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

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

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Foreword

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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).

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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

The committee responsible for this document is ISO/TC 44, *Welding and allied processes*, Subcommittee SC 3, *Welding consumables*.

This third edition cancels and replaces the second edition (ISO 14171:2010), which has been technically revised.

Requests for official interpretations of any aspect of this International Standard 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 International Standard recognizes that there are two somewhat different approaches in the global market to classifying a given 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 International Standard.

This International Standard provides a classification system 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 and elongation 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 are to note that matching weld metal yield strength to parent material yield strength does not necessarily ensure that the weld metal tensile strength matches that of the parent material. Thus, where the application of the material requires matching tensile strengths, selection of the consumable is intended to be made by reference to column 3 of Table 1A or 1B, as appropriate.

Although combinations of electrodes and fluxes supplied by individual companies may have the same classification, the individual wire electrodes and fluxes from different companies are not interchangeable unless verified in accordance with this International Standard.

The mechanical properties of 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 and parent material composition.

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

1 Scope

This International Standard specifies the requirements for the classification of electrode/flux combinations and weld metal in the as-welded condition and in the post-weld heat-treated condition for submerged arc welding of non-alloy and fine grain steels with minimum yield strength of up to 500 MPa or a minimum tensile strength of up to 570 MPa. One flux can be classified with different solid wire electrodes and tubular cored electrodes. The solid wire electrode is also classified separately based on chemical composition.

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

a) Paragraphs and tables which carry the suffix letter "A" are applicable only to electrode/flux combinations and wire electrodes classified using the system based upon the yield strength and the average impact energy for weld metal of 47 J, in accordance with this International Standard.

b) Clauses and tables which carry the suffix letter "B" are applicable only to electrode/flux combinations and wire electrodes classified using the system based upon the tensile strength and the average impact energy for weld metal of 27 J, in accordance with this International Standard.

c) Clauses and tables which do not have either the suffix letter "A" or the suffix letter "B" are applicable to all electrode/flux combinations and wire electrodes classified in accordance with this International Standard.

Fluxes for the single-run and two-run techniques are classified on the basis of the two-run technique.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 15792-2:2000, *Welding consumables — Test methods — Part 2: Preparation of single-run and two-run technique test specimens in steel*

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

3 Classification

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

A solid wire electrode shall be classified in accordance with its chemical composition as given in Table 4A or 4B.

An all-weld metal deposit from a tubular cored electrode shall be classified in accordance with the all-weld metal composition, as given in Table 5A or 5B, obtained with a particular 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 4, as appropriate.

The electrode/flux classification includes weld metal properties obtained with a manufacturer's specific electrode/flux combination as given below. A wire electrode may be separately classified with the symbol for its chemical composition in Table 4A or 4B.

3A Classification by yield strength and 47 J impact energy

The classification is divided into five mandatory parts and an optional sixth part.

1) The first part gives a symbol indicating the process to be identified.

2) The second part gives a symbol indicating the strength and elongation of all-weld metal for multi-run technique or the strength of the parent material used in classification for the two-run technique (see Table 1A or 2A).

3) The third part gives a symbol indicating the impact properties of all-weld metal or welded joint (see Table 3).

3B Classification by tensile strength and 27 J impact energy

The classification is divided into five mandatory parts and an optional sixth part.

1) The first part gives a symbol indicating the process to be identified.

2) The second part gives a symbol indicating the strength and elongation of all-weld metal in either the as-welded or post-weld heat-treated condition for a multi-run technique or the specified minimum tensile strength of the parent material or the weld metal used in classification for the two-run technique (see Table 1B or 2B).

3) The third part gives a symbol indicating the impact properties of all-weld metal or welded joint in the same condition as specified for the tensile strength (see Table 3). The letter "U" after this designator 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 type of flux used in accordance with ISO 14174 (see 4.4).

5) The fifth part gives a symbol indicating the chemical composition of the solid wire electrode used (see Table 4A) or the chemical composition of the all-weld metal obtained with a tubular cored electrode/flux combination (see Table 5A).

6) The sixth part gives an optional symbol indicating the diffusible hydrogen content of the weld metal obtained in accordance with ISO 3690 (see Table 6).

4) The fourth part gives a symbol indicating the type of flux used in accordance with ISO 14174 (see 4.4).

