BRITISH STANDARD

BS EN
10296-2:2005

Welded circular steel tubes for mechanical and general engineering purposes — Technical delivery conditions —

Part 2: Stainless steel

The European Standard EN 10296-2:2005 has the status of a British Standard

ICS 77.140.75

BSI
British Standards

National foreword

This British Standard is the official English language version of EN 10296-2:2005. It supersedes BS 6323-8:1982 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ISE/8, Steel pipes, which has the responsibility to:

— aid enquirers to understand the text;

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— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

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EUROPEAN STANDARD

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English Version

Welded circular steel tubes for mechanical and general engineering purposes - Technical delivery conditions - Part 2: Stainless steel

Tubes ronds soudés en acier pour utilisation en mécanique générale et en construction mécanique - Conditions techniques de livraison - Partie 2: Tubes en acier inoxydable

Geschweißte kreisförmige Stahlrohre für den Maschinenbau und allgemeine technische Anwendungen - Technische Lieferbedingungen - Teil 2: Nichtrostende Stähle

This European Standard was approved by CEN on 4 April 2005.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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Contents

Foreword

This document (EN 10296-2:2005) has been prepared by Technical Committee ECISS/TC 29 “Steel tubes and fittings for steel tubes”, the secretariat of which is held by UNI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2006, and conflicting national standards shall be withdrawn at the latest by June 2006.

Another part of EN 10296 is:

— Part 1: Non-alloy and alloy steel tubes

Another European Standard series, covering seamless steel tubes for mechanical and general engineering purposes, currently being prepared is:

— EN 10297: Seamless circular steel tubes for mechanical and general engineering purposes — Technical delivery conditions.

Other series of European Standards being prepared in this area are prEN 10294 - hollow bars for machining and EN 10305 - steel tubes for precision applications.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

The European Committee for Standardisation (CEN) draws attention to the fact that it is claimed that compliance with this document may involve the use of patents applied to steel grades 1.4362 and 1.4854, the compositions of which are given in Tables 1 and 2.

CEN takes no position concerning the evidence, validity and scope of these patent rights.

The holders of these patent rights have assured CEN that they are willing to negotiate licences, under reasonable and non-discriminatory terms and conditions, with applicants throughout the world. In this respect, the statements of the holders of these patent rights are registered with CEN. Information may be obtained from:

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Attention is drawn to the possibility that some of the elements within this European Standard may be the subject of patent rights other than those indicated above. CEN shall not be responsible for identifying any or all such patent rights.

1 Scope

This European Standard specifies the technical delivery conditions for welded tubes, of circular cross section, made from stainless steels, for mechanical and general engineering purposes.

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.

EN 910, *Destructive tests on welds in metallic materials - Bend tests*

EN 10002-1, *Metallic materials – Tensile testing – Part 1: Method of test (at ambient temperature)*

EN 10020:2000, *Definition and classification of grades of steel*

EN 10021:1993, *General technical delivery requirements for steel and iron products*

EN 10027-1, *Designation systems for steel – Part 1: Steel names, principal symbols*

EN 10027-2, *Designation systems for steel – Part 2: Numerical system*

EN 10052:1993, *Vocabulary of heat treatment terms for ferrous products*

EN 10088-1, *Stainless steels – Part 1: List of stainless steels*

EN 10168, *Steel products – Inspection documents – List of information and description*

EN 10204, *Metallic products – Types of inspection documents*

EN 10246-2, *Non-destructive testing of steel tubes – Part 2: Automatic eddy current testing of seamless and welded (except submerged arc-welded) austenitic and austenitic-ferritic steel tubes for verification of hydraulic leak-tightness*

EN 10246-3, *Non-destructive testing of steel tubes – Part 3: Automatic eddy current testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of imperfections*

EN 10246-7, *Non-destructive testing of steel tubes – Part 7: Automatic full peripheral ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of longitudinal imperfections*

EN 10246-8, *Non-destructive testing of steel tubes – Part 8: Automatic ultrasonic testing of the weld seam of electric welded steel tubes for the detection of longitudinal imperfections*

EN 10246-9, *Non-destructive testing of steel tubes – Part 9: Automatic ultrasonic testing of the weld seam of submerged arc welded steel tubes for the detection of longitudinal and/or transverse imperfections*

EN 10246-10, *Non-destructive testing of steel tubes – Part 10: Radiographic testing of the weld seam of automatic fusion arc welded steel tubes for the detection of imperfections*

EN 10256, *Non-destructive testing of steel tubes – Qualification and competence of level 1 and 2 non-destructive testing personnel.*

EN 10266:2003, *Steel tubes, fittings and steel structural hollow sections - Symbols and definitions of terms for use in product standards.*

CR 10260:1998, *Designation system for steel – Additional symbols*

EN ISO 377, *Steel and steel products – Location and preparation of samples and test pieces for mechanical testing (ISO 377:1997)*

EN ISO 8491, *Metallic materials – Tube (in full section) - Bend test (ISO 8491:1998)*

EN ISO 8492, *Metallic materials – Tube - Flattening test (ISO 8492:1998)*

EN ISO 8493, *Metallic materials – Tube - Drift expanding test (ISO 8493:1998)*

EN ISO 8496, *Metallic materials – Tube - Ring tensile test (ISO 8496:1998)*

EN ISO 1127, *Stainless steel tubes – Dimensions, tolerances and conventional masses per unit length (ISO 1127:1992).*

EN ISO 2566-2, *Steel – Conversion of elongation values – Part 2: Austenitic steels (ISO 2566-2:1984)*

EN ISO 3651-2, *Determination of resistance to intergranular corrosion of stainless steels – Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels – Corrosion test in media containing sulfuric acid (ISO 3651-2:1998)*

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 10020:2000, EN 10021:1993, EN 10052:1993 and EN 10266:2003 together with the following apply.

employer
organisation for which the person works on a regular basis

NOTE The employer may be either the tube manufacturer or a third party organisation providing non-destructive testing (NDT) services.

4 Symbols

For the purposes of this European Standard, the symbols given in EN 10266:2003 and CR 10260:1998 apply.

Not applicable.

5 Classification and designation

5.1 Classification

In accordance with the classification system in EN 10020, the steel grades listed in Tables 1 and 2 are stainless steels.

5.2 Designation

For tubes covered by this document the steel designation consists of:

— number of this document (EN 10296-2);

plus either:

— steel name in accordance with EN 10027-1 and CR 10260; or

— steel number allocated in accordance with EN 10027-2.

