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Welding consumables — Tubular cored electrodes for gas-shielded and non-gas-shielded metal arc welding of high strength steels — Classification

Produits consommables pour le soudage — Fils-électrodes fourrés pour le soudage à l'arc avec ou sans gaz de protection des aciers à haute résistance — Classification

Reference number
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Foreword

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

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 3, *Welding consumables*.

This second edition cancels and replaces the first edition (ISO 18276:2005), which has been technically revised with the following changes:

— content has been aligned with ISO 17632:2015 and ISO 17634:2015;

— shielding gas designations have been updated;

— Table 3B has been extensively revised to align with existing Pacific Rim designations;

— new designations have been added to Table 3B;

— the T4 designator has been deleted from Table 4B;

— heat input ranges given in Table 8B have been modified to match current Pacific Rim values;

— fillet weld tests have been removed;

— an example using the Z designation has been added to Clause 11A.

Requests for official interpretations of any aspect of this document should be directed to the Secretariat of ISO/TC 44/SC 3 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

Introduction

This document proposes a classification system for tubular cored electrodes in terms of the tensile properties, impact properties, chemical composition of the all-weld metal, type of electrode core, shielding gas and welding position. The ratio of yield strength to tensile strength of the weld metal is generally higher than that of the parent metal. Note that matching weld metal yield strength to parent metal yield strength will not necessarily ensure that the weld metal tensile strength matches that of the parent metal. Where the application requires matching tensile strength, therefore, selection of the consumable should be made by reference to column 3 of Table 1A or Table 1B.

Note that the mechanical properties of all-weld metal test specimens used to classify tubular cored electrodes will differ from those obtained with production joints because of differences in welding procedure such as electrode size, width of weave, welding position and parent metal composition.

The classification in accordance with system A is mainly based on EN 12535[1]. The classification in accordance with system B is mainly based upon standards used around the Pacific Rim.

Welding consumables — Tubular cored electrodes for gas-shielded and non-gas-shielded metal arc welding of high strength steels — Classification

1 Scope

This document specifies the requirements for classification of tubular cored electrodes with or without a gas shield for metal arc welding of high-strength steels in the as-welded condition or in the post-weld heat-treated condition with a minimum yield strength higher than 550 MPa or a minimum tensile strength higher than 590 MPa. One tubular cored electrode can be tested and classified with different shielding gases, if used with more than one.

This document is a combined specification providing classification utilizing a system based upon the yield strength and an average impact energy of 47 J of the all-weld metal, or utilizing a system based upon the tensile strength and an average impact energy of 27 J of the all-weld metal.

— Subclauses and tables which carry the suffix letter "A" are applicable only to tubular cored electrodes classified under the system based upon the yield strength and an average impact energy of 47 J of the all-weld metal given in this document.

— Subclauses and tables which carry the suffix letter "B" are applicable only to tubular cored electrodes classified under the system based upon the tensile strength and an average impact energy of 27 J of the all-weld metal given in this document.

— Subclauses and tables which do not have either the suffix letter "A" or the suffix letter "B" are applicable to all tubular cored electrodes classified under this document.

It is recognized that the operating characteristics of tubular cored electrodes can be modified by the use of pulsed current but, for the purposes of this document, pulsed current is not used for determining the electrode classification.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 544, *Welding consumables — Technical delivery conditions for filler materials and fluxes — Type of product, dimensions, tolerances and markings*

ISO 3690, *Welding and allied processes — Determination of hydrogen content in arc weld metal*

ISO 6847, *Welding consumables — Deposition of a weld metal pad for chemical analysis*

ISO 6947:2011, *Welding and allied processes — Welding positions*

ISO 13916, *Welding — Guidance on the measurement of preheating temperature, interpass temperature and preheat maintenance temperature*

ISO 14175, *Welding consumables — Gases and gas mixtures for fusion welding and allied processes*

ISO 14344, *Welding consumables — Procurement of filler materials and fluxes*

ISO 15792-1:2000, *Welding consumables — Test methods — Part 1: Test methods for all-weld metal test specimens in steel, nickel and nickel alloys.* Amended by ISO 15792-1:2000/Amd 1:2011

ISO 80000-1:2009, *Quantities and units — Part 1: General*. Corrected by ISO 80000-1:2009/Cor 1:2011

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

4 Classification

Classification designations are based upon two approaches to indicate the tensile properties and the impact properties of the all-weld metal obtained with a given electrode. The two designation approaches include additional designators for some other classification requirements, but not all, as will be clear from the following subclauses. In most cases, a given commercial product can be classified under both systems. Then, either or both classification designations can be used for the product.

The classification includes all-weld metal properties obtained with a tubular cored electrode and appropriate shielding gas combination as given below. With the exception of the symbol for welding position, the classification of gas-shielded tubular cored electrodes is based on an electrode size of 1,2 mm or, if this size is not manufactured, the next larger diameter manufactured and the classification of self-shielded tubular cored electrodes is based on a diameter of 2,4 mm or the largest diameter manufactured if less than 2,4 mm.

4.1A Classification by yield strength and 47 J impact energy

The classification designation is divided into nine parts:

1) the first part (T) indicates a tubular cored electrode;

2) the second part gives a symbol indicating the strength and elongation of the all-weld metal in the as-welded or post-weld heat-treated condition (see Table 1A);

3) the third part gives a symbol indicating the impact properties of the all-weld metal (see Table 2);

4) the fourth part gives a symbol indicating the chemical composition of the all-weld metal (see Table 3A);

5) the fifth part gives a symbol indicating the type of electrode core (see Table 4A);

4.1B Classification by tensile strength and 27 J impact energy

The classification designation is divided into nine parts:

1) the first part (T) indicates a tubular cored electrode;

2) the second part gives a symbol indicating the strength and elongation of the all-weld metal in either the as-welded or the post-weld heat-treated condition (see Table 1B);

3) the third part gives a symbol indicating the impact properties of the all-weld metal (see Table 2). The symbol “U”, added as an optional supplemental designator at or near the end of the complete tubular cored electrode designation, indicates that the deposit meets an average optional requirement of 47 J at the designated Charpy test temperature;

4) the fourth part gives a symbol indicating the usability characteristics of the electrode (see Table 4B);

5) the fifth part gives a symbol indicating the welding position (see Table 5B);

6) the sixth part gives a symbol indicating the shielding gas (see 5.6);

7) the seventh part gives a symbol indicating the welding position (see Table 5A);

8) the eighth part gives a symbol indicating the hydrogen content of the deposited metal (see Table 6);

9) the ninth part gives a symbol indicating the post-weld heat treatment if this is applied (see 5.9A).

