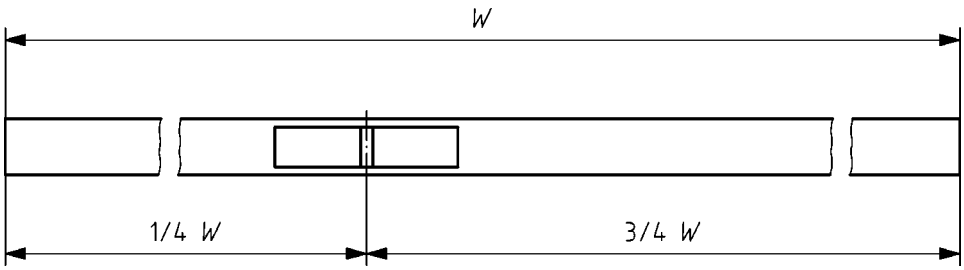
Option 30. For plate thickness greater than 40 mm, the minimum Ni content shall be 0,30 % (see footnote e) of Table 6).



a) Location of impact test pieces



b) Steels of group 1 - test piece parallel to the principal direction of rolling

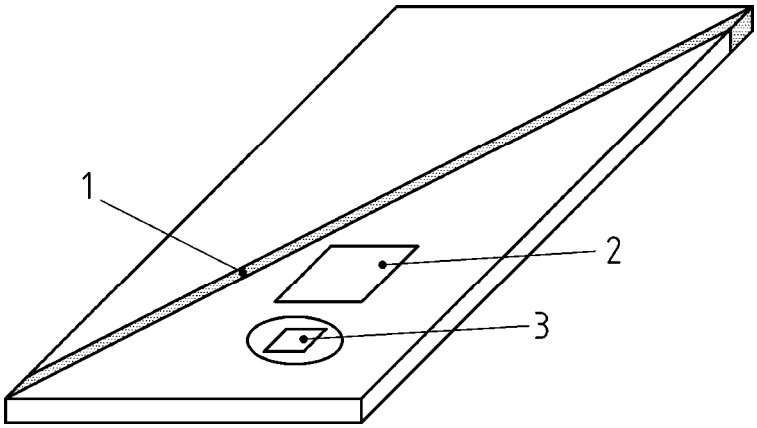


c) Steels of groups 2 and 3 - test piece transverse to the principal direction of rolling

Key

1 Axis of notch
2 Principal direction of rolling
3 Longitudinal test piece
4 Transverse test piece
W Plate width

Figure 1 – Impact test pieces



Key

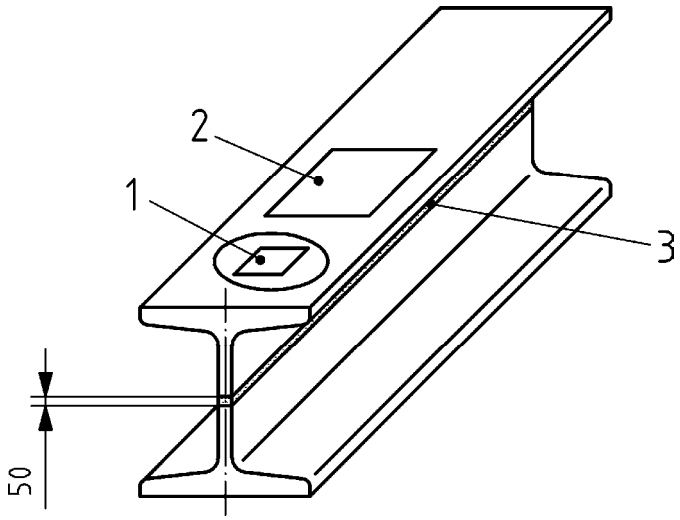
1 Colour of band(s) according to steel type

2 Marking (white paint)

3 Die stamp (ringed with white paint), text line to be at 90° to rolling direction

Figure 2— Plates - marking, die stamping and colour coding

Dimensions in millimetres



Key

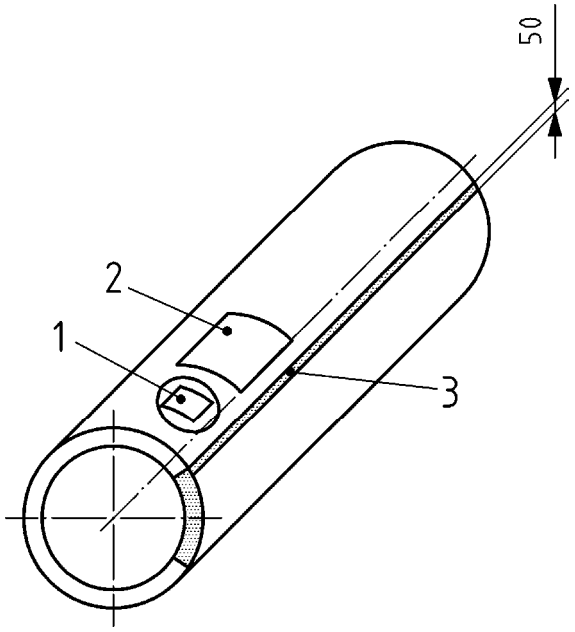
1 Die stamp (ringed with white paint), text line to be at 90° to rolling direction

2 Marking (white paint)

3 Colour of band(s) according to steel type

Figure 3 — Rolled sections – marking, die stamping and colour coding

Dimensions in millimetres



Key

1 Die stamp (ringed with white paint), text line to be at 90° to rolling direction

2 Marking (white paint)

3 Colour of band(s) according to steel type

Figure 4 — Hollow sections - marking, die stamping and colour coding

Table 6 — Chemical composition for plates (% by mass)

Group	Steel name	Steel number	C max.	Si	Mn	P max.	S max.	Cr max.	Mo max.	Ni max.	Al(Total)[b]	Cu max.	N max.	Nb max.	Ti max.	V max.	Cr+Mo+Ni+Cu max.	Nb+V max.	Nb+V+Ti max.
			%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Cast analysis[a]																			
1	S355G2+N	1.8801+N	0,20	0,50 max.	0,90 to 1,65	0,035	0,030	0,30	0,10	0,50	0,020. min	0,35	0,015	0,060	0,030	0,12	-	-	-
1	S355G3+N	1.8802+N	0,18	0,50 max.	0,90 to 1,65	0,030	0,025	0,30	0,10	0,50	0,020. min	0,35	0,015	0,060	0,030	0,12	-	-	-
1	S355G5+M	1.8804+M	0,14	0,50 max.	1,60 max.	0,035	0,030	-	0,20	0,30	0,020 min.	-	0,015	0,050	0,050	0,10	-	-	-
1	S355G6+M	1.8805+M	0,14	0,50 max.	1,60 max.	0,030	0,025	-	0,20	0,30	0,020 min.	-	0,015	0,050	0,050	0,10	-	-	-
Cast and product analysis																			
2	S355G7+M[c] S355G7+N[c]	1.8808+M 1.8808+N	0,14	0,15 to 0,55	1,00 to 1,65	0,020	0,010	0,25	0,08	0,50	0,015 to 0,055	0,30	0,010	0,040	0,025	0,060	0,90	0,06	0,08
3	S355G8+M[c] S355G8+N[c]	1.8810+M 1.8810+N	0,14	0,15 to 0,55	1,00 to 1,65	0,020	0,007	0,25	0,08	0,50	0,015 to 0,055	0,30	0,010	0,040	0,025	0,060	0,90	0,06	0,08
2	S355G9+N[c] S355G9+M[c]	1.8811+N 1.8811+M	0,12	0,15 to 0,55	1,65 max.	0,020	0,010	0,20	0,08[d]	0,70[e]	0,015 to 0,055	0,30	0,010	0,030	0,025	0,060	-	0,06	0,08
3	S355G10+N[c] S355G10+M[c]	1.8813+N 1.8813+M	0,12	0,15 to 0,55	1,65 max.	0,015	0,005	0,20	0,08[d]	0,70[e]	0,015 to 0,055	0,30	0,010	0,030	0,025	0,060	-	0,06	0,08
2	S420G1+QT[c] S420G1+M[c]	1.8830+QT 1.8830+M	0,14[f]	0,15 to 0,55	1,65 max.	0,020	0,010	0,25	0,25	0,70	0,015 to 0,055	0,30	0,010	0,040	0,025	0,080	0,90	0,09	0,11
3	S420G2+QT[c] S420G2+M[c]	1.8857+QT 1.8857+M	0,14[f]	0,15 to 0,55	1,65 max.	0,020	0,007	0,25	0,25	0,70	0,015 to 0,055	0,30	0,010	0,040	0,025	0,080	0,90	0,09	0,11
2	S460G1+QT[c] S460G1+M[c]	1.8878+QT 1.8878+M	0,14[f]	0,15 to 0,55	1,65 max.	0,020	0,010	0,25	0,25	0,70	0,015 to 0,055	0,30	0,010	0,040	0,025	0,080	0,90	0,09	0,11
3	S460G2+QT[c] S460G2+M[c]	1.8887+QT 1.8887+M	0,14[f]	0,15 to 0,55	1,65 max.	0,020	0,007	0,25	0,25	0,70	0,015 to 0,055	0,30	0,010	0,040	0,025	0,080	0,90	0,09	0,11

NOTE For details on delivery conditions refer back to 7.3.1.

a For product chemical composition variations see Table 17.

b The total aluminium to nitrogen ratio shall be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N-ratio does not apply.

c The levels of the residual elements arsenic, antimony, tin, lead, bismuth and calcium shall not exceed 0,03 % As, 0,010 % Sb, 0,020 % Sn, 0,010 % Pb, 0,010 % Bi and 0,005 % Ca. Boron (B) shall not exceed 0,0005 %. These elements shall be checked at least once every 5000 tonnes at each manufacturing location and shall be reported as a cast analysis.

d For thicknesses greater than 75 mm, maximum Mo content of 0,20 % shall apply for delivery condition +M.

e See option 30. For thicknesses greater than 40 mm, the minimum Ni content shall be 0,30 %.

F A maximum carbon value of 0,15 % is permitted for thicknesses less than 15 mm.

Table 7 — Mechanical properties for plates - S355 grades see also Table 10

Group	Steel name	Steel number	Tensile strength R_m[a]		Minimum yield strength R_{eH} for thickness t (mm)						Minimum elongation A on gauge length of 5,65 $\sqrt{s_o}$[a]	Minimum average Charpy V-notch impact energy		Thickness maximum
			Thickness t (mm) ≤ 100	Thickness t (mm) > 100	$t \leq 16$	$16 < t \leq 25$	$25 < t \leq 40$	$40 < t \leq 63$	$63 < t \leq 100$	$100 < t \leq 150$		Temp.	Energy	
			MPa[c]	MPa[c]	MPa[c]	MPa[c]	MPa[c]	MPa[c]	MPa[c]	MPa[c]	%	° C	J	mm
1	S355G2+N	1.8801+N	470 to 630		355	345	-	-	-	-	22	-20	50	20
1	S355G3+N	1.8802+N	470 to 630		355	345	345	-	-	-	22	-40	50	40
1	S355G5+M	1.8804+M	470 to 610		355	345	-	-	-	-	22	-20	50	20
1	S355G6+M	1.8805+M	470 to 610		355	345	345	-	-	-	22	-40	50	40
2	S355G7+N	1.8808+N	470 to 630	460 to 620	355	355	345	335	325	320	22	-40	50	150[b]
3	S355G8+N	1.8810+N	470 to 630	460 to 620	355	355	345	335	325	320	22	-40	50	150[b]
2	S355G7+M	1.8808+M	470 to 630	-	355	355	345	335	325	-	22	-40	50	100[b]
3	S355G8+M	1.8810+M	470 to 630	-	355	355	345	335	325	-	22	-40	50	100[b]
2	S355G9+N	1.8811+N	470 to 630	460 to 620	355	355	345	335	325	320	22	-40	50	150[b]
2	S355G9+M	1.8811+M	470 to 630	-	355	355	345	335	325	-	22	-40	50	100[b]
3	S355G10+N	1.8813+N	470 to 630	460 to 620	355	355	345	335	325	320	22	-40	50	150[b]
3	S355G10+M	1.8813+M	470 to 630	-	355	355	345	335	325	-	22	-40	50	100[b]

[a] The specified tensile strength and elongation values apply to the maximum thickness for which minimum yield strengths are specified.

