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Welding consumables — Solid wire electrodes, tubular cored electrodes and electrode-flux combinations for submerged arc welding of creep-resisting 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 résistant au fluage — 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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 24598 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 24598:2007), which has been technically revised.

The main changes compared to the previous edition are:

a) the composition of 9C1MV is modified on the B side of Table 3 (former Table 4) and Table 4 (former Table 5);

b) different test pieces in accordance with ISO 15792-1 are specified for side A and B in Clauses 5A and 5B, respectively.

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 wire electrode, tubular cored electrode or 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. The classification in accordance with system A is mainly based on EN 12070:1999[2]. The classification in accordance with system B is mainly based upon standards used around the Pacific Rim.

This International Standard provides a classification system for solid wire electrodes in terms of their chemical composition, solid wire electrodes and 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 metal. 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. 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, as appropriate.

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

It should be noted that the mechanical properties of all-weld metal test pieces used to classify the wire electrodes vary from those obtained in production joints because of differences in welding procedure, such as electrode size, welding position and material composition.

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

1 Scope

This International Standard specifies requirements for classification of solid wire electrodes, tubular cored electrodes and electrode/flux combinations (all-weld metal deposits) for submerged arc welding of creep resisting and low-alloy elevated-temperature steels. One electrode can be tested and classified with different fluxes. The solid wire electrode is also classified separately based on its chemical composition.

This International Standard is a combined specification providing for classification utilizing a system based upon the chemical composition of the solid wire electrode and all-weld metal deposit, or utilizing a system based upon the tensile strength of the all-weld metal deposit and the chemical composition of the solid wire electrode and all-weld metal deposit obtained with the electrode/flux combination.

a) Clauses, subclauses and tables which carry the suffix letter “A” are applicable only to solid wire electrodes, tubular cored electrodes and all-weld metal deposits classified in accordance with the system based upon chemical composition.

b) Clauses, subclauses and tables which carry the suffix letter “B” are applicable only to solid wire electrodes, tubular cored electrodes and all-weld metal deposits classified in accordance with the system based upon the tensile strength of all-weld metal deposits and the chemical composition of solid wire electrodes and all-weld metal deposits.

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 under this International Standard.

2 Normative references

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

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

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, *Welding consumables — Test methods — Part 1: Test methods for all-weld metal test specimens in steel, nickel and nickel alloys*

ISO 80000-1:2009, *Quantities and units — Part 1: General*

3 Classification

Classification designations are based upon two approaches to indicate the chemical composition of the solid wire electrode, the chemical composition of the all-weld metal deposit obtained with a solid wire electrode or tubular cored electrode, and the tensile properties and impact properties of the all-weld metal deposits obtained with a given electrode/flux combination. The two designation approaches include additional designators for some other classification requirements, but not all, as is clear from the provisions given in this International Standard. In many 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 3.

An all-weld metal deposit from a solid wire electrode or tubular cored electrode shall be classified in accordance with the all-weld metal deposit composition, as given in Table 4, 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.

3A Classification by chemical composition

The classification is divided into three 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 chemical composition of the solid wire electrode (see Table 3) and all-weld metal deposit (see Table 4);

3) the third part gives a symbol indicating the type of flux used (see 4.5).

3B Classification by tensile strength and chemical composition

The classification is divided into five 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 strength and elongation of the all-weld metal deposit in the post-weld heat-treated condition (see Table 1B);

3) the third part gives a symbol indicating the impact properties of all-weld metal deposits in the same condition as specified for the tensile strength (see Table 2B);

4) the fourth part gives a symbol indicating the type of flux used (see 4.5);

5) the fifth part gives a symbol indicating the chemical composition of the solid wire electrode, if used (see Table 3), and of the all-weld metal deposited by an electrode/flux combination (see Table 4).

4 Symbols and requirements

4.1 General

A solid wire electrode can be classified separately based upon 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 upon 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.

4.2 Symbol for the product/process

The symbol for the weld deposit produced by a solid or tubular electrode using the submerged arc welding process with a particular flux, shall be the letter “S” placed at the beginning of the designation.

4.2A Classification by chemical composition

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 wire electrode designation.

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

4.2B Classification by tensile strength and chemical composition

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

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

4.3A Classification by chemical composition

No symbol shall be used for the mechanical properties of the all-weld metal deposit. The all-weld metal deposit produced in combination with a particular flux shall fulfil the tensile property requirements specified in Table 1A.

4.3B Classification by tensile strength and chemical composition

The symbols in Table 1B indicate the tensile strength, yield strength and elongation of the all-weld metal deposit in the post-weld heat-treated condition determined in accordance with 5.1, with a particular flux.

