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Welding consumables — Solid wire electrodes, tubular cored electrodes and electrode-flux combinations for submerged arc welding of high strength steels — Classification

Produits consommables pour le soudage — Fils-électrodes pleins, fils-électrodes fourrés et couples électrodes-flux pour le soudage à l'arc sous flux des aciers à haute résistance — Classification

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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 voluntary nature of standards, 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 third edition cancels and replaces the second edition (ISO 26304:2011), which has been technically revised. The main changes compared to the previous edition are as follows:

— the chemical compositions of a number of solid wire electrodes and all-weld metal from tubular cored electrode-flux combinations have been changed;

— H2 and H4 are now options for hydrogen content;

— an example of a Z designation has been added to Clause 11.

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 recognizes that there are two somewhat different approaches in the global market to classifying a given solid wire electrode, tubular cored electrode, and electrode-flux combination, and allows for either or both to be used, to suit a particular market need. Application of either type of classification designation (or of both where suitable) identifies a product as classified in accordance with this document. The classification in accordance with system A was originally based on EN 14295. The classification in accordance with system B is mainly based on standards used around the Pacific Rim. Future revisions aim to merge the two approaches into a single classification system.

This document provides a classification for the designation of solid wire electrodes in terms of their chemical composition, tubular cored electrodes in terms of the deposit composition obtained with a particular submerged arc flux, and, where required, electrode-flux combinations in terms of the yield strength, tensile strength, elongation, and impact properties of the all-weld metal deposit. The ratio of yield to tensile strength of weld metal is generally higher than that of parent material. Users should note that matching weld metal yield strength to parent metal yield strength does not necessarily ensure that the weld metal tensile strength matches that of the parent material. Thus, where the application requires matching tensile strength, selection of the consumable should be made by reference to column 3 of Table 1A or Table 1B, as appropriate.

Although combinations of electrodes and fluxes supplied by individual companies can have the same classification, it is possible that the combination of an electrode with a flux from one manufacturer and the same electrode with the flux from another manufacturer — both fluxes having the same classification — might not be interchangeable unless verified in accordance with this document. Two tubular cored wires of the same classification can likewise produce different results with the same flux.

The mechanical properties of the all-weld metal test specimens used to classify the electrode-flux combinations vary from those obtained in production joints because of differences in welding procedures such as electrode size, width of weave, welding position, and material composition.

Welding consumables — Solid wire electrodes, tubular cored electrodes and electrode-flux combinations for submerged arc welding of high strength steels — Classification

1 Scope

This document specifies requirements for classification of solid wire electrodes, tubular cored electrodes, and electrode-flux combinations (the all-weld metal deposits) in the as-welded condition and in the post-weld heat-treated condition for submerged arc welding of high strength steels with a minimum yield strength greater than 500 MPa or a minimum tensile strength greater than 570 MPa. One flux can be tested and classified with different electrodes. One electrode can be tested and classified with different fluxes. The solid wire electrode is also classified separately based on its chemical composition.

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

a) Clauses, subclauses and tables which carry the suffix letter "A" are applicable only to solid wire electrodes, tubular cored electrodes and the all-weld metal deposits classified to the system based on the yield strength and the average impact energy of 47 J for the all-weld metal obtained with electrode-flux combinations in accordance with this document.

b) Clauses, subclauses and tables which carry the suffix letter "B" are applicable only to solid wire electrodes, tubular cored electrodes and the all-weld metal deposits classified to the system based on the tensile strength and the average impact energy of 27 J for the all-weld metal obtained with electrode-flux combinations in accordance with this document.

c) Clauses, subclauses and tables which do not have either the suffix letter "A" or the suffix letter "B" are applicable to all solid wire electrodes, tubular cored electrodes and electrode-flux combinations classified in accordance with this document.

For comparison purposes, some tables include requirements for electrodes classified in accordance with both systems, placing individual electrodes from the two systems, which are similar in composition and properties, on adjacent lines in the particular table. In a particular line of the table that is mandatory in one system, the symbol for the similar electrode from the other system is indicated in parentheses. By appropriate restriction of the formulation of a particular electrode, it is often, but not always, possible to produce an electrode that can be classified in both systems, in which case the electrode, or its packaging, can be marked with the classification in either or both systems.

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

ISO 14174, *Welding consumables — Fluxes for submerged arc welding and electroslag welding — Classification*

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:

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

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

4 Classification

4.1 General

Classification designations are based on two approaches to indicate the tensile properties and the impact properties of the all-weld metal obtained with a given electrode-flux combination. The two designation approaches include additional designators for the chemical composition of a solid wire electrode or the chemical composition of the all-weld metal deposit obtained with a tubular cored electrode and a specific flux. The two designation approaches include additional designators for some other classification requirements, but not all, as is clear from the following clauses. A given commercial product may be classified to the classification requirements in both systems; then either or both classification designations may be used for the product.

The classification includes the all-weld metal properties obtained with a specific electrode-flux combination as given in 4.1A and 4.1B. A solid wire electrode shall be classified in accordance with its chemical composition in Table 3.

A tubular cored electrode shall be classified in accordance with the all-weld metal deposit composition in Table 4, obtained with a specific flux.

When the solid wire electrode or tubular cored electrode is classified in combination with a flux for submerged arc welding, the classification shall be prefixed with a symbol in accordance with Clause 5 as appropriate.

