

Welding — Recommendations for welding of metallic materials —

Part 2: Arc welding of ferritic steels

The European Standard EN 1011-2:2001, with the incorporation of amendment A1:2003 has the status of a British Standard

ICS 25.160.10

National foreword

This British Standard is the official English language version of EN 1011-2:2001 including amendment A1:2003. Together with BS EN 1011-1:1998 it supersedes BS 5135:1984 which is withdrawn.

It is important to that the BS EN 1011 series of standards uses the concept of heat input to the weld where as BS 5135 used arc energy. These two terms are not interchangeable and care should be taken when transposing data from BS 5135 to the BS EN 1011 standards.

Attention is also drawn to the fact that annex C of this standard details two methods for predicting preheat temperatures to avoid hydrogen cracking. The differences in origin and experience used to develop these two methods are detailed in C.1 and this can be used as a guide to their application. Traditionally in the UK the method detailed in BS 5135 has been used in conjunction with weld procedure approval in accordance with the BS EN 288 series. The method detailed in C.2 is that given in BS 5135, in an updated form.

The UK participation in its preparation was entrusted to Technical Committee WEE/17, Metal-arc welding of steel, which has the responsibility to

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

Cross-references

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This British Standard, having been prepared under the direction of the Engineering Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 March 2001

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**Welding — Recommendations for welding of metallic
materials — Part 2: Arc welding of ferritic steels**
(includes amendment A1:2003)

Soudage — Recommandations pour le soudage des
matériaux métalliques — Partie 2: Soudage à l'arc des
aciers ferritiques
(inclut l'amendement A1:2003)

Schweißen — Empfehlungen zum Schweißen metallischer
Werkstoffe — Teil 2: Lichtbogenschweißen von ferritischen
Stählen
(enthält Änderung A1:2003)

This European Standard was approved by CEN on 6 July 2000 and amendment A1 was approved by CEN on 20 November 2003..

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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Management Centre: rue de Stassart, 36 B-1050 Brussels

Contents

Page

Foreword	3
Introduction	4
1 Scope	4
2 Normative references	4
3 Terms and definitions	4
4 Symbols and abbreviations	5
5 Parent metal	6
6 Weldability factors	6
7 Handling of welding consumables	6
8 Weld details	6
9 Welds in holes or slots	7
10 Preparation of joint face	7
11 Alignment of butt welds before welding	8
12 Preheating	8
13 Tack welds	8
14 Temporary attachments	8
15 Heat input	9
16 Welding procedure specification	9
17 Identification	9
18 Inspection and testing	9
19 Correction of non-conforming welds	9
20 Correction of distortion	10
21 Post weld heat treatment	10
Annex A (informative) Possible detrimental phenomena resulting from welding of steels, not covered by other annexes	11
Annex B (informative) Guidance on joint detail design (when there is no application standard)	12
Annex C (informative) Avoidance of hydrogen cracking (also known as cold cracking)	15
Annex D (informative) Heat affected zone toughness and hardness	42
Annex E (informative) Avoidance of solidification cracking	49
Annex F (informative) Avoidance of lamellar tearing	51
Annex G (informative) References in the annexes	57
Bibliography	58

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 121, Welding, the Secretariat of which is held by DS.

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 July 2001, and conflicting national standards shall be withdrawn at the latest by July 2001.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

For relationship with EU Directive(s), see informative annex ZA, which is an integral part of this standard.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Foreword to amendment A1

This document EN 1011-2:2001/A1:2003 has been prepared by Technical Committee CEN/TC 121 Welding, the secretariat of which is held by DS.

This Amendment to the European Standard EN 1011-2:2001 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2004, and conflicting national standards shall be withdrawn at the latest by June 2004.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

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Introduction

This European Standard supplements EN 1011-1. It is issued with several annexes in order that it can be extended to cover the different types of steel which are produced to all the European steel standards for ferritic steels (see clause 5).

This standard gives general guidance for the satisfactory production and control of welds in ferritic steels. Details concerning the possible detrimental phenomena which can occur are given with advice on methods by which they can be avoided. This standard is generally applicable to all ferritic steels and is appropriate regardless of the type of fabrication involved, although the application standard can have additional requirements.