6) the sixth part gives a symbol indicating the shielding gas (see 5.6);

7) the seventh part gives a symbol indicating whether the classification tests were conducted in the as-welded condition (A) or the post-weld heat-treated condition (P);

8) the eighth part gives a symbol indicating the chemical composition of the all-weld metal (see Table 3B);

9) the ninth part gives a symbol indicating the hydrogen content of the deposited metal (see Table 6).

Electrodes may be classified under any number of classifications for either or both the as-welded and post-weld heat-treated condition.

In both systems, the electrode classification shall include all the compulsory section and may include the optional section, as outlined below.

4.2A Compulsory and optional sections in the classification by yield strength and 47 J impact energy

a) Compulsory section

This section includes the symbols for the type of product, the strength and elongation, the impact properties, the chemical composition, the type of electrode core, the shielding gas and the post-weld heat treatment, i.e. the symbols defined in 5.1, 5.2, 5.3A, 5.4, 5.5A, 5.6 and 5.9A.

b) Optional section

This section includes the symbols for the welding positions for which the electrode is suitable and the symbol for hydrogen content, i.e. the symbols defined in 5.7 and 5.8.

4.2B Compulsory and optional sections in the classification by tensile strength and 27 J impact energy

a) Compulsory section

This section includes the symbols for the type of product, the strength and elongation in the as-welded condition or post-weld heat-treated condition, the welding positions for which the electrode is suitable, the usability characteristics, the shielding gas, the impact properties and the chemical composition, i.e. the symbols defined in 5.1, 5.2, 5.3B, 5.4, 5.5B, 5.6, 5.7 and 5.9B.

b) Optional section

This section includes the symbol “U” to indicate that the weld metal will have an average of 47 J impact energy at the classification test temperature and the symbol for hydrogen content, i.e. the symbol “U” defined in 5.3B and the symbols defined in 5.8.

The designation, compulsory section and any chosen elements of the optional section, shall be used on packages and in the manufacturer’s literature and data sheets.

5 Symbols and requirements

5.1 Symbol for the product/process

The symbol for the tubular cored electrodes used in the metal arc welding process is the letter T.

5.2 Symbol for tensile properties of all-weld metal

The symbol in Table 1A or Table 1B indicates the yield strength, tensile strength and elongation of the all-weld metal, determined in accordance with Clause 6.

Table 1A — Symbol for tensile properties of all-weld metal (classification by yield strength and 47 J impact energy)

Symbol	Minimum yield strength[a] MPa	Tensile strength MPa	Minimum elongation[b] %
55	550	640 to 820	18
62	620	700 to 890	18
69	690	770 to 940	17
79	790	880 to 1 080	16
89	890	940 to 1 180	15

[a] For yield strength, the lower yield (R_{eL}) is used when yielding occurs, otherwise the 0,2 % proof strength($R_{p0,2}$) is used.

[b] Gauge length is equal to five times the test specimen diameter.

Table 1B — Symbol for tensile properties of all-weld metal (classification by tensile strength and 27 J impact energy)

Symbol	Minimum yield strength[a] MPa	Tensile strength MPa	Minimum elongation[b] %
59	490	590 to 790	16
62	530	620 to 820	15
69	600	690 to 890	14
76	680	760 to 960	13
78	680	780 to 980	13
83	745	830 to 1 030	12

[a] For yield strength, the lower yield (R_{eL}) is used when yielding occurs, otherwise the 0,2 % proof strength ($R_{p0,2}$) is used.

[b] Gauge length is equal to five times the test specimen diameter.

5.3 Symbol for impact properties of all-weld metal

5.3A Classification by yield strength and 47 J impact energy

The symbols in Table 2 indicate the temperature at which an impact energy of 47 J is achieved under the conditions given in Clause 6.

Three test specimens shall be tested. Only one individual value may be lower than 47 J but not lower than 32 J.

5.3B Classification by tensile strength and 27 J impact energy

The symbols in Table 2 indicate the temperature at which impact energy of 27 J is achieved in the as-welded condition or in the post-weld heat-treated condition under the conditions given in Clause 6.

Five test specimens shall be tested. The lowest and highest values obtained shall be disregarded. Two of the three remaining values shall be greater than the specified 27 J level, one of the three may be lower but shall not be less than 20 J. The average of the three remaining values shall be at least 27 J.

The addition of the optional symbol U, immediately after the symbol for condition of heat treatment, indicates that the supplemental requirement of 47 J impact energy at the normal 27 J impact test temperature has also been satisfied. For the 47 J impact requirement, the number of specimens tested and values obtained shall meet the requirement of 5.3A.

When an all-weld metal has been classified for a certain temperature, it automatically covers any higher temperature in Table 2.

Table 2 — Symbol for impact properties of all-weld metal

Symbol	Temperature for minimum average impact energy of 47 J [a] or 27 J [b] °C
Z	No requirements
A [a] or Y [b]	+ 20
0	0
2	– 20
3	– 30
4	– 40
5	– 50
6	– 60
7	– 70
8	– 80

[a] Classification by yield strength and 47 J impact energy (see 5.3A).

[b] Classification by tensile strength and 27 J impact energy (see 5.3B).

5.4 Symbol for chemical composition of all-weld metal

The symbols in Table 3A or Table 3B indicate the chemical composition of the all-weld metal, determined in accordance with Clause 7.