4.1A Classification by yield strength and 47 J impact energy

The classification is divided into seven parts:

1) the first part gives a symbol indicating the product or process to be identified;

4.1B Classification by tensile strength and 27 J impact energy

The classification is divided into six parts:

1) the first part gives a symbol indicating the product or process to be identified;

2) the second part gives a symbol indicating the tensile properties of the all-weld metal (see Table 1A);	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);	3) the third part gives a symbol indicating the impact properties of the all-weld metal in the same condition as specified for the tensile strength (see Table 2). The letter "U" after this designator indicates that the deposit meets an average optional requirement of 47 J at the designated impact test temperature;
4) the fourth part gives a symbol indicating the type of flux used (see 5.4);	4) the fourth part gives a symbol indicating the type of flux used (see 5.4);
5) the fifth part gives a symbol indicating the chemical composition of the solid wire electrode used (see Table 3) or of the all-weld metal deposited by a tubular cored electrode-flux combination (see Table 4);	5) the fifth part gives a symbol indicating the chemical composition of the solid wire electrode used (see Table 3), or of the all-weld metal deposited by a tubular cored electrode-flux combination (see Table 4);
6) the sixth part gives a symbol indicating the stress relief treatment if this is applied;	6) the sixth part gives an optional symbol indicating the diffusible hydrogen content of the weld metal determined in accordance with ISO 3690.
7) the seventh part gives an optional symbol indicating the diffusible hydrogen content of the weld metal determined in accordance with ISO 3690.	

5 Symbols and requirements

5.1 General

A solid wire electrode can be classified separately based on its chemical composition, as specified in Table 3. The all-weld metal deposit composition and mechanical properties obtained with a particular solid wire electrode or tubular cored electrode vary somewhat depending on the flux used. Accordingly, the classification of the all-weld metal deposit obtained with a particular solid wire electrode or tubular cored electrode can be different for different fluxes. However, deposit composition is only a classification requirement for tubular cored electrode-flux combinations.

5.2 Symbol for the product or process

The symbol for the electrode-flux combination or weld deposit produced by a solid wire electrode or by a tubular cored electrode using the submerged arc welding process with a specific flux, shall be the letter "S" placed at the beginning of the designation.

5.2A Classification by yield strength and 47 J impact energy

The symbol for the solid wire electrode for use in the submerged arc welding process shall be the letter “S” placed at the beginning of the solid wire electrode designation.

The symbol for the tubular cored electrode for use in the submerged arc welding process shall be the letter “T” placed at the beginning of the tubular cored electrode designation.

5.2B Classification by tensile strength and 27 J impact energy

The symbol for the solid wire electrode for use in the submerged arc welding process shall be the letters “SU” placed at the beginning of the solid wire electrode designation.

The symbol for the tubular cored electrode for use in the submerged arc welding process shall be the letters “TU” placed at the beginning of the tubular cored electrode designation.

5.3 Symbols for the tensile properties of the all-weld metal deposit

5.3A Classification by yield strength and 47 J impact energy

The symbols in Table 1A indicate the yield strength, tensile strength, and elongation of the all-weld metal in the as-welded condition or after stress relief treatment in accordance with 5.6A, determined in accordance with Clause 6 (A-side).

Table 1A — Symbol for the tensile properties (Classification by yield strength and 47 J impact energy)

Symbol[a]	Minimum[a] yield strength MPa	Tensile strength MPa	Minimum[b] elongation %
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 strength, 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.

5.3B Classification by tensile strength and 27 J impact energy

The symbols in Table 1B indicate the tensile strength, yield strength, and elongation of the all-weld metal in the as-welded condition or in the post-weld heat-treated condition in accordance with 5.6B, determined in accordance with Clause 6 (B-side).

Table 1B — Symbol for the tensile properties (Classification by tensile strength and 27 J impact energy)

Symbol[a]	Minimum yield strength[b] MPa	Tensile strength MPa	Minimum elongation[c] %
59X	490	590 to 790	16
62X	500	620 to 820	15
69X	550	690 to 890	14
76X	670	760 to 960	13
78X	670	780 to 980	13
83X	740	830 to 1 030	12

[a] X is “A” or “P”, where “A” indicates testing in the as-welded condition and “P” indicates testing in the post-weld heat-treated condition.

[b] For yield strength, the 0,2 % proof strength, $R_{p0,2}$, is used.

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

5.4 Symbol for the impact properties of the all-weld metal

The symbols in Table 2 indicate the temperature at which an average impact energy of 47 J or 27 J is achieved under the conditions given in Clause 6 in the as-welded condition or after post-weld heat treatment.

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

Symbol	Temperature for minimum average impact energy of 47 J[a, b] 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

a When classified in accordance with 5.4A.

b When classified in accordance with 5.4B.

5.4A Classification by yield strength and 47 J impact energy

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

5.4B Classification by tensile strength and 27 J impact energy

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 requirements of 5.4A.

5.5 Symbol for the type of welding flux

The symbols for welding flux shall be in accordance with ISO 14174.

5.6 Symbol for the chemical composition of solid wire electrodes and of the all-weld metal from tubular cored electrode-flux combinations

The symbols in Table 3 indicate the chemical composition of the solid wire electrode, determined under the conditions given in Clause 7.

The symbols in Table 4 indicate the chemical composition of the all-weld metal deposit obtained with the tubular cored electrode and a specific flux, determined under the conditions given in Clause 7.

