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Welding consumables — Tubular cored electrodes and rods for gas shielded and non-gas shielded metal arc welding of stainless and heat-resisting steels — Classification

Produits consommables pour le soudage — Fils et baguettes fourrés pour le soudage à l'arc avec ou sans protection gazeuse des aciers inoxydables et des aciers résistant aux températures élevées — 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.

ISO 17633 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 17633:2004), of which it constitutes a technical revision.

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 provides a classification system for tubular cored electrodes and rods for welding stainless steels. It recognizes that there are two somewhat different approaches in the global market to classifying a given tubular stainless steel welding consumable, 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 according to system A is mainly based on EN 12073:1999[2]. The classification according to system B is mainly based upon standards used around the Pacific Rim.

Welding consumables — Tubular cored electrodes and rods for gas shielded and non-gas shielded metal arc welding of stainless and heat-resisting steels — Classification

1 Scope

This International Standard specifies requirements for classification of tubular flux and metal cored electrodes and rods, based on the all-weld metal chemical composition, the type of electrode core, shielding gas, welding position and the all-weld metal mechanical properties, in the as-welded or heat-treated conditions, for gas shielded and non-gas shielded metal arc welding of stainless and heat-resisting steels.

This International Standard is a combined standard providing for classification utilizing a system based upon nominal composition or utilizing a system based upon alloy type.

a) Clauses, subclauses, and tables which carry the suffix letter “A” are applicable only to products classified using the system based upon nominal composition.

b) Clauses, subclauses, and tables which carry the suffix letter “B” are applicable only to products classified using the system based upon alloy type.

c) Clauses, subclauses, and tables which do not have either the suffix letter “A” or the suffix letter “B” are applicable to all tubular cored electrodes classified in accordance with this International Standard.

It is recognized that the operating characteristics of tubular cored electrodes can be modified by the use of pulsed current. However, this International Standard does not use pulsed current for determining the electrode classification.

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 6947:2010, *Welding and allied processes — Welding positions*

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

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

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

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

ISO 15792-3, *Welding consumables — Test methods — Part 3: Classification testing of positional capacity and root penetration of welding consumables in a fillet weld*

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

3 Classification

Classification designations are based upon two approaches to indicating the chemical composition of the all-weld metal deposit obtained with a given electrode or rod.

The “nominal composition” approach uses designation components indicating directly the nominal levels of certain alloying elements, given in a particular order, and some symbols for low but significant levels of other elements, whose levels are not conveniently expressed as integers. The “alloy type” approach uses tradition-based three- or four-digit designations for alloy families, and an occasional additional character or characters for compositional modifications of each original alloy within the family.

This clause includes the symbols for the type of product, the chemical composition of all-weld metal, the type of electrode core, the shielding gas and the welding position, in accordance with the symbols defined in Clause 4.

In most cases, a given commercial product can be classified in both systems. Then either or both classification designations can be used for the product.

3A Classification according to nominal composition

The classification is divided into five parts:

a) the first part gives a symbol indicating the product to be identified (see 4.1A);

b) the second part gives a symbol indicating the chemical composition of the all-weld metal (see Table 1A);

c) the third part gives a symbol indicating the type of electrode core (see Table 3A);

d) the fourth part gives a symbol indicating the shielding gas (see 4.4);

e) the fifth part gives a symbol indicating the welding position (see Table 4A).

3B Classification according to alloy type

The classification is divided into five parts:

a) the first part gives a symbol indicating the tubular cored electrode and rod (see 4.1B);

b) the second part gives a symbol indicating the chemical composition of the all-weld metal (see Tables 1B-1 to -4);

c) the third part gives a symbol indicating the type of tubular cored electrode or rod (see Table 3B);

d) the fourth part gives a symbol indicating the shielding gas (see 4.4);

e) the fifth part gives a symbol indicating the welding position (see Table 4B).

The full identification (see Clause 11) shall be used on packages and in the manufacturer's literature and data sheets.

4 Symbols and requirements

A given tubular cored electrode may be classified with more than one shielding gas. In such cases, each shielding gas results in a separate classification.

4.1 Symbol for the product

4.1A Classification according to nominal composition

The symbol for the tubular cored electrode used in the metal arc welding process shall be the letter “T”.

4.1B Classification according to alloy type

The symbol for the tubular cored electrode or rod used in the metal arc welding process shall be the letters “TS”. The initial letter, “T”, indicates tubular cored electrode or rod as distinguished from covered electrodes and from solid electrodes and rods. The second letter, “S”, indicates that the alloy system is stainless or heat-resisting steel.

4.2 Symbol for the chemical composition of all-weld metal

4.2A Classification according to nominal composition

The symbols in Table 1A identify the chemical composition of all-weld metal determined in accordance with Clause 6.

The all-weld metal obtained with the tubular cored electrodes in Table 1A under conditions given in Clause 5 shall also fulfil the requirements given in Table 2A. (See Annex A.)

4.2B Classification according to alloy type

The symbols in Table 1B-1 identify the chemical composition of all-weld metal for gas shielded flux cored electrodes determined in accordance with Clause 6.

The symbols in Table 1B-2 identify the chemical composition of all-weld metal for non-gas shielded flux cored electrodes determined in accordance with Clause 6.

The symbols in Table 1B-3 identify the chemical composition of all-weld metal for gas shielded metal cored electrodes determined in accordance with Clause 6.

The symbols in Table 1B-4 identify the chemical composition of all-weld metal for cored rods for gas tungsten arc welding determined in accordance with Clause 6.

The all-weld metal obtained with the tubular cored electrodes and rods in Tables 1B-1, 1B-2, 1B-3 and 1B-4 under conditions given in Clause 5 shall also fulfil the requirements given in Table 2B. (See Annex A.)

Table 1A — Symbols and all-weld metal chemical composition requirements (classification according to nominal composition)