[b] Charpy V-notch mid-thickness verifications are also required for thicknesses over 40 mm.

In the case of piling material the mid-thickness impacts shall be verified at –30 °C in lieu of –40 °C.

[c] 1MPa = 1 N/mm^2

Table 8 — Mechanical properties for plates - S420 grades (see also Table 10)

Group	Steel name	Steel number	Tensile strength R_m for thickness t (mm) [a]		Minimum yield strength R_{eH} for thickness t (mm)					Minimum Elongation[a] A on gauge length of 5,65 $\sqrt{S_o}$	Minimum average Charpy V-notch impact energy		Thickness maximum
			$t \leq 40$	$40 < t \leq 100$	$t \leq 16$	$16 < t \leq 40$	$40 < t \leq 63$	$63 < t \leq 80$	$80 < t \leq 100$		Temp.	Energy	
			MPa[c]	MPa[c]	MPa[c]	MPa[c]	MPa[c]	MPa[c]	MPa[c]	%	°C	J	mm
2	S420G1 +QT	1.8830+QT	500 to 660	480 to 640	420	400	390	380	380	19	-40	60	100[b]
2	S420G1 +M	1.8830+M	500 to 660	480 to 640	420	400	390	380	380	19	-40	60	100[b]
3	S420G2 +QT	1.8857+QT	500 to 660	480 to 640	420	400	390	380	380	19	-40	60	100[b]
3	S420G2 +M	1.8857+M	500 to 660	480 to 640	420	400	390	380	380	19	-40	60	100[b]

[a] The specified tensile strength and elongation values apply to the maximum thickness for which minimum yield strengths are specified.

[b] Charpy V-notch mid-thickness verifications are also required for thicknesses over 40 mm.

[c] 1 MPa = 1 N/mm^2

Table 9 — Mechanical properties for plates - S460 grades (see also Table 10)

Thickness ranges (mm)	≤16	> 16 ≤ 25	> 25 ≤ 40	> 40 ≤ 63[a]	> 63 ≤ 80[a]	> 80 ≤ 100[a]
Minimum yield strength R_{eH} MPa[b]	460	440	420	415	405	400
Tensile strength R_m MPa [b]	540 to 700	530 to 690	520 to 680	515 to 675	505 to 665	500 to 660
Minimum elongation on gauge length 5,65 $\sqrt{S_o}$ %	17	17	17	17	17	17
Minimum average Charpy V-notch impact energy value	60 J at –40 °C					

[a] Charpy V-notch mid-thickness verifications are also required for thicknesses over 40 mm.

[b] 1 MPa = 1 N/mm^2

Table 10 — Yield to tensile strength ratios for plates excluding steels of group 1

Grade		
	Thickness	Yield to tensile strength ratios max.
All S355+N grades	≤ 16 mm	0,87
	> 16 mm	0,85
All S355+M grades	≤ 16 mm	0,93[a]
	> 16 mm	0,90
All S420 grades	≤ 16 mm	0,93
	> 16 mm	0,90
All S460 grades	≤ 16 mm	0,93
	> 16 mm	0,90

[a] For plates ≤ 10 mm, alternative yield to tensile strength ratios may be agreed.

Table 11 — Chemical composition for sections (by mass)

Group	Steel name	Steel number	C max.	Si max.	Mn	P max.	S max.	Cr max.	Mo max.	Ni max.	Al(Total)[b]	Cu max.	N max.	Nb max.	Ti max.	V max.	Cr+Mo+Ni+Cu max.	Nb+V max.	Nb+V+Ti max.
			%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Cast analysis[a]																			
1	S355G1[d] S355G1+N	1.8814 1.8814+N	0,20	0,50	0,90 to 1,65	0,035	0,030	0,30	0,10	0,50	0,020 min.	0,35	0,015	0,050	0,030	0,120	-	-	-
1	S355G4 [d] S355G4+M	1.8803 1.8803+M	0,16	0,50	1,60 max.	0,035	0,030	-	0,20	0,30	0,020 min.	0,35	0,015	0,050	0,050	0,100	-	-	-
Cast and product analysis																			
2	S355G11[c,d] S355G11+N [c] S355G11+M [c]	1.8806 1.8806+N 1.8806+M	0,14	0,55	1,65 max.	0,025	0,015	0,25	0,08	0,50	0,015 to 0,055	0,30	0,012	0,040	0,025	0,060	0,80	0,06	0,08
3	S355G12 [c,d] S355G12+N [c] S355G12+M [c]	1.8809 1.8809+N 1.8809+M	0,14	0,55	1,65 max.	0,020	0,007	0,25	0,08	0,50	0,015 to 0,055	0,30	0,012	0,040	0,025	0,060	0,80	0,06	0,08
2	S420G3 [c,d] S420G3+M[c]	1.8851 1.8851+M	0,14	0,55	1,65 max.	0,025	0,015	0,25	0,08	0,70	0,015 to 0,055	0,30	0,012	0,050	0,025	0,080	0,80	0,09	0,11
3	S420G4 [c,d] S420G4+M [c]	1.8859 1.8859+M	0,14	0,55	1,65 max.	0,020	0,007	0,25	0,08	0,70	0,015 to 0,055	0,30	0,012	0,050	0,025	0,080	0,80	0,09	0,11
2	S460G3[c,d] S460G3+M[c]	1.8883 1.8883+M	0,14	0,55	1,70 max.	0,025	0,015	0,25	0,08	0,70	0,015 to 0,055	0,30	0,012	0,050	0,025	0,080	0,80	0,12	0,13
3	S460G4 [c,d] S460G4+M [c]	1.8889 1.8889+M	0,14	0,55	1,70 max.	0,020	0,007	0,25	0,08	0,70	0,015 to 0,055	0,30	0,012	0,050	0,025	0,080	0,80	0,12	0,13

[a] For product chemical composition variations see Table 17.

[b] The total aluminium to nitrogen ratio shall be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N-ratio does not apply.

[c] The levels of the residual elements arsenic, antimony, tin, lead, bismuth and calcium shall not exceed 0,03 % As, 0,010 % Sb, 0,020 % Sn, 0,010 % Pb, 0,010 % Bi and 0,005 % Ca. Boron (B) shall not exceed 0,0005 %. These elements shall be checked at least once every 5000 tonnes at each manufacturing location and shall be reported as a cast analysis.

[d] As-rolled condition limited to a maximum thickness of 25 mm.

Table 12 — Mechanical properties for sections

Group	Steel name	Steel number	Tensile strength R_m	Minimum yield strength R_{eH} for thickness t (mm)				Minimum on elongation A gauge length of 5,65 $\sqrt{S_o}$	Minimum average Charpy V-notch impact energy	
				$t \leq 16$	$16 < t \leq 40$	$40 < t \leq 63$	R_e/R_m		Temp	Energy
			MPa[f]	MPa[f]	MPa[f]	MPa[f]	maximum ratio	%	°C	J
1	S355G1[e] S355G1+N	1.8814 1.8814+N	470 to 630	355	345[d]	-	0,87	22	-20	50
1	S355G4[e] S355 G4+M	1.8803 1.8803+M	450 to 610	355	345[d]	-	0,87	22	-20	50
2	S355G11[e] S355G11+N S355G11+M	1.8806 1.8806+N 1.8806+M	460 to 620	355	345	335	0,87	22	-40[b]	50
3	S355G12[e] S355G12+N S355G12+M	1.8809 1.8809+N 1.8809+M	460 to 620	355	345	335	0,87	22	-40[b]	50[a]
2	S420G3[e] S420G3+M	1.8851 1.8851+M	500 to 690	420	410	400	0,90	19	-40[b]	60
3	S420G4[e] S420G4+M	1.8859 1.8859+M	500 to 690	420	410	400	0,90	19	-40[b]	60[c]
2	S460G3[e] S460G3+M	1.8883 1.8883+M	530 to 720	460	440	430	0,90	17	-40[b]	60
3	S460G4[e] S460G4+M	1.8889 1.8889+M	530 to 720	460	440	430	0,90	17	-40[b]	60[c]

When agreed at the time of enquiry and order, sections with thicknesses greater than specified shall be supplied, see option 25.

[a] See option 26.

[b] For up to and including 25 mm thickness, test at –20 °C.

[c] See option 27.

[d] Available up to 25 mm thick only.

[e] As rolled condition limited to maximum thickness of 25 mm.

[f] 1 MPa = 1 N/mm^2

Table 13 — Chemical composition for welded hollow sections (% by mass)

Group	**Steel name**	**Steel number**	**C** max.	**Si**	**Mn**	**P** max.	**S** max.	**Cr** max.	**Mo** max.	**Ni** max.	**Al(Total)**[b]	**Cu** max.	**N** max.	**Nb** max.	**V** max.	**Ti** max.	**Cr+Mo+Ni+Cu** max.	**Nb+V** max.	**Nb+V+Ti** max.
			%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Cast analysis[a]																			
1	S355G1+N	1.8814+N	0,20	0,50 max.	0,90 to 1,65	0,035	0,030	0,30	0,10	0,50	0,020 min.	0,35	0,015	0,050	0,120	0,030	-	-	-
Cast and product analysis																			
2	S355G13+N[c] S355G13+QT[c]	1.1182+N 1.1182+QT	0,16	0,15 to 0,55	1,60 max.	0,025	0,015	0,25	0,08	0,30	0,060 max.	0,35	0,014	0,050	0,100	0,020	0,80	0,10	0,12
2	S420G5+QT[c]	1.8853+QT	0,16	0,15 to 0,55	1,00 to 1,65	0,025	0,015	0,30	0,25	0,65	0,060 max.	0,30	0,014	0,050	0,100	0,040	0,80	0,10	0,12
2	S460G5+QT[c]	1.8885+QT	0,16	0,15 to 0,55	1,00 to 1,65	0,025	0,015	0,30	0,25	0,65	0,060 max.	0,30	0,014	0,050	0,100	0,040	0,80	0,10	0,12

a For product chemical composition variations see Table 17.

b The total aluminium to nitrogen ratio shall be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N-ratio does not apply.

c The levels of the residual elements arsenic, antimony, tin, lead, bismuth and calcium shall not exceed 0,02 % As, 0,010 % Sb, 0,020 % Sn, 0,010 % Pb, 0,010 % Bi and 0,005 % Ca. Boron (B) shall not exceed 0,0005 %. These elements shall be checked at least once every 5000 tonnes at each manufacturing location and shall be reported as a cast analysis.

Table 14 — Mechanical properties for welded hollow sections

Group	**Steel name**	**Steel number**	**Tensile strength R_m**	**Minimum yield strength R_{eH} for thickness t** in mm		**Minimum elongation A on gauge length of $5{,}65\sqrt{S_o}$**	**Minimum average Charpy V-notch Impact energy**	
				$t \leq 20$	R_e/R_m		Temp.	Energy[a]
			MPa[b]	MPa[b]	maximum ratio	%	°C	J
1	S355G1+N	1.8814+N	470 to 630	355	0,88	22	-20	50
2	S355G13+N S355G13+QT	1.1182+N 1.1182+QT	460 to 620	355	0,88	22	-40	50
2	S420G5+QT	1.8853+QT	500 to 690	420	0,90	22	-40	60
2	S460G5+QT	1.8885+QT	550 to 700	460	0,90	19	-40	60

When agreed at the time of enquiry and order, hollow sections with thicknesses greater than specified shall be supplied, see option 25.

[a] For transverse weld testing, test temperature is -20 °C with minimum values of 36 J for all grades.