6 Information to be supplied by the purchaser

6.1 Mandatory information

The following information shall be supplied by the purchaser at the time of enquiry and order:

a) quantity (mass or total length or number);

b) term "tube";

c) dimensions (outside diameter D, wall thickness T) (see 8.7);

d) steel designation (see 5.2);

e) delivery condition for austenitic and austenitic-ferritic grades (see 7.2.2).

6.2 Options

A number of options are specified in this document and these are listed below with appropriate clause references. In the event that the purchaser does not indicate a wish to implement any of these options at the time of enquiry and order, the tube shall be supplied in accordance with the basic specification (see 6.1).

1) process route and /or surface condition (see 7.2.1);

2) weld bead finish (see 7.2.1);

3) pickled tube (see 7.2.2);

4) controlled sulphur content (see Table 1);

5) non-destructive testing of the weld (see 8.4.2);

6) leak tightness test (see 8.4.2);

7) straightness (see 8.5);

8) random lengths (see 8.7.2);

9) exact lengths (see 8.7.2);

j) outside diameter tolerances (see 8.7.3.1)

k) specific inspection and testing (see 9.1);

l) test report 2.2 (see 9.2.1);

m) inspection document, 3.2 (see 9.2.1);

n) leak tightness test method (see 11.7.1).

6.3 Example of an order

Fifteen tonnes of welded steel tubes with a specified outside diameter of 60,3 mm, a specified wall thickness of 3,2 mm, in accordance with EN 10296-2, made from steel grade 1.4301, solution annealed, (supplied in 6 m standard length) and with a test report 2.2 (option 12) in accordance with EN 10204.

15 t – Tube - 60,3 x 3.2 - EN 10296-2 - 1.4301+AT- option 12

7 Manufacturing process

7.1 Steelmaking process

The steelmaking process is at the discretion of the manufacturer.

7.2 Tube manufacturing and delivery conditions

7.2.1 Tubes shall be produced from hot or cold rolled strip or plate/sheet, longitudinally welded across the abutting edges, by a continuous automatic process with or without the addition of filler metal. The welding process is at the discretion of the manufacturer.

Acceptable process routes and surface conditions are given in Table A.1. The choice of process route, base material, hot or cold rolled feedstock and the surface condition, is at the discretion of the manufacturer unless Option 1 is specified.

Option 1: *The process route and/or surface condition is specified by the purchaser from those in Table A.1.*

Tubes shall be delivered with one of the following weld bead finishes:

— Finish A: Internal and external weld bead not removed;

— Finish B: External weld bead removed internal weld bead not removed;

— Finish C: Internal and external weld bead rolled or removed.

Finish A shall not be used for high frequency (HF) welded tube.

The weld bead finish is at the discretion of the manufacturer unless Option 2 is specified.

Option 2: *The weld bead finish; A, B or C is specified by the purchaser.*

The finished tubes shall not include the welds used to join the lengths of strip prior to forming the tube. However jointers are permitted when the purchaser specifies lengths in excess of the production maximum, if agreed at the time of enquiry and order.

7.2.2 Tubes produced in accordance with 7.2.1 shall be delivered in the following delivery conditions:

- ferritic steels: as welded (+AR) or annealed (+A), at the discretion of the manufacturer;

- austenitic and austenitic-ferritic steels: as-welded (+AR) or solution annealed (+AT), as specified by the purchaser (see 6.1).

See Annex B for guidance on heat treatment following fabrication and further processing.

When Option 3 is specified, the tubes shall be supplied pickled.

Option 3: *Tubes shall be supplied pickled.*

7.2.3 All NDT activities shall be carried out by qualified and competent level 1, 2 and/or 3 personnel authorised to operate by the employer.

The qualification shall be in accordance with EN 10256 or, at least, an equivalent to it.

It is recommended that the level 3 personnel be certified in accordance with EN 473 or, at least, an equivalent to it.

The operating authorisation issued by the employer shall be in accordance with a written procedure.

NDT operations shall be authorised by a level 3 NDT individual approved by the employer.

NOTE The definition of level 1, 2 and 3 can be found in the appropriate standards, e.g. EN 473 and EN 10256.

8 Requirements

8.1 General

Tubes, when supplied in a delivery condition in accordance with 7.2.2, using a process route and to a surface condition given in Table A.1 and inspected in accordance with Clause 9, shall conform to the requirements of this document.

In addition, the general technical delivery requirements specified in EN 10021 shall apply.

8.2 Chemical composition

The cast analysis reported by the steel producer shall apply and shall conform to the requirements of Tables 1 or 2, as appropriate.

Elements not included in Tables 1 and 2 shall not be intentionally added to the steel without the agreement of the purchaser, except for elements which may be added for finishing the cast. All appropriate measures shall be taken to prevent the addition of undesirable elements from scrap or other materials used in the steelmaking process.

The permissible deviations of a product analysis from the specified limits of the cast analysis are given in Table 3.

NOTE When subsequently welding tubes produced according to this document, account should be taken of the fact that the behaviour of the steel during and after welding is dependent not only on the steel but also on the conditions of preparing for and carrying out the welding. Some of the steels specified in this standard cannot be welded unless specialised techniques are employed by specialist welders.

Table 1 — Chemical composition (cast analysis) for tubes made from ferritic, austenitic and austenitic-ferritic corrosion resistant steel, in % by mass