Alloy designation according to nominal composition	Chemical composition, % (by mass)[a, b]											
	C	Mn	Si	P[c]	S[c]	Cr	Ni	Mo	Nb + Ta[d]	Cu	N	Others
Martensitic/ferritic types												
13	0,12	1,5	1,0	0,030	0,025	11,0 to 14,0	0,3	0,3	—	0,5	—	—
13 Ti	0,10	0,80	1,0	0,030	0,030	10,5 to 13,0	0,3	0,3	—	0,5	—	Ti: 10 × C to 1,5
13 4	0,06	1,5	1,0	0,030	0,025	11,0 to 14,5	3,0 to 5,0	0,4 to 1,0	—	0,5	—	—
17	0,12	1,5	1,0	0,030	0,025	16,0 to 18,0	0,3	0,3	—	0,5	—	—
Austenitic types												
19 9 L	0,04	2,0	1,2	0,030	0,025	18,0 to 21,0	9,0 to 11,0	0,3	—	0,5	—	—
19 9 Nb	0,08	2,0	1,2	0,030	0,025	18,0 to 21,0	9,0 to 11,0	0,3	8 × C to 1,1	0,5	—	—
19 12 3 L	0,04	2,0	1,2	0,030	0,025	17,0 to 20,0	10,0 to 13,0	2,5 to 3,0	—	0,5	—	—
19 12 3 Nb	0,08	2,0	1,2	0,030	0,025	17,0 to 20,0	10,0 to 13,0	2,5 to 3,0	8 × C to 1,1	0,5	—	—
Ferritic-austenitic types (sometimes referred to as austenitic-ferritic types)												
22 9 3 N L	0,04	2,5	1,2	0,030	0,025	21,0 to 24,0	7,5 to 10,5	2,5 to 4,0	—	0,5	0,08 to 0,20	—
23 7 N L	0,04	0,4 to 1,5	1,0	0,030	0,020	22,5 to 25,5	6,5 to 10,0	0,8	—	0,5	0,10 to 0,20	—
25 9 4 N L	0,04	2,5	1,2	0,030	0,025	24,0 to 27,0	8,0 to 10,5	2,5 to 4,5	—	—	0,20 to 0,30	—
25 9 4 Cu N L	0,04	2,5	1,2	0,030	0,025	24,0 to 27,0	8,0 to 10,5	2,5 to 4,5	—	1,0 to 2,5	0,20 to 0,30	—
Fully austenitic types												
18 16 5 N L [e]	0,03	1,0 to 4,0	1,0	0,03	0,02	17,0 to 20,0	16,0 to 19,0	3,5 to 5,0	—	0,5	0,10 to 0,20	—
19 13 4 N L [e]	0,04	1,0 to 5,0	1,2	0,030	0,025	17,0 to 20,0	12,0 to 15,0	3,0 to 4,5	—	0,5	0,08 to 0,20	—
20 25 5 Cu N L [e]	0,03	1,0 to 4,0	1,0	0,03	0,02	19,0 to 22,0	24,0 to 27,0	4,0 to 6,0	—	1,0 to 2,0	0,10 to 0,20	—

Table 1A (*continued*)

Alloy designation according to nominal composition	**Chemical composition,** % (by mass)[a, b]											
	C	Mn	Si	P[c]	S[c]	Cr	Ni	Mo	Nb + Ta[d]	Cu	N	Others
Special types — Often used for dissimilar metal joining												
18 8 Mn	0,20	4,5 to 7,5	1,2	0,035	0,025	17,0 to 20,0	7,0 to 10,0	0,3	—	0,5	—	—
18 9 Mn Mo	0,04 to 0,14	3,0 to 5,0	1,2	0,035	0,025	18,0 to 21,5	9,0 to 11,0	0,5 to 1,5	—	—	—	—
20 10 3	0,08	2,5	1,2	0,035	0,025	19,5 to 22,0	9,0 to 11,0	2,0 to 4,0	—	0,5	—	—
23 12 L	0,04	2,5	1,2	0,030	0,025	22,0 to 25,0	11,0 to 14,0	0,3	—	0,5	—	—
23 12 Nb	0,08	1,0 to 2,5	1,0	0,03	0,02	22,0 to 25,0	11,0 to 14,0	0,3	10 × C to 1,0	0,5	—	—
23 12 2 L	0,04	2,5	1,2	0,030	0,025	22,0 to 25,0	11,0 to 14,0	2,0 to 3,0	—	0,5	—	—
29 9	0,15	2,5	1,2	0,035	0,025	27,0 to 31,0	8,0 to 12,0	0,3	—	0,5	—	—
Heat-resisting types												
16 8 2	0,10	1,0	1,0 to 2,5	0,03	0,02	14,5 to 17,5	7,5 to 9,5	1,0 to 2,5	—	0,5	—	Cr + Mo: 18,5
19 9 H	0,04 to 0,08	1,0	1,0 to 2,5	0,03	0,02	18,0 to 21,0	9,0 to 11,0	0,3	—	0,5	—	—
21 10 N	0,06 to 0,09	0,3 to 1,0	1,0 to 2,0	0,02	0,01	20,5 to 22,5	9,5 to 11,0	0,5	—	0,5	0,10 to 0,20	Ce: 0,05
22 12 H	0,15	2,5	1,2	0,030	0,025	20,0 to 23,0	10,0 to 13,0	0,3	—	0,5	—	—
25 4	0,15	2,0	1,0 to 2,5	0,03	0,02	24,0 to 27,0	4,0 to 6,0	0,3	—	0,5	—	—

Table 1A (*continued*)

Alloy designation according to nominal composition	Chemical composition, % (by mass)[a, b]											
	C	Mn	Si	P[c]	S[c]	Cr	Ni	Mo	Nb + Ta[d]	Cu	N	Others
25 20[e]	0,06 to 0,20	1,0 to 5,0	1,2	0,030	0,025	23,0 to 27,0	18,0 to 22,0	0,3	—	0,5	—	—
Z[f]	Any other agreed composition											

[a] Single values are maximum values.

[b] "No requirement for analysis" is indicated by a dash.

[c] The sum of P and S shall not exceed 0,050 % (by mass), except for 18 16 5 N L, 18 8 Mn, and 29 9.

[d] Up to 20 % (by mass) of the amount of Nb can be replaced by Ta.

[e] The all-weld metal is in most cases fully austenitic and therefore can be susceptible to microfissuring or hot cracking. The occurrence of fissuring or cracking is reduced by increasing the weld metal manganese level and in recognition of this the manganese range is extended for a number of grades.

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

Table 1B-1 — Symbols and all-weld metal chemical composition requirements of gas shielded flux cored electrodes (classification according to alloy type)

Alloy designation according to alloy type	Shielding gas (see 4.4)	Chemical composition, % (by mass)[a, b]											
		C	Mn	Si	P	S	Cr	Ni	Mo	Nb + Ta	Cu	N	Others
307	C1, M12, M21, Z	0,13	3,30 to 4,75	1,0	0,04	0,03	18,0 to 20,5	9,0 to 10,5	0,5 to 1,5	—	0,75	—	—
308	C1, M12, M21, Z	0,08	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	9,0 to 11,0	0,75	—	0,75	—	—
308L	C1, M12, M21, Z	0,04	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	9,0 to 12,0	0,75	—	0,75	—	—
308H	C1, M12, M21, Z	0,04 to 0,08	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	9,0 to 11,0	0,75	—	0,75	—	—
308Mo	C1, M12, M21, Z	0,08	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	9,0 to 11,0	2,0 to 3,0	—	0,75	—	—
308LMo	C1, M12, M21, Z	0,04	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	9,0 to 12,0	2,0 to 3,0	—	0,75	—	—
309	C1, M12, M21, Z	0,10	0,5 to 2,5	1,0	0,04	0,03	22,0 to 25,0	12,0 to 14,0	0,75	—	0,75	—	—
309L	C1, M12, M21, Z	0,04	0,5 to 2,5	1,0	0,04	0,03	22,0 to 25,0	12,0 to 14,0	0,75	—	0,75	—	—
309H	C1, M12, M21, Z	0,04 to 0,10	0,5 to 2,5	1,0	0,04	0,03	22,0 to 25,0	12,0 to 14,0	0,75	—	0,75	—	—
309Mo	C1, M12, M21, Z	0,12	0,5 to 2,5	1,0	0,04	0,03	21,0 to 25,0	12,0 to 16,0	2,0 to 3,0	—	0,75	—	—
309LMo	C1, M12, M21, Z	0,04	0,5 to 2,5	1,0	0,04	0,03	21,0 to 25,0	12,0 to 16,0	2,0 to 3,0	—	0,75	—	—
309LNb	C1, M12, M21, Z	0,04	0,5 to 2,5	1,0	0,04	0,03	22,0 to 25,0	12,0 to 14,0	0,75	0,7 to 1,0	0,75	—	—
309LNiMo	C1, M12, M21, Z	0,04	0,5 to 2,5	1,0	0,04	0,03	20,5 to 23,5	15,0 to 17,0	2,5 to 3,5	—	0,75	—	—