Table 3 — Chemical composition requirements for solid wire electrodes

Symbol for chemical composition		Chemical composition % (by mass)[a]										
Classification by yield strength and 47 J impact energy ISO 26304-A	Classification by tensile strength and 27 J impact energy ISO 26304-B	C	Si	Mn	P	S	Cr	Ni	Mo	Cu[b]	V	Other
	SUN1M3[c,d]	0,10 to 0,18	0,20	1,70 to 2,40	0,025	0,025	—	0,40 to 0,80	0,40 to 0,65	0,35	—	—
	SUN2M1[c,d]	0,12	0,05 to 0,30	1,20 to 1,60	0,020	0,020	—	0,75 to 1,25	0,10 to 0,30	0,35	—	—
	SUN2M3[c,d]	0,15	0,25	0,80 to 1,40	0,020	0,020	0,20	0,80 to 1,20	0,40 to 0,65	0,40	—	—
	SUN2M11	0,07 to 0,15	0,05 to 0,30	1,20 to 1,60	0,020	0,020	—	0,75 to 1,25	0,10 to 0,30	0,35	—	—
	SUN2M31[c,d]	0,15	0,25	1,30 to 1,90	0,020	0,020	0,20	0,80 to 1,20	0,40 to 0,65	0,40	—	—
	SUN2M32[c,d]	0,15	0,25	1,60 to 2,30	0,020	0,020	0,20	0,80 to 1,20	0,40 to 0,65	0.40	—	—
	SUN2M33[c,d]	0,10 to 0,18	0,30	1,50 to 2,40	0,025	0,025	—	0,70 to 1,10	0,40 to 0,65	0,35	—	—
S2Ni1Mo[d,e]	(SUN2M2)	0,07 to 0,15	0,05 to 0,25	0,80 to 1,30	0,020	0,020	0,20	0,80 to 1,20	0,45 to 0,65	0,30	—	0,50
S3Ni1Mo[d,e]	(SUN2M2)	0,07 to 0,15	0,05 to 0,35	1,30 to 1,80	0,020	0,020	0,20	0,80 to 1,20	0,45 to 0,65	0,30	—	0,50
(S2Ni1Mo, S3Ni1Mo)	SUN2M2[c]	0,07 to 0,15	0,15 to 0,35	0,90 to 1,70	0,025	0,025	—	0,95 to 1,60	0,25 to 0,55	0,35	—	—
S3Ni1,5Mo[d,e]		0,07 to 0,15	0,05 to 0,25	1,20 to 1,80	0,020	0,020	0,20	1,20 to 1,80	0,30 to 0,50	0,30	—	0,50
	SUN3M2[c]	0,10	0,20 to 0,60	1,25 to 1,80	0,010	0,015	0,30	1,40 to 2,10	0,25 to 0,55	0,25	0,05	Ti: 0,10 Zr: 0,10 Al: 0,10
	SUN3M3[c,d]	0,15	0,25	0,80 to 1,40	0,020	0,020	0,20	1,20 to 1,80	0,40 to 0,65	0,40	—	—
	SUN3M31[c,d]	0,15	0,25	1,30 to 1,90	0,020	0,020	0,20	1,20 to 1,80	0,40 to 0,65	—	—	—

Table 3 *(continued)*

Symbol for chemical composition		Chemical composition % (by mass)[a]										
Classification by yield strength and 47 J impact energy ISO 26304-A	Classification by tensile strength and 27 J impact energy ISO 26304-B	C	Si	Mn	P	S	Cr	Ni	Mo	Cu[b]	V	Other
	SUN4C1M31	0,07 to 0,15	0,10 to 0,30	1,45 to 1,90	0,015	0,015	0,20 to 0,55	1,75 to 2,25	0,40 to 0,65	0,35	—	—
	SUN4M1[cd]	0,12 to 0,19	0,10 to 0,30	0,60 to 1,00	0,015	0,020	0,20	1,60 to 2,10	0,10 to 0,30	0,35	—	—
	SUN4M3[c]	0,15	0,25	1,30 to 1,90	—	—	—	1,80 to 2,40	0,40 to 0,65	0,40	—	—
	SUN4M31[c]	0,15	0,25	1,60 to 2,30	—	—	—	1,80 to 2,40	0,40 to 0,65	0,40	—	—
	SUN4M2[c]	0,10	0,20 to 0,60	1,40 to 1,80	0,010	0,015	0,55	1,90 to 2,60	0,25 to 0,65	0,25	0,04	Ti: 0,10 Zr: 0,10 Al: 0,10
S2Ni2Mo[e]		0,05 to 0,09	0,15	1,10 to 1,40	0,015	0,015	0,15	2,00 to 2,50	0,45 to 0,60	0,30	—	0,50
	SUN5M3[c]	0,10	0,20 to 0,60	1,40 to 1,80	0,010	0,015	0,60	2,00 to 2,80	0,30 to 0,65	0,25	0,03	Ti: 0,10 Zr: 0,10 Al: 0,10
	SUN5M4[c]	0,15	0,25	1,60 to 2,30	—	—	0,20	2,20 to 3,00	0,40 to 0,90	—	—	—
(S2Ni3Mo)	SUN6M1[c]	0,15	0,25	0,80 to 1,40	—	—	—	2,40 to 3,70	0,15 to 0,40	—	—	—
S2Ni3Mo[e]	(SUN6M1)	0,08 to 0,12	0,10 to 0,25	0,80 to 1,20	0,020	0,020	0,15	2,80 to 3,20	0,10 to 0,25	0,30	—	0,50
	SUN6M11[c]	0,15	0,25	1,30 to 1,90	—	—	—	2,40 to 3,70	0,15 to 0,40	—	—	—
	SUN6M3[c]	0,15	0,25	0,80 to 1,40	—	—	—	2,40 to 3,70	0,40 to 0,65	—	—	—
	SUN6M31[c]	0,15	0,25	1,30 to 1,90	—	—	—	2,40 to 3,70	0,40 to 0,65	—	—	—