[b] 1 MPa = 1 N/mm^2

Table 15 — Chemical composition for seamless hollow sections (% by mass)

Group	**Steel name**	**Steel number**	**C** max.	**Si**	**Mn**	**P** max.	**S** max.	**Cr** max.	**Mo** max.	**Ni** max.	**Al(Total)**[b]	**Cu** max.	**N** max.	**Nb** max.	**Ti** max.	**V** max.	**Cr+Mo+Ni +Cu** max.	**Nb+V** max.	**Nb+V+Ti** max.
			%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Cast analysis[a]																			
1	S355G1 +N	1.8814+N	0,20	0,50 max.	0,90 to 1,65	0,035	0,030	0,30	0,10	0,50	0,020 min.	0,35	0,015	0,050	0,030	0,120	-	-	-
Cast and product analysis																			
2	S355G14 +QT[c]	1.1184+QT	0,18	0,15 to 0,55	1,60 max.	0,025	0,010	0,25	0,08	0,30	0,06 max.	0,35	0,014	0,050	0,02	0,10	0,80	0,10	0,12
	S355G14 +N[c]	1.1184+N																	
3	S355G15 +N[c]	1.1190+N	0,18	0,15 to 0,55	1,60 max.	0,025	0,007	0,25	0,08	0,30	0,06 max.	0,35	0,014	0,050	0,02	0,10	0,80	0,10	0,12
	S355G15 +QT[c]	1.1190+QT																	
2	S420G6 +QT[c]	1.8852+QT	0,16	0,15 to 0,55	1,00 to 1,65	0,025	0,007	0,30	0,25	0,65	0,06 max.	0,30	0,014	0,050	0,04	0,10	0,80	0,10	0,12
2	S460G6 +QT[c]	1.8884+QT	0,16	0,15 to 0,55	1,00 to 1,65	0,025	0,010	0,30	0,25	0,65	0,06 max.	0,30	0,014	0,050	0,04	0,10	0,80	0,10	0,12

[a] For product chemical composition variations see Table 17.

[b] The total aluminium to nitrogen ratio shall be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N-ratio does not apply.

[c] The levels of the residual elements arsenic, antimony, tin, lead, bismuth and calcium shall not exceed 0,02 % As, 0,010 % Sb, 0,020 % Sn, 0,010 % Pb, 0,010 % Bi and 0,005 % Ca. Boron (B) shall not exceed 0,0005 %. These elements shall be checked at least once every 5000 tonnes at each manufacturing location and shall be reported as a cast analysis.

Table 16 — Mechanical properties for seamless hollow sections

Group	Steel name	Steel number	Tensile strength R_m	Minimum yield strength R_{eH} for thickness t [a] (mm)			Minimum elongation A on gauge length of $5{,}65\sqrt{S_o}$	Minimum average Charpy V-notch impact energy	
				$t \leq 20$	$20 < t \leq 40$	R_e/R_m		Temp.	Energy
			MPa [b]	MPa [b]	MPa [b]	max. ratio	%	°C	J
1	S355G1+N	1.8814+N	470 to 630	355	345	0,88	22	-20	50
2	S355G14+N S355G14+QT	1.1184+N 1.1184+QT	460 to 620	355	345	0,88	22	-40	50
3	S355G15+N S355G15+QT	1.1190+N 1.1190+QT	460 to 620	355	345	0,88	22	-40	50
2	S420G6+QT	1.8852+QT	500 to 690	420	400	0,90	22	-40	60
2	S460G6+QT	1.8884+QT	550 to 700	460	440	0,90	19	-40	60

[a] When agreed at the time of enquiry and order, hollow sections with thicknesses greater than specified shall be supplied, see option 25.

[b] 1 MPa = 1 N/mm^2

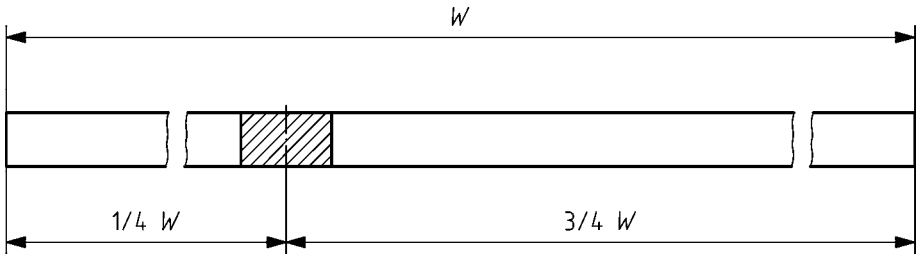
Table 17 — Permissible deviations of the product analysis from the specified limits of the cast analysis applicable to steels of group 1

Element	Permissible maximum content in the cast analysis %	Permissible deviation of the product analysis from specified limits for the cast analysis %
C	0,20	+ 0,02
Si	0,50	+ 0,05
Mn	1,65	- 0,05 + 0,10
P	0,035	+ 0,005
S	0,030	+ 0,005
Nb	0,060	+ 0,010
V	0,12	+ 0,02
Ti	0,050	+ 0,01
Cr	0,30	+ 0,05
Ni	0,70	+ 0,05
Mo	0,25	+ 0,03
Cu	0,35	+ 0,04
N	0,015	+ 0,002
Al total	≥ 0,020	- 0,005

Annex A
(normative)

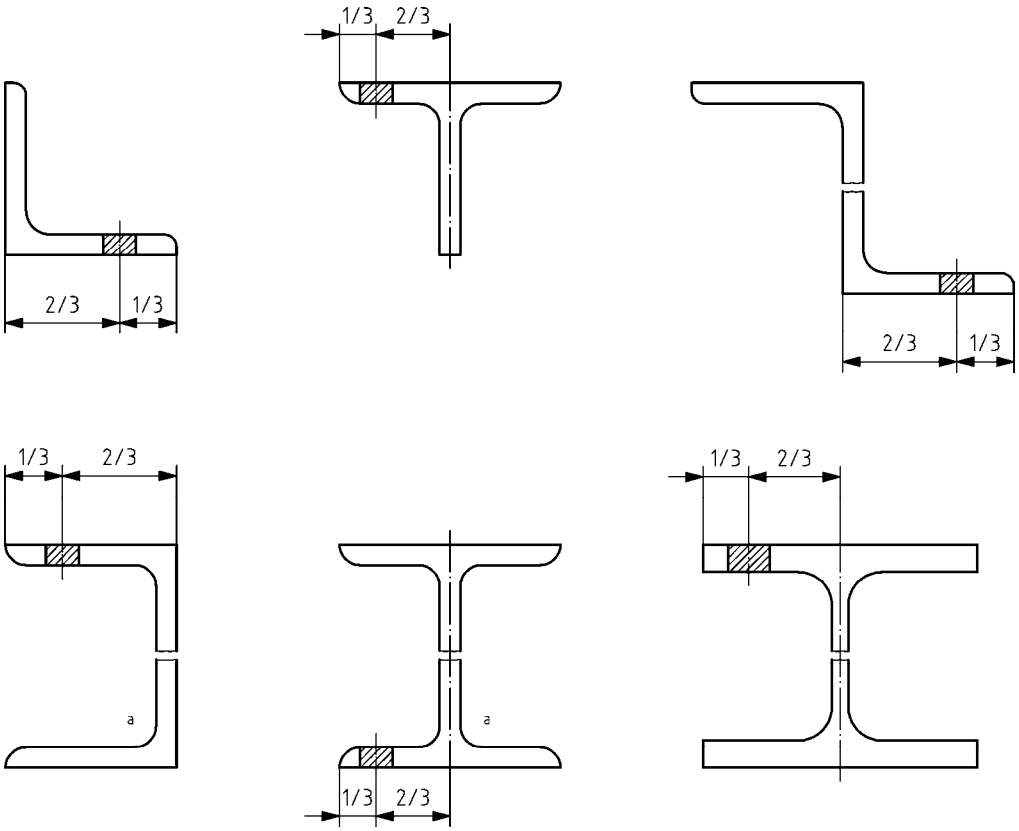
Location of test samples for tensile and impact tests

The location of test samples for tensile and impact tests shall be as shown in Figures A.1 to A.3.



Key
W - Plate width

Figure A.1 — Flat products (see 10.3.2.2 and 10.3.3.2)

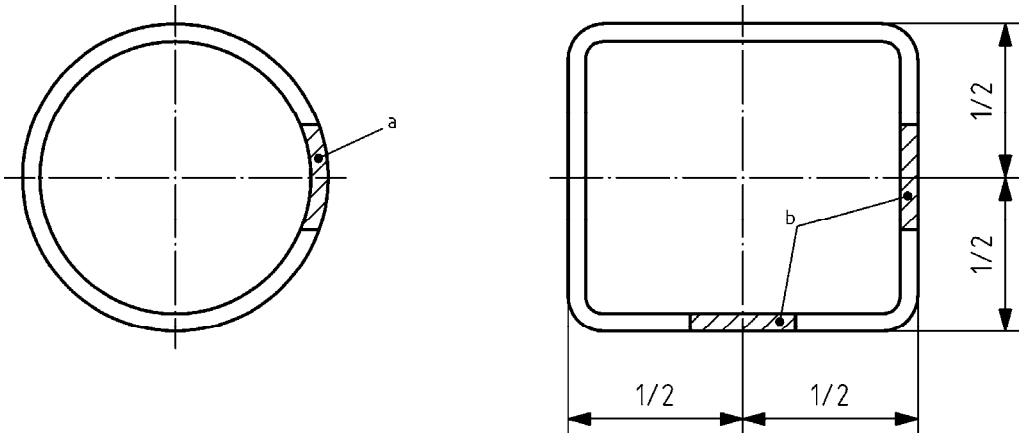


"Location of samples
(test pieces are taken from the samples)":

[a)] At the manufacturer's discretion, the sample can be taken from the web, at a quarter of the total height.

NOTE For sections with inclined flanges, machining of the inclined surface is permitted in order to make it parallel to the other surface.

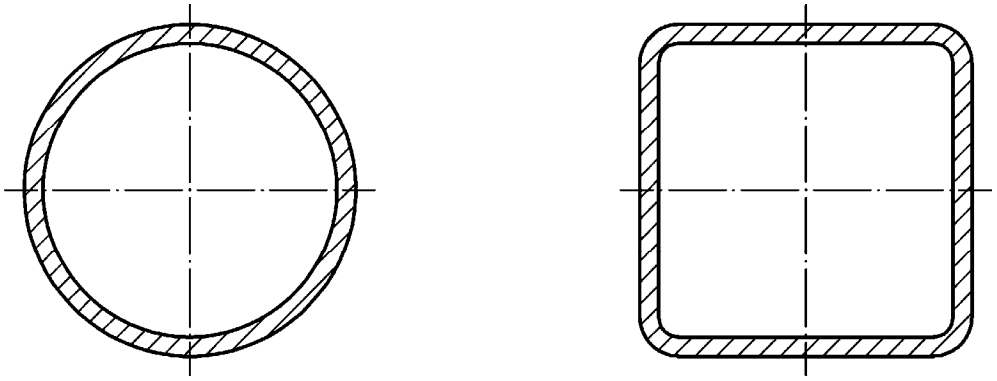
Figure A.2 — Beams, channels, angles, T sections and Z sections(see 10.3.2.3 and 10.3.3.3)



[a] Sample at any point on the circumference but in the case of welded sections remote from the weld.

[b] Sample at alternative positions (on any side except a side containing the weld in welded sections).

a) Tensile test pieces for circular, square and rectangular sections (outside diameter > 219,1 mm or nominal length of side > 150 mm) and impact test pieces



b) Tensile test pieces only for small circular, square or rectangular sections (outside diameter ≤ 219,1 mm or nominal length of side ≤ 150 mm)[1]

[1)] At the manufacturers discretion the sample can be a full tube section or strip section taken in the longitudinal direction to the axis of the hollow section.

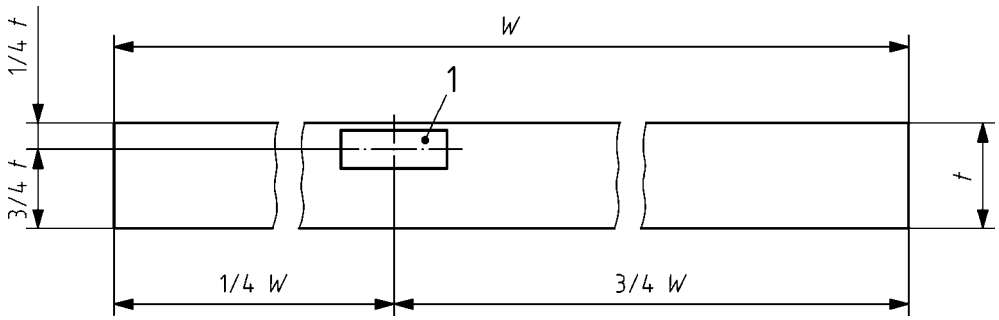
Location of samples
(test pieces are taken from the samples)

Figure A.3 — Hollow sections (See 10.3.2.4 and 10.3.3.4)

Annex B
(normative)

Location of tensile test piece when two rolled surfaces cannot be retained

The location of test samples for tensile testing shall be as shown in Figure B.1.