Steel grade		C	Si	Mn	P	S	Cr		Mo		Ni		Cu		N		Nb		Ti	
Steel name	Steel number	max.	max.	max.	max.	max.	min.	max.	min	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
Ferritic steels																				
X2CrNi12	1.4003	0,030	1,00	1,50	0,040	0,015	10,5`	12,5			0,30	1,00				0,030				
X2CrTi12	1.4512	0,030	1,00	1,00	0,040	0,015	10,5	12,5								0,030			6x (C+N)	0,65
X6Cr17	1.4016	0,08	1,00	1,00	0,040	0,015[a]	16,0	18,0												
X3CrTi17	1.4510	0,05	1,00	1,00	0,040	0,015[a]	16,0	18,0											[4x (C+N) +0,15	0,80[b]
X2CrMoTi18-2	1.4521	0,025	1,00	1,00	0,040	0,015	17,0	20,0	1,80	2,50						0,030			4x (C+N) +0, 15	0,80[b]
X6CrMoNb17-1	1.4526	0,08	1,00	1,00	0,040	0,015	16,0	18,0	0,80	1,40						0,040	7x(C+N) + 0,10	1,00		
X2CrTiNb18	1.4509	0,030	1,00	1,00	0,040	0,015	17,5	18,5									3xC + 0,30	1,00	0,10	0,69
Austenitic steels																				
X2CrNiN18-7	1.4318	0,030	1,00	2,00	0,045	0,015	16,5	18,5			6,0	8,0			0,10	0,20				
X2CrNi18-9	1.4307	0,030	1,00	2,00	0,045	0,015[a]	17,5	19,5			8,0	10,5				0,11				
X2CrNi19-11	1.4306	0,030	1,00	2,00	0,045	0,015[a]	18,0	20,0			10,0	12,0				0,11				
X2CrNiN18-10	1.4311	0,030	1,00	2,00	0,045	0,015[a]	17,0	19,5			8,5	11,5			0,12	0,22				
X5CrNi18-10	1.4301	0,07	1,00	2,00	0,045	0,015[a]	17,0	19,5			8,0	10,5				0,11				
X6CrNiTi18-10	1.4541	0,08	1,00	2,00	0,045	0,015[a]	17,0	19,0			9,0	12,0							5xC	0,70
X6CrNiNb18-10	1.4550	0,08	1,00	2,00	0,045	0,015	17,0	19,0			9,0	12,0					10xC	1,00		
X2CrNiMo17-12-2	1.4404	0,030	1,00	2,00	0,045	0,015[a]	16,5	18,5	2,00	2,50	10,0	13,0				0,11				
X5CrNiMo17-12-2	1.4401	0,07	1,00	2,00	0,045	0,015[a]	16,5	18,5	2,00	2,50	10,0	13,0				0,11				
X6CrNiMoTi17-12-2	1.4571	0,08	1,00	2,00	0,045	0,015[a]	16,5	18,5	2,00	2,50	10,5	13,5							5xC	0,70
X2CrNiMo17-12-3	1.4432	0,030	1,00	2,00	0,045	0,015[a]	16,5	18,5	2,50	3,00	10,5	13,0				0,11				
X2CrNiMoN17-13-3	1.4429	0,030	1,00	2,00	0,045	0,015	16,5	18,5	2,50	3,00	11,0	14,0			0,12	0,22				
X3CrNiMo17-13-3	1.4436	0,05	1,00	2,00	0,045	0,015[a]	16,5	18,5	2,50	3,00	10,5	13,0				0,11				
X2CrNiMo18-14-3	1.4435	0,030	1,00	2,00	0,045	0,015[a]	17,0	19,0	2,50	3,00	12,5	15,0				0,11				
X2CrNiMoN17-13-5	1.4439	0,030	1,00	2,00	0,045	0,015	16,5	18,5	4,0	5,0	12,5	14,5			0,12	0,22				

Table 1 — Chemical composition (cast analysis) for tubes made from ferritic, austenitic and austenitic-ferritic corrosion resistant steel, in %by mass
(concluded)

Steel grade		C	Si	Mn	P	S	Cr		Mo		Ni		Cu		N		Nb		Ti	
Steel name	**Steel number**	max.	max.	max.	max.	max.	min	max.	min	max.	min.	max.	min.	max.	min.	max.	min.	max	min.	max.
X1NiCrMoCu25-20-5	1.4539	0,020	0,70	2,00	0,030	0,010	19,0	21,0	4,0	5,0	24,0	26,0	1,20	2,00		0,15				
X1CrNiMoCuN20-18-7	1.4547	0,020	0,70	1,00	0,030	0,010	19,5	20,5	6,0	7,0	17,5	18,5	0,50	1,00	0,18	0,25				
Austenitic ferritic steels																				
X2CrNiN23-4 [c]	1.4362	0,030	1,00	2,00	0,035	0,015	22,0	24,0	0,10	0,60	3,5	5,5	0,10	0,60	0,05	0,20				
X2CrNiMoN22-5-3	1.4462	0,030	1,00	2,00	0,035	0,015	21,0	23,0	2,50	3,5	4,5	6,5			0,10	0,22				
X2CrNiMoN25-7-4	1.4410	0,030	1,00	2,00	0,035	0,015	24,0	26,0	3,0	4,5	6,0	8,0			0,24	0,35				

[a] Option 4: a controlled sulfur content of 0,015 % to 0,030 % is specified.

[b] Stabilisation may be applied by the use of titanium or niobium or zirconium. According to the atomic number of these elements and the content of carbon and nitrogen, the equivalence shall be the following: $Ti \approx \frac{7}{4} Nb \approx \frac{7}{4} Zr$.

[c] Patented steel grade.

Table 2 — Chemical composition (Cast analysis) for tubes made from austenitic heat resisting steel, in % by mass

Steel grade		C		Si		Mn	P	S	Cr		Ni		N		Ce	
Steel name	**Steel number**	min.	max.	min.	max.	max.	max.	max.	min.	max.	min.	max.	min.	max.	min.	max.
X15CrNiSi20-12	1.4828		0,20	1,50	2,50	2,00	0,045	0,015	19,0	21,0	11,0	13,0		0,11		
X9CrNiSiNCe21-11-2	1.4835	0,05	0,12	1,40	2,50	1,00	0,045	0,015	20,0	22,0	10,0	12,0	0,12	0,20	0,03	0,08
X12CrNi23-13	1.4833		0,15		1,00	2,00	0,045	0,015	22,0	24,0	12,0	14,0		0,11		
X8CrNi25-21	1.4845		0,10		1,50	2,00	0,045	0,015	24,0	26,0	19,0	22,0		0,11		
X6CrNiSiNCe19-10	1.4818	0,04	0,08	1,00	2,00	1,00	0,045	0,015	18,0	20,0	9,0	11,0	0,12	0,20	0,03	0,08
X6NiCrSiNCe35-25 [a]	1.4854	0,04	0,08	1,20	2,00	2,00	0,040	0,015	24,0	26,0	34,0	36,0	0,12	0,20	0,03	0,08
[a] Patented steel grade.																