4.4 Symbols for impact properties of all-weld metal deposits

4.4A Classification by chemical composition

No symbol shall be used for the impact properties of the all-weld metal deposits. The all-weld metal deposits produced in combination with a particular flux shall fulfil the impact property requirements specified in Table 1A.

4.4B Classification by tensile strength and chemical composition

The symbols in Table 2B indicate the temperature at which an impact energy of 27 J is achieved in the post-weld heat-treated condition under the conditions given in Clause 5. Five test pieces 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 be no less than 20 J. The average of the three remaining values shall be at least 27 J.

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

Table 1A — Mechanical properties of all-weld metal deposits
(Classification by chemical composition)

Alloy symbol	Minimum proof strength $R_{p0,2}$ MPa	Minimum tensile strength R_m MPa	Minimum[a] elongation A %	Impact energy at +20 °C J		Heat treatment		
				Minimum average from three test pieces	Minimum single[b] value	Preheat and interpass temperature °C	Post-weld heat treatment of test piece	
							Temperature[c] °C	Time[d] min
Mo MnMo	355	510	22	47	38	< 200	—	—
MoV	355	510	18	47	38	200 to 300	690 to 730	60
CrMo1	355	510	20	47	38	150 to 250	660 to 700	60
CrMoV1	435	590	15	24	21	200 to 300	680 to 730	60
CrMo2 CrMo2Mn	400	500	18	47	38	200 to 300	690 to 750	60
CrMo2L	400	500	18	47	38	200 to 300	690 to 750	60
CrMo5	400	590	17	47	38	200 to 300	730 to 760	60
CrMo9	435	590	18	34	27	200 to 300	740 to 780	120
CrMo91	415	585	17	47	38	250 to 350	750 to 760	180
CrMoWV12	550	690	15	34	27	250 to 350[e] or 400 to 500[e]	740 to 780	120
Z	Any other agreed mechanical properties							

[a] The gauge length is equal to five times the test piece diameter.

[b] Only one single value lower than the minimum average is permitted.

[c] The test piece shall be cooled in the furnace to 300 °C at a rate not exceeding 200 °C/h. The test piece may be removed from the furnace at any temperature below 300 °C and allowed to cool in still air to room temperature.

[d] Tolerance ± 10 min.

[e] Immediately after welding the test piece shall be cooled down to 120 °C to 100 °C and kept at this temperature for at least 1 h.

Table 1B — Symbols for tensile properties
(Classification by tensile strength and chemical composition)

Symbol	Minimum yield strength[a] MPa	Tensile strength MPa	Minimum elongation[b] %
49	400	490 to 660	20
55	470	550 to 700	18
62	540	620 to 760	15
69	610	690 to 830	14

[a] 0,2 % offset ($R_{p0,2}$).

[b] The gauge length is equal to five times the specimen diameter.

Table 2B — Symbols for impact properties of all-weld metal deposits
(Classification by tensile strength and chemical composition)

Symbol	Temperature for minimum average impact energy of 27 J °C
Z	No requirements
Y	+20
0	0
2	−20
3	−30
4	−40

4.5 Symbol for type of welding flux

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

4.6 Symbol for the chemical composition of solid wire electrodes and of all-weld metal deposits

The symbols in Table 3 indicate the chemical composition of the solid wire electrode, determined under the conditions given in Clause 6.

The symbols in Table 4 indicate the chemical composition of the all-weld metal deposit obtained with the solid wire electrode, or with the tubular cored electrode, and a particular flux.