Key

1 - Test piece (min. test piece thickness or diameter = 12,5 mm)

t - Plate thickness

W - Plate width

Figure B.1 — Location of tensile test piece when two rolled surfaces cannot be retained (see 10.3.4)

Annex C
(normative when option 2 is specified by the purchaser)

Details of manufacturing procedures to be supplied by the manufacturer for steels of groups 2 and 3

The following information shall be supplied by the manufacturer to the purchaser at the time of the enquiry and order.

a) Location and name of steel mill(s);

b) Recent production data to demonstrate that the values proposed for cast and product analysis are achievable;

c) Steel manufacturing procedures as follows:

   1) steel making process;

   2) proportions of scrap and hot metal charge;

   3) nominal mass of heat;

   4) any hot metal treatment e.g. degassing, desulfurization or sulfide treatment technique;

   5) ingot or continuous cast (concast).

d) Segregation control procedures (including electromagnetic stirring etc.) for continuous cast steel;

e) Control of sequential casting (for continuous casting);

f) Ingot or slab size (including plate thickness ranges on each size);

g) Details of sulfur printing or alternative method of quality grading and frequency of checks (for continuous casting);

h) Rolling procedures;

i) Dehydrogenation procedures;

j) Heat treatment procedures e.g. quenching and tempering (+QT);

k) Recent production data to demonstrate that the required Charpy V-notch impact values are achievable;

l) Information on the effect of extended times at stress relieving temperatures on tensile and Charpy V-notch impact properties to cover the effects of a second stress relief in case of repair;

m) The above shall include details of the quality procedures to be implemented by the manufacturer during production which should clearly identify all inspection points.

The manufacturer shall not change any of the practices listed without the approval of the purchaser.

Annex D
(normative when option 16 is specified by the purchaser)

Cold forming characteristics for steel plate of groups 2 and 3

When required (see 8.4.1 and option 16) the manufacturer shall provide the following data on the effect of cold-forming plates at outside diameter to thickness ratios of 10:1, 15:1 and 20:1. This shall be provided from simulated tensile or compression tests or actual bending tests at 5 %, 7,5 % and 10 % strain.

The test frequency, in the absence of satisfactory data, shall be one set of the following tests on a maximum of three casts per grade, per process route, per manufacturing location:

a) Trial materials: to be taken from the thicker end of the range;

b) Condition: as follows:

   1) as strained and aged 1 h at 250 °C;

   2) as strained and aged 1 h at 250 °C plus stress relief for 4 h at 580 °C ± 20 °C;

   3) When agreed, for +M grade steels the above shall also be conducted with ageing temperatures of 150 °C.

c) Testing. The following tests shall be carried out for each strained and aged condition:

   1) Tensile: For information purposes one test at ambient temperature shall be carried out;

   2) Charpy V-notch impact: Transition curves shall be derived from unstrained, strained and strain-aged material. Tests shall be performed from +20 °C down to –80 °C at 20 °C intervals; three specimens shall be tested at each temperature.

      For the 5 % strain condition only, the following minimum values shall be met at –40 °C:

      i) For grades S355G7+N, G9+N, G7+M, G9+M and S355G8+N, G10+N, G8+M and G10+M an average value of 36 J and an individual value of 26 J;

      ii) For grades S420G1+QT, G1+M, G2+QT, and G2+M an average value of 42 J and an individual value of 29 J;

      iii) For grades S460G1+QT, G1+M, G2+QT and G2+M an average value of 46 J and an individual value of 32 J.

Annex E
(normative when option 18 is specified by the purchaser)

Weldability testing for steels of groups 2 and 3 and mechanical testing of butt welds

E.1 General requirements

A series of butt welds with heat inputs in accordance with E.3.5 shall be made. The welds shall be carried out in accordance with normal fabrication practices but square-edge weld preparation shall be used for one side of the preparation. The welds shall comply with the mechanical properties specified in E.5.

NOTE Precautions should be taken to prevent the occurrence of defects which could invalidate the test.

Additional welds and test criteria, if specified by the purchaser at the time of the enquiry and/or order, shall be subject to agreement between the purchaser and the supplier.

E.2 Welding processes and procedure

The welding processes referred to in this standard are defined in Table E.1 (the process numbers are in accordance with EN ISO 4063).

Table E.1 — Welding process

Process	Process number
Flux-cored wire metal-arc arc welding (FCAW)	
- without gas shield	114
- with active gas shield	136
- with inert gas shield	137
Submerged arc welding (SAW)	12
- with wire electrode	121
Metal arc welding with covered electrode (SMAW/MMA)	111
Gas shielded metal arc welding (GMAW)	13
- metal-arc inert gas welding (MIG)	131
- metal-arc active gas welding (MAG)	135
Tungsten inert gas arc welding (TIG/GTAW)	141

The manufacturer shall submit detailed welding procedure specification in accordance with EN ISO 15614-1. The procedures shall include wire or electrode size, welding parameters, welding position and other relevant parameters, e.g. number of submerged arc welding (SAW) wires, iron powder additions and weld bevel angle.

Only welding consumables, which have previously demonstrated consistently high CTOD values at -10 °C, shall be used. Welding of test plates shall be carried out by fabricators or other organizations employing suitably qualified personnel, acceptable to the purchaser. Such organizations shall have previous satisfactory experience of qualifying CTOD tested welding procedures typical of those used on off-shore structures or sub-assemblies.

NOTE Parameters chosen for the test welding procedures should reflect good practice for the chosen process.

E.3 Butt-weld requirements

E.3.1 General

The weldability test requirements for butt welds on plates, sections and seamless hollow sections are given in Tables E.2, E.3 and E.4.

E.3.2 Test piece dimensions

The test piece thickness shall either correspond to the maximum thickness of material to be supplied by concast and ingot routes or a value to be agreed between supplier and purchaser.

The direction of welding for plates shall be parallel to the principal direction of rolling. For sections, the direction of welding relative to the principal rolling direction shall be such as to allow the same orientation of Charpy and CTOD specimens as required by Table 12 or option 24 or option 25.

The length and width of each welded test plate shall be sufficient to accommodate the testing requirements of this annex plus any re-tests. The width of the welded test piece shall not be less than 500 mm or 10 times the thickness, whichever is greater, to a maximum of 750 mm.

Table E.2 — Weldability test requirements for butt welds on plates

Grade	Quality	Test piece condition	Nominal heat input (kJ/mm)		
			FCAW[a] 0,7± 0,2	SAW[b] 5,0± 0,2	SAW[b] 3,5± 0,2
			Min. preheat temperature = 125 °C[c] Max. interpass temperature = 250 °C[c]		
S355	G8+N G10+N G8+M	As welded	×	×	×[d]
	G10+M	Post-weld heat treated	×	×	×[d]
S420	G2+QT G2+M	As welded	×	×	×[e]
		Post-weld heat treated	–	×	×[e]
S460	G2+QT G2+M	As welded	×	×[f]	×
		Post-weld heat treated	–	×[f]	×

× indicates that testing is required
– indicates that testing is not required

a FCAW for t < 50 mm only when requested by the purchaser.

b Where agreed between purchaser and supplier SMAW may be used instead of SAW (see E.3.5).

c Alternative preheat/interpass temperatures may be adopted subject to agreement between purchaser and supplier. Such temperatures should reflect accepted practice and should be based on maximum carbon equivalent and material thickness.

d S355G8+N and G8+M and S355G10+N and G10+M tests may also be required at 3,5 kJ/mm if tests at 5,0 kJ/mm produce results below the purchaser's acceptance criteria.

e S420G2+QT and G2+M tests may also be required at 3,5 kJ/mm if tests at 5,0 kJ/mm produce results below the purchaser's acceptance criteria.

f S460G2+QT and G2+M shall not be welded above 3,5 kJ/mm.

Table E.3 — Weldability test requirements for butt welds on sections

Grade	**Type**	**Test piece condition**	**Nominal heat input** (kJ/mm)			
			FCAW[a] 0,7 ± 0,2	SAW[b] 3,0 ± 0,2	SAW [b] 5,0 ± 0,2	SAW [b] 3,5 ± 0,2
			Min. preheat temperature = 125 °C[c] Max. interpass temperature = 250 °C[c]			
S355	G12 G12+N G12+M	As welded	×	×[d]	×[e]	×
S420	G4 G4+M	As welded	–	×[d]	×[e]	×
S460	G4 G4+M	As welded	–	×[d]	×[e]	×

× indicates that testing is required
– indicates that testing is not required

[a] Flux-cored arc welding (FCAW).

[b] Where agreed between purchaser and supplier SMAW may be used instead of SAW (see E.3.5).

[c] Alternative preheat/interpass temperatures may be adopted subject to agreement between purchaser and supplier. Such temperatures should reflect accepted practice and should be based on maximum carbon equivalent and material thickness.

[d] For all grades tests may also be required at 3,0 kJ/mm if tests at 3,5 kJ/mm produce results below the purchaser's acceptance criteria.

[e] If specified by the purchaser.

Table E.4 — Weldability test requirements for butt welds on seamless hollow sections

Grade	Type	Test piece Condition	Nominal heat input (kJ/mm)			
			FCAW[a] 0,7± 0,2	SAW [b] 3,0 ± 0,2	SAW[b] 5,0 ± 0,2	SAW [b] 3,5 ± 0,2
			Min. preheat temperature = 125 °C[c] Max. interpass temperature = 250 °C[c]			
S355	G15+N G15+QT	As welded	×	×[d]	–	×
S420	G6+QT	As welded	–	×[d]	–	×
S460	G6+QT	As welded	–	×[d]	–	×

× indicates that testing is required
– indicates that testing is not required

[a] Flux-cored arc welding (FCAW).

[b] Where agreed between purchaser and supplier SMAW may be used instead of SAW (see E.3.5).

[c] Alternative preheat/interpass temperatures may be adopted subject to agreement between purchaser and supplier. Such temperatures should reflect accepted practice and should be based on maximum carbon equivalent and material thickness.

[d] For all grades tests may also be required at 3,0 kJ/mm if tests at 3,5 kJ/mm produce results below the purchaser's acceptance criteria.

E.3.3 Bevel detail

For all test welds a square-edge weld preparation shall be adopted for one side of the preparation in order to facilitate the production of a straight fusion line and heat affected zone (HAZ) normal to the rolled surface. The preferred weld preparation for the other side of the preparation is a single bevel having an angle of not greater than 45°. The joint shall be fully restrained and may be made with or without backing strip. The root gap shall not exceed 10 mm.

E.3.4 Welding processes

Tack welds and initial passes of each test plate may be deposited by the gas metal arc (GMAW) or shielded metal arc welding (SMAW) or flux-cored arc welding (FCAW) process. Subsequent weld passes shall be deposited by FCAW, SMAW or SAW, as appropriate.

E.3.5 Nominal heat input

The nominal heat input for each weld pass other than initial e.g. root passes apply unless other values consistent with the proposed fabrication procedures, or base material are agreed at the time of enquiry and order.

A record shall be kept of all process parameters including preheat and interpass temperatures.

Heat input, Q (in kJ/mm) shall be calculated from the following equation:

$$Q = k\frac{UI}{v}\times 10^{-3} \qquad \text{(E.1)}$$

where

k is the thermal efficiency factor for the welding process as defined in EN 1011-1 (*k* = 0,7 for FCAW and 1,0 for SAW);

U is the arc voltage (in V);

I is the welding current (in A);

v is the welding speed (in mm/s).

For the purposes of this standard the heat input for tandem arc welding shall be calculated in accordance with EN 1011-1.

E.3.6 Heat treatment

E.3.6.1 S355, S420 and S460 grades in delivery condition +N or +M

After welding, test welds which are to be tested in the PWHT condition shall be post-weld heat treated at either 580 ± 20 °C or at another temperature to be agreed by the purchaser and the supplier. They shall be subjected to a soaking period of either not less than 1 h per 25 mm thickness of plate or 4 h, whichever is the greater. Heating and cooling rates shall be in accordance with the following:

The rate of heating shall not exceed (5500/*t*) °C/h or 55 °C/h, whichever is the greater, where *t* is the plate thickness in mm.

Test welds shall be cooled to a temperature of 400 °C at a rate not exceeding (6875/*t*) °C/h or 55 °C/h, whichever is the greater.

NOTE Below 400 °C, plates may be cooled in still air.