Table 3 *(continued)*

Symbol for chemical composition		Chemical composition % (by mass)[a]										
Classification by yield strength and 47 J impact energy ISO 26304-A	Classification by tensile strength and 27 J impact energy ISO 26304-B	C	Si	Mn	P	S	Cr	Ni	Mo	Cu[b]	V	Other
	SUN1C1M1[c]	0,16 to 0,23	0,15 to 0,35	0,60 to 0,90	0,025	0,030	0,40 to 0,60	0,40 to 0,80	0,15 to 0,30	0,35	—	—
(S3Ni1,5CrMo)	SUN2C1M3[c]	0,15	0,40	1,30 to 2,30	—	—	0,05 to 0,70	0,40 to 1,75	0,30 to 0,80	—	—	—
S3Ni1,5CrMo[e]	(SUN2C1M3)	0,07 to 0,14	0,05 to 0,15	1,30 to 1,50	0,020	0,020	0,15 to 0,35	1,50 to 1,70	0,30 to 0,50	0,30	—	0,50
	SUN2C2M3[c]	0,15	0,40	1,00 to 2,30	—	—	0,50 to 1,20	0,40 to 1,75	0,30 to 0,90	—	—	—
	SUN4C2M3[c]	0,15	0,40	1,20 to 1,90	—	—	0,50 to 1,20	1,50 to 2,25	0,30 to 0,80	—	—	—
(S3Ni2,5CrMo)	SUN4C1M3[c]	0,15	0,40	1,20 to 1,90	0,018	0,018	0,20 to 0,65	1,50 to 2,25	0,30 to 0,80	0,40	—	—
S3Ni2,5CrMo[e]	(SUN4C1M3)	0,07 to 0,15	0,10 to 0,25	1,20 to 1,80	0,020	0,020	0,30 to 0,85	2,00 to 2,60	0,40 to 0,70	0,30	—	0,50
S1Ni2,5CrMo[e]		0,07 to 0,15	0,10 to 0,25	0,45 to 0,75	0,020	0,020	0,50 to 0,85	2,10 to 2,60	0,40 to 0,70	0,30	—	0,50
(S4Ni2CrMo)	SUN5C2M3[c]	0,10	0,40	1,30 to 2,30	—	—	0,60 to 1,20	2,10 to 3,10	0,30 to 0,70	—	—	—
S4Ni2CrMo[e]	(SUN5C2M3)	0,08 to 0,11	0,30 to 0,40	1,80 to 2,00	0,015	0,015	0,85 to 1,00	2,10 to 2,60	0,55 to 0,70	0,30	—	0,50
	SUN5CM3[c]	0,10 to 0,17	0,20	1,70 to 2,20	0,010	0,015	0,25 to 0,50	2,30 to 2,80	0,45 to 0,65	0,50	—	—
	SUN7C3M3[c]	0,08 to 0,18	0,40	0,20 to 1,20	—	—	1,00 to 2,00	3,00 to 4,00	0,30 to 0,70	0,40	—	—

Table 3 *(continued)*

Symbol for chemical composition		Chemical composition % (by mass)[a]										
Classification by yield strength and 47 J impact energy ISO 26304-A	Classification by tensile strength and 27 J impact energy ISO 26304-B	C	Si	Mn	P	S	Cr	Ni	Mo	Cu[b]	V	Other
	SUN10C1M3[c]	0,08 to 0,18	0,40	0,20 to 1,20	—	—	0,30 to 0,70	4,50 to 5,50	0,30 to 0,70	0,40	—	—
SZ	SUG	Any other agreed composition[f]										

[a] Single values are maxima.

[b] The copper limit includes any copper coating that may be applied to the electrode.

[c] The electrode shall be analysed for the specific elements for which values are shown. 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).

[d] This solid wire electrode composition, with a lower strength requirement, is also found in ISO 14171.

[e] If not specified: Al, Sn, As and Sb ≤ 0,02 % (by mass) each and Ti, Pb and N ≤ 0,01 % (by mass) each.

[f] Consumables for which the chemical composition is not listed shall be symbolized similarly and prefixed by the letters “SZ” or “SUG”, as appropriate. The chemical composition ranges are not specified and it is possible that two electrodes with the same classification are not interchangeable.

Table 4 — Chemical composition requirements for the all-weld metal from tubular cored electrode-flux combinations