5) The fifth part gives a symbol indicating the chemical composition of the solid wire electrode used (see Table 4B) or the chemical composition of the all-weld metal obtained with a tubular cored electrode/flux combination (see Table 5B).

6) The sixth part gives an optional symbol indicating the diffusible hydrogen content of the weld metal obtained in accordance with ISO 3690 (see Table 6).

4 Symbols and requirements

4.1 Symbol for the process

The symbol for an electrode/flux combination used in the submerged arc welding process shall be the letter S at the beginning of the designation.

4.2 Symbol for tensile properties

4.2.1 Multi-run technique

4.2.1A Classification by yield strength and 47 J impact energy

For products suitable for multi-run welding, the symbols in Table 1A indicate yield strength, tensile strength and elongation of the all-weld metal in the as-welded condition determined in accordance with 5.1A.

4.2.1B Classification by tensile strength and 27 J impact energy

For products suitable for multi-run welding, the symbols in Table 1B indicate yield strength, tensile strength and elongation of the all-weld metal in the as-welded condition or in the post-weld heat-treated condition determined in accordance with 5.1B.

Table 1A — Symbols for tensile properties by multi-run technique
(Classification by yield strength and 47 J impact energy)

Symbol	Minimum yield strength[a] MPa	Tensile strength MPa	Minimum elongation[b] %
35	355	440 to 570	22
38	380	470 to 600	20
42	420	500 to 640	20
46	460	530 to 680	20
50	500	560 to 720	18

[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.

Table 1B — Symbols for tensile properties by multi-run technique
(Classification by tensile strength and 27 J impact energy)

Symbol	Minimum yield strength[a] MPa	Tensile strength MPa	Minimum elongation[b] %
43X	330	430 to 600	20
49X	390	490 to 670	18
55X	460	550 to 740	17
57X	490	570 to 770	17

[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.

4.2.2 Two-run technique

For products suitable for two-run welding, the symbols in Table 2A or 2B indicate the minimum tensile strength of the welded joint in relation to the specified minimum strength of the parent material used in two-run welding tests satisfactorily completed in accordance with 5.2.

Table 2A — Symbols for tensile properties by two-run technique
(Classification by yield strength and 47 J impact energy)

Symbol	Minimum parent material yield strength MPa	Minimum tensile strength of welded joint MPa
2T	275	370
3T	355	470
4T	420	520
5T	500	600

Table 2B — Symbols for tensile properties by two-run technique
(Classification by tensile strength and 27 J impact energy)

Symbol	Minimum tensile strength of parent material and welded joint MPa
43S	430
49S	490
55S	550
57S	570

4.3 Symbol for the impact properties of all-weld metal or two-run welded joint

The symbols in Table 3 indicate the temperature at which an impact energy of 47 J or 27 J is achieved under the conditions given in Clause 5.

4.3A Classification by yield strength and 47 J impact energy

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

4.3B Classification by tensile strength and 27 J impact energy

Five test specimens shall be tested. The lowest and highest values obtained shall be disregarded. The average of the three remaining values shall be at least 27 J. Only one of the three values may be lower than 27 J, but shall not be less than 20 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 4.3A.

When an all-weld metal or a welded joint has been classified for a certain temperature, it automatically covers any higher temperature in Table 3.

Table 3 — Symbols for impact properties of all-weld metal or welded joint

Symbol	Temperature for minimum average impact energy of 47 J[ab] 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
9	−90
10	−100

[a] See 4.3A.

[b] See 4.3B.

4.4 Symbol for type of welding flux

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

4.5 Symbol for the chemical composition

4.5.1 Solid wire electrodes

The symbols in Tables 4A and 4B indicate the chemical composition of the solid wire electrode and include an indication of characteristic alloying elements.

The symbol for a wire electrode used in the submerged arc welding process shall be the letters S or SU at the beginning of the wire electrode designation.

NOTE The chemical composition of the weld metal is dependent on the chemical composition of the wire electrode and the metallurgical behaviour of the flux (see ISO 14174).

4.5.2 Tubular cored electrode/flux combinations

The symbols in Tables 5A and 5B indicate the chemical composition of the all-weld metal obtained with a tubular cored electrode/flux combination and include an indication of characteristic alloying elements.

The symbol for all-weld metal obtained with a tubular cored electrode used in the submerged arc welding process shall be the letters T or TU at the beginning of the wire electrode designation.