E.3.6.2 S420 and S460 grades in delivery condition +QT

Where applicable, post weld heat treatment shall be within the temperature range 550 °C to 620 °C, with a maximum temperature of 25 °C below the tempering range on the test certificate, for either 1 h per 25 mm thickness of plate or 4 h, whichever is the greater. Heating and cooling rates shall be in accordance with those in E.3.6.1.

E.3.7 Dehydrogenation of test pieces

When considered necessary, dehydrogenation of as-welded test pieces shall be carried out by a low temperature heat treatment, prior to CTOD testing. The use of any dehydrogenation treatment shall be declared with the test results.

Heat treatment conditions of 150 °C for 48 h are recommended, and the exact parameters shall be notified with the CTOD test results.

In some instances, e.g. test pieces of exceptionally high thickness, alternative parameters may be necessary to reduce hydrogen content and these may be agreed between the steelmaker and purchaser. This may involve higher temperatures and/or longer times, but in no instance should the temperature exceed 250 °C.

E.4 Mechanical testing

E.4.1 General

A series of mechanical tests shall be carried out in accordance with Tables E.5, E.6 and E.7. A sufficient amount of each test weld should be prepared to permit repeat testing particularly in case of invalid CTOD test (see E.4.3.2).

E.4.2 Charpy-V-notch impact tests

Charpy V-notch impact test specimen locations shall be in accordance with Figure E.1 and testing shall be carried out in accordance with EN 10045-1.

Prior to notching, all samples shall be etched to allow the notch location to be marked.

Table E.5 — Mechanical test requirements for plates for each butt weld[a]

Type of test	No. of tests	Position of tests	Acceptance criteria
Macro/hardness	2	See E.4.4 and Figure E.2.	325 HV10 max., except for 0,7 kJ/mm heat input when acceptance value is 350 HV10 max. (see E.5c)).
Charpy V-notch	One set of 3 tests per position	Position of tests as follows: a) transverse to rolling direction; b) FL-2, FL, FL+2 and FL+5 on specimens from cap, mid-thickness and root from the straight edge (see E.4.2, E.5. a) and Figure E.1). Tests may also be taken from the bevel edge preparation if agreed between purchaser and supplier.	Tested at -40°C to meet the following: a) for S355 grades a minimum average of 36 J and a minimum individual value of 26 J; b) for S420 grades a minimum average of 42 J and a minimum individual value of 29 J . c) for S460 grades a minimum average of 46J and a minimum individual value of 32 J.
CTOD	3 tests per position	Position of tests as follows: a) transverse to rolling direction; b) at each of the following positions: 1) GCHAZ; 2) SCHAZ/ICHAZ boundary; 3) weld metal. (See E.4.3.2)	Tested at –10 °C to meet a CTOD value as defined by the purchaser .
Cross-weld tensile	2	Cross-weld (see E.4.5)	(See E.5 d).

[a] For details of butt welds see E.3 and Table E.2.

Table E.6 — Mechanical test requirements for sections for each butt weld

Type of test	No. of tests	Position of tests	Acceptance criteria
Macro/ hardness	2	See E.4.4 and Figure E.2.	325 HV10, except for 0,7 kJ/mm heat input when acceptance value is 350 HV10 (see E.5 c)).
Charpy V-notch	One set of 3 tests per position	Position of tests as follows: a) - longitudinal to rolling direction (or transverse for grades S355G12, S420G4 and S460G4 if agreed between purchaser and supplier); b) at FL-2; FL; FL+2, FL+5 on specimens from cap, mid-thickness and root from the straight edge (see E.4.2, E.5 a) and Figure E.1). Tests may also be taken from the bevel edge preparation if agreed between purchaser and supplier.	Tested at -40 °C to meet the following: a) for S355 grades a minimum average of 36 J and a minimum individual value of 26 J; b) for S420 grades a minimum average of 42 J and a minimum, individual value of 29 J; c) for S460 grades a minimum average of 46 J and a minimum individual value of 32 J.
CTOD	3 tests per position	Position of tests as follows: a) - longitudinal to rolling direction (or transverse for grades S355G12, S420G4 and S460G4 if agreed between supplier and purchaser); b) at each of the following positions: 1) GCHAZ; 2) SCHAZ/ICHAZ boundary; 3) weld metal. (See E.4.3.2).	Tested at –10 °C to meet a CTOD value as defined by the purchaser (see E.5 b)).
Cross-weld tensile	2	Cross-weld (see E.4.5).	See E.5 d).

NOTE For sections, weldability testing shall be carried out on the cut-off flanges but welded together in such a way as to allow either testing in the longitudinal or in the transverse directions (see Figures E.6 a) and b)). In all cases pieces shall be taken from the 1/6 flange width positions.

Table E.7 — Mechanical test requirements for hollow sections for each butt weld

Type of test	No. of tests	Position of tests	Acceptance criteria
Macro/hardness	2	See E.4.4 and Figure E.2.	325 HV10, except for 0,7 kJ/mm heat input when acceptance value is 350 HV10 (see E.5 c)).
Charpy V-notch	One set of 3 tests per position	Position of tests as follows: a) longitudinal to the tube rolling direction; b) at FL-2; FL; FL+2, FL+5 on specimens from cap, mid-thickness and root from the straight edge (see E.4.2, E.5 a) and Figure E.1). Tests may also be taken from the bevel edge preparation if agreed between purchaser and supplier.	Tested at –40 °C to meet the following: a) for S 355 grades a minimum average of 36 J and a min. individual value of 26 J; b) for S 420 grades a minimum average of 42 J and a min, individual value of 29 J; c) for S 460 grades a minimum average of 46 J and a min. individual value of 32 J.
CTOD	Optional	As agreed between supplier and purchaser.	-
Cross-weld tensile	2	Cross-weld (see E.4.5).	See E.5 d).
NOTE For tubulars, weldability testing shall be carried out on either full or partial tubulars in such a way as to allow testing in the longitudinal direction. The welding position shall be flat (PA) rotated according to EN ISO 6947 unless otherwise agreed between the supplier and the purchaser.			

E.4.3 CTOD test

E.4.3.1 Classification of HAZ structures

When a single weld bead is deposited on a plate, the following four HAZ zones shall be defined in the plate in order moving away from the weld depending on the peak temperature experienced:

a) grain-coarsened HAZ (GCHAZ): 1400 °C $\geq \vartheta >$ 1100 °C;

b) fine grained HAZ (FGHAZ): 1100 °C $\geq \vartheta > A_{C3}$;

c) intercritical HAZ (ICHAZ): $A_{C3} \geq \vartheta > A_{C1}$;

d) subcritical HAZ (SCHAZ): $A_{C1} \geq \vartheta$.

In a multi-pass weld some regions of the HAZ of the first pass are eliminated, others are significantly altered and others remain unaltered. In a single bevel multi-pass weld the overlapping heat affected zones that penetrate the unbevelled edge appear as shown in Figure E.3.

NOTE The zones of particular importance are as follows and are highlighted in Figure E.3.

e) the intercritically re-heated GCHAZ (IRGCHAZ);

f) the subcritically re-heated GCHAZ (SRGCHAZ);

g) the SCHAZ/ICHAZ boundary.

E.4.3.2 Test requirements

Three CTOD tests shall be conducted for each of the following:

— grain-coarsened HAZ (GCHAZ);

— the subcritical HAZ (SCHAZ) intercritical HAZ (ICHAZ) boundary;

NOTE 1 At the option of the purchaser CTOD tests shall be carried out on weld metal (2 mm into the weld metal from the fusion line).

All CTOD samples shall be transverse to the plate rolling direction.

Testing should be carried out preferably in accordance with EN ISO 12737 using displacement control and test pieces which shall be notched in the through-thickness direction. For thicknesses less than 75 mm a rectangular section bend specimen shall be used and for thicknesses equal to and greater than 75 mm a square section shall be used.

Tests shall be checked for validity (see note 2) and invalid specimens shall be disregarded and test(s) repeated.

NOTE 2 In addition to the requirements of BS 7448-1 validity of test specimens should be checked according to the following criteria.

— Grain-coarsened HAZ. To be considered a valid test, the fatigue crack shall maximise the amount of grain coarsened region sampled and a proportion should be within 0,5 mm of the fusion line. It is important to sample the grain coarsened region in the central 75 % portion of the material thickness. The percentage grain coarsened HAZ shall be reported. In order to maximise the chance of meeting the requirements of fatigue crack position, the objective, when manufacturing the weldment from which the CTOD testpiece will be prepared, should be to create a fusion line that is as planar in form as possible.

— Subcritical/intercritical HAZ boundary. To be considered a valid test, the fatigue crack shall sample the boundary between the subcritical HAZ and the intercritical HAZ;

— Weld metal. To be considered a valid test, the fatigue crack shall sample 90 % minimum weld metal and remain as close as possible to the fusion line.

E.4.3.3 Sectioning methods

E.4.3.3.1 Grain-coarsened HAZ

Following testing, each CTOD specimen shall be examined as follows to confirm that the fatigue crack sampled the grain-coarsened HAZ (GCHAZ):

a) Remove a 15 mm slice containing the fracture face from each specimen half;

b) Section the sample from the weld metal side. If required to confirm validation, sample both fracture faces parallel to the root of the machined notch as shown in Figure E.4;

NOTE 1 Specimens should be sectioned to allow examination of the central ¾ of the fatigue crack. If fracture initiation falls outside the central ¾ of the specimen, sectioning should include this point.

c) Polish and etch the exposed top face of the bottom half for micro examination as shown in Figure E.5;

d) Examine and take a photomicrograph at an appropriate magnification. The recorded evidence shall show the full plate thickness;

e) The percentage of grain coarsened areas sampled by the fatigue crack shall be calculated as shown in Figure E.5. The percentage should include the ICGCHAZ and the SCGCHAZ adjacent to the columnar weld metal.

NOTE 2 If the distance between the polished face and the deepest point of the fatigue crack exceeds 2 mm, as a result of excessive bowing or the existence of an irregular fatigue crack profile, additional sections may be required as agreed with the purchaser.

E.4.3.3.2 Subcritical/intercritical HAZ boundary

For each SCHAZ CTOD specimen, sectioning and relevant reporting shall be as given in E.4.3.3.1.

E.4.3.3.3 Weld metal

For each weld metal CTOD specimen only one of the two specimen halves shall be sectioned. The half containing the HAZ (not the half containing the bulk of the weld metal) shall be sectioned, prepared and photographed.

E.4.4 Macrohardness

Macro specimens shall be prepared from each test weld and hardness surveys shall be performed on each specimen at the positions shown in Figure E.2 in accordance with EN ISO 6507-1.

Starting as close to the fusion line as possible with indents 1,0 mm between centres through to base material the centre of all indents shall be as close as possible but clear of the fusion line. To ensure all regions of the HAZ are sampled a second traverse may be made parallel to and at a distance of 1,0 mm to 1,5 mm from the first traverse and with staggered hardness indentation.

All hardness surveys shall be performed with 10 kg load (HV10 = 98,07 N).

NOTE When required by the purchaser, additional parallel spaced hardness traverses may be specified.

E.4.5 Cross-weld tensile test

If specified by the purchaser, two cross-weld tensile tests shall be carried out in accordance with EN 895.

E.5 Specific test requirements

The following mechanical test requirements shall be achieved for each weld:

a) Charpy V-notch tests. Specimens shall be taken from locations and orientations and shall meet test acceptance criteria specified in Table E.5 (plates) and Table E.6 (sections) and Table E.7 (hollow sections);

   Retest procedures shall be in accordance with EN 10021.

b) CTOD tests. The test pieces shall be tested at –10 °C and shall meet the purchaser's acceptance criteria;

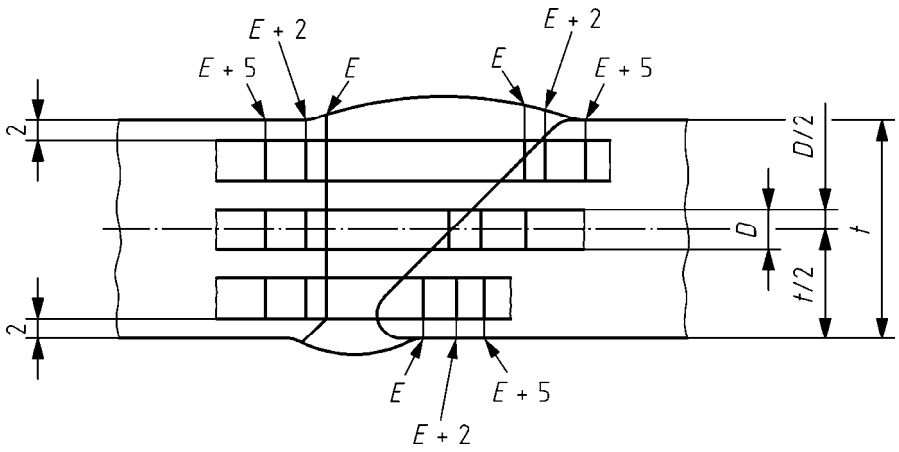
c) Hardness tests. Hardness tests shall be made on transverse sections of the test weld as specified in E.4.4 and Figure E.2, and meet the acceptance criteria defined in Tables E.5, E.6 and E.7 as appropriate;

d) Cross-weld tensile tests. These tests shall be as specified in Tables E.5, E.6 and E.7 as appropriate. The tensile strength of the test specimen shall not be less than the corresponding specified minimum value for the parent metal.