Symbol for chemical composition		Chemical composition % (by mass)[a]										
Classification by yield strength and 47 J impact energy ISO 26304-A	Classification by tensile strength and 27 J impact energy ISO 26304-B	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Other
	TUN1M3[bc]	0,17	0,80	1,25 to 2,25	0,030	0,030	—	0,40 to 0,80	0,40 to 0,65	0,35	—	—
T3NiMo[d]		0,05 to 0,12	0,20 to 0,60	1,30 to 1,90	0,02	0,02	—	0,60 to 1,00	0,15 to 0,45	—	—	—
	TUN2M1	0,10	0,80	1,80	0,030	0,025	—	0,70 to 1,10	0,10 to 0,35	0,35	—	—
(T3Ni1Mo)	TUN2M2[b]	0,12	0,80	0,70 to 1,50	0,030	0,030	0,15	0,90 to 1,70	0,55	0,35	—	—
T3Ni1Mo[d]	(TUN2M2)	0,03 to 0,09	0,10 to 0,50	1,30 to 1,80	0,02	0,02	—	1,00 to 1,50	0,45 to 0,65	—	—	—
	TUN2M3[b]	0,17	0,80	1,25 to 2,25	0,030	0,030	—	0,70 to 1,10	0,40 to 0,65	0,35	—	—
	TUN2M11	0,14	0,80	1,80	0,030	0,025	—	0,70 to 1,10	0,10 to 0,35	0,35	—	—
	TUN3M1[b]	0,10	0,80	0,60 to 1,60	0,030	0,030	0,15	1,25 to 2,00	0,35	0,30	—	Ti + V + Zr: 0,03
	TUN3M2[b]	0,10	0,80	0,90 to 1,80	0,020	0,020	0,35	1,40 to 2,10	0,25 to 0,65	0,30	—	Ti + V + Zr: 0,03
	TUN3M21[b]	0,12	0,50	1,60 to 2,50	0,015	0,015	0,40	1,40 to 2,10	0,20 to 0,50	0,30	0,02	Ti: 0,03 Zr: 0,02
	TUN3M4[b]	0,12	0,50	1,60 to 2,50	0,015	0,015	0,40	1,40 to 2,10	0,70 to 1,00	0,30	0,02	Ti: 0,03 Zr: 0,02
	TUN3M11	0,14	0,80	1,60	0,030	0,025	—	1,40 to 2,10	0,10 to 0,35	0,35	—	—
T3Ni2MoV[d]		0,03 to 0,09	0,20	1,20 to 1,70	0,02	0,02	—	1,60 to 2,00	0,20 to 0,50	—	0,05 to 0,15	—
T3Ni2Mo[d]		0,03 to 0,09	0,40 to 0,80	1,30 to 1,80	0,02	0,02	—	1,80 to 2,40	0,20 to 0,40	—	—	—

Table 4 *(continued)*

Symbol for chemical composition		Chemical composition % (by mass)[a]										
Classification by yield strength and 47 J impact energy ISO 26304-A	Classification by tensile strength and 27 J impact energy ISO 26304-B	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Other
	TUN4M2[b]	0,10	0,80	0,90 to 1,80	0,020	0,020	0,65	1,80 to 2,60	0,20 to 0,70	0,30	—	Ti + V + Zr: 0,03
	TUN5M3[b]	0,10	0,80	1,30 to 2,25	0,020	0,020	0,80	2,00 to 2,80	0,30 to 0,80	0,30	—	Ti + V + Zr: 0,03
T3Ni3Mo[d]		0,03 to 0,09	0,20 to 0,70	1,60 to 2,10	0,02	0,02	—	2,70 to 3,20	0,20 to 0,40	—	—	—
	TUN1C1M1[b]	0,17	0,80	1,60	0,030	0,035	0,60	0,40 to 0,80	0,25	0,35	—	Ti + V + Zr: 0,03
	TUN4C1M3[b]	0,14	0,80	0,80 to 1,85	0,030	0,020	0,65	1,50 to 2,25	0,60	0,40	—	—
(T3Ni2,5CrMo)	TUN5CM3[b]	0,17	0,80	1,20 to 1,80	0,020	0,020	0,65	2,00 to 2,80	0,30 to 0,80	0,50	—	—
T3Ni2,5CrMo[d]	(TUN5CM3)	0,03 to 0,09	0,10 to 0,50	1,20 to 1,70	0,02	0,02	0,40 to 0,70	2,20 to 2,60	0,30 to 0,60	—	—	—
T3Ni2,5Cr1Mo[d]		0,04 to 0,10	0,20 to 0,70	1,20 to 1,70	0,02	0,02	0,70 to 1,20	2,20 to 2,60	0,40 to 0,70	—	—	—
TZ[d]	TUG[b]	Any other agreed composition[e]										

[a] Single values are maxima.

[b] The weld metal shall be analysed for the specific elements for which values are shown. 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] This composition symbol, for a tubular cored electrode, with a lower strength requirement, is also found in ISO 14171.

[d] Al, Sn, As, Sb and Ti shall be less than 0,02 % (by mass) each, and Pb and N shall be less than 0,01 % (by mass) each; total of other elements shall be 0,30 % (by mass) maximum.

[e] Consumables for which the chemical composition is not listed shall be symbolized similarly and prefixed by the letters "TZ" or "TUG", as appropriate. The chemical composition ranges are not specified and it is possible that two electrodes with the same classification are not interchangeable.

5.7 Symbol for the post-weld heat treatment

5.7A Classification by yield strength and 47 J impact energy

The letter "P" placed after the symbol for composition 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 at 560 °C to 600 °C for 1 h. The test piece shall be left in the furnace for cooling down to 300 °C.

5.7B Classification by tensile strength and 27 J impact energy

The symbol for the as-welded condition or for the post-weld heat-treated condition is included with the symbol for tensile properties (see Table 1B). The post-weld heat treatment conditions are specified in Table 5B.

NOTE Post-weld heat treatment can alter the impact properties of the weld metal from those obtained in the as-welded condition.