Table 3 — Permissible deviations of the product analysis from the specified limits on cast analysis given in Table 1 and Table 2

Element	Limiting values for the cast analysis in accordance with Tables 1 and 2 % by mass	Permissible deviation of the product analysis % by mass
C	≤ 0,030	+ 0,005
	> 0,03 ≤ 0,20	± 0,010
Si	≤ 1,00	+ 0,05
	>1,00 ≤2,50	± 0,10
Mn	≤ 2,00	+ 0,04
P	≤ 0,045	+ 0,005
S	≤ 0,015	+ 0,003
	> 0,015 ≤ 0,030	± 0,005
Cr	≥ 10,5 ≤ 15,0	± 0,15
	> 15,0 ≤ 20,0	± 0,20
	> 20,0 ≤ 26,0	± 0,25
Mo	> 0,80 < 1,75	± 0,05
	≥ 1,75 ≤ 7,0	± 0,10
Ni	≤ 1,00	± 0,03
	≥4,5 ≤ 10,0	± 0,10
	> 10,0 ≤ 20,0	± 0,15
	> 20,0 ≤ 36,0	± 0,20
Cu	≤ 1,00	± 0,07
	>1,00 ≤ 2,00	± 0,10
N	≤ 0,35	± 0,01
Nb	≤ 1,00	± 0,05
Ti	≤ 0,80	± 0,05

8.3 Mechanical properties

The mechanical properties of the tubes covered by this document shall conform to the requirements in Tables 4 and 5 and, those tests specified in Clause 11, as applicable.

Table 4 — Mechanical properties for tubes made from ferritic or austenitic or austenitic-ferritic corrosion resistant steels in thicknesses ≤ 30 mm

Steel Grade		Proof strength min MPa *)		Tensile strength min MPa*)	Elongation A min %		Resistance to intergranular corrosion [a]
Steel Name	Steel Number	$R_{p0,2}$	$R_{p1,0}$	R_m	l [b]	T[b]	
Ferritic steels							
X2CrNi12	1.4003	280	290	450	20	18	No
X2CrTi12	1.4512	210	220	380	25	23	No
X6Cr17	1.4016	240	250	430	20	18	Yes [c]
X3CrTi17	1.4510	230	240	420	23	21	Yes
X2CrMoTi18-2	1.4521	280	290	400	20	20	Yes
X6CrMoNb17-1	1.4526	280	290	480	25	23	Yes
X2CrTiNb18	1,4509	230	240	430	18	16	Yes
Austenitic steels							
X2CrNiN18-7	1.4318	330	370	630	45	45	Yes
X2CrNi18-9	1.4307	180	215	470	40	35	Yes
X2CrNi19-11	1.4306	180	215	460	40	35	Yes
X2CrNiN18-10	1.4311	270	305	550	35	30	Yes
X5CrNi18-10	1.4301	195	230	500	40	35	Yes [c]
X6CrNiTi18-10	1.4541	200	235	500	35	30	Yes
X6CrNiNb18-10	1.4550	205	240	510	35	30	Yes
X2CrNiMo17-12-2	1.4404	190	225	490	40	30	Yes
X5CrNiMo17-12-2	1.4401	205	240	510	40	30	Yes [c]
X6CrNiMoTi17-12-2	1.4571	210	245	510	35	30	Yes
X2CrNiMo17-12-3	1.4432	190	225	490	40	30	Yes
X2CrNiMo17-13-3	1.4429	295	330	580	35	30	Yes
X3CrNiMo17-3-3	1.4436	205	240	510	40	30	Yes [c]
X2CrNiMo18-14-3	1.4435	190	225	490	40	35	Yes
X2CrNiMoN17-13-5	1.4439	285	315	580	35	30	Yes
X1NiCrMoCu25-20-5	1.4539	220	250	520	35	30	Yes
X1CrNiMoCuN20-18-7	1.4547	300	340	650	35	30	Yes
Austenitic -ferritic steels							
X2CrNiN23-4 [d]	1.4362	400		600	20		Yes
X2CrNiMoN27-5-2	1.4462	450		700	22	-	Yes
X2CrNiMoN25-7-4	1.4410	550		800	15		Yes

*) 1 MPa = 1 N/mm^2

a When tested in accordance with EN ISO 3651-2.

b l = longitudinal, t = transverse

c Normally not fulfilled in the sensitized or as-welded condition.

d Patented steel grade.

Table 5 — Mechanical properties for tubes made from austenitic heat resistant steels in the solution annealed (+AT) condition

Steel grade		Proof strength min MPa *)		Tensile strength min MPa *	Elongation A min %	
Steel name	**Steel number**	$R_{p\,0,2}$	$R_{p\,1,0}$	R_m	l [a] [b]	t [a] [b]
X15CrNiSi20-12	1.4828	230	270	550	30	30
X9CrNiSiNCe21-11-2	1.4835	310	350	650	40	40
X12CrNi23-13	1.4833	210	250	500	35	35
X8CrNi25-21	1.4845	210	250	500	35	35
X6CrNiSiNCe19-10	1.4818	290	330	600	40	40
X6NiCrSiNCe35-25 [c]	1.4854	300	340	650	40	40

* 1 MPa = 1 N/mm^2

a l = longitudinal, t = transverse.

b Elongation 20% min for wall thickness ≤ 35 mm after cold deformation.

c Patented steel grade.

8.4 Appearance and soundness

8.4.1 Appearance

8.4.1.1 Tubes shall be free from external and internal surface defects that can be detected by visual examination.

8.4.1.2 The internal and external surface finish of the tubes shall be typical of the manufacturing process and, where applicable, the heat treatment employed. The finish and surface condition shall be such that any surface imperfections requiring dressing can be identified.

8.4.1.3 It shall be permissible to remove surface imperfections only by grinding or machining provided that, after so doing, the tube thickness in the dressed area is not less than the specified minimum wall thickness. All dressed areas shall blend smoothly into the contour of the tube.

8.4.1.4 Surface imperfections which encroach on the minimum wall thickness shall be considered defects and tubes containing these shall be deemed not to conform to this document.

8.4.1.5 For tubes with an outside diameter D greater than or equal to 114,3 mm, repair of the weld shall be permitted, provided that a compatible filler metal is used. Such weld repairs shall not exceed 20 % of the seam length.

The repair welding shall be carried out according to a written welding procedure specification (WPS).

The repaired tube shall conform to all the requirements of this document.

8.4.2 Soundness

When Option 5 is specified, the seam weld of tubes supplied with specific inspection and testing shall be subjected to non-destructive testing.