Table 3A — Symbol for chemical composition of all-weld metal (classification by yield strength and 47 J impact energy)

Symbol	**Chemical composition**, % (by mass) [a, b]								
	C	**Mn**	**Si**	**P**	**S**	**Ni**	**Cr**	**Mo**	**V**
MnMo	0,03 to 0,10	1,4 to 2,0	0,90	0,020	0,020	0,3	0,2	0,3 to 0,6	0,05
Mn1Ni	0,03 to 0,10	1,4 to 2,0	0,90	0,020	0,020	0,6 to1,2	0,2	0,2	0,05
Mn1,5Ni	0,03 to 0,10	1,1 to 1,8	0,90	0,020	0,020	1,3 to 1,8	0,2	0,2	0,05
Mn2,5Ni	0,03 to 0,10	1,1 to 2,0	0,90	0,020	0,020	2,1 to 3,0	0,2	0,2	0,05
1NiMo	0,03 to 0,10	1,4	0,90	0,020	0,020	0,6 to 1,2	0,2	0,3 to 0,6	0,05
1,5NiMo	0,03 to 0,10	1,4	0,90	0,020	0,020	1,2 to 1,8	0,2	0,3 to 0,7	0,05
2NiMo	0,03 to 0,10	1,4	0,90	0,020	0,020	1,8 to 2,6	0,2	0,3 to 0,7	0,05
Mn1NiMo	0,03 to 0,10	1,4 to 2,0	0,90	0,020	0,020	0,6 to 1,2	0,2	0,3 to 0,7	0,05
Mn2NiMo	0,03 to 0,10	1,4 to 2,0	0,90	0,020	0,020	1,8 to 2,6	0,2	0,3 to 0,7	0,05
Mn2NiCrMo	0,03 to 0,10	1,4 to 2,0	0,90	0,020	0,020	1,8 to 2,6	0,3 to 0,6	0,3 to 0,6	0,05
Mn2Ni1CrMo	0,03 to 0,10	1,4 to 2,0	0,90	0,020	0,020	1,8 to 2,6	0,6 to 1,0	0,3 to 0,6	0,05
Z[c]	Any other agreed composition								

[a] Single values shown in this table are maximum values.

[b] Cu ≤ 0,3, Nb ≤ 0,05.

[c] Consumables for which the chemical composition is not listed in this table shall be symbolized similarly and prefixed by the letter Z. The chemical composition ranges are not specified and therefore, it is possible that two electrodes with the same Z classification are not interchangeable.

Table 3B — Symbol for chemical composition of all-weld metal (classification by tensile strength and 27 J impact energy)

Symbol	Chemical composition, % (by mass) [a, b, c]								
	C	Mn	Si	P	S	Ni	Cr	Mo	V
3M2	0,12	1,25 to 2,00	0,80	0,030	0,030	—	—	0,25 to 0,55	—
3M3	0,12	1,00 to 1,75	0,80	0,030	0,030	—	—	0,40 to 0,65	—
4M2	0,15	1,65 to 2,25	0,80	0,030	0,030	—	—	0,25 to 0,55	—
N1M2	0,15	1,00 to 2,00	0,80	0,030	0,030	0,40 to 1,00	0,20	0,50	0,05
N2	0,15	1,00 to 2,00	0,40	0,030	0,030	0,50 to 1,50	0,20	0,20	0,05
N2M1	0,15	2,25	0,80	0,030	0,030	0,40 to 1,50	0,20	0,35	0,05
N2M2	0,15	2,25	0,80	0,030	0,030	0,40 to 1,50	0,20	0,20 to 0,65	0,05
N3C1M2	0,10 to 0,25	0,60 to 1,60	0,80	0,030	0,030	0,75 to 2,00	0,20 to 0,70	0,15 to 0,55	0,05
N3M1	0,15	0,50 to 1,75	0,80	0,030	0,030	1,00 to 2,00	0,15	0,35	0,05
N3M2	0,15	0,75 to 2,25	0,80	0,030	0,030	1,25 to 2,60	0,15	0,25 to 0,65	0,05
N4M1	0,12	2,25	0,80	0,030	0,030	1,75 to 2,75	0,20	0,35	0,05
N4M2	0,15	2,25	0,80	0,030	0,030	1,75 to 2,75	0,20	0,20 to 0,65	0,05
N4M21	0,12	1,25 to 2,25	0,80	0,030	0,030	1,75 to 2,75	0,20	0,50	—
N4C1M2	0,15	1,20 to 2,25	0,80	0,030	0,030	1,75 to 2,60	0,20 to 0,60	0,20 to 0,65	0,03
N4C2M2	0,15	2,25	0,80	0,030	0,030	1,75 to 2,75	0,60 to 1,00	0,20 to 0,65	0,05
N5M2	0,07	0,50 to 1,50	0,60	0,015	0,015	1,30 to 3,75	0,20	0,50	0,05
N6C1M4	0,12	2,25	0,80	0,030	0,030	2,50 to 3,50	1,00	0,40 to 1,00	0,05
G		1,75 min[d]	0,80 min[d]	0,030	0,030	0,50 min[d]	0,30 min[d]	0,20 min[d]	0,10 min[d]

[a] Single values shown in this table are maximum values.

[b] The weld metal shall be analysed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0,50 % (by mass).

[c] Al ≤ 1,8 for self-shielded electrodes.

[d] In order to meet the alloy requirements of G, the all-weld metal shall contain at least one of these elements. Additional chemical-composition requirements may be agreed between purchaser and supplier.

5.5 Symbol for type of electrode core or the usability characteristics of the electrodes

5.5A Classification by yield strength and 47 J impact energy

The symbols in Table 4A indicate the different types of tubular cored electrode relative to their core composition and slag characteristics. Manufacturers shall provide information on recommended polarity.

5.5B Classification by tensile strength and 27 J impact energy

The symbols in Table 4B indicate the usability characteristics of the electrode.

Table 4A — Symbol for type of electrode core (classification by yield strength and 47 J impact energy)

Symbol	Characteristics
R	Slow-freezing rutile slag
P	Fast-freezing rutile slag
B	Basic
M	Metal powder
Z	Other types
NOTE A description of the characteristics of each of the types of core is given in Annex C.	