Table 1B-1 (*continued*)

Alloy designation according to alloy type	**Chemical composition**, % (by mass)[a, b]												
	Shielding gas (see 4.4)	C	Mn	Si	P	S	Cr	Ni	Mo	Nb + Ta	Cu	N	Others
310	C1, M12, M21, Z	0,20	1,0 to 2,5	1,0	0,03	0,03	25,0 to 28,0	20,0 to 22,5	0,75	—	0,75	—	—
312	C1, M12, M21, Z	0,15	0,5 to 2,5	1,0	0,04	0,03	28,0 to 32,0	8,0 to 10,5	0,75	—	0,75	—	—
316	C1, M12, M21, Z	0,08	0,5 to 2,5	1,0	0,04	0,03	17,0 to 20,0	11,0 to 14,0	2,0 to 3,0	—	0,75	—	—
316L	C1, M12, M21, Z	0,04	0,5 to 2,5	1,0	0,04	0,03	17,0 to 20,0	11,0 to 14,0	2,0 to 3,0	—	0,75	—	—
316H	C1, M12, M21, Z	0,04 to 0,08	0,5 to 2,5	1,0	0,04	0,03	17,0 to 20,0	11,0 to 14,0	2,0 to 3,0	—	0,75	—	—
316LCu	C1, M12, M21, Z	0,04	0,5 to 2,5	1,0	0,04	0,03	17,0 to 20,0	11,0 to 16,0	1,25 to 2,75	—	1,0 to 2,5	—	—
317	C1, M12, M21, Z	0,08	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	12,0 to 14,0	3,0 to 4,0	—	0,75	—	—
317L	C1, M12, M21, Z	0,04	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	12,0 to 14,0	3,0 to 4,0	—	0,75	—	—
318	C1, M12, M21, Z	0,08	0,5 to 2,5	1,0	0,04	0,03	17,0 to 20,0	11,0 to 14,0	2,0 to 3,0	8 × C to 1,0	0,75	—	—
347	C1, M12, M21, Z	0,08	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	9,0 to 11,0	0,75	8 × C to 1,0	0,75	—	—
347L	C1, M12, M21, Z	0,04	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	9,0 to 11,0	0,75	8 × C to 1,0	0,75	—	—
347H	C1, M12, M21, Z	0,04 to 0,08	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	9,0 to 11,0	0,5	8 × C to 1,0	0,75	—	—
409	C1, M12, M21, Z	0,10	0,80	1,0	0,04	0,03	10,5 to 13,5	0,6	0,75	—	0,75	—	Ti: 10 × C to 1,5
409Nb	C1, M12, M21, Z	0,10	1,2	1,0	0,04	0,03	10,5 to 13,5	0,6	0,75	8 × C to 1,5	0,75	—	—

Table 1B-1 (*continued*)

Alloy designation according to alloy type	Chemical composition, % (by mass)[a, b]												
	Shielding gas (see 4.4)	C	Mn	Si	P	S	Cr	Ni	Mo	Nb + Ta	Cu	N	Others
410	C1, M12, M21, Z	0,12	1,2	1,0	0,04	0,03	11,0 to 13,5	0,6	0,75	—	0,75	—	—
410NiMo	C1, M12, M21, Z	0,06	1,0	1,0	0,04	0,03	11,0 to 12,5	4,0 to 5,0	0,4 to 0,7	—	0,75	—	—
430	C1, M12, M21, Z	0,10	1,2	1,0	0,04	0,03	15,0 to 18,0	0,6	0,75	—	0,75	—	—
430Nb	C1, M12, M21, Z	0,10	1,2	1,0	0,04	0,03	15,0 to 18,0	0,6	0,75	0,5 to 1,5	0,75	—	—
16-8-2	C1, M12, M21, Z	0,10	0,5 to 2,5	0,75	0,04	0,03	14,5 to 17,5	7,5 to 9,5	1,0 to 2,0	—	0,75	—	Cr + Mo: 18,5
2209	C1, M12, M21, Z	0,04	0,5 to 2,0	1,0	0,04	0,03	21,0 to 24,0	7,5 to 10,0	2,5 to 4,0	—	0,75	0,08 to 0,20	—
2553	C1, M12, M21, Z	0,04	0,5 to 1,5	0,75	0,04	0,03	24,0 to 27,0	8,5 to 10,5	2,9 to 3,9	—	1,5 to 2,5	0,10 to 0,25	—
2594	C1, M12, M21, Z	0,04	0,5 to 2,5	1,0	0,04	0,03	24,0 to 27,0	8,0 to 10,5	2,5 to 4,5	—	1,5	0,20 to 0,30	W: 1,0
Z [c]	C1, M12, M21, Z	Any other agreed composition											

[a] Single values are maximum values.

[b] "No requirement for analysis" is indicated by a dash.

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

Table 1B-2 — Symbols and all-weld metal chemical composition requirements of non-gas shielded flux cored electrodes (classification according to alloy type)