Option 5 *Non-destructive testing of the weld for the full length of each tube shall be carried out in accordance with 11.10.*

When Option 6 is specified, tubes supplied with specific inspection and testing shall be subjected to a leak tightness test.

Option 6 *Leak tightness testing of each tube shall be carried out in accordance with 11.7.*

8.5 Straightness

For tubes with a specified outside diameter equal to or greater than 33,7 mm, the deviation from straightness over any tube length L, where L is the manufacturer's delivered length, shall not exceed 0,0020 L, unless Option 7 is specified. For tubes with outside diameters less than 33,7 mm, the straightness and the method of measurement shall be agreed at the time of enquiry and order.

Option 7 *The deviation from straightness shall not exceed 0,0015 L.*

8.6 End preparation

Tubes shall be delivered with square cut ends. The ends shall be free from excessive burrs.

8.7 Dimensions, masses, lengths, tolerances and sectional properties

8.7.1 Outside diameter, wall thickness and mass

Outside diameters and wall thicknesses for tube covered by this document shall be as given in EN ISO 1127.

For calculation of mass, the densities given in EN 10088-1 shall apply.

NOTE Dimensions that are not included in EN ISO 1127 may be agreed at the time of enquiry and order.

8.7.2 Lengths

Tubes shall be supplied in a standard length of 6 000 mm, unless Options 8 or 9 are specified. For tolerances on length see 8.7.3.4.

NOTE Other lengths to a standard length tolerance may be available by agreement.

Option 8 *Random lengths shall be supplied. The length range shall be agreed at the time of enquiry and order.*

Option 9 *Exact lengths shall be supplied. The length required shall be agreed at the time of enquiry and order.*

8.7.3 Tolerances

8.7.3.1 Outside diameter

Unless Option 10 is specified, the tolerance on specified outside diameter, including ovality, shall be:

— ≤ 168,3 mm ± 0,75 % or ± 0,3 mm, whichever is the greater;

— > 168,3 mm ± 1,0%.

Option 10 *Tubes of specified outside diameter ≤ 114,3 mm shall be supplied with a tolerance, including ovality, of ± 0,5 % or ± 0,15 mm, whichever is the greater.*

8.7.3.2 Thickness

The tolerance on wall thickness, excluding the weld area, shall be ± 10 % or ± 0,2 mm, whichever is the greater.

8.7.3.3 Height of weld seam

The outside weld bead of HF welded tube shall be removed completely i.e. flush with the outside surface of the tube.

The maximum heights of the external and internal weld seams shall otherwise be as given in Table 6.

Table 6 — Maximum height of the weld seam

Dimensions in millimetres

Weld finish (see 7.2.1)	**Maximum height of the weld seam**	
	$T \leq 8$	$T > 8$
Finish A	(0,20) T + 0,5	T /3
Finish B for $D \leq$ 114,3 mm	(0,06) T +0,3	-
Finish B for $D >$ 114,3 mm	(0,05) T + 0,5	T /6
Finish C	0,15	-

8.7.3.4 Length

The tolerances on length shall be as given in Table 7.

Table 7 — Tolerances on length

Dimensions in millimetres

Type of length	**Length** L	**Tolerance**
Standard	6 000	+100 0
Random	Length range by agreement	
Exact	≤ 6 000	+5 0
	6 000 < L ≤ 12 000	+10 0
	>12 000	0 / + by agreement

8.7.4 Sectional properties

The nominal sectional properties shall be calculated in accordance with Annex C.

9 Inspection and testing

9.1 Types of inspection and testing

Conformity to the requirements of the order, for tubes supplied in accordance with this document, shall be checked by:

— non-specific inspection and testing (see EN 10021), unless Option 11 is specified.

Option 11 *Tubes shall be supplied with specific inspection and testing.*

9.2 Inspection documents

9.2.1 Types of inspection documents

The following inspection documents, in accordance with EN 10204, shall be issued:

— For tubes supplied with non-specific inspection and testing, a declaration of compliance with the order, 2.1, unless Option 12 is specified.

Option 12 *A test report 2.2 shall be supplied.*

— For tubes supplied with specific inspection and testing, an inspection certificate, 3.1, unless Option 13 is specified.

Option 13 *An inspection certificate 3.2 shall be supplied.*

When an inspection certificate 3.2 is specified, the purchaser shall inform the manufacturer of the name and address of the organization or person nominated to carry out the inspection and testing and validate the certificate. It shall also be agreed which party shall issue the document.

9.2.2 Content of inspection documents

9.2.2.1 The contents of the inspection documents shall be in accordance with EN 10168 as shown in 9.2.2.2, 9.2.2.3 and 9.2.2.4.

9.2.2.2 For tubes supplied with non-specific inspection and testing, the declaration of compliance with the order, 2.1, shall contain the following codes and information:

A - Commercial transactions and parties involved;

B - Description of products to which the certificate of compliance applies;

Z - Validation.

9.2.2.3 For tubes supplied with non-specific inspection and testing and a test report 2.2, this shall contain the following codes and information:

A - Commercial transactions and parties involved;

B - Description of products to which the test report applies;

C02 - Direction of test pieces;

C10 — C13 - Tensile test;

C60 — C69 - Other tests (e.g. options invoked which require test pieces);

C71 — C92 - Chemical composition;

D01 - Marking and identification, surface appearance, shape and dimensional properties;

Z - Validation.

9.2.2.4 For tubes supplied with specific inspection and testing, the inspection certificate 3.1 or 3.2 shall contain the following codes and information:

A - Commercial transactions and parties involved;

B - Description of products to which the inspection document applies;

C02- Direction of test pieces;

C10 — C13 - Tensile test;

C50 — C59 - Bend test;

C60 — C69 - Other tests (e.g. options invoked which require test pieces);

C71 — C92 - Chemical composition;

D01 - Marking and identification, surface appearance, shape and dimensional properties;

D02 — D99 - Other tests (e.g. options invoked which do not require test pieces);

Z - Validation.

9.3 Summary of inspection and testing

The requirements for inspection and testing are given in Table 8.