Table 4B — Usability characteristics (classification by tensile strength and 27 J impact energy)

Usability designator	Shielding gas	Operating polarity	Transfer of droplet	Type of core	Welding position[a]	Characteristics
T1	Required	DC (+)	Spray type	Rutile	0 or 1	Low spatter loss, flat to slightly convex bead and high deposition rates
T5	Required	DC (+)	Globular type	Lime-fluoride	0 or 1	Slightly convex bead, a thin slag without completely covering the weld bead, good impact properties and hot and cold crack resistance compared with “T1”
T7	Not required	DC (−)	Small droplet to spray type	Not specified	0 or 1	High deposition rates and excellent resistance to hot cracking
T8	Not required	DC (−)	Small droplet or spray type	Not specified	0 or 1	Very good low-temperature impact properties
T11	Not required	DC (−)	Spray type	Not specified	0 or 1	Not recommended on thicknesses greater than 19 mm without maintaining preheat and interpass temperature control
T15	Required	DC (+)	Very fine droplet spray type	Metal	0 or 1	Core consisting of metal alloys and iron powder, and minimal slag cover
TG [b]	As agreed between purchaser and supplier					

NOTE A description of the usability characteristics of the electrodes is given in Annex D.

[a] See Table 5B.

[b] For electrodes that are not covered by any currently defined usability designator.

5.6 Symbol for shielding gas

The symbols for shielding gases shall be in accordance with ISO 14175, except that the symbol NO shall be used for non-gas shielded tubular cored electrodes.

5.7 Symbol for welding position

The symbols in Table 5A or Table 5B indicate the positions for which the electrode is suitable for classification to ISO 18276-A or ISO 18276-B.

Table 5A — Symbol for welding position (classification by yield strength and 47 J impact energy)

Symbol	Welding positions[a]
1	PA, PB, PC, PD, PE, PF and PG
2	PA, PB, PC, PD, PE and PF
3	PA and PB
4	PA
5	PA, PB and PG

[a] PA = Flat position
PB = Horizontal vertical position
PC = Horizontal position
PD = Horizontal overhead position
PE = Overhead position
PF = Vertical up position
PG = Vertical down position

In accordance with ISO 6947:2011.

Table 5B — Symbol for welding position (classification by tensile strength and 27 J impact energy)

Symbol	Welding positions[a]
0	PA and PB
1	PA, PB, PC, PD, PE, PF or PG, or both

[a] PA = Flat position
PB = Horizontal vertical position
PC = Horizontal position
PD = Horizontal overhead position
PE = Overhead position
PF = Vertical up position
PG = Vertical down position

In accordance with ISO 6947:2011.

5.8 Symbol for hydrogen content of deposited metal

The symbols in Table 6 indicate the hydrogen content determined in accordance with the method given in ISO 3690.

Table 6 — Symbol for hydrogen content of deposited metal

Symbol	Hydrogen content max. in ml/100 g of deposited metal
H5	5
H10	10
H15	15

When the hydrogen symbol is included in the designation, the manufacturer shall state in its literature what restrictions need to be placed on the conditions of storage and on current, arc voltage, electrode extension, polarity and shielding gas to remain within this limit.

5.9 Symbol for conditions of post-weld heat treatment

5.9A Classification by yield strength and 47 J impact energy

The letter T indicates that strength, elongation and impact properties in the classification of the all-weld metal fulfil the classification criteria after a post-weld heat treatment. The post-weld heat-treated conditions shall be as specified in 7.3A.

5.9B Classification by tensile strength and 27 J impact energy

If the electrode has been classified in the as-welded condition, the symbol A shall be added to the classification. If the electrode has been classified in the post-weld heat-treated condition, the conditions of the post-weld heat treatment shall be as specified in 7.3B, and the symbol P shall be added to the classification. If the electrode has been classified in both conditions, the symbol AP shall be added to the classification.

6 Rounding procedure

Actual test values obtained shall be subject to ISO 80000-1:2009, B.3, Rule A. If the measured values are obtained by equipment calibrated in units other than those of this document, the measured values shall be converted to the units of this document before rounding. If an average value is to be compared to the requirements of this document, rounding shall be done only after calculating the average. The rounded results shall fulfil the requirements of the appropriate table for the classification under test.

7 Mechanical tests

Tensile and impact tests shall be carried out on the weld metal in the as-welded condition or in the post-weld heat-treated condition using a type 1.3 all-weld metal test assembly in accordance with ISO 15792-1, using a 1,2 mm electrode in the case of gas-shielded electrodes or, if this size is not manufactured, the next larger diameter manufactured, and 2,4 mm in the case of self-shielded electrodes, or the largest size manufactured if less than 2,4 mm, and welding conditions and PWHT conditions as described in 7.1A or 7.1B, 7.2, and 7.3A or 7.3B

When diffusible hydrogen removal treatment is specified by the manufacturer, it shall be carried out in accordance with ISO 15792-1.

7.1 Preheating and interpass temperatures

7.1A Classification by yield strength and 47 J impact energy

Welding of the all-weld metal test specimen shall be executed in a temperature range from 120 °C to 180 °C, with the exception of the first layer in the test assembly which may be welded without preheat. The interpass temperature shall be measured using temperature indicator crayons, surface thermometers or thermocouples in accordance with ISO 13916.

The interpass temperature shall not exceed 180 °C. If, after any pass, this interpass temperature is exceeded, the test assembly shall be cooled in air to a temperature within the limits of the interpass temperature.

7.1B Classification by tensile strength and 27 J impact energy

Preheating and interpass temperatures shall be selected for the appropriate weld metal type from Table 7B. The preheating and interpass temperature shall be measured using temperature indicator crayons, surface thermometers or thermocouples in accordance with ISO 13916.

The interpass temperature shall not exceed the maximum temperature indicated in Table 7B. If, after any pass, this interpass temperature is exceeded, the test assembly shall be cooled in air to a temperature within the limits indicated. If below the interpass temperature, reheat to within the limits.

Table 7B — Preheating and interpass temperatures (classification by tensile strength and 27 J impact energy)

Symbol for composition	Preheat temperature °C	Interpass temperature °C
All except G	100 min	150 ± 15
G	Preheat and interpass temperature shall be as agreed between purchaser and supplier.	

