BRITISH STANDARD

BS EN 10297-2:2005

Incorporating corrigendum no. 1

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

Part 2: Stainless steel

The European Standard EN 10297-2:2005 has the status of a British Standard

ICS 77.140.75

BSI British Standards

National foreword

This British Standard was published by BSI. It is the UK implementation of EN 10297-2:2005, incorporating corrigendum February 2007.

The UK participation in its preparation was entrusted to Technical Committee ISE/8, Steel pipes.

A list of organizations represented on ISE/8 can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Amendments issued since publication

Amd. No.	Date	Comments
17060 Corrigendum No. 1	30 April 2007	English title changed to: "Seamless circular steel tubes ..." Table 1, footnote b: formula replaced with: "*Nb* (% by mass) = *Zr* (% by mass) = 7/4 *Ti* (% by mass)"

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EUROPEAN STANDARD

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English Version

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

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

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

This European Standard was approved by CEN on 25 March 2005.

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Foreword

This document (EN 10297-2:2005) 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of an identical text or by endorsement, at the latest by June 2006, and conflicting national standards shall be withdrawn at the latest by June 2006.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 10297 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 10296-2 Welded circular steel tubes for mechanical and general engineering purposes — Technical delivery conditions – Part 2: Stainless steel.

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, 1.4410, 1.4477 and 1.4854, the compositions of which are given in Tables 3 and 4.

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 document 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 seamless 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 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, St*eel 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 10246-5, *Non-destructive testing of steel tubes – Part 5: Automatic full peripheral magnetic transducer/flux leakage testing of seamless and welded (except submerged arc-welded) ferromagnetic steel tubes for the detection of longitudinal 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 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 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 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, 2, 3 and 4 are stainless steels.

5.2 Designation

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

— number of this document (EN 10297-2);

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 8.7.1);

d) steel designation according to this document (see 5.2);

e) delivery condition, where necessary (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) controlled sulphur content (see Tables 1, 2, and 3);

3) non-destructive testing (see 8.4.2);

4) leak tightness test (see 8.4.2);

5) straightness (see 8.5);

6) exact lengths (see 8.7.2);

7) outside diameter and thickness tolerances (see 8.7.3.1);

8) specific inspection and testing (see 9.1);

9) test report 2.2 (see 9.2.1);

10) inspection certificate, 3.2 (see 9.2.1);

11) leak tightness test method (see 11.2.1).

6.3 Example of an order

Twenty five tonnes of seamless steel tubes with a specified outside diameter of 60,3 mm, a specified wall thickness of 3,6 mm, in accordance with EN 10297-2, made from steel grade 1.4016, and with a test report 2.2 (option 9) in accordance with EN 10204.

25 t - tube - 60,3 x 3,6 - EN 10297-2 – 1.4016 - Option 9

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 manufactured by a seamless process, and may be hot finished or cold finished. The terms “hot finished “ and “ cold finished “ apply to the condition of the tube before it is heat treated in accordance with 7.2.2. Acceptable process routes and surface conditions are given in Table A.1. The choice of process route and surface condition is left to 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.*

7.2.2 Tubes shall be supplied in the delivery conditions given in Tables 6, 7, 8 or 9, as applicable. Possible delivery conditions are annealed (+A) for ferritic steels, quenched and tempered (+QT) for martensitic steels and

solution annealed (+AT) for austenitic and austenitic-ferritic steels. (See Annex B for guidance on heat treatment following fabrication and further processing.)

For steel grade 1.4006, the purchaser shall specify the delivery condition, either QT 550 or QT 650. The process route and surface condition for this grade shall be at the discretion of the manufacturer unless Option 1 (see 7.2.1) is specified.

Solution heat treatment shall consist of heating the tubes uniformly to the appropriate required temperature and then cooling rapidly. The solution treatment may be omitted if the conditions during hot working and subsequent cooling are such that the mechanical properties of the product can be met and the requirements for resistance to intergranular corrosion as defined in EN ISO 3651-2 can be obtained. See Annex B for guidance on heat treatment during fabrication and hot working as part of further processing.

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 comply with the requirements of this document.

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

Grades additional to those in Tables 1, 2, 3 and 4 may be supplied by agreement; the chemical analysis and the mechanical properties for these shall be agreed at the time of enquiry and order.