Table 8 — Requirements for inspection and testing

Types of inspection or test		Non-specific inspection and testing	Specific inspection and testing	Reference subclauses
Mandatory tests	Cast analysis	Manufacturers procedure	1/cast	8.2
	Tensile test	Manufacturers procedure	1/test unit	8.3, 11.1
	Flattening test [a]	Manufacturers procedure	1/test unit	8.3, 11.2
	Drift expanding test [a b]	Manufacturers procedure	1/test unit	8.3, 11.3
	Bend test (full tube section) [a]	Manufacturers procedure	1/test unit	8.3, 11.4
	Ring tensile test [c]	Manufacturers procedure	1/test unit	8.3, 11.5
	Weld bend test [c d]	Manufacturers procedure	1/test unit	8.3, 11.6
	Dimensional inspection	See 11.8		
	Visual examination	See 11.9		
	Material identification	individual	individual	11.11
Optional tests	Leak tightness test (Option 6)	Not applicable	individual	8.4.2, 11.7
	Non-destructive test of weld (Option 5)	Not applicable	individual	8.4.2, 11.10

[a] The choice of flattening, drift expanding or bend test (full tube section) is at the discretion of the manufacturer.

NOTE The bend test (full tube section) is only applicable for outside diameters ≤ 65 mm. The flattening and drift expansion test are only applicable for outside diameters ≤ 150 mm.

[b] The test shall not be carried out on tubes with specified elongation values less than 15 %.

[c] The choice of ring tensile test or weld bend test is at the discretion of the manufacturer.

[d] One root and one face test.

10 Sampling

10.1 Frequency of tests

10.1.1 Test unit

In the case of specific inspection and testing, a test unit shall comprise tubes of the same specified diameter and wall thickness, the same steel grade, the same cast and the same process route, subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch-type furnace.

The maximum quantity of tubes per test unit shall be in accordance with Table 9.

Table 9 — Test unit

Outside Diameter *D* mm	Maximum number of tubes per test unit [a]
≤ 114,3	400
114,3 < *D* ≤ 323,9	200
> 323,9	100
[a] Based on a maximum tube length of 20 m.	

10.1.2 Number of sample tubes/test unit

One sample tube shall be taken from each test unit.

10.2 Preparation of samples and test pieces

10.2.1 General

Samples and test pieces shall be taken at the tube ends and in accordance with the requirements of EN ISO 377.

10.2.2 Test piece for the tensile test

The test piece shall be taken in accordance with the requirements of EN 10002-1:

— For tubes with an outside diameter $D \leq 219{,}1$ mm, the test piece shall be either a full tube section or a strip section and shall be taken in a direction longitudinal to the axis of the tube.

— For tubes with an outside diameter $D > 219{,}1$ mm, the test piece shall either be a machined test piece with a circular cross section, taken from an unflattened sample, or a strip section and shall be taken in a direction either longitudinal or transverse to the axis of the tube at the discretion of the manufacturer.

In all cases the test piece shall be taken from the tube diametrically opposite the weld.

10.2.3 Test piece for the flattening test or drift expanding test

The test piece for the flattening test or drift expanding test shall consist of a full tube section in accordance with EN ISO 8492 or EN ISO 8493 respectively.

10.2.4 Test piece for the bend test on tube in full section

The test piece shall consist of a full section tube in accordance with EN ISO 8491.

10.2.5 Test piece for the ring tensile test

The test piece shall consist of a full tube section in accordance with EN ISO 8496.

10.2.6 Test piece for the weld bend test

The test piece shall be in accordance with EN 910.

11 Test methods

11.1 Tensile test

The test shall be carried out at room temperature in accordance with EN 10002-1 and the following determined:

— tensile strength (R_m);

— 0,2% proof strength ($R_{p0,2}$) and, where applicable, the 1,0 % proof strength ($R_{p1,0}$);

— percentage elongation after fracture with reference to a gauge length of $5{,}65\sqrt{S_0}$. If a non-proportional test piece is used, the percentage elongation value shall be converted to the value for a gauge length L_0 = $5{,}65\sqrt{S_0}$ using the conversion tables given in EN ISO 2566-2.

11.2 Flattening test

The test shall be carried out in accordance with EN ISO 8492 with the weld placed at 90° to the direction of flattening. The tube section shall be flattened in a press until the distance between the platens reaches 67 % of the original outside diameter. After testing, the test piece shall be free from cracks or breaks, however, slight incipient cracking at the edges shall not be regarded as cause for rejection.

11.3 Drift expanding test

The test shall be carried out in accordance with EN ISO 8493. The tube section shall be expanded using a conical mandrel with an angle of 60° until the % increase in outside diameter reaches the applicable value shown in Table 10:

Table 10 — Drift expanding test requirements

d/D[a] ratio	% increase in outside diameter
> 0,8	17
≤0,8 > 0,6	15
≤ 0,6	9
[a] $d = D - 2T$	

After testing the test piece shall be free from cracks or breaks, however, slight incipient cracking at the edges shall not be regarded as cause for rejection.

11.4 Bend test on tube in full section

The test shall be carried out at room temperature in accordance with EN ISO 8491. The angle of the bend shall be 180° and the diameter of the former 6 times the original outside diameter of the tube. After testing, the test piece shall show no visible cracks, without the use of magnifying aids.

11.5 Ring tensile test

The test shall be carried out in accordance with EN ISO 8496 on tube with specified outside diameter (D) > 150 mm.

11.6 Weld bend test

The tests shall be carried out in accordance with EN 910 on tube with specified outside diameter (D) > 150 mm using a mandrel of diameter 6 T. One test shall be a root bend test and the other a face bend test. After testing, the test piece shall show no cracks or flaws, however imperfections less than 3 mm long on the specimen edges shall not be regarded as a cause for failure of the test.

11.7 Leak tightness test

11.7.1 General

When Option 6 is specified ERW and laser beam welded tubes shall be leak tightness tested in accordance with 11.7.2 or 11.7.3. The choice of test method shall be at the discretion of the manufacturer unless Option 14 is specified.

Option 14: *The test method for verification of the leak tightness of tubes according to 11.7.2 or 11.7.3 shall be chosen by the purchaser.*

Submerged arc-welded tubes shall be tested in accordance with 11.7.3.

11.7.2 Electromagnetic test

The test shall be carried out in accordance with EN 10246-2.

11.7.3 Hydrostatic Test

The hydrostatic test shall be carried out at a test pressure of 70 bar or P, calculated from the following equation, whichever is the lower.

$$P = \frac{20 \times ST}{D}$$

where

P is the test pressure expressed in bar;

D is the specified outside diameter expressed in mm;

T is the specified wall thickness expressed in mm;

S is the stress, in MPa, corresponding to 70 % of the specified minimum proof strength ($R_{p0,2}$ - see Tables 4 and 5) for the steel grade concerned.