Alloy designation according to alloy type	Chemical composition, % (by mass)[a, b]												
	Shielding gas (see 4.4)	C	Mn	Si	P	S	Cr	Ni	Mo	Nb + Ta	Cu	N	Others
307	NO	0,13	3,30 to 4,75	1,0	0,04	0,03	19,5 to 22,0	9,0 to 10,5	0,5 to 1,5	—	0,75	—	—
308	NO	0,08	0,5 to 2,5	1,0	0,04	0,03	19,5 to 22,0	9,0 to 11,0	0,75	—	0,75	—	—
308L	NO	0,04	0,5 to 2,5	1,0	0,04	0,03	19,5 to 22,0	9,0 to 12,0	0,75	—	0,75	—	—
308H	NO	0,04 to 0,08	0,5 to 2,5	1,0	0,04	0,03	19,5 to 22,0	9,0 to 11,0	0,75	—	0,75	—	—
308Mo	NO	0,08	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	9,0 to 11,0	2,0 to 3,0	—	0,75	—	—
308LMo	NO	0,04	0,5 to 2,5	1,0	0,04	0,03	18,0 to 21,0	9,0 to 12,0	2,0 to 3,0	—	0,75	—	—
308HMo	NO	0,07 to 0,12	1,25 to 2,25	0,25 to 0,80	0,04	0,03	19,0 to 21,5	9,0 to 10,7	1,8 to 2,4	—	0,75	—	—
309	NO	0,10	0,5 to 2,5	1,0	0,04	0,03	23,0 to 25,5	12,0 to 14,0	0,75	—	0,75	—	—
309L	NO	0,04	0,5 to 2,5	1,0	0,04	0,03	23,0 to 25,5	12,0 to 14,0	0,75	—	0,75	—	—
309Mo	NO	0,12	0,5 to 2,5	1,0	0,04	0,03	21,0 to 25,0	12,0 to 16,0	2,0 to 3,0	—	0,75	—	—
309LMo	NO	0,04	0,5 to 2,5	1,0	0,04	0,03	21,0 to 25,0	12,0 to 16,0	2,0 to 3,0	—	0,75	—	—
309LNb	NO	0,04	0,5 to 2,5	1,0	0,04	0,03	23,0 to 25,5	12,0 to 14,0	0,75	0,7 to 1,0	0,75	—	—
310	NO	0,20	1,0 to 2,5	1,0	0,03	0,03	25,0 to 28,0	20,0 to 22,5	0,75	—	0,75	—	—
312	NO	0,15	0,5 to 2,5	1,0	0,04	0,03	28,0 to 32,0	8,0 to 10,5	0,75	—	0,75	—	—
316	NO	0,08	0,5 to 2,5	1,0	0,04	0,03	18,0 to 20,5	11,0 to 14,0	2,0 to 3,0	—	0,75	—	—
316L	NO	0,04	0,5 to 2,5	1,0	0,04	0,03	18,0 to 20,5	11,0 to 14,0	2,0 to 3,0	—	0,75	—	—
316H	NO	0,04 to 0,08	0,5 to 2,5	1,0	0,04	0,03	18,0 to 20,5	11,0 to 14,0	2,0 to 3,0	—	0,75	—	—
316LCu	NO	0,03	0,5 to 2,5	1,0	0,04	0,03	18,0 to 20,5	11,0 to 16,0	1,25 to 2,75	—	1,0 to 2,5	—	—
317	NO	0,08	0,5 to 2,5	1,0	0,04	0,03	18,5 to 21,0	13,0 to 15,0	3,0 to 4,0	—	0,75	—	—
317L	NO	0,04	0,5 to 2,5	1,0	0,04	0,03	18,5 to 21,0	13,0 to 15,0	3,0 to 4,0	—	0,75	—	—

Table 1B-2 (*continued*)

Alloy designation according to alloy type	**Chemical composition,** % (by mass)[a, b]												
	Shielding gas (see 4.4)	C	Mn	Si	P	S	Cr	Ni	Mo	Nb + Ta	Cu	N	Others
318	NO	0,08	0,5 to 2,5	1,0	0,04	0,03	18,0 to 20,5	11,0 to 14,0	2,0 to 3,0	8 × C to 1,0	0,75	—	—
347	NO	0,08	0,5 to 2,5	1,0	0,04	0,03	19,0 to 21,5	9,0 to 11,0	0,75	8 × C to 1,0	0,75	—	—
347L	NO	0,04	0,5 to 2,5	1,0	0,04	0,03	19,0 to 21,5	9,0 to 11,0	0,75	8 × C to 1,0	0,75	—	—
409	NO	0,10	0,80	1,0	0,04	0,03	10,5 to 13,5	0,6	0,75	—	0,75	—	Ti: 10 × C to 1,5
409Nb	NO	0,12	1,0	1,0	0,04	0,03	10,5 to 14,0	0,6	0,75	8 × C to 1,5	0,75	—	—
410	NO	0,12	1,0	1,0	0,04	0,03	11,0 to 13,5	0,6	0,75	—	0,75	—	—
410NiMo	NO	0,06	1,0	1,0	0,04	0,03	11,0 to 12,5	4,0 to 5,0	0,4 to 0,7	—	0,75	—	—
430	NO	0,10	1,0	1,0	0,04	0,03	15,0 to 18,0	0,6	0,75	—	0,75	—	—
430Nb	NO	0,10	1,0	1,0	0,04	0,03	15,0 to 18,0	0,6	0,75	0,5 to 1,5	0,75	—	—
16-8-2	NO	0,10	0,5 to 2,5	0,75	0,04	0,03	14,5 to 17,5	7,5 to 9,5	1,0 to 2,0	—	0,75	—	Cr + Mo: 18,5
2209	NO	0,04	0,5 to 2,0	1,0	0,04	0,03	21,0 to 24,0	7,5 to 10,0	2,5 to 4,0	—	0,75	0,08 to 0,20	—
2553	NO	0,04	0,5 to 1,5	0,75	0,04	0,03	24,0 to 27,0	8,5 to 10,5	2,9 to 3,9	—	1,5 to 2,5	0,10 to 0,20	—
2594	NO	0,04	0,5 to 2,5	1,0	0,04	0,03	24,0 to 27,0	8,0 to 10,5	2,5 to 4,5	—	1,5	0,20 to 0,30	W: 1,0
Z[c]	NO	Any other agreed composition											

[a] Single values are maximum values.

[b] "No requirement for analysis" is indicated by a dash.

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

Table 1B-3 — Symbols and all-weld metal chemical composition requirements of gas shielded metal cored electrodes (classification according to alloy type)

Alloy designation according to alloy type	Chemical composition, % (by mass)[a, b]												
	Shielding gas (see 4.4)	C	Mn	Si	P	S	Cr	Ni	Mo	Nb + Ta	Cu	N	Others
308L	M12, M13, M21, I1, Z	0,04	1,0 to 2,5	1,0	0,03	0,03	19,0 to 22,0	9,0 to 11,0	0,75	—	0,75	—	—
308Mo	M12, M13, M21, I1, Z	0,08	1,0 to 2,5	0,30 to 0,65	0,03	0,03	18,0 to 21,0	9,0 to 12,0	2,0 to 3,0	—	0,75	—	—
309L	M12, M13, M21, I1, Z	0,04	1,0 to 2,5	1,0	0,03	0,03	23,0 to 25,0	12,0 to 14,0	0,75	—	0,75	—	—
309LMo	M12, M13, M21, I1, Z	0,04	1,0 to 2,5	1,0	0,03	0,03	23,0 to 25,0	12,0 to 14,0	2,0 to 3,0	—	0,75	—	—
316L	M12, M13, M21, I1, Z	0,04	1,0 to 2,5	1,0	0,03	0,03	18,0 to 20,0	11,0 to 14,0	2,0 to 3,0	—	0,75	—	—
347	M12, M13, M21, I1, Z	0,08	1,0 to 2,5	0,30 to 0,65	0,04	0,03	19,0 to 21,5	9,0 to 11,0	0,75	10 × C to 1,0	0,75	—	—
409	M12, M13, M21, I1, Z	0,08	0,8	0,8	0,03	0,03	10,5 to 13,5	0,6	0,75	—	0,75	—	Ti: 10 × C to 1,5
409Nb	M12, M13, M21, I1, Z	0,12	1,2	1,0	0,04	0,03	10,5 to 13,5	0,6	0,75	8 × C to 1,5	0,75	—	—
410	M12, M13, M21, I1, Z	0,12	0,6	0,5	0,03	0,03	11,5 to 13,5	0,6	0,75	—	0,75	—	—
410NiMo	M12, M13, M21, I1, Z	0,06	1,0	1,0	0,03	0,03	11,0 to 12,5	4,0 to 5,0	0,4 to 0,7	—	0,75	—	—
430	M12, M13, M21, I1, Z	0,10	0,6	0,5	0,03	0,03	15,5 to 18,0	0,6	0,75	—	0,75	—	—
430Nb	M12, M13, M21, I1, Z	0,10	1,2	1,0	0,04	0,03	15,0 to 18,0	0,6	0,75	0,5 to 1,5	0,75	—	—
Z[c]	M12, M13, M21, I1, Z	Any other agreed composition											