Table 3 — Chemical composition requirements for solid wire electrodes

Symbol for classification in accordance with		Chemical composition % (by mass)[b]										
Chemical composition[a] ISO 24598-A	Tensile strength and chemical composition[a] ISO 24598-B	C	Si	Mn	P	S	Cr	Ni	Mo	Cu[c]	V	Other
Mo	(1M3)	0,08 to 0,15	0,05 to 0,25	0,80 to 1,20	0,025	0,025	0,2	0,3	0,45 to 0,65	0,3	0,03	Nb: 0,01
(Mo)	1M3[d]	0,05 to 0,15	0,25	0,65 to 1,00	0,025	0,025	—	—	0,45 to 0,65	0,35	—	—
MnMo[e]	(3M31)	0,08 to 0,15	0,05 to 0,25	1,30 to 1,70	0,025	0,025	0,2	0,3	0,45 to 0,65	0,3	0,03	Nb: 0,01
(MnMo)	3M31[d,e]	0,18	0,60	1,10 to 1,90	0,025	0,025	—	—	0,30 to 0,70	0,35	—	—
	4M3[d,e]	0,05 to 0,17	0,20	1,65 to 2,20	0,025	0,025	—	—	0,45 to 0,65	0,35	—	—
	4M31[d,e]	0,18	0,60	1,70 to 2,60	0,025	0,025	—	—	0,30 to 0,70	0,35	—	—
MoV		0,08 to 0,15	0,10 to 0,30	0,60 to 1,00	0,020	0,020	0,30 to 0,60	0,3	0,50 to 1,00	0,3	0,25 to 0,45	Nb: 0,01
	CM[d]	0,10	0,05 to 0,30	0,40 to 0,80	0,025	0,025	0,40 to 0,75	—	0,45 to 0,65	0,35	—	—
	CM1[d]	0,15	0,40	0,30 to 1,20	0,025	0,025	0,30 to 0,70	—	0,30 to 0,70	0,35	—	—
	C1MH[d]	0,15 to 0,23	0,40 to 0,60	0,40 to 0,70	0,025	0,025	0,45 to 0,65	—	0,90 to 1,20	0,30	—	—
CrMo1	(1CM) (1CM1)	0,08 to 0,15	0,05 to 0,25	0,60 to 1,00	0,020	0,020	0,90 to 1,30	0,3	0,40 to 0,65	0,3	0,03	Nb: 0,01
(CrMo1)	1CM[d,f]	0,07 to 0,15	0,05 to 0,30	0,45 to 1,00	0,025	0,025	1,00 to 1,75	—	0,45 to 0,65	0,35	—	—
(CrMo1)	1CM1[d]	0,15	0,60	0,30 to 1,20	0,025	0,025	0,80 to 1,80	—	0,40 to 0,65	0,35	—	—
	1CMVH[d]	0,28 to 0,33	0,55 to 0,75	0,45 to 0,65	0,015	0,015	1,00 to 1,50	—	0,40 to 0,65	0,30	0,20 to 0,30	—
CrMoV1		0,08 to 0,15	0,05 to 0,25	0,80 to 1,20	0,020	0,020	0,90 to 1,30	0,3	0,90 to 1,30	0,3	0,10 to 0,35	Nb: 0,01

Table 3 (*continued*)

Symbol for classification in accordance with		Chemical composition % (by mass)[b]										
Chemical composition[a] ISO 24598-A	Tensile strength and chemical composition[a] ISO 24598-B	C	Si	Mn	P	S	Cr	Ni	Mo	Cu[c]	V	Other
CrMo2	(2C1M)	0,08 to 0,15	0,05 to 0,25	0,30 to 0,70	0,020	0,020	2,2 to 2,8	0,3	0,90 to 1,15	0,3	0,03	Nb: 0,01
(CrMo2) (CrMo2Mn)	2C1M[d,f]	0,05 to 0,15	0,05 to 0,30	0,40 to 0,80	0,025	0,025	2,25 to 3,00	—	0,90 to 1,10	0,35	—	—
(CrMo2) (CrMo2Mn)	2C1M1[d]	0,15	0,35	0,30 to 1,20	0,025	0,025	2,20 to 2,80	—	0,90 to 1,20	0,35	—	—
	2C1M2[d]	0,08 to 0,18	0,35	0,30 to 1,20	0,025	0,025	2,20 to 2,80	—	0,90 to 1,20	0,35	—	—
CrMo2Mn[g]	(2C1M) (2C1M1)	0,10	0,50	0,50 to 1,20	0,020	0,015	2,0 to 2,5	0,3	0,90 to 1,20	0,3	0,03	Nb: 0,01
CrMo2L		0,05	0,05 to 0,25	0,30 to 0,70	0,020	0,020	2,2 to 2,8	0,3	0,90 to 1,15	0,3	0,03	Nb: 0,01
	2C1MV	0,05 to 0,15	0,40	0,50 to 1,50	0,025	0,025	2,20 to 2,80	—	0,90 to 1,20	0,35	0,15 to 0,45	Nb: 0,01 to 0,10
(CrMo5)	5CM[d]	0,10	0,05 to 0,50	0,35 to 0,70	0,025	0,025	4,50 to 6,50	—	0,45 to 0,70	0,35	—	—
(CrMo5)	5CM1[d]	0,15	0,60	0,30 to 1,20	0,025	0,025	4,50 to 6,00	—	0,40 to 0,65	0,35	—	—
CrMo5	(5CM) (5CM1)	0,03 to 0,10	0,20 to 0,50	0,40 to 0,75	0,020	0,020	5,5 to 6,5	0,3	0,50 to 0,80	0,3	0,03	Nb: 0,01
	5CMH[d]	0,25 to 0,40	0,25 to 0,50	0,75 to 1,00	0,025	0,025	4,80 to 6,00	—	0,45 to 0,65	0,35	—	—
CrMo9	(9C1M)	0,06 to 0,10	0,30 to 0,60	0,30 to 0,70	0,025	0,025	8,5 to 10,0	1,0	0,80 to 1,20	0,3	0,15	Nb: 0,01
(CrMo9)	9C1M[d]	0,10	0,05 to 0,50	0,30 to 0,65	0,025	0,025	8,00 to 10,50	—	0,80 to 1,20	0,35	—	—