7.2 Pass sequence

The procedures used for the welding of multi-run test assemblies shall conform to the requirements given in Table 8A or Table 8B.

Table 8A — Pass and layer sequence (classification by yield strength and 47 J impact energy)

Diameter mm	Passes per layer		No. of layers	Welding current[b, c] A
	First layer	Other[a] layers		
0,9 to 1,2	1 or 2	2 or 3	6 to 9	240 to 280
1,4 to 2,0	1 or 2	2 or 3	5 to 8	290 to 350

[a] The final layer may have four passes.

[b] The welding voltage will depend on the choice of shielding gas.

[c] The contact tube distance shall be 20 mm ± 2 mm.

Table 8B — Pass and layer sequence (classification by tensile strength and 27 J impact energy)

Diameter mm	Required average heat input kJ/mm	Passes per layer		No. of layers
		First layer	Other[a] layers	
0,8 0,9	0,8 to 1,4	1 or 2	2 or 3	6 to 9
1,0 1,2	1,0 to 2,0	1 or 2	2 or 3	6 to 9
1,4 1,6	1,0 to 2,2	1 or 2	2 or 3	5 to 8
2,0	1,4 to 2,6	1 or 2	2 or 3	5 to 8
2,4	1,6 to 2,6	1 or 2	2 or 3	4 to 8
2,8	2,0 to 2,8	1 or 2	2 or 3	4 to 7
3,2	2,2 to 3,0	1 or 2	2	4 to 7

[a] The final layer may have four passes.

7.3 Post-weld heat treatment (PWHT) condition

7.3A Classification by yield strength and 47 J impact energy

Test assemblies made with electrodes classified in the PWHT condition shall be heat treated at 560 °C to 600 °C for 1 h. The test assembly shall be left in the furnace to cool down to 300 °C. The heating rate shall not exceed 280 °C per hour and the cooling rate shall not exceed 195 °C per hour.

7.3B Classification by tensile strength and 27 J impact energy

Test assemblies made with electrodes classified in the PWHT condition shall be heat treated at (620 ± 15) °C for 1 h $^{+15}_{0}$ min. The furnace shall be at a temperature not higher than 315 °C when the test assembly is placed in it. The heating rate, from that point to the (620 ± 15) °C holding temperature, shall not exceed 280 °C per hour. When the holding time has been completed, the assembly shall be allowed to cool in the furnace to a temperature below 315 °C at a rate not exceeding 195 °C per hour. The assembly may be removed from the furnace at any temperature below 315 °C and allowed to cool in still air to room temperature.

8 Chemical analysis

Chemical analysis can be performed on any suitable all-weld metal test specimen. The referee method for preparation of the specimen shall be ISO 6847. Any analytical technique may be used, but in cases of dispute reference shall be made to established published methods.

9 Retesting

If any test fails to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for the retest may be taken from the original test assembly or from a new test assembly. For chemical analysis, retesting need be only for those specific elements that failed to meet their test requirement. If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this document for that classification.

In the event that, during preparation or after completion of any test, it is clearly determined that prescribed or proper procedures were not followed in preparing the weld test assembly or test specimen(s), or in conducting the tests, the test shall be considered invalid, without regard to whether the test was actually completed or whether the test results met, or failed to meet, the requirement. That test shall be repeated, following proper prescribed procedures. In this case, the requirement for doubling the number of test specimens does not apply.

10 Technical delivery conditions

Technical delivery conditions shall meet the requirements in ISO 544 and ISO 14344.

11 Examples of designations

The designation of the tubular cored electrode shall follow the principle given in the examples below.

11A Classification by yield strength and 47 J impact energy

EXAMPLE 1A

A tubular cored electrode (T) for gas-shielded metal arc welding deposits a weld metal with a minimum yield strength of 620 MPa (62) and a minimum average impact energy of 47 J at − 50 °C (5) in the as-welded condition and has a chemical composition of 1,7 % Mn, 1,4 % Ni (Mn1,5Ni). The electrode with a basic type of core (B) was tested under mixed gas (M21) and can be used in all positions (1). Hydrogen, determined in accordance with ISO 3690, does not exceed 5 ml/100 g of deposited metal (H5).

The designation will be:

ISO 18276-A - T62 5 Mn1,5Ni B M21 1 H5

Compulsory section:

ISO 18276-A - T62 5 Mn1,5Ni B M21

where

ISO 18276-A = document number, with classification by yield strength and 47 J impact energy;

T = tubular cored electrode/metal arc welding (see 5.1);

62 = strength properties (see Table 1A);

5 = impact properties (see Table 2);

Mn1,5Ni = chemical composition of all-weld metal (see Table 3A);

B = type of electrode core (see Table 4A);

M21 = shielding gas (see 5.6);

1 = welding position (see Table 5A);

H5 = hydrogen content (see Table 6).

11B Classification by tensile strength and 27 J impact energy

EXAMPLE 1B

A tubular cored electrode (T) for gas-shielded metal arc welding deposits a weld metal with a minimum tensile strength of 690 MPa (69) and a minimum average impact energy of 27 J at − 50 °C (5) in the as-welded condition (A). The symbol “U”, added as an optional supplemental designator, indicates that the deposit also meets a minimum optional requirement of 47 J at the designated Charpy test temperature (− 50 °C). The electrode with a usability designator (T5) was tested using Ar + 20 % CO_2 (M21) and can be used in all positions (1). The weld deposit has a chemical composition of 1,7 % Mn, 1,4 % Ni (N3M1). Hydrogen, determined in accordance with ISO 3690, does not exceed 5 ml/100 g of deposited metal (H5).

The designation will be:

ISO 18276-B - T695T5-1M21A-N3M1-UH5

Compulsory section:

ISO 18276-B - T695T5-1M21A-N3M1

where

ISO 18276-B = document number, with classification by tensile strength and 27 J impact energy;

T = tubular cored electrode/metal arc welding (see 5.1);

69 = tensile properties (see Table 1B);

5 = impact properties, 27 J minimum (see Table 2);

T5 = usability designator (see Table 4B);

1 = welding position (see Table 5B);

M21 = shielding gas (see 5.6);

A = tested in the as-welded condition;

N3M1 = chemical composition of all-weld metal (see Table 3B);

U = indicates (optional designator) that weld deposit in the as-welded condition will have impact properties of 47 J minimum at the classification test temperature;

H5 = hydrogen content (see Table 6).