[a] Single values are maximum values.

[b] "No requirement for analysis" is indicated by a dash.

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

Table 1B-4 — Symbols and all-weld metal chemical composition requirements of cored rods for gas tungsten arc welding (classification according to alloy type)

Alloy designation according to alloy type	Shielding gas (see 4.4)	**Chemical composition,** % (by mass) [a, b]											
		C	Mn	Si	P	S	Cr	Ni	Mo	Nb + Ta	Cu	N	Others
308L	I1, Z	0,03	0,5 to 2,5	1,2	0,04	0,03	18,0 to 21,0	9,0 to 11,0	0,5	—	0,5	—	—
309L	I1, Z	0,03	0,5 to 2,5	1,2	0,04	0,03	22,0 to 25,0	12,0 to 14,0	0,5	—	0,5	—	—
316L	I1, Z	0,03	0,5 to 2,5	1,2	0,04	0,03	17,0 to 20,0	11,0 to 14,0	2,0 to 3,0	—	0,5	—	—
347	I1, Z	0,08	0,5 to 2,5	1,2	0,04	0,03	18,0 to 21,0	9,0 to 11,0	0,5	8 × C to 1,0	0,5	—	—
Z[c]	I1, Z	Any other agreed composition											

[a] Single values are maximum values.

[b] "No requirement for analysis" is indicated by a dash.

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

Table 2A — Tensile properties of all-weld metal (classification according to nominal composition)

Alloy designation according to nominal composition	Minimum proof strength $R_{p0,2}$ MPa	Minimum tensile strength R_m MPa	Minimum elongation[a] %	Post-weld heat treatment
13	250	450	15	[b]
13 Ti	250	450	15	[b]
13 4	500	750	15	[c]
16 8 2	320	510	25	None
17	300	450	15	[d]
19 9 L	320	510	30	None
19 9 Nb	350	550	25	
19 12 3 L	320	510	25	
19 12 3 Nb	350	550	25	
19 13 4 N L	350	550	25	
19 9 H	350	550	30	
22 9 3 N L	450	550	20	
18 16 5 N L	300	480	25	
18 8 Mn	350	500	25	
18 9 Mn Mo	350	500	25	
20 10 3	400	620	20	
20 25 5 Cu N L	320	510	25	
21 10 N	350	550	30	
23 7 N L	450	570	20	
23 12 L	320	510	25	
23 12 Nb	350	550	25	
23 12 2 L	350	550	25	
29 9	450	650	15	
22 12 H	350	550	25	
25 20	350	550	20	
25 4	450	650	15	
25 9 4 Cu N L	550	620	18	
25 9 4 N L	550	620	18	
Z	Not specified			

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

[b] The weld test assembly (or the blank from it, from which the tensile test specimen is to be machined) shall be heated to a temperature between 840 °C and 870 °C, held for 2 h, then furnace cooled to 600 °C, then cooled in air.

[c] The weld test assembly (or the blank from it, from which the tensile test specimen is to be machined) shall be heated to a temperature between 580 °C and 620 °C, held for 2 h, then cooled in air.

[d] The weld test assembly (or the blank from it, from which the tensile test specimen is to be machined) shall be heated to a temperature between 760 °C and 790 °C, held for 2 h, then furnace cooled to 600 °C, then cooled in air.

Table 2B — Tensile properties of all-weld metal (classification according to alloy type)

Alloy designation according to alloy type	Minimum tensile strength MPa	Minimum elongation[a] %	Post-weld heat treatment
307	590	25	None
308	550	25	
308L	520	25	
308H	550	25	
308Mo	550	25	
308LMo	520	25	
308HMo	550	25	
309	550	25	
309L	520	25	
309H	550	25	
309Mo	550	15	
309LMo	520	15	
309LNiMo	520	15	
309LNb	520	25	
310	550	25	
312	660	15	
316	520	25	
316L	485	25	
316H	520	25	
316LCu	485	25	
317	550	20	
317L	520	20	
318	520	20	
347	520	25	
347L	520	25	
347H	550	25	
409	450	15	
409Nb	450	15	[b]
410	520	15	[b]
410NiMo	760	10	[c]
430	450	15	[d]
430Nb	450	13	[d]
16-8-2	520	25	None
2209	690	15	
2553	760	13	
2594	760	13	
Z	Not specified		

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

[b] The weld test assembly (or the blank from it, from which the tensile test specimen is to be machined) shall be heated to a temperature between 730 °C and 760 °C, held for 1 h, then furnace cooled to 315 °C, then cooled in air.

[c] The weld test assembly (or the blank from it, from which the tensile test specimen is to be machined) shall be heated to a temperature between 590 °C and 620 °C, held for 1 h, then cooled in air.

[d] The weld test assembly (or the blank from it, from which the tensile test specimen is to be machined) shall be heated to a temperature between 760 °C and 790 °C, held for 2 h, then furnace cooled to 600 °C, then cooled in air.

4.3 Symbol for type of electrode core

The symbols in Tables 3A and 3B indicate different types of tubular cored electrodes and rods relative to their core composition and slag characteristics.

Table 3A — Symbol for type of electrode core (classification according to nominal composition)

Symbol	Characteristics
B	Basic slag
R	Rutile, slow freezing slag
P	Rutile, fast freezing slag
M	Metal powder
U	Self-shielding
Z	Other types
See Annex B.	

Table 3B — Symbol for type of tubular cored electrode and rod (classification according to alloy type)

Symbol	Characteristics
F	Flux cored electrodes
M	Metal cored electrodes
R	Cored rods for gas tungsten arc welding
See Annex C.	

4.4 Symbol for shielding gas

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

4.5 Symbol for welding position

The symbols in Tables 4A and 4B indicate the welding positions for which the electrode is suitable in accordance with ISO 15792-3. See Clause 7 for testing requirements.