Table 3 (*continued*)

Symbol for classification in accordance with		Chemical composition % (by mass)[b]										
Chemical composition[a] ISO 24598-A	**Tensile strength and chemical composition[a] ISO 24598-B**	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Ni**	**Mo**	**Cu[c]**	**V**	**Other**
CrMo91	(9C1MV)	0,07 to 0,15	0,60	0,4 to 1,5	0,020	0,020	8,0 to 10,5	0,4 to 1,0	0,8 to 1,2	0,25	0,15 to 0,30	Nb: 0,03 to 0,10 N: 0,02 to 0,07
	9C1MV[d,h]	0,07 to 0,13	0,50	1,25	0,010	0,010	8,5 to 10,5	1,00	0,85 to 1,15	0,10	0,15 to 0,25	Nb: 0,02 to 0,10 N: 0,03 to 0,07 Al: 0,04
	9C1MV1[d]	0,12	0,50	0,50 to 1,25	0,025	0,025	8,00 to 10,50	0,10 to 0,80	0,80 to 1,20	0,35	0,10 to 0,35	Nb: 0,01 to 0,12 N: 0,01 to 0,05
	9C1MV2[d]	0,12	0,50	1,20 to 1,90	0,025	0,025	8,00 to 10,50	0,20 to 1,00	0,80 to 1,20	0,35	0,15 to 0,50	Nb: 0,01 to 0,12 N: 0,01 to 0,05
CrMoWV12		0,22 to 0,30	0,05 to 0,40	0,40 to 1,20	0,025	0,020	10,5 to 12,5	0,8	0,80 to 1,20	0,3	0,20 to 0,40	W: 0,35 to 0,80 Nb: 0,01
Z[i]	G[i]	Any other agreed composition										

[a] A designation in parentheses, e.g. (CrMo1) or (1CM), indicates a near match in the other designation system, but not an exact match. The correct designation for a given composition is the one without parentheses. A given product may, by having a more restricted chemical composition that fulfils both sets of requirements, be assigned both designations independently, provided that the mechanical property requirements of Tables 1A, 1B and 2B are also satisfied.

[b] Single values are maxima.

[c] If a copper coating is applied to the solid wire electrode, the chemical analysis shall include the coating.

[d] 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 Fe) does not exceed 0,50 % (by mass).

[e] Compositions containing approximately 0,5 % (by mass) Mo, without Cr, and with Mn significantly in excess of 1 % (by mass), may not provide optimum creep resistance.

[f] The letter “R”, when added as a suffix, is an optional supplemental designator indicating that the following limits apply in place of those shown in the table: S: 0,010 % (by mass); P: 0,010 % (by mass); Cu: 0,15 % (by mass); As: 0,005 % (by mass); Sn: 0,005 % (by mass); Sb: 0,005 % (by mass).

[g] An Mn/Si ratio greater than 2,0 is desirable.

[h] Mn + Ni = 1,50 % (by mass) maximum.

[i] Consumables for which the chemical composition is not listed in the table shall be symbolized similarly and prefixed by the letter Z (ISO 24598-A) or G (ISO 24598-B). The chemical composition ranges are not specified and therefore it is possible that two electrodes with the same Z or G classification are not interchangeable.

5 Mechanical tests

5A Classification by chemical composition

Tensile and impact tests and any required retests shall be carried out on weld metal in the as-welded or postweld heat-treated condition using a type 1.3 all-weld metal test piece in accordance with ISO 15792-1 prepared using the solid wire electrode, or tubular cored electrode, and flux of the particular trade designation to be classified. Welding conditions (single wire welding) shall be selected from Table 6A as appropriate.

5B Classification by tensile strength and chemical composition

Tensile and impact tests and any required retests shall be carried out on weld metal in the as-welded or postweld heat-treated condition using a type 1.4 all-weld metal test piece in accordance with ISO 15792-1, prepared using the solid wire electrode, or tubular cored electrode, and flux of the particular trade designation to be classified. Welding conditions (single wire welding) shall be selected from Table 6B as appropriate.

5.1 Preheating, interpass and post-weld heat treatment temperatures

Preheating and interpass temperatures shall be as specified for the electrode/all-weld metal deposit type in Table 1A or Table 5B as appropriate.

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 be within the interpass temperature range indicated in Table 1A or Table 5B, as appropriate. If, after any pass, the interpass temperature range is exceeded, the test piece shall be cooled in air to a temperature within the limits of the interpass temperature range.

Post-weld heat treatment, if used, shall be performed in accordance with Table 1A or Table 5B, as appropriate.