Table 5B — Post-weld heat treatment conditions (Classification by tensile strength and 27 J impact energy)

Symbol for solid wire electrode composition or tubular cored electrode deposit composition	Post-weld heat treatment temperature[a] °C
SUN1M3, TUN1M3	620 ± 15
SUN2M1	620 ± 15
SUN2M3, TUN2M3	620 ± 15
SUN2M31	620 ± 15
SUN2M32	620 ± 15
SUN2M33	620 ± 15
SUN2M2, TUN2M2	620 ± 15
SUN2M11	620 ± 15
TUN2M1	620 ± 15
TUN2M11	620 ± 15
TUN3M1	605 ± 15[b]
SUN3M2, TUN3M2	605 ± 15[b]
TUN3M11	620 ± 15
TUN3M21	605 ± 15[b]
SUN3M3	620 ± 15
SUN3M31	620 ± 15
TUN3M4	605 ± 15[b]
SUN4C1M31	565 ± 15

[a] Post-weld heat treatment time shall be $1\ \mathrm{h}_{0}^{+15\ \mathrm{min}}$ at the specified temperature. 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 temperature to the specified post-weld heat treatment temperature shall not exceed 220 °C/h. When the time at the post-weld heat treatment temperature is completed, the assembly shall be allowed to cool in the furnace to a temperature below 315 °C at a rate not exceeding 195 °C/h. The assembly may be removed from the furnace at any temperature below 315 °C and allowed to cool in still air to room temperature.

[b] This classification is normally used in the as-welded condition.

[c] As agreed by user and supplier.

Table 5B *(continued)*

Symbol for solid wire electrode composition or tubular cored electrode deposit composition	Post-weld heat treatment temperature[a] °C
SUN4M1	620 ± 15
SUN4M3	620 ± 15
SUN4M31	620 ± 15
SUN4M2, TUN4M2	605 ± 15[b]
SUN5M3, TUN5M3	605 ± 15[b]
SUN5M4	605 ± 15
SUN6M1	605 ± 15
SUN6M11	605 ± 15
SUN6M3	605 ± 15
SUN6M31	605 ± 15
SUN1C1M1, TUN1C1M1	565 ± 15[b]
SUN2C1M3	565 ± 15
SUN2C2M3	565 ± 15
SUN4C2M3	565 ± 15
SUN4C1M3, TUN4C1M3	565 ± 15[b]
SUN5CM3, TUN5CM3	565 ± 15[b]
SUN5C2M3	565 ± 15
SUN7C3M3	565 ± 15
SUN10C1M3	565 ± 15
SUG, TUG	—[c]

[a] Post-weld heat treatment time shall be $1\ \mathrm{h}_{0}^{+15\ \mathrm{min}}$ at the specified temperature. 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 temperature to the specified post-weld heat treatment temperature shall not exceed 220 °C/h. When the time at the post-weld heat treatment temperature is completed, the assembly shall be allowed to cool in the furnace to a temperature below 315 °C at a rate not exceeding 195 °C/h. The assembly may be removed from the furnace at any temperature below 315 °C and allowed to cool in still air to room temperature.

[b] This classification is normally used in the as-welded condition.

[c] As agreed by user and supplier.

5.8 Optional symbol for hydrogen content of deposited metal

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

Table 6 — Symbol for hydrogen content of deposited metal

Symbol	Hydrogen content ml/100 g deposited metal, max.
H2	2
H4	4
H5	5
H10	10
H15	15

When a hydrogen symbol in accordance with Table 6 is included in the classification, the manufacturer shall state in their literature what restrictions need to be placed on the conditions of storage and redrying, and on current, arc voltage, electrode extension, and polarity to remain within the limit for that symbol.

NOTE Information on possible risks of weld metal hydrogen cracking is given in Annex A.

6 Mechanical tests

6.1 Tensile and impact tests

6.1A Classification by yield strength and 47 J impact energy

Tensile and impact tests shall be carried out on weld metal in the as-welded condition using an all-weld metal test assembly type 1.3 in accordance with ISO 15792-1:2000 using 4,0 mm or nearest commercially available diameter wire electrodes.

6.1B Classification by tensile strength and 27 J impact energy

Tensile and impact tests shall be carried out on weld metal in the as-welded condition or in the post-weld heat-treated condition using an all-weld metal test assembly type 1.4 in accordance with ISO 15792-1:2000 using 4,0 mm or nearest commercially available diameter wire electrodes.

6.2 Preheating and interpass temperature

6.2A Classification by yield strength and 47 J impact energy

Welding of the all-weld metal test piece 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 preheating.

6.2B Classification by tensile strength and 27 J impact energy

Welding of the all-weld metal test piece shall be executed in a temperature range from 135 °C to 165 °C.

The interpass temperature shall be measured using temperature indicator crayons, surface thermometers or thermocouples in accordance with ISO 13916.

6.3 Welding conditions and pass sequence

The test assembly weld shall be completed in two passes per layer, except that the top layer may be completed in three passes, if necessary. Welding shall be performed by machine or automatic welding with straight progression (no weaving), in the flat position. Each pass shall be completed without interruption.

6.3A Classification by yield strength and 47 J impact energy

The weld test assembly shall be produced using a 4,0 mm, 3,2 mm, 3,0 mm or 2,8 mm electrode, whichever is the largest size being produced. Welding conditions for solid wire electrodes shall be as given in Table 7A. The length of the weld deposit shall be 200 mm minimum. Welding conditions for tubular cored electrodes shall be in accordance with the manufacturer's recommendations except that the interpass temperature specified in 6.2A is required.

Table 7A — Welding conditions for solid wire electrodes (classification by yield strength and 47 J impact energy)

Electrode diameter mm	Welding current[a] A ±20	Welding voltage[b] V ±1	Contact-tip-to-work distance mm	Travel speed mm/min
No corresponding values				
2,8	440	27	25 to 35	350 to 450
3,0	440	27	25 to 35	350 to 450
3,2	440	27	25 to 35	350 to 450
4,0	580	29	25 to 35	500 to 600
No corresponding values				

[a] If AC and DC operation are claimed, test welding shall be carried out using AC only; AC means alternating current; DC means direct current. The stated current range applies to the average value, not to instantaneous values.