Table 4A — Symbol for welding position (classification according to nominal composition)

Symbol	Welding positions in accordance with ISO 6947:2010[a]
1	PA, PB, PC, PD, PE, PF and PG
2	PA, PB, PC, PD, PE and PF
3	PA and PB
4	PA
5	PA, PB and PG

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

Table 4B — Symbol for welding position (classification according to alloy type)

Symbol	Welding positions in accordance with ISO 6947:2010[a]
0	PA and PB
1	PA, PB, PC, PD, PE, PF or PG, or PF and PG

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

5 Mechanical test

5A Classification according to nominal composition

Tensile tests and any required retests for tubular cored electrodes shall be carried out on weld metal in the condition specified in Table 2A (as-welded or post-weld heat treated) using an all-weld metal test piece in accordance with ISO 15792-1:2000 of a type specified in Table 6 using 1,2 mm, or, if this diameter is not manufactured, the next larger diameter manufactured as specified in 5.1 and 5.2.

5B Classification according to alloy type

Tensile tests for tubular cored electrodes shall be carried out on weld metal in the condition specified in Table 2B (as-welded or post-weld heat treated) using an all-weld metal test piece in accordance with ISO 15792-1:2000 of a type specified in Table 6 using 1,2 mm, or, if this diameter is not manufactured, the next larger diameter manufactured as specified in 5.1 and 5.2.

Tensile tests for tubular cored rods shall be carried out on weld metal in the condition specified in Table 2B using an all-weld metal test piece in accordance with ISO 15792-1:2000 of a type specified in Table 6 using 2,2 mm, or if this diameter is not manufactured, the next larger diameter manufactured as specified in 5.1 and 5.2.

5.1 Preheating and interpass temperatures

Preheating and interpass temperatures shall be selected for the appropriate weld metal type from Table 5A or Table 5B.

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

The interpass temperature shall not exceed the maximum temperature indicated in Table 5A or Table 5B. If, after any pass, the interpass temperature is exceeded, the test assembly shall be cooled in air to a temperature within the limits of the interpass temperature.

Table 5A — Preheating and interpass temperatures (classification according to nominal composition)

Alloy designation according to nominal composition	Type of weld metal	Preheating and interpass temperatures °C
13 13Ti 17	Martensitic and ferritic chromium steel	200 to 300
13 4	Soft martensitic stainless steel	100 to 180
All others	Austenitic and ferritic-austenitic stainless steel	⩽150

Table 5B — Preheating and interpass temperatures (classification according to alloy type)

Alloy designation according to alloy type	Type of weld metal	Preheating and interpass temperatures °C
410	Martensitic and ferritic chromium steel	200 to 300
409 409Nb 430 430Nb		150 to 260
410NiMo	Soft martensitic stainless steel	100 to 260
All others	Austenitic and ferritic-austenitic stainless steel	⩽150

5.2 Pass sequence

The total number of runs, the number of runs per layer and the total number of layers shall be as given in Table 6.

Table 6 — Pass sequence

Process	Diameter mm	ISO 15792-1:2000 test piece type	Passes per layer		Total number of layers
			First layer	Other layers	
Gas shielded and non-gas shielded metal arc welding	<1,2	1,0	1 or 2	2 or 3[a]	6 to 9
	1,2	1,3	1 or 2	2 or 3[a]	5 to 9
	1,4 1,6 2,0	1,3	1 or 2	2 or 3[a]	5 to 8
	2,4 3,2	1,3	1 or 2	1 or 2[b]	4 to 7
Gas tungsten arc welding	2,0 2,2 2,4	1,0	1 or 2	2 or 3[a]	5 to 8

[a] Final layer may have four passes.

[b] Final layer may have three passes.

6 Chemical analysis

Chemical analysis shall be performed on any suitable all-weld metal test specimen. In cases of dispute, the sample shall be prepared in accordance with ISO 6847. Any analytical technique can be used, but in cases of dispute, reference shall be made to established published methods.

7 Fillet weld test

The fillet weld test assembly shall be as shown in ISO 15792-3.

7A Classification according to nominal composition

The plate material shall be selected from the range of materials for which the electrode is recommended by the manufacturer. The fillet welds shall be deposited as a single run using the diameter of electrode and welding position shown in Table 7A. Throat thickness, leg length and convexity shall conform to the requirements of Table 7A.

7B Classification according to alloy type

For electrodes classified as symbol 1 in Table 4B, fillet weld tests shall be performed in PD and PF positions. The steel to be used shall conform to the following specifications.

a) For 300 series electrodes: matching or type 304 stainless steel.

b) For 400 series electrodes: matching or non alloy steel.

c) For duplex alloy electrodes: matching or type 304 stainless steel.

The fillet weld tests shall be conducted on the largest diameter electrodes manufactured for a specific usability symbol.

A single-pass fillet weld shall be deposited on one side of the joint.

The maximum convexity and length difference shall conform to the following dimensional requirements:

1) maximum convexity: 2,0 mm for $<$7,0 mm in measured fillet weld size and 2,5 mm for $\geqslant$7,0 mm in measured fillet weld size;

2) maximum leg length difference, in millimetres, is $0,5l - 0,5$, where l is the the fillet weld size, in millimetres.

Table 7A — Test requirements for fillet welds (classification according to nominal composition)

Symbol of position for classification	Test position	Electrode size[a] mm	Fillet theoretical throat mm	Leg length difference mm	Convexity mm
1 or 2	PB	2,4	5,5 min.	2,0	3,0
3	PB	2,4	5,5 min.	2,0	3,0
5	PB	2,4[b]	5,5 min.	2,0	3,0
1 or 2	PF	2,4[c]	7,0 max.	—	2,0
1, 2 or 5	PD	1,2[d]	4,5 max.	1,5	2,5
5	PG	1,2[d]	4,5 min.	—	1,5[e]

[a] Where the largest size claimed for positional welding is smaller than that specified, use the largest size and adjust criteria pro rata.

[b] Or largest size made up to 2,4 mm.

[c] Maximum size for which positional classification is sought.

[d] Or as recommended by the manufacturer.

[e] Maximum concavity.

8 Rounding procedure

For purposes of determining compliance with the requirements of this International Standard, the actual test values obtained shall be subjected to the rounding rules of ISO 80000-1:2009, Annex B, 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 average value is to be compared to the requirements of this International Standard, rounding shall be done only after calculating the average. In the case where the testing standard cited in Clause 2 contains instructions for rounding that conflict with the instructions of this International Standard, the rounding requirements of the testing standard shall apply. 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, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for the retest may be taken from the original test assembly or from a new test assembly. For chemical analysis, retests need be only for those specific elements that failed to meet their test requirement. If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this International Standard for that classification.

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

10 Technical delivery conditions

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

11 Examples of designation

The designation of tubular cored electrodes shall follow the principles given in the examples below.

11A Classification according to nominal composition

EXAMPLE

A tubular cored electrode (T) for gas shielded arc welding deposits a weld metal of chemical composition within the limits for the nominal composition 19 12 3 L of Table 1A.