8.2 Chemical composition

The cast analysis reported by the steel producer shall apply and shall conform to the requirements in Tables 1, 2, 3 or 4, as appropriate.

Elements not included in Tables 1, 2, 3 and 4 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 5.

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 document cannot be welded unless specialised techniques are employed by specialist welders.

Table 1 — Chemical composition (cast analysis) for tubes made fromferritic and martensitic corrosion resistant steels, in % by mass

Steel grade		C		Si	Mn	P	S	Cr		Ni	Ti		Others	
Steel name	**Steel number**	min.	max.	max.	max.	max.	max.	min.	max.	max.	min.	max.	min.	max.
Ferritic steels														
X2CrTi12	1.4512		0,030	1,00	1,00	0,040	0,015	10,5	12,5		6 x (C + N)	0,65		
X6CrAl13	1.4002		0,08	1,00	1,00	0,040	0,015 [a]	12,0	14,0				Al0,10	Al 0,30
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		[4 x (C+N) + 0,15] [b]	0,80 [b]		
Martensitic steel														
X12Cr13	1.4006	0,08	0,15	1,00	1,50	0,040	0,015 [a]	11,5	13,5	0,75				

[a] **Option 2** a controlled sulphur 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: *Nb* (% by mass) = *Zr* (% by mass) = 7/4 *Ti* (% by mass).

Table 2 — Chemical composition (cast analysis) for tubes made from austenitic corrosion resistant steels, in % by mass

Steel grade		C		Si		Mn	P	S		Cr		Mo		Ni		Cu		N		Others	
Steel name	**Steel number**	min.	max.	min.	max.	max.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
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		
X8CrNiS18-9	1.4305		0,10		1,00	2,00	0,045	0,15	0,35	17,0	19,0			8,0	10,0		1,00		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 [b]					Ti 5 x C	Ti 0,70
X6CrNiNb18-10	1.4550		0,08		1,00	2,00	0,045		0,015	17,0	19,0			9,0	12,0 [b]					Nb 10 x C	Nb 1,00
X1CrNi25-21	1.4335		0,020		0,25	2,00	0,025		0,010	24,0	26,0		0,20	20,0	22,0				0,11		
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	14,5				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		
X1CrNiMoN25-22-2	1.4466		0,020		0,70	2,00	0,025		0,010	24,0	26,0	2,00	2,50	21,0	23,0			0,10	0,16		
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	14,0					Ti 5 x C	Ti 0,70
X6CrNiMoNb17-12-2	1.4580		0,08		1,00	2,00	0,045		0,015	16,5	18,5	2,00	2,50	10,5	13,5					Nb 10 x C	Nb 1,00
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	15,0			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	14,0				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		
X1NiCrMoCu31-27-4	1.4563		0,020		0,70	2,00	0,030		0,010	26,0	28,0	3,0	4,0	30,0	32,0	0,70	1,50		0,11		
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		

Table 2 — Chemical composition (cast analysis) for tubes made from austenitic corrosion resistant steels, in % by mass
(*concluded*)

X1NICrMoCuN25-20-7	1.4529		0,020		0,50	1,00	0,030		0,010	19,0	21,0	6,0	7,0	24,0	26,0	0,50	1,50	0,15	0,25		
X2NiCrAlTi32-20	1.4558		0,030		0,70	1,00	0,020		0,015	20,0	23,0			32,0	35,0					Ti 8 x (C+N) Al 0,15	Ti 0,60 Al 0,45

[a] ***Option 2*** *a controlled sulphur content of 0,015 % to 0,030 % is specified.*

[b] Where for special reasons, e.g. hot workability, it is necessary to minimize the delta ferrite content, or with the aim of low permeability, the maximum nickel content may be increased by 1,00 %.