Table 4 — Chemical composition requirements for all-weld metal deposits

Symbol for classification in accordance with		Chemical composition % (by mass)[b]										
Chemical composition[a] ISO 24598-A	Tensile strength and chemical composition[a] ISO 24598-B	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Other
Mo	(1M3)	0,15	0,80	1,4	0,030	0,030	0,2	0,3	0,40 to 0,65	0,35	0,03	Nb: 0,01
(Mo)	1M3[c]	0,12	0,80	1,00	0,030	0,030	—	—	0,40 to 0,65	0,35	—	—
MnMo	(3M31)	0,15	0,80	2,0	0,030	0,030	0,2	0,3	0,40 to 0,65	0,35	0,03	Nb: 0,01
(MnMo)	3M31[c]	0,15	0,80	1,60	0,030	0,030	—	—	0,40 to 0,65	0,35	—	—
	4M3[c] 4M31[c]	0,15	0,80	2,10	0,030	0,030	—	—	0,40 to 0,65	0,35	—	—

Table 4 (*continued*)

Symbol for classification in accordance with		Chemical composition % (by mass)[b]										
Chemical composition[a] ISO 24598-A	Tensile strength and chemical composition[a] ISO 24598-B	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Other
MoV		0,15	0,80	1,4	0,030	0,030	0,20 to 0,60	0,3	0,45 to 1,00	0,35	0,20 to 0,45	Nb: 0,01
	CM[c] CM1[c]	0,12	0,80	1,60	0,030	0,030	0,40 to 0,65	—	0,40 to 0,65	0,35	—	—
	C1MH[c]	0,18	0,80	1,20	0,030	0,030	0,40 to 0,65	—	0,90 to 1,20	0,35	—	—
CrMo1	(1CM) (1CM1) (1CM2)	0,15	0,80	1,20	0,030	0,030	0,80 to 1,30	0,25	0,35 to 0,65	0,40	0,03	Nb: 0,01
(CrMo1)	1CM[c,d] 1CM1[c]	0,05 to 0,15	0,80	1,20	0,030	0,030	1,00 to 1,50	—	0,40 to 0,65	0,35	—	—
	1CMVH[c]	0,10 to 0,25	0,80	1,20	0,020	0,020	1,00 to 1,50	—	0,40 to 0,65	0,35	0,30	—
CrMoV1		0,15	0,80	1,40	0,030	0,030	0,80 to 1,30	0,3	0,80 to 1,30	0,35	0,10 to 0,35	Nb: 0,01
CrMo2	(2C1M)	0,15	0,80	1,20	0,030	0,030	2,0 to 2,8	0,3	0,80 to 1,15	0,35	0,03	Nb: 0,01
(CrMo2) (CrMo2Mn)	2C1M[c,d] 2C1M1[c] 2C1M2[c]	0,05 to 0,15	0,80	1,20	0,030	0,030	2,00 to 2,50	—	0,90 to 1,20	0,35	—	—
CrMo2Mn[e]	(2C1M) (2C1M1)	0,10	0,80	1,40	0,030	0,020	1,8 to 2,5	0,3	0,80 to 1,20	0,35	0,03	Nb: 0,01
CrMo2L		0,05	0,80	1,20	0,030	0,030	2,0 to 2,8	0,3	0,80 to 1,15	0,35	0,03	Nb: 0,01
	2C1MV[c]	0,05 to 0,15	0,80	1,30	0,030	0,030	2,00 to 2,60	—	0,90 to 1,20	0,35	0,40	Nb: 0,01 to 0,10
(CrMo5)	5CM[c] 5CM1[c]	0,12	0,80	1,20	0,030	0,030	4,50 to 6,00	—	0,40 to 0,65	0,35	—	—
CrMo5	(5CM) (5CM1)	0,10	0,80	1,20	0,030	0,030	4,5 to 6,50	0,3	0,45 to 0,80	0,35	0,03	Nb: 0,01
	5CMH[c]	0,10 to 0,25	0,80	1,20	0,030	0,030	4,50 to 6,00	—	0,40 to 0,65	0,35	—	—
CrMo9	(9C1M)	0,10	0,80	1,20	0,030	0,030	8,0 to 10,0	1,0	0,70 to 1,20	0,35	0,15	Nb: 0,01

Table 4 (*continued*)