The electrode with a rutile type core with a slow freezing slag (R) was tested under mixed gas (M21) and can be used in flat and horizontal-vertical positions (3).

This is designated as follows:

ISO 17633-A — T 19 12 3 L R M21 3

where

ISO 17633-A	is the number of this International Standard with classification according to nominal composition;
T	indicates a tubular cored electrode for metal arc welding (see 4.1A);
19 12 3 L	represents the chemical composition of the all-weld metal (see Table 1A);
R	is the type of electrode core (see Table 3A);
M21	is the shielding gas (see 4.4);
3	is the welding position (see Table 4A).

11B Classification according to alloy type

EXAMPLE

A tubular cored electrode (TS) for gas shielded arc welding deposits a weld metal of chemical composition within the limits for the alloy type 316L of Table 1B-1.

The flux cored electrode type (F) was tested under mixed gas (M21) and can be used in flat and horizontal-vertical positions (0).

This is designated as follows:

ISO 17633-B — TS 316L-F M21 0

where

ISO 17633-B	is the number of this International Standard with classification according to alloy type;
TS	indicates a tubular cored stainless steel electrode for metal arc welding (see 4.1B);
316L	represents the chemical composition of the all-weld metal (see Tables 1B-1 to -4);
F	is the type of tubular cored electrode (see Table 3B);
M21	is the shielding gas (see 4.4);
0	is the welding position (see Table 4B).

Annex A
(informative)

Comparison charts of alloy designation according to nominal composition and alloy type

Table A.1A — Correspondence of alloy, designated according to nominal composition, with alloy, designated according to alloy type, of similar, but not identical, requirements

Nominal composition	Alloy type[a]
13	410
13 Ti	409
13 4	410NiMo
16 8 2	16-8-2
17	430
19 9 L	308L
19 9 Nb	347
19 12 3 L	316L
19 12 3 Nb	318
19 13 4 N L	—
19 9 H	308H
22 9 3 N L	2209
18 16 5 N L	—
18 8 Mn	—
18 9 Mn Mo	—
20 10 3	308Mo
20 25 5 Cu N L	—
21 10 N	—
23 7 N L	—
23 12 L	309L
23 12 Nb	309Nb
23 12 2 L	309LMo
29 9	312
22 12 H	309H
25 20	310
25 4	—
25 9 4 N L and 25 9 4 Cu L	2594

[a] "No correspondence of alloy designation in the classification according to alloy type" is indicated by a dash.

Table A.1B — Correspondence of alloy, designated according to alloy type, with alloy, designated according to nominal composition, of similar, but not identical, requirements

Alloy type	Nominal composition[a]
307	—
308	—
308L	19 9 L
308H	19 9H
308Mo	20 10 3
308LMo	—
308HMo	—
309	—
309L	23 12 L
309H	22 12 H
309Mo	—
309LMo	23 12 2 L
309LNb	—
310	25 20
312	29 9
316	—
316L	19 12 3 L
316H	—
316LCu	—
317	—
317L	—
318	19 12 3 Nb
347	19 9 Nb
347L	—
347H	19 9 Nb
409	13 Ti
409Nb	—
410	13
410NiMo	13 4
430	17
430Nb	—
16-8-2	16 8 2
2209	22 9 3 N L
2553	25 9 4 Cu N L
2594	25 9 4 N L and 25 9 4 Cu L

[a] "No correspondence of alloy designation in the classification according to nominal composition" is indicated by a dash.

Annex B
(informative)

Description of types of electrode core — Classification according to nominal composition

B.1 Symbol B in Table 3A

Tubular cored electrodes of the B type are characterized by a coarse droplet metal transfer and a slightly convex fillet weld. These tubular cored electrodes are primarily used with argon and carbon dioxide shielding gas mixtures in the flat and horizontal-vertical positions. The slag consists mainly of fluorides and oxides of alkaline earth metals. Welds with high impact resistance and low sensitivity for cracks are deposited.

B.2 Symbol R in Table 3A

Tubular cored electrodes of the R type are characterized by a spray metal transfer, low spatter loss, and a rutile-based slag that fully covers the weld bead. These tubular cored electrodes are designed for single and multiple pass welding in the flat and horizontal-vertical position. Tubular cored electrodes of the R type may be welded using carbon dioxide or mixed gases, however, the use of argon and carbon dioxide mixtures, when recommended by the manufacturer, can be used to improve arc transfer and reduce spatter.

B.3 Symbol P in Table 3A

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

B.4 Symbol M in Table 3A

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

B.5 Symbol U in Table 3A

Tubular cored electrodes of the U type are used without a gas shield for single and multiple pass welding in the flat and horizontal-vertical welding positions. With some tubular cored electrodes, vertical down welding is possible.

B.6 Symbol Z in Table 3A

Other types that are not covered by the descriptions in B.1 to B.5.

Annex C
(informative)

Description of types of tubular cored electrodes and rods — Classification according to alloy type

C.1 Flux cored electrodes (symbol F in Table 3B)

Flux cored electrodes show the suitable amount of slag generation for complete or nearly complete slag cover, and the core contains both metallic and non-metallic ingredients.

C.2 Metal cored electrodes (symbol M in Table 3B)

Metal cored electrodes show a small amount of slag generation with minimal slag cover, and the core contains metallic and minimum amount of non-metallic ingredients.

C.3 Cored rods for gas tungsten arc welding (symbol R in Table 3B)

Cored rods are used primarily for root pass welding of stainless steel piping joints when an inert gas backing purge is either not possible or not desirable. This rod can only be used with the gas tungsten arc welding process, but caution is advised as it produces a slag cover that requires removal before additional weld layers can be deposited.

Annex D
(informative)

Considerations on weld metal ferrite contents

D.1 General

See Reference [3].

The ferrite content in stainless steel weld metals plays an important role in determining the fabrication and service performance of a welded construction. To prevent problems, a certain ferrite level is often specified. Originally, ferrite level was described in terms of ferrite percentage (by volume), but currently the Ferrite Number (FN) concept is used, as specified in ISO 8249[1].

D.2 Effects of ferrite

The most important beneficial effect of ferrite in nominally austenitic stainless steel weldments is the well-established relationship between a reduced sensitivity to hot cracking and the presence of a certain amount of ferrite. The minimum ferrite limit necessary to assure freedom from cracking depends, among other factors, on the weld metal composition. The upper limit results from possible impairment of either mechanical or corrosion properties, or both. The required amount of ferrite can be obtained by adjusting the ratio of ferrite formers (such as chromium) to austenite promoters (such as nickel) within the limits allowed by the applicable specification.