EXAMPLE 2A

A tubular cored electrode (T) for gas-shielded metal arc welding deposits a weld metal with a minimum yield strength of 890 MPa (89) and a minimum average impact energy of 47 J at − 20 °C (2) in the as-welded condition and has a chemical composition of 2 % Mn, 2 % Ni, 0,5 % Cr and 0,5 % Mo. The electrode with a metal powder type of core (M) was tested under mixed gas (M21) and can be used in all positions except vertical down (2). Hydrogen, determined in accordance with ISO 3690, does not exceed 5 ml/100 g of deposited metal (H5).

The designation will be:

ISO 18276-A - T89 2 ZMn2NiCrMo M M21 2 H5

Compulsory section:

ISO 18276-A - T89 2 ZMn2NiCrMo M M21

where

ISO 18276-A = document number, with classification by yield strength and 47 J impact energy;

T = tubular cored electrode/metal arc welding (see 5.1);

89 = strength properties (see Table 1A);

2 = impact properties (see Table 2);

Z = chemical composition of all-weld metal not specified (see Table 3A);

Mn2NiCrMo = nominal chemical composition of all-weld metal (Table 3A);

M = type of electrode core (see Table 4A);

M21 = shielding gas (see 5.6);

2 = welding position (see Table 5A);

H5 = hydrogen content (see Table 6).

Annex A
(informative)

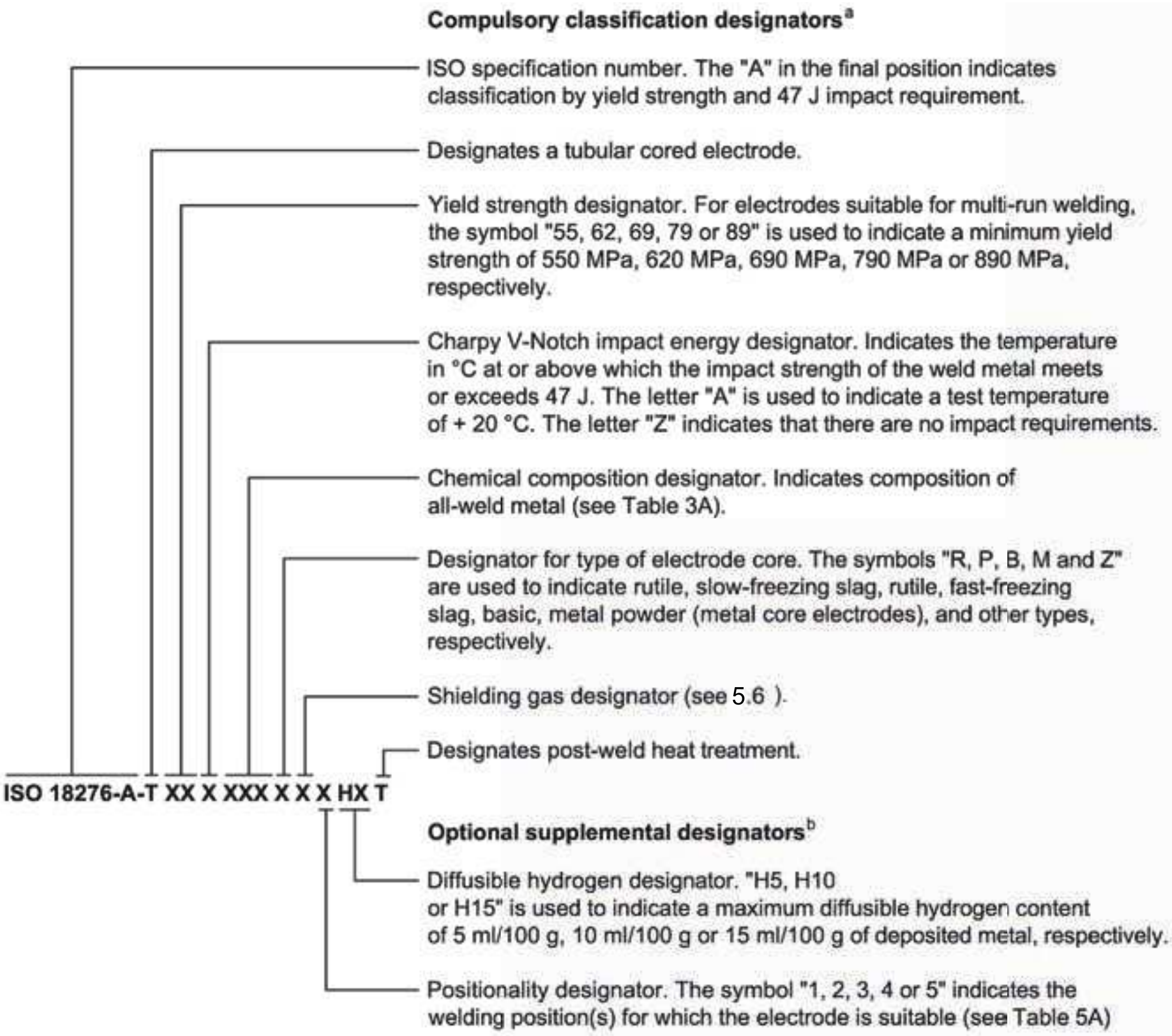
Classification systems

A.1 ISO 18276-A

The ISO 18276 classification system for tubular cored electrodes based upon yield strength and 47 J minimum impact strength is shown in Figure A.1.