[b] The stated voltage range applies to the average value, not to instantaneous values.

6.3B Classification by tensile strength and 27 J impact energy

Classification is based on the properties of weld metal produced from 4,0 mm electrodes, or the closest size to 4,0 mm if 4,0 mm is not produced. Welding conditions for solid wire electrodes shall be as given in Table 7B. Welding conditions for tubular cored electrodes shall be in accordance with the manufacturer's recommendations.

Table 7B — Welding conditions for solid wire electrodes (classification by tensile strength and 27 J impact energy)

Electrode diameter mm	Welding current[a] A ±50	Welding voltage[b] V	Contact-tip-to-work distance[c] mm	Travel speed mm/min
1,6	300	26 to 29	13 to 19	280 to 320
2,0	350	26 to 29	13 to 19	310 to 350
2,5 or 2,4	400	27 to 30	19 to 32	340 to 380
2,8	450	27 to 30	19 to 32	340 to 380
3,0	450	27 to 30	25 to 38	360 to 400
3,2	475	27 to 30	25 to 38	360 to 400
4,0	525	28 to 31	25 to 38	380 to 420
4,8	575	28 to 31	25 to 38	400 to 440
5,0	600	28 to 31	25 to 38	400 to 440
5,6	625	28 to 31	32 to 44	430 to 470
6,0	675	28 to 31	32 to 44	460 to 500
6,4	750	28 to 32	38 to 50	490 to 530

[a] A lower current may be used for the first layer. The stated current range applies to the average value, not to instantaneous values.

[b] AC. or DC, either polarity, may be used. The reference method shall be DC electrode positive. The stated voltage range applies to the average value, not to instantaneous values.

[c] If the electrode manufacturer recommends a contact-tip-to-work distance outside the specified range, that recommendation shall be followed to within ±6 mm.

7 Chemical analysis

Chemical analysis shall be performed on any specimen appropriate for the analytical method to be used. In case of dispute, specimens in accordance with ISO 6847 shall be used

Any analytical technique may be used, but in case of dispute, reference shall be made to established published methods.

The test results shall meet the requirements of Table 3 or Table 4 for the classification under test.

8 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.

9 Retests

If any test fails to meet the requirement(s), 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 sample or from one or two new test assemblies. For chemical analysis, retests need only be for those specific elements that failed to meet the 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 sample(s) or test specimen(s), or in conducting the tests, the test shall be considered invalid. This determination is made without regard to whether the test was actually completed, or whether the test results met, or failed to meet, the requirements. 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 be in accordance with ISO 544 and ISO 14344.

11 Examples of designation

The designation of the solid wire electrode, the solid wire electrode-flux combination, and the tubular cored electrode-flux combination, shall follow the principles given in the examples below.

11A Classification by yield strength and 47 J impact energy

EXAMPLE 1A:

A solid wire electrode-flux combination for submerged arc welding (S) deposits weld metal with a minimum yield strength of 620 MPa (62) and a minimum average impact energy of 47 J at −40 °C (4) produced with an aluminate-basic flux (AB) and a wire S2Ni2Mo. Hydrogen is determined in accordance with ISO 3690 and does not exceed 5 ml/100 g deposited metal (H5). The solid wire electrode-flux combination is designated:

ISO 26304-A - S 62 4 AB S2Ni2Mo H5

where

ISO 26304-A	is the number of this document, with classification by yield strength and 47 J impact energy
S	indicates submerged arc welding (see 5.2);
62	indicates the tensile properties (see Table 1A);
4	indicates the impact properties (see Table 2);
AB	is the type of welding flux (see 5.5);
S2Ni2Mo	is the chemical composition of the solid wire electrode (see Table 3);
H5	indicates the maximum diffusible hydrogen content (see Table 6).

EXAMPLE 2A:

A solid wire electrode-flux combination for submerged arc welding (S) deposits weld metal with a minimum yield strength in the post-weld heat-treated condition of 550 MPa (55) and a minimum average impact energy of 47 J at −40 °C (4) produced with an aluminate-basic flux (AB) and a wire S2Ni2Mo, with mechanical tests performed after post-weld heat treatment (P). Hydrogen is not specified. The solid wire electrode-flux combination is designated:

11B Classification by tensile strength and 27 J impact energy

EXAMPLE 1B:

A solid wire electrode-flux combination for submerged arc welding (S) deposits weld metal with a tensile strength of 690 MPa to 830 MPa in the as-welded condition (69A) and a minimum average impact energy of 27 J at −40 °C (4) produced with an aluminate-basic flux (AB) and a solid wire electrode SUN2M2. Hydrogen is determined in accordance with ISO 3690 and does not exceed 5 ml/100 g deposited metal (H5). The solid wire electrode-flux combination is designated:

ISO 26304-B - S 69A 4 AB SUN2M2 H5

where

ISO 26304-B	is the number of this document, with classification by tensile strength and 27 J impact energy;
S	indicates submerged arc welding (see 5.2);
69A	indicates the tensile properties in the as-welded condition (see Table 1B);
4	indicates the impact properties (see Table 2);
AB	is the type of welding flux (see 5.5);
SUN2M2	indicates a solid wire electrode of chemical composition N2M2 (see Table 3) for submerged arc welding;
H5	indicates the maximum diffusible hydrogen content (see Table 6).