In cases of dispute, the sample for all-weld metal deposit shall be in accordance with ISO 6847.

Table 4A — Chemical composition of solid wire electrodes for submerged arc welding
(Classification by yield strength and 47 J impact energy)

Symbol	Chemical composition, % (by mass)[abc]								
	C	Si	Mn	P	S	Mo	Ni	Cr	Cu
S1	0,05 to 0,15	0,15	0,35 to 0,60	0,025	0,025	0,15	0,15	0,15	0,30
S2	0,07 to 0,15	0,15	0,80 to 1,30	0,025	0,025	0,15	0,15	0,15	0,30
S3	0,07 to 0,15	0,15	1,30 to 1,75	0,025	0,025	0,15	0,15	0,15	0,30
S4	0,07 to 0,15	0,15	1,75 to 2,25	0,025	0,025	0,15	0,15	0,15	0,30
S1Si	0,07 to 0,15	0,15 to 0,40	0,35 to 0,60	0,025	0,025	0,15	0,15	0,15	0,30
S2Si	0,07 to 0,15	0,15 to 0,40	0,80 to 1,30	0,025	0,025	0,15	0,15	0,15	0,30
S2Si2	0,07 to 0,15	0,40 to 0,60	0,80 to 1,30	0,025	0,025	0,15	0,15	0,15	0,30
S3Si	0,07 to 0,15	0,15 to 0,40	1,30 to 1,85	0,025	0,025	0,15	0,15	0,15	0,30
S4Si	0,07 to 0,15	0,15 to 0,40	1,85 to 2,25	0,025	0,025	0,15	0,15	0,15	0,30
S1Mo	0,05 to 0,15	0,05 to 0,25	0,35 to 0,60	0,025	0,025	0,45 to 0,65	0,15	0,15	0,30
S2Mo	0,07 to 0,15	0,05 to 0,25	0,80 to 1,30	0,025	0,025	0,45 to 0,65	0,15	0,15	0,30
S2MoTiB[d]	0,05 to 0,15	0,15 to 0,35	1,00 to 1,35	0,025	0,025	0,40 to 0,65	—	—	0,30
S3Mo	0,07 to 0,15	0,05 to 0,25	1,30 to 1,75	0,025	0,025	0,45 to 0,65	0,15	0,15	0,30
S4Mo	0,07 to 0,15	0,05 to 0,25	1,75 to 2,25	0,025	0,025	0,45 to 0,65	0,15	0,15	0,30

[a] Finished product chemical composition, Cu inclusive of a copper coating, Al ≤ 0,030 % (by mass).

[b] Single values are maxima.

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

[d] Ti: 0,10 % (by mass) to 0,20 % (by mass), B: 0,005 % (by mass) to 0,020 % (by mass).

Table 4A *(continued)*

Symbol	Chemical composition, % (by mass)[abc]								
	C	Si	Mn	P	S	Mo	Ni	Cr	Cu
S2Ni1	0,07 to 0,15	0,05 to 0,25	0,80 to 1,30	0,020	0,020	0,15	0,80 to 1,20	0,15	0,30
S2Ni1,5	0,07 to 0,15	0,05 to 0,25	0,80 to 1,30	0,020	0,020	0,15	1,20 to 1,80	0,15	0,30
S2Ni2	0,07 to 0,15	0,05 to 0,25	0,80 to 1,30	0,020	0,020	0,15	1,80 to 2,40	0,15	0,30
S2Ni3	0,07 to 0,15	0,05 to 0,25	0,80 to 1,30	0,020	0,020	0,15	2,80 to 3,70	0,15	0,30
S2Ni1Mo	0,07 to 0,15	0,05 to 0,25	0,80 to 1,30	0,020	0,020	0,45 to 0,65	0,80 to 1,20	0,20	0,30
S3Ni1,5	0,07 to 0,15	0,05 to 0,25	1,30 to 1,70	0,020	0,020	0,15	1,20 to 1,80	0,20	0,30
S3Ni1Mo	0,07 to 0,15	0,05 to 0,25	1,30 to 1,80	0,020	0,020	0,45 to 0,65	0,80 to 1,20	0,20	0,30
S3Ni1Mo0,2	0,07 to 0,15	0,10 to 0,35	1,20 to 1,60	0,015	0,015	0,15 to 0,30	0,80 to 1,25	0,15	0,30
S3Ni1,5Mo	0,07 to 0,15	0,05 to 0,25	1,20 to 1,80	0,020	0,020	0,30 to 0,50	1,20 to 1,80	0,20	0,30
S2Ni1Cu	0,08 to 0,12	0,15 to 0,35	0,70 to 1,20	0,020	0,020	0,15	0,65 to 0,90	0,40	0,40 to 0,65
S3Ni1Cu	0,05 to 0,15	0,15 to 0,40	1,20 to 1,70	0,025	0,025	0,15	0,60 to 1,20	0,15	0,30 to 0,60
SZ[c]	Any other agreed composition								