A.2 ISO 18276-B

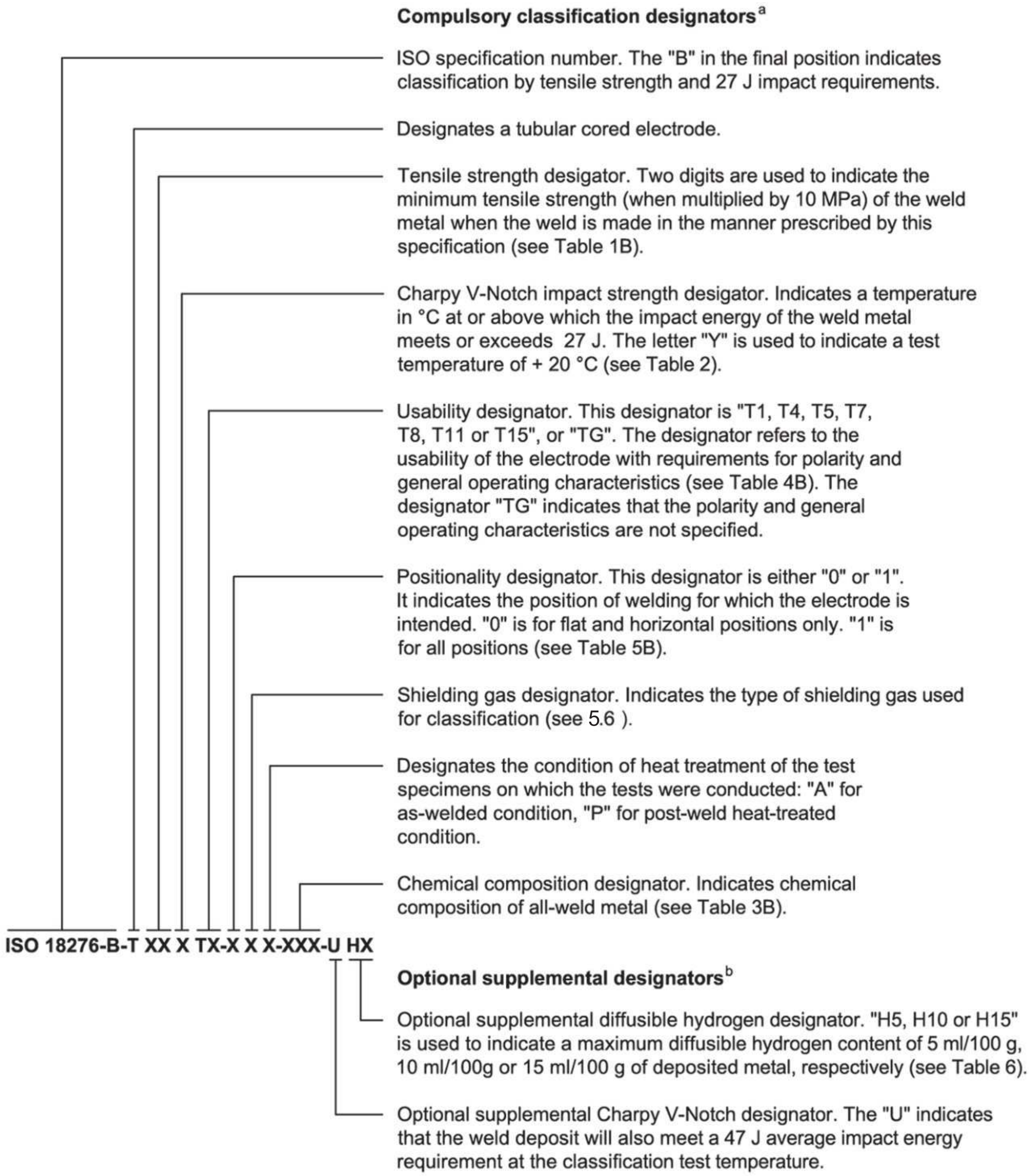
The ISO 18276 classification system for tubular cored electrodes based upon tensile strength and 27 J minimum impact strength is shown in Figure A.2.



a The combination of these designators constitutes the tubular cored electrode classification.

b These designators are optional and do not constitute part of the tubular cored electrode classification.

Figure A.1 — Classification system for tubular cored electrodes based upon yield strength and 47 J minimum impact energy



a The combination of these designators constitutes the tubular cored electrode classification.

b These designators are optional and do not constitute part of the tubular cored electrode classification.

Figure A.2 — Classification system for tubular cored electrodes based upon tensile strength and 27 J minimum impact energy

Annex B
(informative)

Description of composition designations for electrodes in the classification system based upon tensile strength and average impact energy of 27 J

B.1 XMX type

For electrodes containing Mo as the only alloy element, which differentiates them from non-alloy steel electrodes, the designation consists of an integer approximately equal to twice the nominal Mn content, followed by the letter “M” to indicate molybdenum, and a digit to indicate the nominal Mo level, as follows:

1 = about 0,25 % Mo = low Mo

2 = about 0,4 % Mo = medium Mo

3 = about 0,5 % Mo = high Mo

4 = about 0,7 % Mo = extra-high Mo

B.2 NXMX type

For electrodes in which Ni and Mo are the only significant alloying elements, the designation consists of “N” followed by an integer equal to about twice the nominal nickel content, and “M” followed by an integer to indicate the nominal Mo content in accordance with B.1.

B.3 NXCXMX type

For electrodes containing Ni, Cr and Mo, the designation consists of “N” followed by an integer equal to about twice the nominal Ni content, “C” followed by an integer equal to about twice the nominal Cr content, and “M” followed by an integer to indicate the nominal Mo level in accordance with B.1.

Annex C
(informative)

Description of types of electrode core in the classification system based upon yield strength and average impact energy of 47 J

C.1 R type

Tubular cored electrodes of the R type are characterized by a spray metal transfer, low spatter loss and a rutile-based slag that fully covers the weld bead. These tubular cored electrodes are designed for single- and multiple-pass welding in the flat and horizontal-vertical positions. Tubular cored electrodes of the R type are generally designed for use with carbon dioxide as shielding gas. However, argon/carbon dioxide mixtures can be used to improve arc transfer and reduce spatter.

C.2 P type

Tubular cored electrodes of the P type are similar to the R type, but the rutile-based slag is designed for fast-freezing characteristics that allow welding in all positions. These tubular cored electrodes are generally produced in smaller diameters and exhibit spray metal transfer when using carbon dioxide shielding gas. The running characteristics can be improved with the use of argon/carbon dioxide mixtures when recommended by the manufacturer.