Symbol for classification in accordance with		Chemical composition % (by mass)[b]										
Chemical composition[a] ISO 24598-A	**Tensile strength and chemical composition[a] ISO 24598-B**	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Ni**	**Mo**	**Cu**	**V**	**Other**
(CrMo9)	9C1M[c]	0,12	0,80	1,20	0,030	0,030	8,00 to 10,00	—	0,80 to 1,20	0,35	—	—
CrMo91	(9C1MV)	0,15	0,80	1,80	0,030	0,030	8,0 to 10,5	1,0	0,70 to 1,20	0,35	0,10 to 0,30	Nb: 0,02 to 0,10 N: 0,02 to 0,07
	9C1MV[c]	0,08 to 0,13	0,80	1,20[f]	0,010	0,010	8,0/***?*/** to 10,5	0,80[f]	0,85 to 1,20	0,10	0,15 to 0,25	Nb: 0,02 to 0,10 N: 0,02 to 0,07 Al: 0,04
	9C1MV1[c,f]	0,12	0,60	1,25	0,030	0,030	8,00 to 10,50	1,00	0,80 to 1,20	0,35	0,10 to 0,50	Nb: 0,01 to 0,12 N: 0,01 to 0,05
	9C1MV2[c]	0,12	0,60	1,25 to 2,00	0,030	0,030	8,00 to 10,50	1,00	0,80 to 1,20	0,35	0,10 to 0,50	Nb: 0,01 to 0,12 N: 0,01 to 0,05
CrMoWV12		0,24	0,80	1,4	0,030	0,030	9,5 to 12,0	0,80	0,70 to 1,20	0,35	0,15 to 0,40	Nb: 0,01 W: 0,30 to 0,80
Z[g]	G[g]	Any other agreed composition										

Symbol for classification in accordance with		Chemical composition % (by mass)[b]										
Chemical composition[a] ISO 24598-A	Tensile strength and chemical composition[a] ISO 24598-B	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Other

[a] A designation in parentheses, e.g. (CrMo1) or (1CM)],indicates a near match in the other designation system, but not an exact match. The correct designation for a given composition is the one without parentheses. A given product may, by having a more restricted chemical composition that fulfils both sets of requirements, be assigned both designations independently, provided that the mechanical property requirements of Tables 1A, 1B and 2B are also satisfied.

[b] Single values are maxima.

[c] The all-weld metal deposit 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 Fe) does not exceed 0,50 % (by mass).

[d] The letter R when added as a suffix is an optional supplemental designator indicating that the following limits apply in place of those shown in the table: S: 0,010 % (by mass); P: 0,010 % (by mass); Cu: 0,15 % (by mass); As: 0,005 % (by mass); Sn: 0,005 % (by mass); Sb: 0,005 % (by mass).

[e] A Mn/Si ratio greater than 2,0 is desirable.

[f] Mn + Ni = 1,50 % (by mass)maximum.

[g] Consumables for which the chemical composition is not listed in the table shall be symbolized similarly and prefixed by the letter Z (ISO 24598-A) or G (ISO 24598-B). The chemical-composition ranges are not specified and therefore it is possible that two electrodes with the same Z or G classification are not interchangeable.

5.2 Welding conditions and pass sequence

The test piece weld shall be completed in two passes per layer, except for the top layer, which 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.

5.2A Classification by chemical composition

The weld test piece shall be produced using a 4,0 mm or 3,2 mm or 3,0 mm electrode, whichever is the largest diameter manufactured. The flux used shall be recorded in the test report. The welding conditions for solid wire electrodes shall be as given in Table 6A. The welding conditions for tubular cored electrodes shall be in accordance with the manufacturer's recommendations.

5.2B Classification by tensile strength and chemical composition

Classification is based on the properties of the weld metal produced from 4,0 mm electrodes, or the closest size to 4,0 mm if 4,0 mm is not manufactured. The welding conditions for solid wire electrodes shall be as given in Table 6B. The welding conditions for tubular cored electrodes shall be in accordance with the manufacturer's recommendations.

Table 5B — Preheat, interpass and post-weld heat treatment temperatures
(Classification by tensile strength and chemical composition)

Alloy symbol	Preheat and interpass temperature °C	Post-weld heat treatment of test piece[a]	
		Temperature °C	Time min
1M3	150 ± 15	620 ± 15	60^{+15}_{0}
2M3	150 ± 15	620 ± 15	60^{+15}_{0}
2M31	150 ± 15	620 ± 15	60^{+15}_{0}
3M3	150 ± 15	620 ± 15	60^{+15}_{0}
3M31	150 ± 15	620 ± 15	60^{+15}_{0}
4M3	150 ± 15	620 ± 15	60^{+15}_{0}
4M31	150 ± 15	620 ± 15	60^{+15}_{0}
4M32	150 ± 15	620 ± 15	60^{+15}_{0}
CM	150 ± 15	620 ± 15	60^{+15}_{0}
CM1	150 ± 15	620 ± 15	60^{+15}_{0}
C1MH	150 ± 15	620 ± 15	60^{+15}_{0}
1CM	150 ± 15	690 ± 15	60^{+15}_{0}
1CM1	150 ± 15	690 ± 15	60^{+15}_{0}
1CMVH	150 ± 15	690 ± 15	60^{+15}_{0}
2C1M	205 ± 15	690 ± 15	60^{+15}_{0}
2C1M1	205 ± 15	690 ± 15	60^{+15}_{0}
2C1M2	205 ± 15	690 ± 15	60^{+15}_{0}
2C1MV	205 ± 15	690 ± 15	60^{+15}_{0}
5CM	205 ± 15	745 ± 15	60^{+15}_{0}
5CM1	205 ± 15	745 ± 15	60^{+15}_{0}
5CMH	205 ± 15	745 ± 15	60^{+15}_{0}
9C1MV	[b]	760 ± 15	120^{+15}_{0}
9C1MV1	205 ± 15	745 ± 15	60^{+15}_{0}
9C1MV2	205 ± 15	745 ± 15	60^{+15}_{0}