The test pressure shall be held for not less than 5 s for tubes with specified outside diameters ≤ 457 mm and for not less than 10 s for tubes with specified outside diameters > 457 mm.

The tube shall withstand the test without leakage or visible deformation.

NOTE This hydrostatic leak tightness test is not a strength test.

11.8 Dimensional inspection

Specified dimensions shall be verified.

The outside diameter is normally measured using a gauge, however, for tubes of D ≥168,3 mm, a circumference tape may be used. The wall thickness shall be measured within 100 mm of the tube ends.

11.9 Visual examination

Tubes shall be visually examined to ensure compliance with the requirements of 8.4.1.

11.10 Non-destructive testing of the weld

When Option 5 is specified testing should be carried out in accordance with one of the following non-destructive testing standards to the acceptance level indicated. The calibration shall be carried out using only an external reference notch or, as an alternative for eddy current testing, a hole:

— EN 10246-3 - acceptance level E3 or E3H;

NOTE Only for tubes of wall thickness ≤ 6 mm.

— EN 10246-7 - acceptance level U4;

— EN 10246-8 - acceptance level U4;

— EN 10246-9 - acceptance level U4.

— EN 10246-10 - image quality class R2, except that radioscopic methods, whose sensitivity can be demonstrated to be equivalent, are permitted at the discretion of the manufacturer.

The choice of test method, as appropriate for the type of tube, is at the discretion of the manufacturer.

11.11 Material identification

Each tube shall be tested by an appropriate method to ensure that the correct grade is being supplied.

11.12 Retests, sorting and reprocessing

For retests, sorting and reprocessing the requirements of EN 10021 shall apply.

12 Marking

12.1 General

Except as provided for in 12.2 for tubes which are supplied bundled, each tube shall be marked, by suitable and durable methods such as ink spraying, stamping, adhesive labels or attached tags, with the following information:

— manufacturer’s name or trademark;

— dimensions;

— steel designation;

— cast number or code number;

— symbol for the delivery condition, e.g. +AR where applicable;

— in the case of specific inspection:

  — mark of the inspection representative;

  — identification number (e.g. order or item number) which permits the correlation of the product or delivery unit to the related document

and at the discretion of the manufacturer:

— symbol for the process route and surface condition, where applicable (see Option 1 and Table A.1).

EXAMPLE OF MARKING

X - 48,3 x 3,6 -EN 10296-2 - 1.4301 – C - - Y - Z

where

X is the manufacturer's name or trademark;

C is the cast number or code number;

Y is the mark of inspection representative;

Z is the identification number (e.g. order or item number).

12.2 Bundles

Where the products are supplied bundled, the marking required in 12.1 may be on a label which shall be securely attached to the bundle.

13 Handling and packaging

Tubes shall be protected from carbon steel strapping which shall not be allowed to come into contact with the tubes.

Special measures to protect the tube during delivery or storage may be agreed between the purchaser and manufacturer at the time of enquiry and order.

Annex A
(normative)

Process route and surface conditions

Table A.1 — Process route and surface conditions

Symbol [a]	Process route [b]	Surface condition
W0 [c]	Welded from hot or cold rolled plate, sheet or strip 1D, 2D, 2E, 2B	As welded
W1 [c]	Welded from hot rolled plate, sheet or strip 1D, descaled	Metallically clean
W1A [c]	Welded from hot rolled plate, sheet or strip 1D, heat treated, descaled	Metallically clean
W1R [c]	Condition W1 + heat treatment under controlled atmosphere	Metallically bright
W2 [c]	Welded from cold rolled plate, sheet or strip 2D, 2E, 2B, descaled	Metallically clean
W2A [c]	Welded from cold rolled plate, sheet or strip 2D, 2E, 2B, heat treated, descaled	Except for the weld, essentially smoother than for types W1 and W1A
W2R [c]	Welded from cold rolled plate, sheet or strip 2D, 2E, 2B, bright heat treated	Metallically bright
WCA	Welded from hot rolled or cold rolled plate, sheet or strip 1D, 2D, 2E, 2B, heat treated if appropriate, at least 20 % cold formed, heat treated, with re-crystallized weld metal, descaled	Metallically clean, weld scarcely recognizable
WCR	Welded from hot rolled or cold rolled plate, sheet or strip 1D, 2D, 2E, 2B, heat treated if appropriate, at least 20 % cold formed, bright heat treated, with re-crystallized weld metal	Metallically bright, weld scarcely recognizable
WG	Ground [d]	Metallically bright-ground, the type of grinding and degree of roughness shall be agreed at the time of enquiry and order [e]
WP	Polished [d]	Metallically bright-polished, the type of polishing and degree of roughness shall be agreed at the time of enquiry and order [e]

[a] The symbols W0, W1 and W2 are not applicable to ferritic steels.

[b] Symbols of flat products according to EN 10088-2.

[c] For tubes ordered with smoothed welds ("bead worked"), the letter “b” shall be appended to the symbol for the type of condition (e.g. W2Ab).

[d] Conditions W2, W2A, W2R, WCA or WCR are usually used as the starting condition.

[e] The enquiry and order shall indicate whether the requirements for grinding or polishing applies only to the internal or external tube surface, or both the internal and external surfaces.

Annex B
(informative)

Guideline data on heat treatment during fabrication and hot working as part of further processing

Table B.1 — Guideline data for ferritic corrosion resistant steels [a]

Steel grade		Heat treatment during fabrication and further processing		Hot working during further processing e.g. hot bending	
Steel name	Steel number	Annealing temperature	Type of cooling	Temperature °C	Type of cooling
X2CrNi12	1.4003	700 to 750	water or air or gas	1 100 to 800	Air or gas
X2CrTi12	1.4512	750 to 850	water or air or gas	1 100 to 800	Air or gas
X6Cr17	1.4016	750 to 850	water or air or gas	1 100 to 800	Air or gas
X3CrTi17	1.4510	750 to 850	water or air or gas	1 100 to 800	Air or gas
X2CrMoTi18-2	1.4521	820 to 880	water or air or gas	1 100 to 800	Air or gas
X6CrMoNb17-1	1.4526	820 to 880	water or air or gas	1 100 to 800	Air or gas
X2CrTiNb18	1.4509	870 to 930	water or air or gas	1 100 to 800	Air or gas
[a] In special cases furnace cooling is also permitted.					