C.3 B type

Tubular cored electrodes of the B type are characterized by a globular metal transfer, slightly convex bead shape, and a slag that may or may not cover the weld bead surface. These tubular cored electrodes are primarily used in the flat and horizontal-vertical welding positions with carbon dioxide or argon-based shielding-gas mixtures. The slag composition consists of fluorides and alkaline earth metal oxides. Weld deposits produced with these tubular cored electrodes have superior impact properties and crack resistance.

C.4 M type

Tubular cored electrodes of the M type are characterized by a very fine droplet spray metal transfer and minimal slag cover. The core of these tubular cored electrodes consists of metal alloys and iron powder along with other arc enhancers which enable these tubular cored electrodes to produce high deposition rates with an insensitivity to lack of fusion. These tubular cored electrodes are primarily used with argon/carbon dioxide shielding-gas mixtures in the flat and horizontal-vertical positions. However, welds in other positions are also possible using the short-circuiting or pulsed-arc modes of transfer.

C.5 Z type

Other types not covered by these descriptions.

Annex D
(informative)

Descriptions of types of usability characteristics in the classification system based upon tensile strength and average impact energy of 27 J

D.1 Electrodes having a usability designator of “T1”

These electrodes have rutile-type slags and are designed for single- and multiple-pass welding using DCEP polarity. The larger diameters (usually 2,0 mm and larger) are used for welding in the flat position and for welding fillet welds in the horizontal position. The smaller diameters (usually 1,6 mm and smaller) are used for welding in all positions. These electrodes are characterized by a spray transfer, low spatter loss, flat to slightly convex bead contour and a moderate volume of slag, which completely covers the weld bead. Electrodes of this classification have a rutile-base slag and produce high deposition rates.

D.2 Electrodes having a usability designator of “T5”

Electrodes of this type are used primarily for single- and multiple-pass welds in the flat position and for welding fillet welds in the horizontal position using DCEP or DCEN, depending on the manufacturer’s recommendations. These electrodes are characterized by a globular transfer, slightly convex bead contour and a thin slag that may not completely cover the weld bead. They have a lime-fluoride base slag. Weld deposits produced by these electrodes typically have impact properties and hot and cold crack resistance that are superior to those obtained with rutile-base slags. These electrodes, using DCEN, can be used for welding in all positions. However, the operator appeal of these electrodes is not as good as that of those with rutile-base slags.

D.3 Electrodes having a usability designator of “T7”

Electrodes of this type are self-shielded, operate on DCEN and have a small droplet to spray transfer. The slag system is designed to allow the larger sizes to be used for high deposition rates in the horizontal and flat positions, and to allow the smaller sizes to be used for all welding positions. The electrodes are used for single- and multiple-pass welding and produce very low sulfur weld metal which is very resistant to hot cracking.

D.4 Electrodes having a usability designator of “T8”

Electrodes of this type are self-shielded, operate on DCEN and have a small droplet or spray-type transfer. They are suitable for all welding positions and the weld metal has very good low-temperature notch toughness and crack resistance. They are used for single- and multiple-pass welds.

D.5 Electrodes having a usability designator of “T11”

Electrodes of this type are self-shielded, operate on DCEN and have a smooth spray-type transfer. They are general-purpose electrodes for single- and multiple-pass welding in all positions. Their use is generally not recommended on thicknesses greater than 19 mm, unless preheat and interpass temperature control are maintained. The electrode manufacturer should be consulted for specific recommendations.

D.6 Electrodes having a usability designator of “T15”

The core of these tubular electrodes consists of metal alloys and iron powder along with other arc enhancers which enable the electrodes to produce high deposition rates with good resistance to lack of fusion. They are characterized by a very fine droplet spray metal transfer and minimal slag cover. They are primarily used with argon/CO_2 shielding-gas mixtures in the flat and horizontal-vertical positions. However, welds in other positions are also possible using the short-circuiting or pulsed-arc modes of transfer. DCEN can also be used to advantage in some applications.

D.7 Electrodes having a usability designator of “TG”

This designation is for electrodes that have usability characteristics not covered by any currently defined classification. The requirements for this class are not specified. They are agreed between the purchaser and supplier.

Annex E
(informative)

Notes on hydrogen content

E.1 Hydrogen-induced cracks

Cracks in welded joints can be caused or significantly influenced by hydrogen. The risk of hydrogen-induced cracks increases with rising alloy content and stress level. Such cracks generally develop after the joint has become cold and are therefore termed cold cracks.

Under given material and stress conditions, the risk of cold cracking diminishes with decreasing hydrogen content of the weld metal.

E.2 Hydrogen sources in tubular cored electrodes

Assuming that the external conditions are satisfactory (weld areas clean and dry), the hydrogen in the weld metal stems from hydrogen-containing compounds in the consumables; in the case of basic tubular cored electrodes, the water taken up by the core is the main source.

The water and hydrogen-containing compounds dissociate in the arc and give rise to atomic hydrogen which is absorbed by the weld metal.

E.3 Effect of operating condition on hydrogen level

The manufacturer may specify boundary conditions for the tubular cored electrode diameter, and operating conditions applicable to each hydrogen level achieved. This does not exclude more than one level arising under different operating conditions. For example, shielding gases with high CO_2 contents generally give lower weld hydrogen levels than those with high argon contents, and this can lead to a tubular cored electrode being differently categorized when used with different gases. Categorization of tubular cored electrodes is intended to provide the best basis for the calculation of preheat levels, which characterizes a welding consumable by a single hydrogen level. Hydrogen levels generally decrease with increasing electrode extension and/or increasing arc voltage and/or with decreasing tubular cored electrode feed speed (current). Care should be taken, however, that electrode extension and/or arc voltage and/or tubular cored electrode feed speed (current) are not adjusted to levels outside the manufacturer's recommended limits.

Bibliography

[1] EN 12535:2000, *Welding consumables — Tubular cored electrodes for gas shielded metal arc welding of high strength steels — Classification*

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