1 Scope

This European Standard gives guidance for manual, semi-mechanized, mechanized and automatic arc welding of ferritic steels (see clause 5), excluding ferritic stainless steels, in all product forms.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 288-2:1997, *Specification and approval of welding procedures for metallic materials — Part 2: Welding procedure specification for arc welding*.

EN 1011-1:1998, *Welding — Recommendations for welding of metallic materials — Part 1: General guidance for arc welding*.

EN 29692, *Metal-arc welding with covered electrode, gas-shielded metal-arc — Welding and gas welding — Joint preparations for steel (ISO 9692:1992)*.

EN ISO 13916, *Welding — Guidance for the measurement of preheating temperature, interpass temperature and preheat maintenance temperature (ISO 13916:1996)*.

CR ISO 15608, *Welding — Guidelines for a metallic material grouping system (ISO/TR 15608:2000)*.

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions listed in EN 1011-1:1998 and the following apply.

3.1

cooling time $t_{8/5}$

time taken, during cooling, for a weld run and its heat affected zone to pass through the temperature range from 800 °C to 500 °C

3.2

run out length

length of a run produced by the melting of a covered electrode

3.3

run out ratio R_r

ratio of the run out length to the length of electrode consumed

3.4

shape factor F_x

describes the influence of the form of a weld on the cooling time $t_{8/5}$. In the case of two-dimensional heat flow it is called F_2 and in the case of three-dimensional heat flow it is called F_3

3.5

three-dimensional heat flow

heat introduced during welding which flows parallel and perpendicular to the plate surface

3.6

transition thickness d_t

plate thickness at which the transition from three-dimensional to two-dimensional heat flow takes place

3.7

two-dimensional heat flow

heat introduced during welding which flows only parallel to the plate surface

3.8

preheat maintenance temperature T_m

minimum temperature in the weld zone which should be maintained if welding is interrupted

4 Symbols and abbreviations

Table 1 — Symbols and abbreviation

Symbols/Abbreviations	Terms	Units
CE	Carbon equivalent (see C.2.1)	%
CET	Carbon equivalent (see C.3.2)	%
D	Diameter	mm
d	Thickness of plate	mm
d_t	Transition thickness	mm
F_2	Shape factor for two-dimensional heat flow	—
F_3	Shape factor for three-dimensional heat flow	—
HAZ	Heat affected zone	—
HD	Diffusible hydrogen content	ml/100g deposited weld metal
Q	Heat input	kJ/mm
R_r	Run out ratio	—
$t_{8/5}$	Cooling time (from 800 °C to 500 °C)	s
t	Melting time of an electrode	s
T_i	Interpass temperature	°C
T_m	Preheat maintenance temperature	°C
T_o	Initial plate temperature	°C
T_p	Preheat temperature	°C
T_t	Impact transition temperature	°C
UCS	Unit of crack susceptibility	—
λ	Thermal conductivity	J/cm K s
ρ	Density	kg/m ³
C	Specific heat capacity	J/kg K

5 Parent metal

This standard applies to ferritic steels excluding ferritic stainless steels. This includes steels referenced in groups 1 to 7 of CR ISO 15608. When ordering steel it may be necessary to specify requirements concerning weldability, which can involve specifying additional requirements to those given in the relevant steel standard.

6 Weldability factors

The properties and the quality of welds are particularly influenced by the welding conditions. Thus, the following factors should be taken into consideration:

- joint design;
- hydrogen induced cracking;
- toughness and hardness of the heat affected zone (*HAZ*);
- solidification cracking;
- lamellar tearing;
- corrosion.

The mechanical and technological properties, in particular the hardness and toughness of the heat affected zone in a narrowly delineated area, can be influenced to a greater or lesser degree, compared with the properties of the parent metal and depend on the welding conditions. Experience and tests indicate that not only the properties of the narrow affected zone of lower strength and better flexibility, but also the load distribution effect of the tougher adjacent zones should be taken into account when assessing the ductility and safety against fracture of welded joints as this could affect the choice of steel.