Table B.2 — Guideline data for austenitic and austenitic-ferritic corrosion resistant steels

Steel grade		Heat treatment during fabrication and further processing		Hot working during further processing e.g. Hot bending	
Steel name	Steel number	Solution annealing temperature [a] °C	Type of cooling [b]	Temperature °C	Type of cooling
Austenitic steels					
X2CrNiN18-7	1.4318	1 020 to 1 100	Quenching in water or air or gas	1 150 to 850	Air or gas
X2CrNi18-9	1.4307	1 000 to 1 100	Quenching in water or air or gas	1 150 to 850	Air or gas
X2CrNi19-11	1.4306	1 000 to 1 100	Quenching in water or air or gas	1 150 to 850	Air or gas
X2CrNiN18-10	1.4311	1 000 to 1 100	Quenching in water or air or gas	1 150 to 850	Air or gas
X5CrNi18-10	1.4301	1 000 to 1 100	Quenching in water or air or	1 150 to 750	Air or gas
X6CrNiTi18-10	1.4541	1 000 to 1 100	Quenching in water or air or gas	1 150 to 850	Air or gas
X6CrNiNb18-10	1.4550	1 020 to 1 100	Quenching in water or air or gas	1 150 to 850	Air or gas

Table B.2 (*concluded*)

Steel grade		Heat treatment during fabrication and further processing		Hot working during further processing e.g. Hot bending	
Steel name	**Steel number**	**Solution annealing temperature** [a] **°C**	**Type of cooling** [b]	**Temperature °C**	**Type of cooling**
X2CrNiMo17-12-2	1.4404	1 030 to 1 110	Quenching in water or air or gas	1 150 to 850	Air or gas
X5CrNiMo17-12-2	1.4401	1 030 to 1 110	Quenching in water or air or gas	1 150 to 850	Air or gas
X6CrNiMoTi17-12-2	1.4571	1 030 to 1 110	Quenching in water or air or gas	1 150 to 850	Air or gas
X2CrNiMo17-12-3	1.4432	1 030 to 1 110	Quenching in water or air or gas	1 150 to 850	Air or gas
X2CrNiMo17-13-3	1.4429	1 030 to 1 110	Quenching in water or air or gas	1 150 to 850	Air or gas
X3CrNiMo17-3-3	1.4436	1 030 to 1 110	Quenching in water or air or gas	1 150 to 850	Air or gas
X2CrNiMo18-14-3	1.4435	1 070 to 1 150	Quenching in water or air or gas	1 150 to 850	Air or gas
X2CrNiMoN17-13-5	1.4439	1 060 to 1 140	Quenching in water or air or gas	1 150 to 850	Air or gas
X1NiCrMoCu25-20-5	1.4539	1 100 to 1 160	Quenching in water or air or gas	1 150 to 850	Air or gas
X1CrNiMoCuN20-18-7	1.4547	1 180 to 1 200	Quenching in water or air or gas	1 150 to 850	Air or gas
Austentic-ferritic steels					
X2CrNiN23-4	1.4362	950 to 1 050	Quenching in water or air or gas	1 150 to 950	Air or gas
X2CrNiMoN22-5-3	1.4462	1 020 to 1 100	Quenching in water or air or gas	1 150 to 950	Air or gas
X2CrNiMoN25-7-4	1.4410	1 040 to 1 120	Quenching in water or air or gas	1 150 to 1 000	Air or gas

[a] When heat treatment forms part of further processing of the product, an attempt should be made to achieve the lower values of the range for solution annealing. If hot working has been carried out at a temperature of at least 850 °C or if the product has been cold worked, the temperature used for subsequent solution annealing may be 20 °C less than the lower limit stipulated for solution annealing.

[b] Cooling should be sufficiently rapid.

Table B.3 —Guideline data for austenitic heat resisting stainless steels

Steel grade		Heat treatment		Hot working during further processing e.g. hot bending	
Steel name	Steel number	Temperature °C	Type of cooling [a]	Temperature °C	Type of cooling
X15CrNiSi20-12	1.4828	1 050 to 1 150	Quenching in water, air or gas	1 150 to 850	Air or gas
X9CrNiSiNCe21-11-2	1.4835	1 020 to 1 120	Quenching in water, air or gas	1 100 to 850	Air or gas
X12CrNi23-13	1.4833	1 050 to 1 150	Quenching in water, air or gas	1 100 to 850	Air or gas
X8CrNi25-21	1.4845	1 050 to 1 150	Quenching in water, air or gas	1 100 to 850	Air or gas
X6CrNiSiNCe19-10	1.4818	1 020 to 1 120	Quenching in water, air or gas	1 100 to 850	Air or gas
X6NiCrSiNCe35-25	1.4854	1 100 to 1 150	Quenching in water, air or gas	1 100 to 850	Air or gas

[a] Cooling should be sufficiently rapid.

Annex C
(normative)

Formulae for calculation of nominal sectional properties

The nominal sectional properties for tubes are calculated from the following geometric properties using the formulae given below:

Specified outside diameter	D	(mm)
Specified thickness	T	(mm)
Calculated inside diameter	$d = D - 2T$	(mm)
Superficial area/unit length	$A_s = \frac{\pi D}{10^3}$	(m^2/m)
Cross sectional area	$A = \frac{\pi(D^2 - d^2)}{4 \times 10^2}$	(cm^2)
Mass per unit length	$M = \rho A$	(kg/m)
	where ρ is the density of the steel in accordance with EN 10088-1	
Second moment of area	$I = \frac{\pi(D^4 - d^4)}{64 \times 10^4}$	(cm^4)
Radius of gyration	$i = \sqrt{\frac{I}{A}}$	(cm)
Elastic section modulus	$W_{el} = \frac{2I \times 10}{D}$	(cm^3)
Plastic section modulus	$W_{pl} = \frac{D^3 - d^3}{6 \times 10^3}$	(cm^3)
Torsional inertia constant (polar moment of inertia)	$I_t = 2I$	(cm^4)
Torsional modulus constant	$C_t = 2W_{el}$	(cm^3)

Bibliography

[1] EN 473, *Non-destructive testing - Qualification and certification of NDT personnel - General principles.*

[2] EN 10088-2, *Stainless steels - Part 2: Technical delivery conditions for sheet/plate and strip for general purposes*

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