[a] Finished product chemical composition, Cu inclusive of a copper coating, Al ≤ 0,030 % (by mass).

[b] Single values are maxima.

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

[d] Ti: 0,10 % (by mass) to 0,20 % (by mass), B: 0,005 % (by mass) to 0,020 % (by mass).

Table 4B — Chemical composition of solid wire electrodes for submerged arc welding
(Classification by tensile strength and 27 J impact energy)

Symbol	Chemical composition, % (by mass)[abc]								
	C	Si	Mn	P	S	Mo	Ni	Cr	Cu[f]
SU08	0,10	0,10 to 0,25	0,25 to 0,60	0,030	0,030	—	—	—	0,35
SU10	0,07 to 0,15	0,05 to 0,25	1,30 to 1,70	0,025	0,025	—	—	—	0,35
SU11	0,15	0,15	0,20 to 0,90	0,025	0,025	0,15	0,15	0,15	0,40
SU111	0,07 to 0,15	0,65 to 0,85	1,00 to 1,50	0,025	0,030	—	—	—	0,35
SU12	0,15	0,10 to 0,60	0,20 to 0,90	0,025	0,025	0,15	0,15	0,15	0,40
SU21	0,05 to 0,15	0,10 to 0,35	0,80 to 1,25	0,025	0,025	0,15	0,15	0,15	0,40
SU22	0,15	0,15	0,80 to 1,40	0,025	0,025	0,15	0,15	0,15	0,40
SU23	0,18	0,15 to 0,60	0,80 to 1,40	0,025	0,025	0,15	0,15	0,15	0,40
SU24[d]	0,06 to 0,19	0,35 to 0,75	0,90 to 1,40	0,025	0,025	0,15	0,15	0,15	0,40
SU25	0,06 to 0,16	0,35 to 0,75	0,90 to 1,40	0,030	0,030	0,15	0,15	0,15	0,40
SU31	0,06 to 0,15	0,80 to 1,15	1,40 to 1,85	0,030	0,030	0,15	0,15	0,15	0,40
SU32	0,15	0,05 to 0,60	1,30 to 1,90	0,025	0,025	0,15	0,15	0,15	0,40
SU33	0,15	0,15	1,30 to 1,90	0,025	0,025	0,15	0,15	0,15	0,40

[a] The electrode 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).

[b] Single values are maxima.

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

[d] Ti: 0,03 % (by mass) to 0,17 % (by mass).

[e] Ti: 0,05 % (by mass) to 0,30 % (by mass) and B: 0,005 % (by mass) to 0,030 % (by mass).

[f] Cu is inclusive of a copper coating.