7 Handling of welding consumables

When special protection or other treatment during storage or immediately prior to use is recommended by the consumable manufacturer, these consumables should be treated in accordance with the conditions detailed by the manufacturer.

When drying or baking, consumables should be removed from their original containers. After removal from the oven, the consumables should be protected from exposure to conditions conducive to moisture absorption. In the case of welding consumables that have been specially packaged, e.g. vacuum or other moisture resistance means, advice from the consumable manufacturer should be sought as to further steps required for drying and baking.

If controlled hydrogen levels are required, it is recommended that welders be issued with electrodes in heated quivers or sealed containers.

Drying ovens, e.g. for welding consumables, shall be provided with means of measuring the oven temperature.

8 Weld details

8.1 Butt welds

Butt joints between parts of unequal cross-section should be made and subsequently shaped such that a severe stress concentration at the junction is avoided.

Some examples of joint preparations for use with metal arc welding with covered electrodes and gas-shielded metal arc welding are given in EN 29692.

Partial penetration butt joints may be permitted dependant on the design specification. Consideration should be given to the choice of weld preparation and welding consumables in order to achieve the specified throat thickness.

Under fatigue conditions, partial penetration joints or the use of permanent backing material may be undesirable.

Backing material may consist of another steel part of the structure when this is appropriate.

When it is not appropriate to use part of the structure as backing material, the material to be used shall be such that detrimental effects on the structure are avoided and shall be agreed in the design specification.

Care shall be taken when using copper as a backing material as there is a risk of copper pick-up in the weld metal.

Where temporary or permanent backing material is employed, the joint shall be arranged in such a way as to ensure that complete fusion of the parts to be joined is readily achieved.

Wherever the fabrication sequence allows, tack welds attaching permanent backing should be positioned for subsequent incorporation into the weld (see clause 14 of EN 1011-1:1998).

8.2 Fillet welds

Unless otherwise specified, the edges and surfaces to be joined by fillet welding shall be in as close contact as possible since any gap may increase the risk of cracking. Unless otherwise specified, the gap shall not exceed 3 mm. Consideration shall be given to the need to increase the throat of the fillet weld to compensate for a large gap.

Unless otherwise specified, welding should not start/stop near corners, instead, it should be continued around the corners.

9 Welds in holes or slots

Due to the risk of cracking, holes or slots should not be filled with weld metal unless required by the design specification. Holes or slots that are required to be filled with weld metal shall only be filled after the first run has been found to be acceptable (see also B.4).

10 Preparation of joint face

10.1 General

Any large notches or any other errors in joint geometry which might occur shall be corrected by applying a weld deposit according to an approved welding procedure. Subsequently, they shall be ground smooth and flush with the adjacent surface to produce an acceptable finish.

Prefabrication primers (shop primers) may be left on the joint faces provided that it is demonstrated they do not adversely affect the welding.

10.2 Fusion faces

When shearing is used, the effect of work hardening should be taken into account and precautions shall be taken to ensure that there is no cracking of the edges.

Single-U and double-U and single-J weld preparations usually have to be machined. In assessing the methods of preparation and type of joint, the requirements of the chosen welding process should be taken into account.

10.3 Un-welded faces

Where a cut edge is not a fusion face, the effect of embrittlement from shearing, thermal cutting or gouging shall not be such as to adversely affect the workpiece.

Local hardening can be reduced by suitable thermal treatment or removed by mechanical treatment. The removal of 1 mm to 2 mm from a cut face normally eliminates the hardened layer. When using thermal cutting, local hardening can be lessened by a reduction in usual cutting speed or by preheating before cutting. If necessary the steel supplier should be consulted for recommendations on achieving a reduction in hardness.

U and J weld preparations as compared with V and bevel weld preparations serve to reduce distortion by virtue of the smaller amount of weld metal required. Likewise, double preparations are better than single preparations in that the weld metal can be deposited in alternate runs on each side of the joint. In the control of distortion, accuracy of preparation and fit-up of parts are important considerations, as well as a carefully planned and controlled welding procedure.