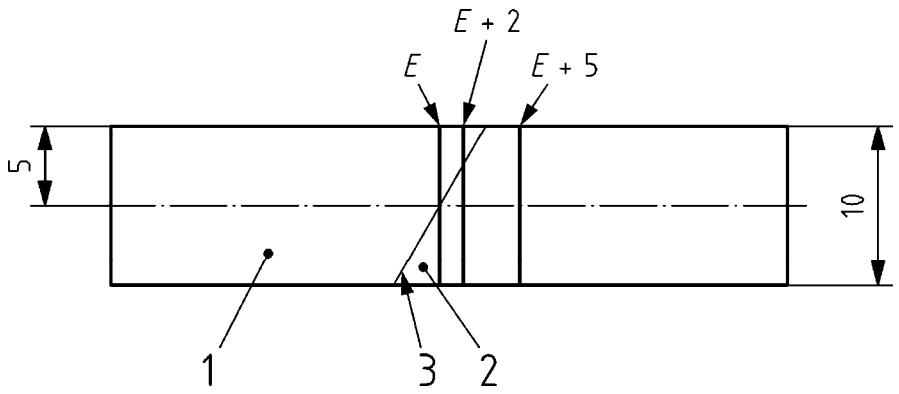
E.6 Testing on hollow sections and sections

Where weldability testing of hollow sections and sections exceeding 40 mm thick is specified by the purchaser, test welds shall be prepared as given in Tables E.3 and E.4. Testing shall be confined to macro/hardness (see E.5 c)) and Charpy V-notch (see E.5 a)). CTOD testing (see E.5 b)) shall only be carried out at the discretion of the purchaser.

Dimensions in millimetres



a) Single bevel



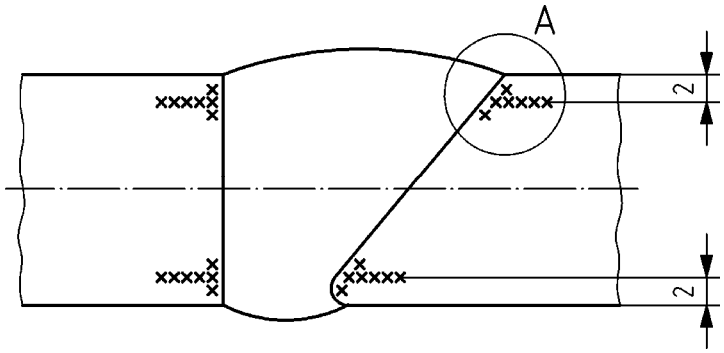
b) Notch positions for HAZ Charpy V-notch test pieces on bevelled side of weld

Key

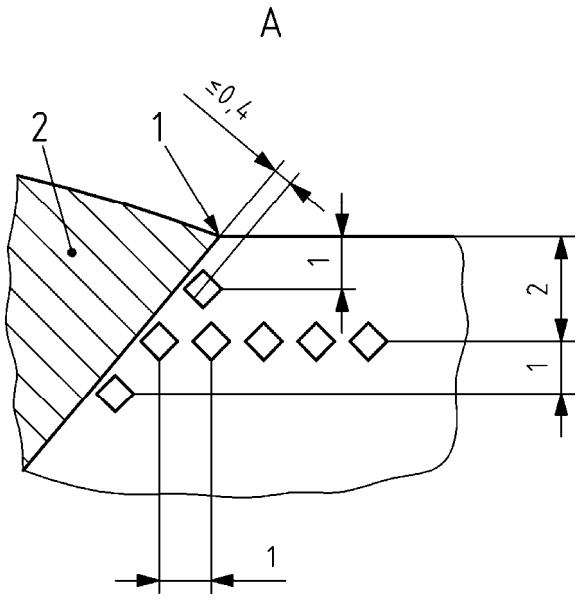
1 Weld metal
2 Heat affected zone (HAZ)
3 Weld fusion line
D Specimen size
E fusion line
t Plate thickness

Figure E.1 — Location of Charpy V-notch impact test pieces for plate butt weld (see E.4.2)

Dimensions in millimetres



a) General arrangement

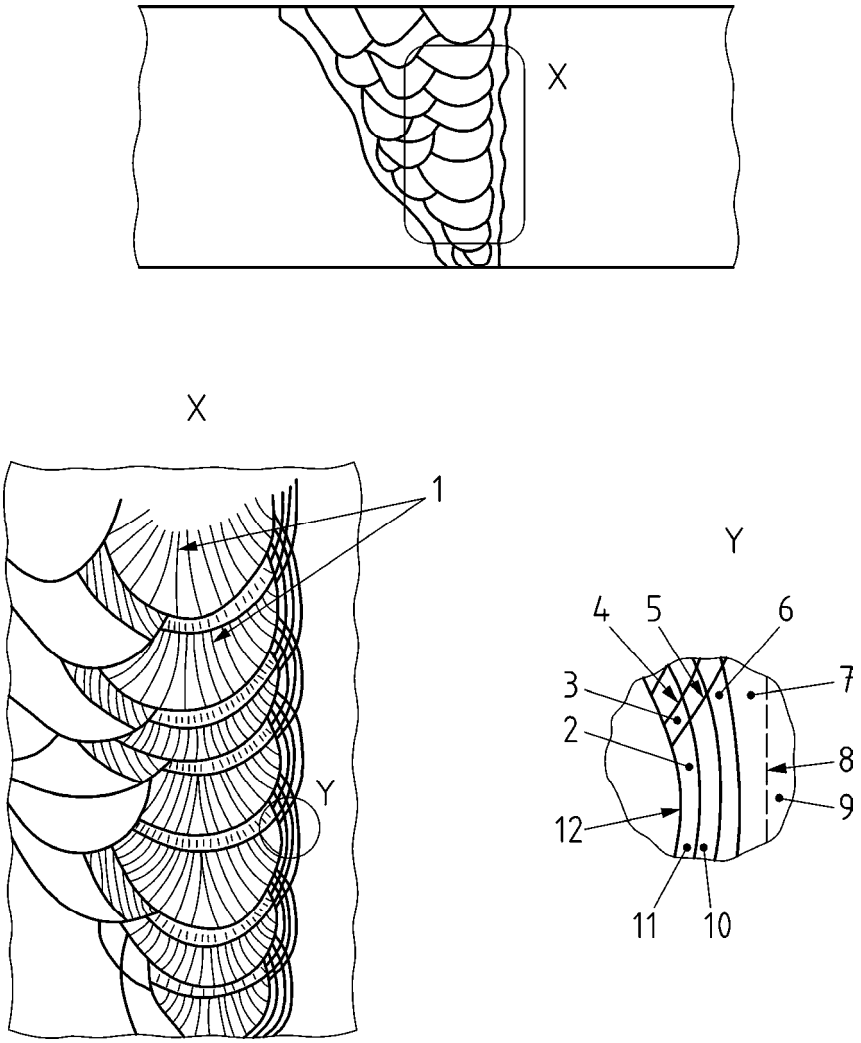


b) Enlargement of area A.

Key

1 Fusion line
2 Weld

Figure E.2 — Hardness surveys on butt weld test pieces (see E.4.4)



Key

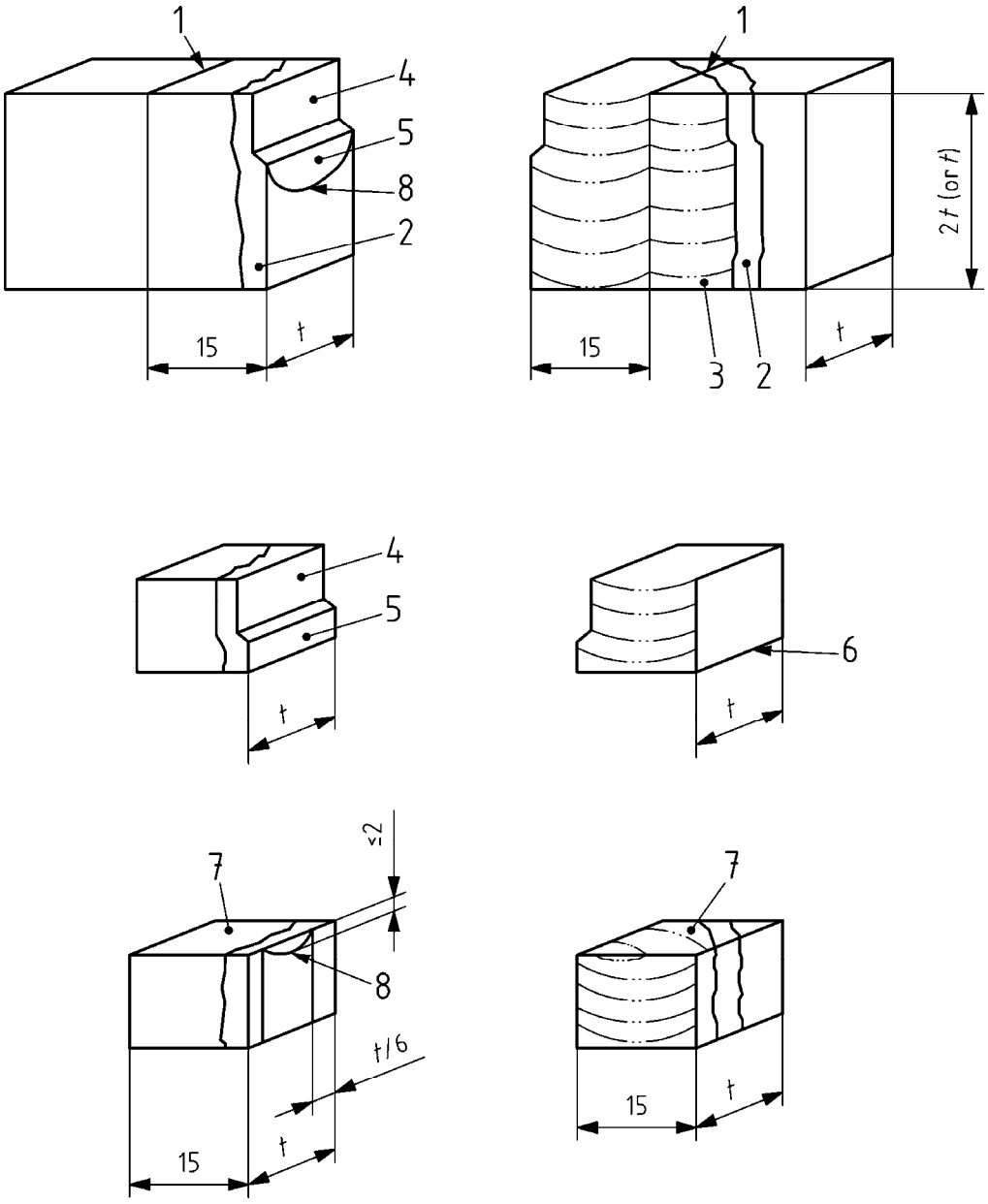
1 Columnar weld metal
2 SRGCHAZ Subcritically re heated GCHAZ (grain coarsened heat affected zone) [a]
3 IRGCHAZ Intercritically re heated GCHAZ (grain coarsened heat affected zone) [a]
4 Ac_3
5 Ac_1
6 Unaltered [b] ICHAZ (intercritical heat affected zone)
7 Unaltered [b] SCHAZ (subcritical heat affected zone)
8 Non visible boundary
9 Parent metal
10 Unaltered [b] FGHAZ (fine grain heat affected zone)
11 Unaltered [b] GCHAZ (grain coarsened heat affected zone)
12 Fusion line