Table 4B *(continued)*

Symbol	Chemical composition, % (by mass)[abc]								
	C	Si	Mn	P	S	Mo	Ni	Cr	Cu[f]
SU41	0,20	0,15	1,60 to 2,30	0,025	0,025	0,15	0,15	0,15	0,40
SU42	0,15	0,15 to 0,65	1,50 to 2,30	0,025	0,025	0,15	0,15	0,15	0,40
SU51	0,15	0,15	2,20 to 2,80	0,025	0,025	0,15	0,15	0,15	0,40
SU1M3	0,15	0,25	0,20 to 1,00	0,025	0,025	0,40 to 0,65	0,15	0,15	0,40
SU1M3TiB[e]	0,05 to 0,15	0,20	0,65 to 1,00	0,025	0,025	0,45 to 0,65	0,15	0,15	0,35
SU2M1	0,15	0,25	0,80 to 1,40	0,025	0,025	0,15 to 0,40	0,15	0,15	0,40
SU3M1	0,15	0,25	1,30 to 1,90	0,025	0,025	0,15 to 0,40	0,15	0,15	0,40
SU2M3	0,17	0,25	0,80 to 1,40	0,025	0,025	0,40 to 0,65	0,15	0,15	0,40
SU2M3TiB[e]	0,05 to 0,17	0,20	0,95 to 1,35	0,025	0,025	0,40 to 0,65	0,15	0,15	0,35
SU3M3	0,17	0,25	1,20 to 1,90	0,025	0,025	0,40 to 0,65	0,15	0,15	0,40
SU4M1	0,15	0,25	1,60 to 2,30	0,025	0,025	0,15 to 0,40	0,15	0,15	0,40
SU4M3	0,17	0,25	1,60 to 2,30	0,025	0,025	0,40 to 0,65	0,15	0,15	0,40
SU4M31	0,05 to 0,15	0,50 to 0,80	1,60 to 2,10	0,025	0,025	0,40 to 0,60	0,15	0,15	0,40
SU5M3	0,15	0,25	2,20 to 2,80	0,025	0,025	0,40 to 0,65	0,15	0,15	0,40
SUN2	0,15	0,30	0,75 to 1,40	0,020	0,020	0,15	0,75 to 1,25	0,20	0,40
SUN21	0,12	0,40 to 0,80	0,80 to 1,40	0,020	0,020	0,15	0,75 to 1,25	0,20	0,40
SUN3	0,15	0,25	0,80 to 1,40	0,020	0,020	0,15	1,20 to 1,80	0,20	0,40
SUN31	0,15	0,25	1,30 to 1,90	0,020	0,020	0,15	1,20 to 1,80	0,20	0,40
SUN5	0,15	0,30	0,75 to 1,40	0,020	0,020	0,15	1,80 to 2,90	0,20	0,40
SUN7	0,15	0,30	0,60 to 1,40	0,020	0,020	0,15	2,40 to 3,80	0,20	0,40

[a] The electrode 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).

[b] Single values are maxima.

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

[d] Ti: 0,03 % (by mass) to 0,17 % (by mass).

[e] Ti: 0,05 % (by mass) to 0,30 % (by mass) and B: 0,005 % (by mass) to 0,030 % (by mass).

[f] Cu is inclusive of a copper coating.

Table 4B *(continued)*

Symbol	Chemical composition, % (by mass)[abc]								
	C	Si	Mn	P	S	Mo	Ni	Cr	Cu[f]
SUCC	0,15	0,30	0,80 to 1,90	0,030	0,030	0,15	0,15	0,30 to 0,60	0,20 to 0,45
SUNCC1	0,12	0,20 to 0,35	0,35 to 0,65	0,025	0,030	0,15	0,40 to 0,80	0,50 to 0,80	0,30 to 0,80
SUNCC3	0,15	0,30	0,80 to 1,90	0,030	0,030	0,15	0,05 to 0,80	0,50 to 0,80	0,30 to 0,55
SUN1M3	0,10 to 0,18	0,20	1,70 to 2,40	0,025	0,025	0,40 to 0,65	0,40 to 0,80	0,20	0,35
SUN2M1	0,12	0,05 to 0,30	1,20 to 1,60	0,020	0,020	0,10 to 0,30	0,75 to 1,25	0,20	0,40
SUN2M3	0,15	0,25	0,80 to 1,40	0,020	0,020	0,40 to 0,65	0,80 to 1,20	0,20	0,40
SUN2M31	0,15	0,25	1,30 to 1,90	0,020	0,020	0,40 to 0,65	0,80 to 1,20	0,20	0,40
SUN2M32	0,15	0,25	1,60 to 2,30	0,020	0,020	0,40 to 0,65	0,80 to 1,20	0,20	0,40
SUN3M3	0,15	0,25	0,80 to 1,40	0,020	0,020	0,40 to 0,65	1,20 to 1,80	0,20	0,40
SUN3M31	0,15	0,25	1,30 to 1,90	0,020	0,020	0,40 to 0,65	1,20 to 1,80	0,20	0,40
SUN4M1	0,12 to 0,19	0,10 to 0,30	0,60 to 1,00	0,015	0,030	0,10 to 0,30	1,60 to 2,10	0,20	0,35
SUZ[c]	Any other agreed composition								

[a] The electrode 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).

[b] Single values are maxima.

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

[d] Ti: 0,03 % (by mass) to 0,17 % (by mass).