Table 3 — Chemical composition (cast analysis) for tubes made from austenitic-ferritic corrosion resistant steels, in % by mass

Steel grade		C	Si		Mn		P	S	Cr		Mo		Ni		Cu		N		Others	
Steel name	**Steel number**	max.	min.	max.	min.	max.	max.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
X2CrNiN23-4 [a]	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		
X3CrNiMoN27-5-2	1.4460	0,05		1,00		2,00	0,035	0,015 [b]	25,0	28,0	1,30	2,00	4,5	6,5			0,05	0,20		
X2CrNiMoN29-7-2 [a]	1.4477	0,030		0,50	0,80	1,50	0,030	0,015	28,0	30,0	1,50	2,60	5,8	7,5			0,30	0,40		
X2CrNiMoN22-5-3	1.4462	0,030		1,00		2,00	0,035	0,015	21,0	23,0	2,5	3,5	4,5	6,5			0,10	0,22		
X2CrNiMoCuN25-6-3	1.4507	0,030		0,70		2,00	0,035	0,015	24,0	26,0	2,7	4,0	5,5	7,5	1,00	2,50	0,15	0,30		
X2CrNiMoN25-7-4 [a]	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		
X2CrNiMoCuWN25-7-4	1.4501	0,030		1,00		1,00	0,035	0,015	24,0	26,0	3,0	4,0	6,0	8,0	0,50	1,00	0,20	0,30	W 0,50	W 1,00
X2CrNiMoSi18-5-3	1.4424	0,030	1,40	2,00	1,20	2,00	0,035	0,015	18,0	19,0	2,50	3,00	4,5	5,2			0,05	0,10		

[a] Patented steel grade.

[b] ***Option 2*** *a controlled sulphur content of 0,015 % to 0,030 % is specified.*

Table 4 — Chemical composition (cast analysis) for tubes made from ferritic and austenitic heat resisting steels, in % by mass

Steel grade		C		Si		Mn	P	S	Cr		Ni		N		Ti		Others	
Steel name	**Steel number**	min.	max.	min.	max.	max.	max.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
Ferritic steels																		
X18CrN28	1.4749	0,15	0,20		1,00	1,00	0,040	0,015	26,0	29,0			0,15	0,25				
Austenitic steels																		
X8CrNiTi18-10	1.4878		0,10		1,00	2,00	0,045	0,015	17,0	19,0	9,0	12,0			5xC	0,80		
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			Ce 0,03	Ce 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				
X10NiCrAlTi32-21	1.4876		0,12		1,00	2,00	0,030	0,015	19,0	23,0	30,0	34,0			0,15	0,60	Al 0,15	Al 0,60
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			Ce 0,03	Ce 0,08

[a] Patented steel grade

Table 5 — Permissible deviations of the product analysis from the specified limits on cast analysis given in Tables 1 to 4

Element	Limiting values for the cast analysis in accordance with Tables 1, 2, 3 and 4 % by mass	Permissible deviation of the product analysis % by mass
C	≤ 0,030	+ 0,005
	> 0,030 ≤ 0,20	± 0,01
Si	≤ 1,00	+ 0,05
	> 1,00 ≤ 2,50	±0,10
Mn	≤ 1,00	± 0,03
	> 1,00 ≤ 2,00	±0,04
P	≤ 0,045	+ 0,005
S	≤ 0,015	+ 0,003
	> 0,015 ≤ 0,030	±0,005
	> 0,15 ≤ 0,35	± 0,02
Cr	> 10,50 ≤ 15,0	± 0,15
	> 15,0 ≤ 20,0	± 0,20
	> 20,0 ≤ 30,0	± 0,25
Mo	≤0,60	±0,03
	> 0,60 < 1,75	± 0,05
	≥ 1,75 ≤ 7,00	± 0,10
Ni	<1,00	± 0,03
	≥ 1,0 ≤ 5,0	± 0,07
	> 5,0 ≤ 10,0	± 0,10
	> 10,0 ≤ 20,0	± 0,15
	> 20,0 ≤ 36,0	± 0,20
Al	≥ 0,10 ≤ 0,30	± 0,05
	> 0,30 ≤ 0,60	± 0,10
Cu	≤ 1,00	± 0,07
	> 1,00 ≤ 2,50	± 0,10
N	≤ 0,40	± 0,01
Nb	≤ 1,00	± 0,05
Ti	≤ 0,80	± 0,05
W	≥ 0,50 ≤ 1,00	± 0,05
Ce	≤ 0,08	± 0,01

8.3 Mechanical properties

The mechanical properties of the tubes covered by this document shall conform to the requirements in Tables, 6, 7, 8 and 9.