[a] The furnace shall be at a temperature not higher than 315 °C when the test piece is placed in it. The heating rate from that point to the specified holding temperature shall not exceed 220 °C/h. When the holding time at temperature has been completed, the test piece shall be allowed to cool in the furnace to a temperature below 315 °C at a rate not exceeding 195 °C/h. The test piece may be removed from the furnace at any temperature below 315 °C and allowed to cool in still air to ambient temperature.

[b] The preheat and interpass temperature range shall be 205 °C to 320 °C.

6 Chemical analysis

For solid wire electrodes, chemical analysis shall be performed on specimens of the solid wire electrode. For all electrode/flux combinations to be classified, chemical analysis shall be performed on the all-weld metal deposit prepared according to ISO 6847. Any analytical technique may be used, but in case of dispute reference shall be made to established published methods.

7 Rounding procedure

For purposes of determining compliance with the requirements of this International Standard, the 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 International Standard, the measured values shall be converted to the units of this International Standard before rounding. If an arithmetic average value is to be compared to the requirements of this International Standard, rounding shall be done only after calculating the arithmetic average. If the test method cited in Clause 2 contains instructions for rounding that conflict with the instructions of this International Standard, the rounding requirements of the test method standard shall apply. The rounded results shall fulfil the requirements of the appropriate table for the classification under test.

8 Retests

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 piece or from a new test piece. For chemical analysis, retest need be only for those specific elements that fail to meet its 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 specification 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 piece or test piece(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 pieces does not apply.

Table 6A — Welding conditions for solid wire electrodes
(Classification by chemical composition)

Electrode diameter	Welding current	Welding voltage[a]	Contact-tip-to-work distance	Travel speed
mm	A	V	mm	mm/min
No corresponding values				
3,0	380 ± 20	29 ± 2	24 ± 3	550 ± 50
3,2	380 ± 20	29 ± 2	24 ± 3	550 ± 50
4,0	580 ± 20	29 ± 2	30 ± 5	550 ± 50
No corresponding values				

[a] The polarity may be a.c. or d.c. The reference method shall be as recommended by the manufacturer.

Table 6B — Welding conditions for solid wire electrodes
(Classification by tensile strength and chemical composition)

Electrode diameter	Welding current[a]	Welding voltage[b]	Contact-tip-to-work distance[c]	Travel speed
mm	A	V	mm	mm/min
1,6	300 ± 50	26 to 29	13 to 19	300 ± 30
2,0	350 ± 50	26 to 29	13 to 19	330 ± 30
2,5 or 2,4	400 ± 50	27 to 30	19 to 32	360 ± 30
2,8	450 ± 50	27 to 30	19 to 32	360 ± 30
3,0	450 ± 50	27 to 30	25 to 38	390 ± 30
3,2	475 ± 50	27 to 30	25 to 38	390 ± 30
4,0	525 ± 50	27 to 30	25 to 38	420 ± 30
4,8	575 ± 50	27 to 30	25 to 38	420 ± 30
5,0	600 ± 50	27 to 30	25 to 38	420 ± 30
5,6	625 ± 50	28 to 31	32 to 44	450 ± 30
6,0	675 ± 50	28 to 31	32 to 44	480 ± 30
6,4	750 ± 50	28 to 32	38 to 50	510 ± 30

[a] A lower current may be used for the first layer.

[b] The polarity may be a.c. or d.c. The reference method shall be as recommended by the manufacturer.

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

9 Technical delivery conditions

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

10 Examples of designation

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

10A Classification by chemical composition

EXAMPLE 1A

A solid wire electrode for submerged arc welding with the chemical composition within the limits of the alloy symbol CrMo1 of Table 3 is designated as follows:

ISO 24598-A – S S CrMo1

where

ISO 24598-A is the number of this International Standard, with classification by chemical composition;

the first S indicates the submerged arc welding process;

the second S designates a solid wire electrode;

CrMo1 is the chemical composition of the solid wire electrode (see Table 3).