[a] Zone created by a multiple weld run

[b] Zone created by a single weld run

Figure E.3 — The HAZ regions in a single bevel multi-pass weld (see E.4.3.1)

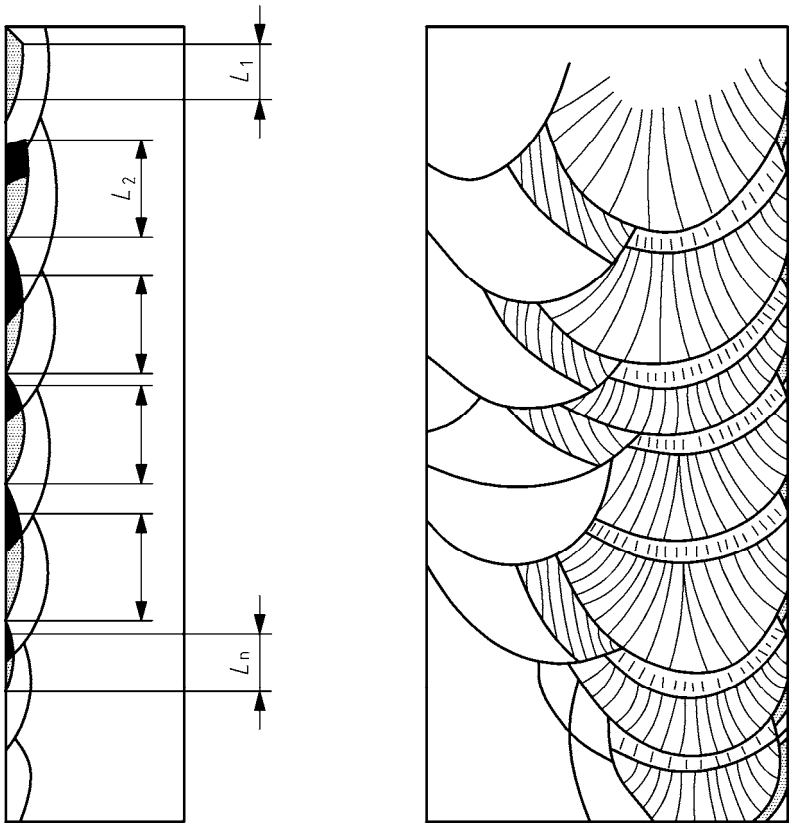
Dimensions in millimetres



Key

1	Saw cut lines	5	Fatigue crack
2	Heat affected zone	6	Sectioned plane
3	Weld cap	7	Polished and etched surface
4	Machined notch	8	Fatigue crack tip
t	Sample thickness		

Figure E.4 — CTOD specimen sectioning details (see E.4.3.3)



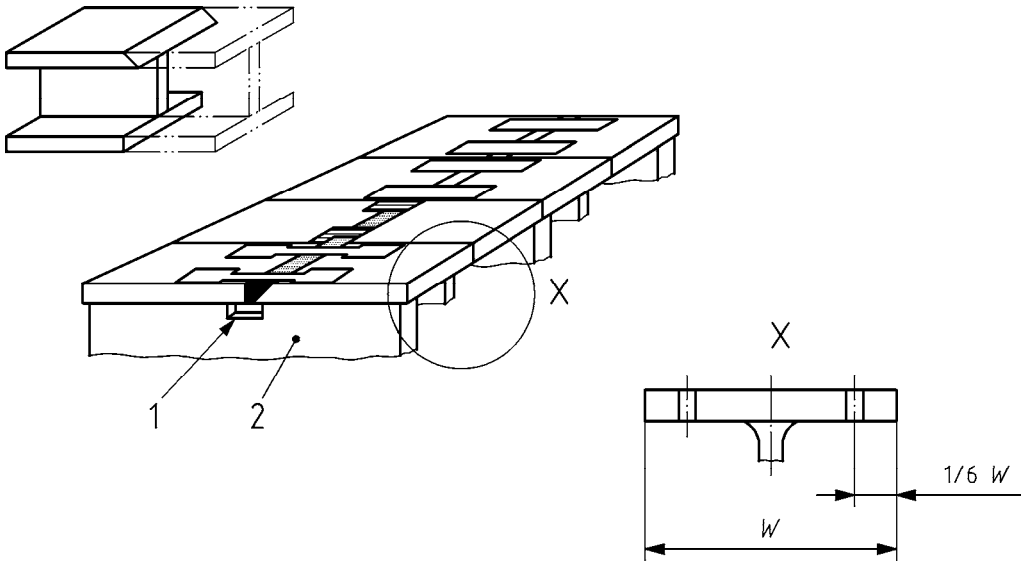
$$\% \text{ GC areas sampled} = 100\left\{\frac{\sum_1^n L}{t}\right\}$$

Key

L Sum of grain coarsened areas measured

t Plate thickness

Figure E.5 — Plan view of polished section halves showing method to calculate GCHAZ percentage (see E.4.3.3.1 e) including note 1)



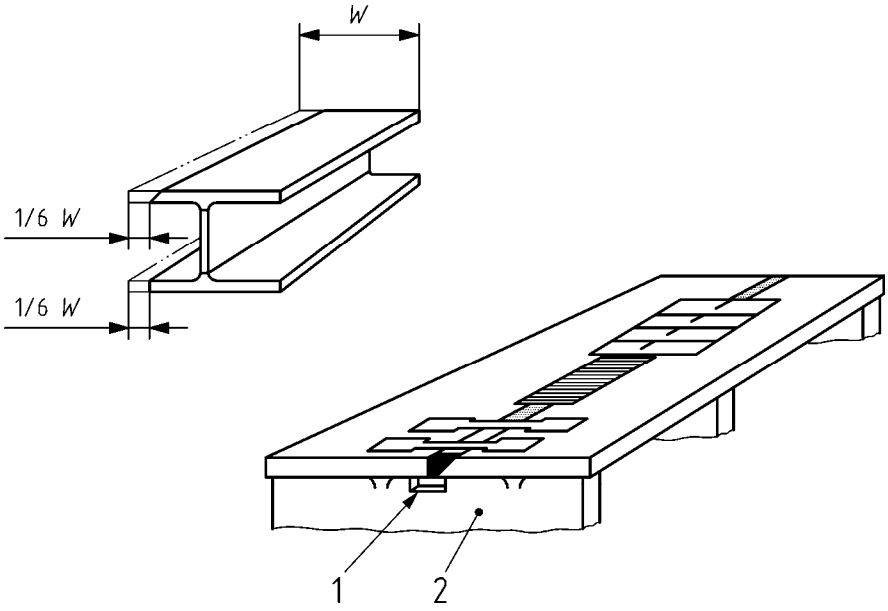
a) Longitudinal testing

Key

1 Backing (optional)

2 Strong backs (fillet welded on test plate)

W Flange width



b) Transverse testing

Key

1 Backing (optional)

2 Strong backs (fillet welded on test plates)

W Flange width

Figure E.6 — Welding assembly for longitudinal and transverse testing of sections

Annex F
(normative when option 18 is specified by the purchaser)

Weldability testing for steels of groups 2 and 3 - Bead-on-plate

F.1 Objective

The manufacturer shall carry out bead-on-plate tests and determination of HAZ hardness either:

a) as part of the programme to categorise the steel; and/or

b) to assess the response of individual heats in terms of hardenability during welding.

The purchaser shall specify which applies.

When called for as part of the programme to categorize the steel, the tests shall be performed on the same type and thickness of material as in Annex E. When used to assess the responses in terms of hardenability of individual heats the tests shall be performed on the thickest plate rolled from each heat.

F.2 Test material dimension

The minimum dimensions of each test piece shall be 300 mm long and 150 mm wide.

F.3 Welding method

This shall take the form of a mechanised autogenous tungsten inert gas arc welded (see E.2) bead-on-plate weld in accordance with Table F.1, the weld being made full length within 10 mm of the longitudinal centreline of the test piece in accordance with Figure F.1.

Before welding, the welding line along the centre of the plate shall be cleaned of dirt and mill scale by grinding or rubbing with emery paper. The preheat shall be measured and recorded immediately before welding.

Table F.1 — Bead-on-plate heat input and preheat conditions

Welding position	PA [a]
Electrode diameter (mm)	2.4
Arc voltage (V, d.c. neg.)	10 ± 0,5
Current (A)	200 ± 5
Travel speed (mm/min)	120 ± 5
Preheat: (°C maximum) thickness above 40 mm	125

[a] In accordance with EN ISO 6947.

F.4 Test condition

All testing shall be carried out with the test plate in the "as welded" condition.

F.5 Specific test requirements

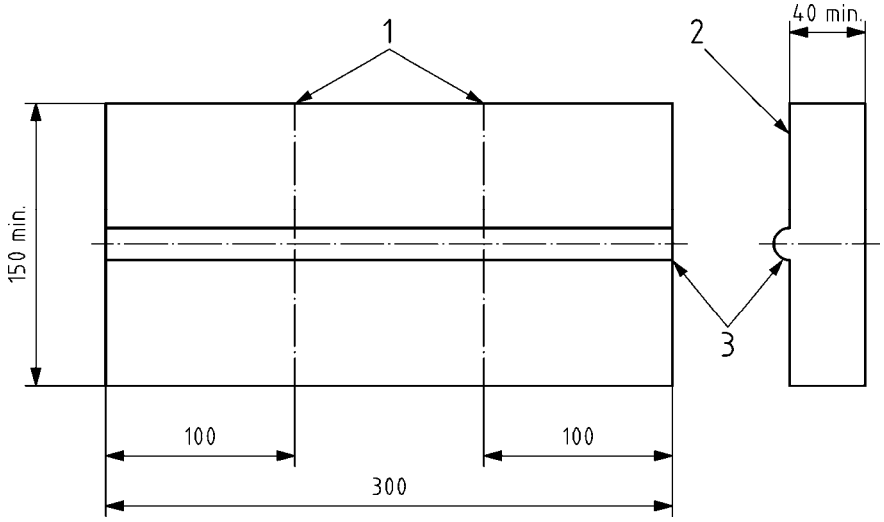
F.5.1 Macrosection and hardness tests

Cross sections shall be cut through the weld at 100 mm from each end of the weld. These shall be polished and etched to identify the fusion line. Vickers hardness indents shall be made in the HAZ and in the parent metal in accordance with EN ISO 6507-1 using a 10 kg load (HV10 = 98,07N) at the locations indicated in Figure F.1.

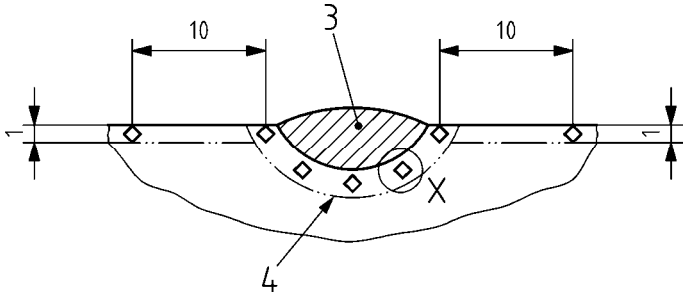
The centre of all indents should be as close as possible to, but shall be clear of, the fusion line.

NOTE Maximum hardness to be agreed between the manufacturer and the purchaser.

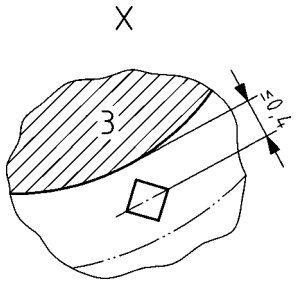
Dimensions in millimetres



a) Test plate



b) Typical detail for hardness surveys



c) Typical location of a hardness indentation

Key

1 Location for hardness surveys
2 Cleaned plate surface
3 Weld bead
4 Heat affected zone, HAZ

Figure F.1 — Detail of test plate and location of hardness indentations for bead-on-plate hardenability test (see F.3 and F.5)

Annex G
(normative when option 18 is specified by the purchaser)

Weldability testing for steels of groups 2 and 3 - Controlled thermal severity tests (CTS)

G.1 Objective

The manufacturer shall carry out CTS tests in order to assess the susceptibility of the material to HAZ hydrogen cracking. The tests shall be performed on the same type and thickness of plate as in Annex E. Additionally the purchaser may also specify further testing on thinner plate materials.