11 Alignment of butt welds before welding

Unless specified otherwise (e.g. in a welding procedure specification or an application standard), the root edges or root faces of butt joints shall not be out of alignment by more than 25 % of the thickness of the thinner material for material up to and including 12 mm thick, or by more than 3 mm for material thicker than 12 mm.

For certain applications and welding processes, closer tolerances may be necessary.

NOTE For the purposes of Directive 97/23/EC, an application standard means a relevant product standard.

12 Preheating

The points of temperature measurement shall be in accordance with EN ISO 13916 except that for all thicknesses the distance for measurement shall be at least 75 mm from the weld centre-line.

Particular attention should be paid to the need for preheating when making low heat input welds, e.g. tack welds.

13 Tack welds

It is recommended that the minimum length of a tack weld should be 50 mm, but for material thicknesses less than 12 mm the minimum length of a tack weld shall be four times the thicker part. For materials of thickness greater than 50 mm or of yield strength over 500 N/mm² consideration should be given to increasing the length and size of tack welds, which may involve the use of a two run technique. Consideration should also be given to the use of lower strength and/or higher ductility consumables when welding higher alloy steel.

14 Temporary attachments

If a thermal process is used to remove a temporary attachment or run on/off pieces after welding, sufficient attachment or run on/off piece shall be left to allow subsequent removal of the heat affected material by careful grinding.

15 Heat input

Heat input is calculated from the weld travel speed (see clause 19 of EN 1011-1:1998). When weaving with manual metal arc welding, the weave width should be restricted to three times the diameter of the core rod.

For multi-wire arc welding, the heat input is calculated as the sum of the heat input for each individual wire using the individual current and voltage parameters.

16 Welding procedure specification

The welding procedure specification shall comply with EN 288-2 and shall include the following:

- a) whether shop or site welding;
- b) maximum combined thickness (see C.2.4), if annex C.2 is applied; plate thickness, if annex C.3 is applied;
- c) heat input (see clause 15);
- d) hydrogen scale (see C.2.3 and C.3.2);
- e) tack welds (see clause 13).

17 Identification

Where the use of hard stamp marks is required by the contract, guidance on their location and size shall be given. Indentations used for marking in radiographic examination require equal consideration.

18 Inspection and testing

Due to the risk of delayed cracking, a period of at least 16 h is generally required before the final inspection is made of as-welded fabrications. The minimum time may be reduced for thin materials below 500 N/mm² yield strength or increased for materials of thickness greater than 50 mm or of yield strength over 500 N/mm². Whatever period is used it shall be stated in the inspection records.

Welds that have been heat-treated to reduce the hydrogen content or which have been stress relieved, need no additional time interval following the heat treatment before final inspection is made.

Tungsten inert gas welding (TIG) and other re-melting processes, if required for post weld treatment, shall be performed before final inspection.

Welds which are to be inspected and approved shall not be painted or otherwise treated until they have been accepted.

19 Correction of non-conforming welds

All welds which do not conform to the design specification shall be corrected.

NOTE Fracture mechanics or other assessment techniques may be used to determine whether a non-conforming weld needs to be corrected.

20 Correction of distortion

The temperature of heated areas, measured by appropriate methods, should be in accordance with the recommendations of the material supplier or the design specification.

21 Post weld heat treatment

When post weld heat treatment of welds is required but no application standard exists, the heat treatment details shall be stated in the design specification taking account of the effect on the properties of the parent metal, *HAZ* and weld metal.

Annex A (informative)

Possible detrimental phenomena resulting from welding of steels, not covered by other annexes

Possible detrimental phenomena resulting from welding	Causes	Counter measures
Stress relief heat treatment cracks	Carbide or nitride precipitation can occur during stress relief heat treatment if the stress relief heat treatment and/or steel composition are unfavourable. This can reduce the ductility of the steel such that relaxation of stress leads not only to plastic deformation but also to crack formation.	Reduce stress concentrations by grinding the toes of welds. Minimize the amount of coarse-grained <i>HAZ</i> by correct weld run sequence. Use optimum heat treatment procedures.
Corrosion a) General attack b) Stress corrosion cracking	Differences in chemical composition, grain size and stress levels between the weld and the parent material can lead to different corrosion rates. In most cases the weld and heat affected zone are attacked preferentially. Caused by a critical combination of stress, microstructure and environment.	Avoid large differences in plate and weld metal compositions. Avoid stress concentrations. Minimize weld stress levels. Reduce hardness levels.