EXAMPLE 2A

A solid wire electrode/flux combination for submerged arc welding, with the solid wire electrode chemical composition within the limits of the alloy symbol CrMo1 of Table 3, produces an all-weld metal deposit having proof strength of at least 355 MPa in the post-weld heat-treated condition, impacts of at least 47 J energy at +20 °C according to Table 1A and a deposit composition within the limits of the alloy symbol CrMo1 of Table 4, with a flux of a specific trade name that is aluminate-basic (AB), is designated as follows:

ISO 24598-A – S S CrMo1 AB

where

ISO 24598-A is the number of this International Standard, with classification by chemical composition;

the first S indicates the submerged arc welding process;

the second S designates a solid wire electrode;

CrMo1 indicates:

— the tensile and impact properties in the post-weld heat-treated condition (see Table 1A),

— that the solid wire electrode meets the CrMo1

10B Classification by tensile strength and chemical composition

EXAMPLE 1B

A solid wire electrode for submerged arc welding with the chemical composition within the limits of the alloy symbol SU1CM of Table 3 is designated as follows:

ISO 24598-B – SU 1CM

where

ISO 24598-B is the number of this International Standard, with classification by tensile strength and chemical composition;

SU designates a solid wire electrode for submerged arc welding;

1CM is the chemical composition of the solid wire electrode (see Table 3).

EXAMPLE 2B

A solid wire electrode/flux combination for submerged arc welding, with the solid wire electrode chemical composition within the limits of the alloy symbol 1CM of Table 3, produces an all-weld metal deposit having tensile strength of at least 550 MPa (55) in the post-weld heat-treated condition, impacts of at least 27 J energy at –40 °C (4) and deposit composition within the limits of the alloy symbol 1CM of Table 4, with a flux of a specific trade name that is aluminate-basic (AB), is designated as follows:

ISO 24598-B – S 55 4 AB SU 1CM

where

ISO 24598-B is the number of this International Standard, with classification by tensile strength and chemical composition;

S designates an electrode/flux combination for submerged arc welding;

55 indicates the tensile properties in the post-weld heat-treated condition (see Table 1B);

4 indicates the impact properties (see Table 2B);

AB indicates that the specific trade name flux is aluminate-basic (see 4.5);

composition limits of Table 3 and the all-weld metal deposit meets the CrMo1 composition limits of Table 4;

AB indicates that the specific trade name flux is aluminate-basic (see 4.5).

EXAMPLE 3A

A tubular cored wire electrode/flux combination for submerged arc welding produces an all-weld metal deposit having proof strength of at least 355 MPa in the post-weld heat-treated condition, impacts of at least 47 J energy at +20 °C according to Table 1A and a deposit composition within the limits of the alloy symbol CrMo1 of Table 4, with a flux of a specific trade name that is aluminate-basic (AB), is designated as follows:

ISO 24598-A – S T CrMo1 AB

where

ISO 24598-A is the number of this International Standard, with classification by chemical composition;

S indicates the submerged arc welding process;

T designates a tubular cored wire electrode;

CrMo1 indicates:

— the tensile and impact properties in the post-weld heat-treated condition (see Table 1A),

— that the all-weld metal deposit meets the CrMo1 composition limits of Table 4;

AB indicates that the specific trade name flux is aluminate-basic (see 4.5).

SU indicates a solid wire electrode for submerged arc welding;

1CM indicates that the solid wire electrode meets the 1CM composition limits of Table 3 and the all-weld metal deposit meets the 1CM composition limits of Table 4.

EXAMPLE 3B

A tubular cored electrode/flux combination (TU) produces an all-weld metal deposit having tensile strength of at least 550 MPa (55) in the post-weld heat-treated condition, impacts of at least 27 J energy at –40 °C (4) and deposit composition within the limits of the alloy symbol 1CM of Table 4, with a flux of a specific trade name that is aluminate-basic (AB), is designated as follows:

ISO 24598-B – S 55 4 AB TU1CM

where

ISO 24598-B is the number of this International Standard, with classification by tensile strength and chemical composition;

S designates an electrode/flux combination for submerged arc welding;

55 indicates the tensile properties in the post-weld heat-treated condition (see Table 1B);

4 indicates the impact properties (see Table 2B);

AB indicates that the specific trade name flux is aluminate-basic (see 4.5);

TU indicates a tubular cored electrode for submerged arc welding;

1CM indicates that the all-weld metal deposit with a particular flux meets the 1CM composition limits of Table 4.

Bibliography

[1] EN 12070:1999, *Welding consumables — Wire electrodes, wires and rods for arc welding of creep-resisting steels — Classification*

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