A series of tests shall be conducted to obtain a crack/no crack boundary which shall be defined in terms of preheat temperature to within 25 °C. The uncracked test apparently defining the boundary shall be repeated. If this test also gives an uncracked result no further testing shall be required. If cracking is observed in the duplicate test further tests shall be performed to define the boundary.

G.2 Test block dimensions

The general arrangement of the test block and related dimensions, together with surface finish requirements are detailed in Figure G.1 and Table G.1.

The rolling direction of the top and bottom plates shall be parallel to the direction of the test welds.

G.3 General welding details

G.3.1 Anchor welds

The anchor welds (Figure G.1) shall be made with a welding consumable having a yield strength equal to or greater than the yield strength of the material under test.

The anchor welds shall start and finish 10 mm from the corners of the top plate and shall be of the following throat sizes:

a) for plates up to 15 mm thick, a throat size of 6 mm;

b) for plates equal to or greater than 15 mm, a throat size of 13 mm.

The anchor welds shall be deposited using a procedure to avoid hydrogen cracking, controlling pre-heat, inter-pass and post-heating temperatures as necessary.

All consumables used for the anchor welds shall be dried in accordance with manufacturers' recommendations to give the lowest possible hydrogen levels. Details of the consumables and drying conditions shall be recorded.

The torque on the bolt in the test rig (see Figure G.1) shall be checked against the requirements of Table G.1 and the bolt tightened where necessary. The assembly shall be left for 12 h before further welding.

G.3.2 Test welds

Two test welds shall be performed on plates in the test assembly shown in Figure G.1.

The test assembly shall be preheated for welding, in a suitable oven. The surface temperature of the assembly shall be checked immediately prior to welding and the temperature of the top and bottom blocks in the test area shall not differ by more than 5 °C.

The test welds shall be deposited by either metal-arc welding with covered electrodes (process 111) or flux-cored arc welding (process 114) in accordance with EN ISO 4063 (see E.2). Welding shall take place in the flat position, the assembly being held at 45 ° (see Figure G.2). The test weld shall be made at a heat input of 1 kJ/mm and the welding consumables shall be dried in accordance with the manufacturer's recommendations to achieve an agreed level of hydrogen within the range 3 ml to 5 ml hydrogen/100 g or 10 ml to 15 ml hydrogen/100 g of deposited weld metal. The hydrogen levels achieved during test welding shall be determined and reported for test pieces being welded under the same conditions. All welding variables such as arc voltage, current travel speed and drying conditions of consumables shall be recorded.

Immediately after completion of the first test weld, the end of the block opposite to the weld shall be placed vertically in cold flowing water to a depth of about 60 mm (see Figure G.3). It shall be removed when the whole block has cooled to ambient temperature. The same procedure shall be followed for the second test weld.

A minimum period of 72 h shall be allowed to elapse between the first and second test weld and between the second test weld and sectioning.

G.4 Evaluation of the test welds

The test welds shall be cut from the assembly and sectioned for metallographic examination as shown in Figure G.4. The six cut faces shall be polished for micro examination and the HAZ and weld metal shall be examined for cracking at a minimum magnification of x 50. The absence of cracking shall be confirmed by examination at x 200 minimum.

One of the central section faces shall be examined first.

If cracking is detected, the length of such cracks should be measured preferably in accordance with BS 7363. If individual cracks are less than 5 % of the leg length of the weld (Figure G.5), the sample shall be reported as "Not cracked" and the next face examined.

If there are HAZ cracks longer than 5 % of the leg length, the test weld shall be reported as "cracked" and the metallographic examination terminated. All six faces shall be examined if no cracking is found.

If the weld metal is found to display root cracking of total length greater than 5 % of the throat thickness as measured preferably in accordance with BS 7363, the test piece is invalid and examination shall be terminated.

G.5 Hardness testing

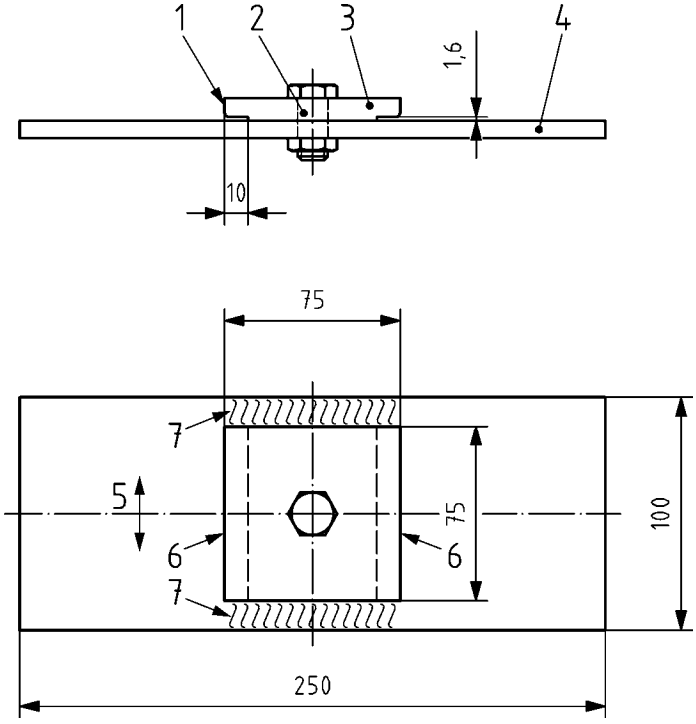
One of the central faces from each test weld shall be subjected to Vickers hardness testing at a load of 5 kg (HV5 = 49,03N) at the positions shown in Figure G.6. Hardness indentations shall be located in the grain coarsened HAZ and indentations either entering the weld metal or the grain refined HAZ shall be discarded and repeated.

All results shall be recorded, including the maximum, minimum and average values of hardness.

Table G.1 — CTS test pieces dimensions/conditions and tolerances

Dimensions/conditions	Value
Material thickness, *t*	6 mm min.
Top block	(75 ± 1) x (75 ± 1) x *t* mm^3
Bottom block	(250 ± 3) x (100 ± 3) x *t* mm^3
Root notch	
width	10 ± 0,5 mm
depth	1,6 ± 0,10 mm
Torque on bolt	100 ± 5 Nm
Surface finish on mating faces	3,2 μ R_a max.
Surface finish on area to be welded	6,3 μ R_a max.
Mating face gap	0,05 mm max.

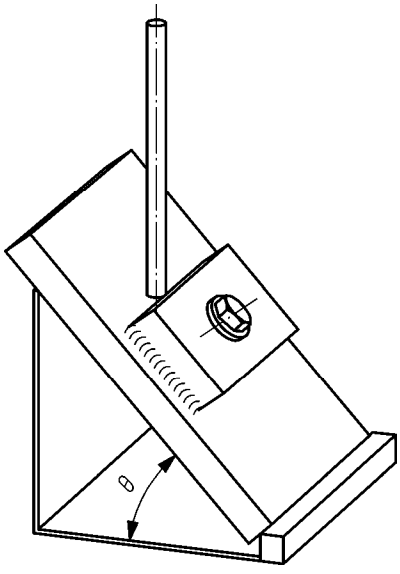
Dimensions in millimetres



Key

1 Root notch
2 Clearance hole 13 mm diameter
3 Top plate
4 Bottom plate
5 Preferred principal rolling direction
6 Test welds
7 Anchor welds

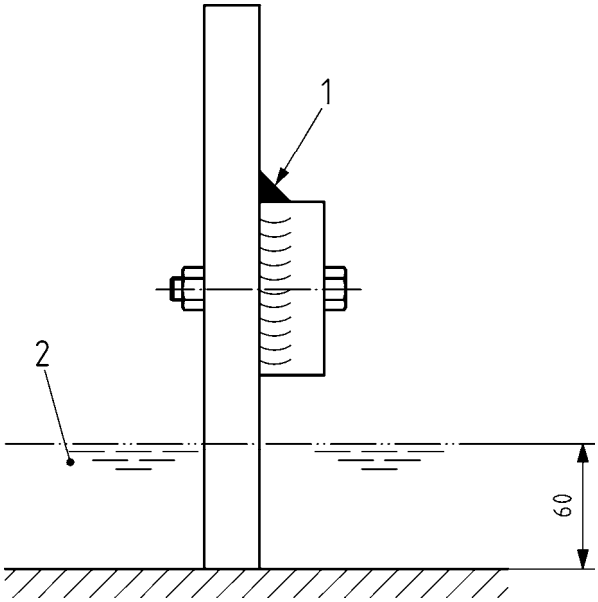
Figure G.1 — CTS test



$\theta = 45^{o} \pm 10^{o}$

Figure G.2 — Jig used to position test assembly

Dimensions in millimetres

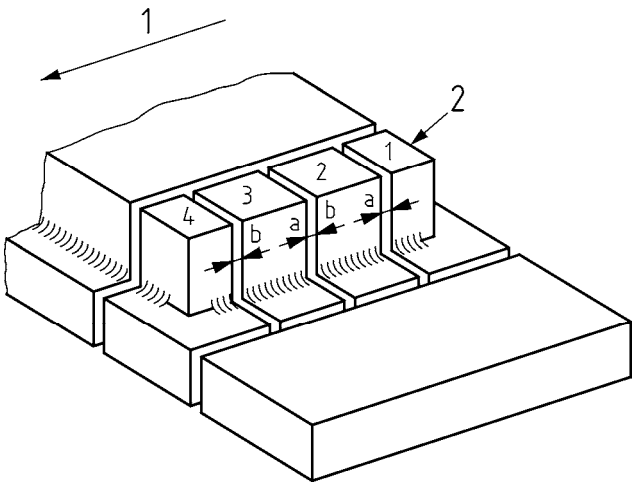


Key

1 Test weld
2 Water

Figure G.3 — Cooling bath arrangement

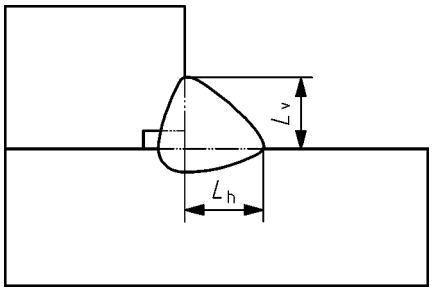
Dimensions in millimetres



Key

1 Welding direction
2 Faces polished and examined for cracking

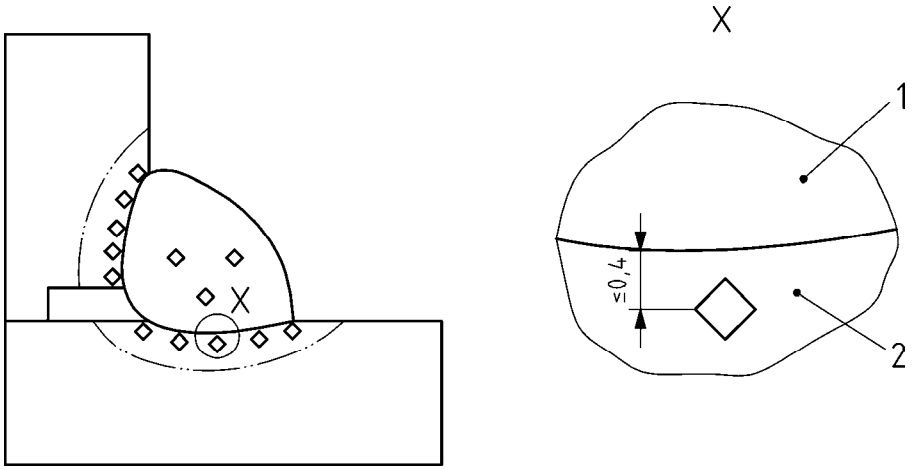
Figure G.4 — Sectioning of CTS test piece



$$\text{Leg length} = \frac{L_v + L_h}{2}$$

Figure G.5 — Measurement of leg length

Dimension in millimetres



Key

1 Weld
2 Heat affected zone, HAZ

Figure G.6 — Typical positions of hardness test indentations

Bibliography

[1] BS 7363, *Method for bead-on-plate (BOP) tests for welds*

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