Annex B (informative)

Guidance on joint detail design (when there is no application standard)

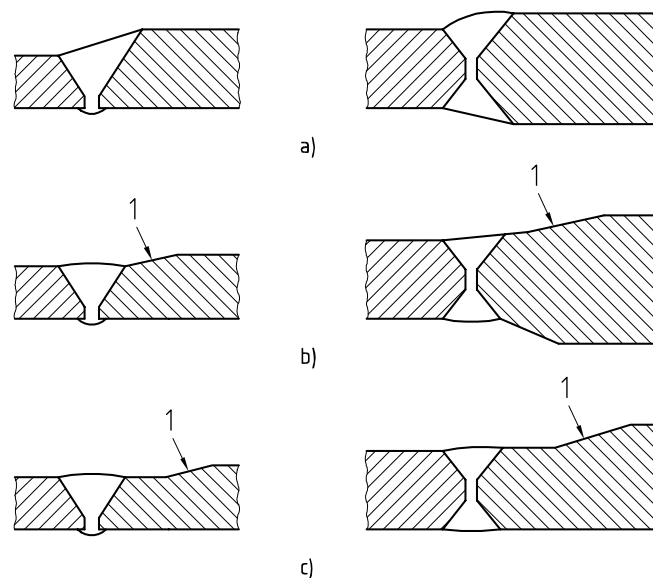
B.1 General

This annex may be used where no guidance from an application standard exists. Further information is given in other documents, e.g. EN 1708-1:1999, EN 1708-2. Particular guidance on design to avoid lamellar tearing is given by annex F.

B.2 Butt joints

Butt joints between parts of unequal cross-section, arranged in line, will result in a local increase in stress in addition to the stress concentration caused by the profile of the weld itself. If the centre planes of the two parts joined do not coincide, local bending also will be induced at the joint. If the stresses induced by these effects are unacceptable, then the parts should be shaped before welding by a slope of not greater than 1 in 4 so as to reduce the stresses. Examples of plain and shaped parts are shown in Figure B.1, where a) and b) are the more common types with c) being a special configuration to facilitate non-destructive testing.

A partial penetration butt weld which is welded from one side only should not be subjected to a bending moment about the longitudinal axis of a weld. It would cause the root of the weld to be in tension. Therefore it should be avoided and only used when permitted by the design. Under such circumstances it may be allowed by an application standard or contract.



Key

- 1 Slope approximately 1 in 4
- a) Slope in the weld
- b) Slope in the thicker plate
- c) Special configuration to facilitate non-destructive testing

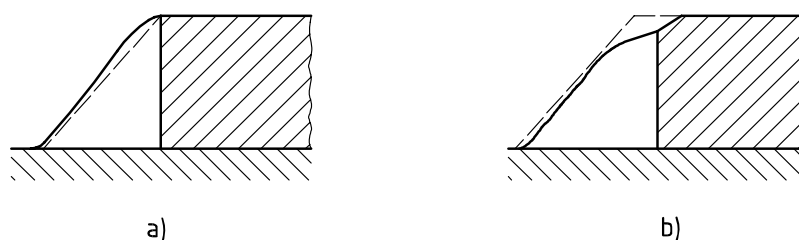
Figure B.1 — Butt joints of unequal cross-section

B.3 Fillet welds

The effective length of an open ended fillet weld should be taken as the overall length less twice the leg length. In any case, the effective length should be not less than 25 mm or four times the leg length whichever is the greater.

For fillet welded joints carrying a compressive load, it should not be assumed that the parts joined are in contact under the joint. For critical applications the use of a partial or even a full penetration butt weld should be considered.

Where the specified leg length of a fillet weld, at the edge of a plate or section, is such that the parent metal does not project beyond the weld, melting of the outer corner or corners, which reduces the throat thickness, is not allowed (see Figure B.2).