[e] Ti: 0,05 % (by mass) to 0,30 % (by mass) and B: 0,005 % (by mass) to 0,030 % (by mass).

[f] Cu is inclusive of a copper coating.

Table 5A — All-weld metal classification symbols for tubular cored electrode/flux combinations
(Classification by yield strength and 47 J impact energy)

Symbol	Chemical composition, % (by mass)[abc]			
	Mn	Ni	Mo	Cu
T2	1,4	—	—	0,3
T3	1,4 to 2,0	—	—	0,3
T2Mo	1,4	—	0,3 to 0,6	0,3
T3Mo	1,4 to 2,0	—	0,3 to 0,6	0,3
T2Ni1	1,4	0,6 to 1,2	—	0,3
T2Ni1,5	1,6	1,2 to 1,8	—	0,3
T2Ni2	1,4	1,8 to 2,6	—	0,3
T2Ni3	1,4	2,6 to 3,8	—	0,3
T3Ni1	1,4 to 2,0	0,6 to 1,2	—	0,3
T2Ni1Mo	1,4	0,6 to 1,2	0,3 to 0,6	0,3
T2Ni1Cu	1,4	0,8 to 1,2	—	0,3 to 0,6
TZ[c]	Any other agreed composition			

[a] If not specified, Mo: ≤ 0,2 % (by mass), Ni: ≤ 0,5 % (by mass), Cr: ≤ 0,2 % (by mass), V: ≤ 0,08 % (by mass), Nb: ≤ 0,05 % (by mass), C: 0,03 % (by mass) to 0,15 % (by mass), Si: ≤ 0,8 % (by mass), S: ≤ 0,025 % (by mass), P: ≤ 0,025 % (by mass).

[b] Single values are maxima.

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

Table 5B — All-weld metal classification symbols for tubular cored electrode/flux combinations
(Classification by tensile strength and 27 J impact energy)

Symbol	Chemical composition, % (by mass)[abc]									
	C	Mn	Si	S	P	Cr	Ni	Mo	Cu	Other
TU3M	0,15	1,80	0,90	0,035	0,035	—	—	—	0,35	—
TU2M3	0,12	1,00	0,80	0,030	0,030	—	—	0,40 to 0,65	0,35	—
TU2M31	0,12	1,40	0,80	0,030	0,030	—	—	0,40 to 0,65	0,35	—
TU4M3	0,15	2,10	0,80	0,030	0,030	—	—	0,40 to 0,65	0,35	—
TU3M3	0,15	1,60	0,80	0,030	0,030	—	—	0,40 to 0,65	0,35	—
TUN2	0,12[d]	1,60[d]	0,80	0,025	0,030	0,15	0,75 to 1,10	0,35	0,35	Ti + V + Zr: 0,05
TUN5	0,12[d]	1,60[d]	0,80	0,025	0,030	—	2,00 to 2,90	—	0,35	—
TUN7	0,12	1,60	0,80	0,025	0,030	0,15	2,80 to 3,80	—	0,35	—
TUN4M1	0,14	1,60	0,80	0,025	0,030	—	1,40 to 2,10	0,10 to 0,35	0,35	—
TUN2M1	0,12[d]	1,60[d]	0,80	0,025	0,030	—	0,70 to 1,10	0,10 to 0,35	0,35	—
TUN3M2	0,12	0,70 to 1,50	0,80	0,030	0,030	0,15	0,90 to 1,70	0,55	0,35	—
TUN1M3	0,17	1,25 to 2,25	0,80	0,030	0,030	—	0,40 to 0,80	0,40 to 0,65	0,35	—
TUN2M3	0,17	1,25 to 2,25	0,80	0,030	0,030	—	0,70 to 1,10	0,40 to 0,65	0,35	—
TUN1C2	0,17	1,60	0,80	0,035	0,030	0,60	0,40 to 0,80	0,25	0,35	Ti + V + Zr: 0,03
TUN5C2M3	0,17	1,20 to 1,80	0,80	0,020	0,020	0,65	2,00 to 2,80	0,30 to 0,80	0,50	—
TUN4C2M3	0,14	0,80 to 1,85	0,80	0,020	0,030	0,65	1,50 to 2,25	0,60	0,40	—

[a] 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).

[b] Single values are maxima.

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

[d] Manganese in the N2 and N5 designated weld metals may be 1,80 % (by mass) maximum when the carbon is restricted to 0,10 % (by mass) maximum.