D.3 Relation between composition and structure

As discussed in the following, ferrite is normally measured by means of magnetic instruments and stated in terms of Ferrite Number (FN). Ferrite can also be estimated by means of constitution diagrams. The most accurate version recommended is the WRC-1992 constitution diagram (Reference [4]) developed by the Welding Research Council (WRC). The composition is related to the structure through grouping the elements which promote ferrite in the so-called “chromium equivalent” and austenitizing elements in the “nickel equivalent”. By using Reference [4], the structure can be predicted with an accuracy of approximately ± 4 FN ferrite at a calculated level of up to 18 FN. It can be used for FN up to 100 (i.e. it can be used for duplex alloys).

D.4 Ferrite formation

It is generally agreed that hot cracking is governed by the solidification mode. The final ferrite content and morphology result from reactions during solidification and subsequently in the solid state. The hot cracking sensitivity decreases in the following order of solidification mode:

a) single-phase austenitic;

b) primary austenitic;

c) mixed-type and single phase ferritic;

d) primary ferritic.

Although both Ferrite Number and solidification mode depend mainly on composition, the relationship is not always unambiguous. However, the system is standardized and it is more practical to specify and to measure ferrite on this basis.

D.5 Effects of welding conditions

The ferrite content of weld metal is not determined solely by the filler metal selected. Apart from the effects of dilution from the base material, the ferrite content can be significantly affected by the welding conditions. Several factors can change the chemical composition of the weld metal. The most important of these is nitrogen, which can enter the weld metal through the welding arc. A high arc voltage, or a disturbance in the shielding gas flow, can result in a significantly decreased Ferrite Number. Another factor is the reduction of chromium by oxidizing materials in the shield gas or the increase of carbon from carbon dioxide. Very high heat input can also have an effect, especially with duplex steels. When the ferrite content in undiluted weld metal is found to be significantly different from that quoted in the manufacturer's certification, one or more of the above factors are most likely to be the cause of the difference.

D.6 Effects of heat treatment

Stainless steel base metals are generally supplied in the solution annealed and quenched condition. In contrast, most welded joints are put into service in the as-welded condition. In some cases, however, a post-weld heat treatment can, or should, be applied. This can reduce the magnetically determined FN to some extent, even to zero. The effects of heat treatment on mechanical and corrosion properties can be significant, but are beyond the scope of this annex.

D.7 Determination of ferrite content

D.7.1 The several parties concerned with the integrity of a stainless steel weldment should all be able to agree upon the ferrite content. These parties could include the manufacturer of the filler material, the fabricator of the weldment, a code or regulatory body, and an insurance company. It is therefore essential that the method for the determination of ferrite be reproducible. Early observations of ferrite in stainless steel weld metals were largely by metallography. Etchants that darkened ferrite but left austenite untouched were used to estimate the percentage (by volume) of ferrite present. Unfortunately, the ferrite phase is extremely fine and very irregular in shape, and is also not uniformly distributed in the matrix. The reliability and reproducibility of this method of estimation was poor. In addition, metallographic examination is a destructive test, which is not suitable for in-process quality assurance monitoring.

D.7.2 As ferrite is ferromagnetic, it is easily distinguishable from austenite. The magnetic response of an otherwise austenitic weld metal is approximately proportional to the amount of ferrite present. (The magnetic response is also affected by the composition of the ferrite — a more highly alloyed ferrite has a smaller magnetic response than an equivalent amount of lower alloyed ferrite.) This property can therefore be used for ferrite determination if it is possible to establish a calibration procedure for magnetic instruments. Of course, it would be desirable to establish a magnetic calibration procedure in such a fashion that the results are directly convertible into “per cent ferrite”. However, because of the composition effect noted above, and because agreement on the true “per cent ferrite” proved to be impossible to achieve, an arbitrary “Ferrite Number” scale was adopted. The Ferrite Number was initially believed to be a reasonable approximation of the “per cent ferrite” in a type 19 9 or type 308 weld metal, but later studies indicate that the FN appreciably overstates the “per cent ferrite” in a weld metal. From a practical standpoint, this is unimportant. Of much greater import is the ability of numerous measuring agencies to reproduce the same value for ferrite content within a small scatter band on a given weldment, and this the Ferrite Number measurement system accomplishes.

D.7.3 In the Ferrite Number system, calibration of certain laboratory instruments is established using, as primary standards, coating thickness standards[1)] consisting of a non-magnetic coating over a carbon steel substrate. To each coating thickness standard, a Ferrite Number is assigned in accordance with ISO 8249:2000[1], Table 1. Further, in the Ferrite Number system, instruments calibrated by primary standards can be used to assign Ferrite Numbers to weld metal samples which can in turn be used as secondary standards for the calibration of numerous other instruments more suitable for a shop or field environment.

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1) Available from the US National Institute for Standards and Technology (NIST). This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the supplier named. Equivalent suppliers may be used if their products can be shown to lead to the same results.

D.7.4 Using either primary or secondary calibration, round robin tests have established that the reproducibility of Ferrite Number determination on given samples of weld metal is within ± 1 FN or less over the range 0 FN to 28 FN provided in ISO 8249[1]. This is far better reproducibility than could be achieved using metallographic measurements. Principles for the extension of the system to ferrite levels appropriate to duplex steels have been established, and this extension is specified in ISO 8249[1]. Secondary standards are also now available1) 2).

D.8 Implementation of FN measurement

For both specification and determination of ferrite, it is important to be realistic about what can be expected in a weldment. It is not realistic to specify, and expect to measure, 0 FN in nominally fully austenitic weld metal. Specification of 0,5 FN maximum is realistic and achievable. It is not realistic to specify, and expect to measure, a Ferrite Number within a range that approaches the reproducibility of the welding operation and of measurement. Thus, specification of 5 FN to 10 FN, or 40 FN to 70 FN, is realistic and achievable. However, specification of 5 FN to 6 FN is not realistic, nor is specification of 45 FN to 55 FN.

It is not realistic to specify, and expect to measure, a narrow Ferrite Number range for all points in a weld deposit because reheating of the overlap areas between passes constitutes a heat treatment and generally reduces the local ferrite content. It is not realistic to specify, and expect to measure, the same Ferrite Number range on curved surfaces, surfaces very close to edges or to strongly magnetic materials, or on rough surfaces (including those containing the ripples of a normal weld deposit surface), as would be measured along the centreline of a weld run that is properly prepared smooth and flat after welding.

2) Secondary standards were formerly available from The Welding Institute, UK.

Bibliography

[1] ISO 8249:2000, *Welding — Determination of Ferrite Number (FN) in austenitic and duplex ferritic-austenitic Cr-Ni stainless steel weld metals*

[2] EN 12073:1999, *Welding consumables — Tubular cored electrodes for metal arc welding with or without a gas shield of stainless and heat-resisting steels — Classification*[3)]

[3] LEFEBVRE, J. Guidance on specifications of ferrite in stainless steel weld metal. *Weld. World* 1993, **31**(6), pp. 390-406

[4] KOTECKI, D.J., SIEWERT, T.A. WRC-1992 constitution diagram for stainless steel weld metals: A modification of the WRC-1988 diagram. *Weld. J.* 1992, **71**(5), pp. 171s-178s

3) Superseded by this International Standard.

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