- a) Desirable
- b) Not acceptable because of reduced throat thickness

Figure B.2 — Fillet welds applied to the edge of a part

A single fillet weld should not be subjected to a bending moment about the longitudinal axis of the joint which would cause the root of the weld to be in tension.

Fillet welds connecting parts, where the fusion faces form an angle of more than 120° or less than 60°, should not be relied upon to transmit calculated loads at the full working stresses unless permitted to do so by the application standard.

The design throat thickness of a flat or convex fillet weld connecting parts, where the fusion faces form an angle between 60° and 120°, can be derived by multiplying the leg length by the appropriate factor as given in Table B.1.

Table B.1 — Factors for deriving design throat thickness of flat or convex fillet welds based on leg angle

Angle between fusion faces (degrees)			Factor
60	to	90	0,7
91	to	100	0,65
101	to	106	0,60
107	to	113	0,55
114	to	120	0,50

Due account should be taken of fabrication, transport, and erection stresses particularly for those fillet welds which have been designed to carry only a light load during service.

B.4 Holes and slots

In order to provide access for welding, the diameter of a hole or the width of a slot should be not less than three times the material thickness or 25 mm, whichever is the greater. Ends of slots should be rounded with a radius of not less than 1,5 times the material thickness or 12 mm, whichever is the greater. The distance between the edge of the part and the edge of the hole or slot, or between the adjacent slots or holes, should be not less than twice the thickness and not less than 25 mm for holes (see also clause 9).

Annex C (informative)

Avoidance of hydrogen cracking (also known as cold cracking)

C.1 General

This annex gives recommendations for the avoidance of hydrogen cracking.

In preparing this annex, full account was taken of the fact that many methods have been proposed for predicting preheat temperatures to avoid hydrogen cracking in non-alloyed, fine grained and low alloy steel weldments. Examples are given in IIW documents IX-1602-90 and IX-1631-91. Two methods are included in this annex as C.2 and C.3. Method A given in C.2 is based on extensive experience and data which is mainly, but not exclusively, for carbon manganese type steels. Method B given in C.3 is based on experience and data which is mainly, but not exclusively, for low alloy high strength steels. The differences in origin and experience used to develop these two methods can be used as a guide as to their application.

The method described under C.4 shall be used for creep resisting and low temperature steels.

The recommendations apply only to normal fabrication restraint conditions. Higher restraint situations may need higher preheat temperature or other precautions to prevent hydrogen cracking.

Clauses C.2 and C.3 refer to welding of parent metal at temperatures above 0 °C. When welding is carried out below this temperature it is possible that special requirements will be needed.

Alternative procedures to those derived from this annex may be used, for example lower preheat temperatures, provided they are supported by evidence of their effectiveness. The evidence should include all the factors also considered for the welding procedures as given in this annex.

C.2 Method A for the avoidance of hydrogen cracking in non-alloyed, fine grained and low alloy steels

C.2.1 Parent metal

Clause C.2 covers non-alloyed, fine grained and low alloy steels.

The range of chemical composition in percentage by weight of the main alloy constituents is:

— Carbon	0,05 to 0,25
— Silicon	0,8 max.
— Manganese	1,7 max.
— Chromium	0,9 max.
— Copper	1,0 max.
— Nickel	2,5 max.
— Molybdenum	0,75 max.
— Vanadium	0,20 max.

The determination of safe, but economic, preheating levels for the prevention of hydrogen cracking is critically dependent on an accurate knowledge of parent metal composition and carbon equivalent, CE , and on the weld metal composition (see C.2.9).

Carbon equivalent (CE) values for parent material are calculated using the following formula:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad \text{in \%} \quad (C.1)$$

Clause C.2 is applicable to steels with a carbon equivalent (CE) in the range 0,30 to 0,70.

If, of the elements in this formula, only carbon and manganese are stated on the mill sheet for carbon and carbon manganese steels, then 0,03 should be added to the calculated value to allow for residual elements. Where steels of different carbon equivalent or grade are being joined, the higher carbon equivalent value should be used.