Table 5B *(continued)*

Symbol	Chemical composition, % (by mass)[abc]									
	C	Mn	Si	S	P	Cr	Ni	Mo	Cu	Other
TUN3	0,10	0,60 to 1,60	0,80	0,030	0,030	0,15	1,25 to 2,00	0,35	0,30	Ti + V + Zr: 0,03
TUN4M2	0,10	0,90 to 1,80	0,80	0,020	0,020	0,35	1,40 to 2,10	0,25 to 0,65	0,30	Ti + V + Zr: 0,03
TUN4M3	0,10	0,90 to 1,80	0,80	0,020	0,020	0,65	1,80 to 2,60	0,20 to 0,70	0,30	Ti + V + Zr: 0,03
TUN5M3	0,10	1,30 to 2,25	0,80	0,020	0,020	0,80	2,00 to 2,80	0,30 to 0,80	0,30	Ti + V + Zr: 0,03
TUN4M21	0,12	1,60 to 2,50	0,50	0,015	0,015	0,40	1,40 to 2,10	0,20 to 0,50	0,30	Ti: 0,03 V: 0,02 Zr: 0,02
TUN4M4	0,12	1,60 to 2,50	0,50	0,015	0,015	0,40	1,40 to 2,10	0,70 to 1,00	0,30	Ti: 0,03 V: 0,02 Zr: 0,02
TUNCC	0,12	0,50 to 1,60	0,80	0,030	0,035	0,45 to 0,70	0,40 to 0,80	—	0,30 to 0,75	—
TUZ[c]	Any other agreed composition									

[a] 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).

[b] Single values are maxima.

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

[d] Manganese in the N2 and N5 designated weld metals may be 1,80 % (by mass) maximum when the carbon is restricted to 0,10 % (by mass) maximum.

4.6 Symbol for hydrogen content of deposited metal

The 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.

5 Mechanical tests

5.1 Multi-run technique

5.1A Welding conditions in the 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 the nearest commercially available diameter wire electrodes.

Welding conditions (single wire welding) and details of the test assembly shall be selected from Table 7A.

5.1B Welding conditions in the 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 the nearest commercially available diameter wire electrodes.

Welding conditions (single wire welding) and details of the test assembly shall be selected from Table 7B. Solid wire diameters not specified and all tubular cored electrodes shall be welded based on the manufacturer's recommendations.

Preheating is not required; welding may start from room temperature.

The interpass temperature shall be measured using temperature indicator crayons, surface thermometers or thermocouples (see ISO 13916).

The interpass temperature shall not exceed the interpass temperature range indicated in Table 7A. If, after any pass, the interpass temperature range is exceeded, the test assembly shall be cooled in air to a temperature within the indicated range. If the interpass temperature is below the indicated interpass temperature range, the test assembly shall be reheated into the interpass temperature range.

The interpass temperature shall be measured using temperature indicator crayons, surface thermometers or thermocouples (see ISO 13916).

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

Test assemblies made with electrodes classified in the post-weld heat-treated condition shall be heat-treated at 620 °C ± 15 °C for 60 min to 75 min. The furnace shall be at a temperature no higher than 315 °C when the test assembly is placed in it. The heating rate, from that point to the 620 °C ± 15 °C holding temperature, shall not exceed 220 °C/h. 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/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.

Table 7A — Welding conditions for multi-run single solid wire welding
(Classification by yield strength and 47 J impact energy)

Conditions[a]	Solid wire electrode diameter[b] mm		Tubular cored electrode diameter[b] mm	
	2,8 to 3,2	4,0	3,0 to 3,2	4,8
Type of current	DC[c]			
Length of weld deposit, mm	≥350			
Welding current, A	440 ± 20	580 ± 20	480 ± 20	550 ± 20
Welding voltage, V	27 ± 2	29 ± 2	30 ± 2	
Welding speed, mm/min	400 ± 50	550 ± 50	450 ± 50	
Interpass temperature range, °C (no preheat)	150 ± 25			
Electrode extension, mm	30 ± 5			

[a] AC or DC, either polarity, may be used. The reference method shall be as recommended by the manufacturer.

[b] Diameters not specified are to be welded following the recommendations of the electrode manufacturer.

[c] Direct current welding polarity shall follow the recommendation of the manufacturer.