EXAMPLE 2B:

A solid wire electrode-flux combination for submerged arc welding (S) deposits weld metal with a tensile strength in the post-weld heat-treated condition of 620 MPa to 760 MPa (62P) and a minimum average impact energy of 27 J at −40 °C (4) produced with an aluminate-basic flux (AB) and a solid wire electrode SUN2M2. Hydrogen is not specified. The solid wire electrode-flux combination is designated:

ISO 26304-A - S 55 4 AB S2Ni2Mo P

EXAMPLE 3A:

A solid wire electrode complying with the chemical requirement of S2Ni2Mo in Table 3 is designated:

ISO 26304-A - S2Ni2Mo

EXAMPLE 4A:

A tubular cored electrode-flux combination for submerged arc welding (S) deposits weld metal with a minimum yield strength of 620 MPa (62) and a minimum average impact energy of 47 J at −40 °C (4) produced with an aluminate-basic flux (AB) and the all-weld metal chemical composition T3Ni2Mo. Hydrogen is determined in accordance with ISO 3690 and does not exceed 5 ml/100 g deposited metal (H5). The tubular cored electrode-flux combination is designated:

ISO 26304-A - S 62 4 AB T3Ni2Mo H5

where

ISO 26304-A	is the number of this document, with classification by yield strength and 47 J impact energy;
S	indicates submerged arc welding (see 5.2);
62	indicates the tensile properties (see Table 1A);
4	indicates the impact properties (see Table 2);
AB	is the type of welding flux (see 5.5);
T3Ni2Mo	is the chemical composition of the all-weld metal deposited with the tubular cored electrode-flux combination (see Table 4);
H5	indicates the maximum diffusible hydrogen content (see Table 6).

EXAMPLE 5A:

A solid wire electrode with a chemical composition outside the limits given in Table 3 (Z) with a nominal composition 0,1 %C, 0,05 %Si, 1,5 %Mn, 0,6 %Cr, 0,5 %Mo and 2,5 %Ni (3Ni2,5CrMoSi0,05) is designated:

ISO 26304-B - S 62P4 AB SUN2M2

EXAMPLE 3B:

A solid wire electrode complying with the chemical requirement of N2M2 in Table 3 is designated:

ISO 26304-B - SUN2M2

EXAMPLE 4B:

A tubular cored electrode-flux combination for submerged arc welding (S) deposits weld metal with a tensile strength of 690 MPa to 830 MPa in the as-welded condition (69A) and a minimum average impact energy of 27 J at −40 °C (4) produced with an aluminate-basic flux (AB) and the all-weld metal chemical composition N3M2. Hydrogen is determined in accordance with ISO 3690 and does not exceed 5 ml/100 g deposited metal (H5). The solid wire electrode-flux combination is designated:

ISO 26304-B - S 69A4 AB TUN3M2 H5

where

ISO 26304-B	is the number of this document, with classification by tensile strength and 27 J impact energy;
S	indicates submerged arc welding (see 5.2);
69A	indicates the tensile properties in the as-welded condition (see Table 1B);
4	indicates the impact properties (see Table 2);
AB	is the type of welding flux (see 5.5);
TUN3M2	indicates the chemical composition of the all-weld metal deposited with the tubular cored electrode-flux combination (see Table 4);
H5	indicates the maximum diffusible hydrogen content (see Table 6).

ISO 26304-A - S Z 3Ni2,5CrMoSi0,05

where

ISO 26304-A	is the number of this document with classification by yield strength and 47 J impact energy;
S	indicates submerged arc welding (see 4.1);
Z	indicates that the chemical composition ranges are not specified (see Table 3);
3Ni2,5CrMoSi0,05	indicates the nominal chemical composition of the solid wire electrode

Annex A
(informative)

Possible risk of weld metal hydrogen cracking

The user should note that, in modern high-strength steels, the risk of hydrogen cracking tends to be greater in the weld metal than in the parent steel heat-affected zone (HAZ). It is possible that procedures developed to minimize the risk of hydrogen cracking in the HAZ are not sufficient to avoid cracking in the weld metal. In particular, steels with yield strengths of about 700 MPa and above are particularly at risk and require special safe welding procedures to be developed and qualified. Research work has shown that weld metal hydrogen contents significantly less than 5 ml/100 g of weld metal can be required to help ensure crack-free deposits.

Manufacturers and suppliers of submerged arc welding consumables designed for these steels should be consulted to establish the necessary working practices for storage, handling, and use of consumables to produce the lowest possible weld metal hydrogen contents. It should be noted that welding conditions outside the manufacturer's recommended ranges can produce significantly higher diffusible hydrogen levels than the symbol indicates.

There are other approaches to lessening the likelihood of hydrogen cracking, such as increasing interpass temperature, increasing the time between weld runs, and post-weld soaking to remove hydrogen before cooling from the interpass temperature. As the weld metal strength increases, the need for these other approaches increases. Also, it needs to be appreciated that zero hydrogen is unobtainable.

Since there is a real risk of cracking in weld metals, users are strongly recommended to review suitable non-destructive crack detection methods and carry out “fitness for purpose” assessments using a fracture mechanics methodology. This is particularly important for thicker walled, safety critical structures.

Bibliography

[1] EN 14295, *Welding consumables — Wire and tubular cored electrodes and electrode-flux combinations for submerged arc welding of high strength steels — Classification*

[2] ISO 14171, *Welding consumables — Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non alloy and fine grain steels — Classification*

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