This carbon equivalent formula may not be suitable for boron-containing steels.

C.2.2 Factors affecting cracking

The occurrence of hydrogen cracking depends on a number of factors: composition of the steel, the welding procedure, welding consumables and the stress involved. If the $t_{8/5}$ time (cooling time from 800 °C to 500 °C) associated with welding is too short, excessive hardening can occur in the heat affected zone. When the hydrogen in the weld is above a critical level the hardened zone can crack spontaneously under the influence of residual stress after the weld has cooled to near ambient temperature. Welding conditions may be selected to avoid cracking by ensuring that the heat affected zone cools sufficiently slowly, by control of weld run dimensions in relation to metal thickness, and if necessary, by applying preheat and controlling interpass temperature. Procedures for avoiding hydrogen cracking, as well as selecting cooling times through the transformation temperature range to avoid hardened and susceptible microstructures, may involve controlling cooling in the lower temperature part of the thermal cycle, typically from 300 °C to 100 °C, thereby beneficially influencing the evolution of hydrogen from the welded joint. In particular, this can be achieved by the application of a post-heat on completion of welding which is typically a maintenance of the preheat temperature.

The hydrogen content of the weld can be controlled by using hydrogen controlled welding processes and consumables, and also to some extent, by the application of post-heat as described previously.

Similar considerations apply to hydrogen cracking in the weld metal, where although hardening will be on a reduced scale, actual hydrogen and stress levels are likely to be higher than in the heat affected zone. In general, welding procedures selected to avoid heat affected zone hydrogen cracking will also avoid cracking in the weld metal. However, under some conditions such as high restraint, low CE steels, thick sections, or alloyed weld metal, weld metal hydrogen cracking can become the dominant mechanism.

The most effective assurance of avoiding hydrogen cracking is to reduce the hydrogen input to the weld metal from the welding consumables. The benefits resulting from a growing number of possibilities where no preheat temperature > 20 °C is required, can (as shown by examples in Table C.1) be increased by using filler materials with lower hydrogen content.

Table C.1 — Examples of maximum combined thickness (see C.2.4) weldable without preheat

Diffusible hydrogen content ^a ml/100 g of deposited metal	Maximum combined thickness			
	<i>CE</i> of 0,49		<i>CE</i> of 0,43	
	Heat input 1,0 kJ/mm	Heat input 2,0 kJ/mm	Heat input 1,0 kJ/mm	Heat input 2,0 kJ/mm
	mm	mm	mm	mm
> 15	25	50	40	80
10 ≤ 15	30	55	50	90
5 ≤ 10	35	65	60	100
3 ≤ 5	50	100	100	100
≤ 3	60	100	100	100
^a Measured in accordance with ISO 3690				

Welding conditions for avoiding hydrogen cracking in carbon manganese steels have been drawn up in graphical form in Figure C.2 for the normal range of compositions, expressed as carbon equivalent, covered by this standard and these conditions should be followed for all types of joint whenever practicable.

The conditions have been drawn up to take account of differences in behaviour between different steels of the same carbon equivalent (making allowances for scatter in hardness) and of normal variations between ladle and product analysis. They are valid for the avoidance of both heat affected zone and weld metal cracking in the majority of welding situations (see also C.2.9).

C.2.3 Hydrogen content of welding consumables

C.2.3.1 General

The manufacturer should be able to demonstrate that he has used the consumables in the manner recommended by the consumable manufacturer and that the consumables have been stored and dried or baked to the appropriate temperature levels and times.

C.2.3.2 Hydrogen scales

The hydrogen scale to be used for any arc welding process depends principally on the weld diffusible hydrogen content and should be as given in Table C.2. The value used should be stated by the consumable manufacturer in accordance with the relevant standard where it exists (or as independently determined) in conjunction with a specified condition of supply and treatment.

Table C.2 — Hydrogen scales

Diffusible hydrogen content ml/100 g of deposited metal	Hydrogen scale
> 15	A
10 ≤ 15	B
5 ≤ 10	C
3 ≤ 5	D
≤ 3	E