Table 6 — Delivery conditions and mechanical properties for tubes made from ferritic and martensitic corrosion resistant steels

Steel grade		Delivery condition	Proof strength min. MPa [a]		Tensile strength min. MPa	Elongation A min. %		Resistance to intergranular corrosion [b]
Steel name	Steel number		$R_{p0,2}$	$R_{p1,0}$	R_m	l [c]	t [c]	
Ferritic steels								
X2CrTi12	1.4512	+A	210	220	380	25	25	No
X6CrAl13	1.4002	+A	210	220	400	17	17	No
X6Cr17	1.4016	+A	240	250	430	20	20	Yes [d]
X3CrTi17	1.4510	+A	230	240	420	23	23	Yes
Martensitic steels								
X12Cr13	1.4006	+QT 550	400	410	550	15	15	No
		+QT 650	450	460	650	12	12	No

a 1 MPa = 1 N/mm^2

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

c l = longitudinal, t = transverse.

d Not if welding is subsequently carried out.

Table 7 — Delivery conditions and mechanical properties for tubes made from austenitic corrosion resistant steels

Steel grade		Delivery condition	Proof strength min. MPa [a]		Tensile strength min MPa	Elongation A min. %		Resistance to intergranular corrosion [b]
Steel name	Steel number		$R_{p0,2}$	$R_{p1,0}$	R_m	l [c]	t [c]	
X2CrNi18-9	1.4307	+AT	180	215	460	40	35	Yes
X2CrNi19-11	1.4306	+AT	180	215	460	40	35	Yes
X2CrNiN18-10	1.4311	+AT	270	305	550	35	30	Yes
X5CrNi18-10	1.4301	+AT	195	230	500	40	35	Yes [d]
X8CrNiS18-9	1.4305	+AT	190	230	500	35	35	No
X6CrNiTi18-10	1.4541	+AT (Cold finished)	200	235	500	35	30	Yes
		+AT (Hot finished)	180	215	460	35	30	Yes
X6CrNiNb18-10	1.4550	+AT	205	240	510	35	30	Yes
X1CrNi25-21	1.4335	+AT	180	210	470	45	40	Yes
X2CrNiMo17-12-2	1.4404	+AT	190	225	490	40	30	Yes
X5CrNiMo17-12-2	1.4401	+AT	205	240	510	40	30	Yes [d]
X1CrNiMoN25-22-2	1.4466	+AT	260	295	540	40	30	-
X6CrNiMoTi17-12-2	1.4571	+AT (Cold finished)	210	245	500	35	30	Yes
		+AT(Hot finished)	190	225	490	35	30	Yes
X6CrNiMoNb17-12-22	1.4580	+AT	215	250	510	35	30	Yes
X2CrNiMoN17-13-3	1.4429	+AT	295	330	580	35	30	Yes
X3CrNiMo17-13-3	1.4436	+AT	205	240	510	40	30	Yes [d]
X2CrNiMo18-14-3	1.4435	+AT	190	225	490	40	35	Yes
X2CrNiMoN17-13-5	1.4439	+AT	285	315	580	35	30	Yes
X1NiCrMoCu31-27-4	1.4563	+AT	215	245	500	40	35	Yes
X1NiCrMoCu25-20-5	1.4539	+AT	230	250	520	35	30	Yes
X1CrNiMoCuN20-18-7	1.4547	+AT	300	340	650	35	30	Yes
X1NICrMoCuN25-20-7	1.4529	+AT	270	310	600	35	-	Yes
X2NiCrAlTi32-20	1.4558	+AT	180	210	450	35	-	-

[a] 1 MPa = 1 N/mm^2

[b] When tested in accordance with EN ISO 3651-2.

[c] l = longitudinal, t = transverse.

[d] Normally not fulfilled in the sensitized condition.

Table 8 — Delivery conditions and mechanical properties for tubes made from austenitic-ferritic corrosion resistant steels

Steel grade		Delivery condition	Proof strength min MPa [a]		Tensile strength min MPa	Elongation A min %		Resistance to intergranular corrosion [b]
Steel name	Steel number		$R_{p0,2}$	$R_{p1,0}$	R_m	l [c]	t [c]	
Austenitic-ferritic steels								
X3CrNiMoN27-5-2	1.4460	+AT	460	470	620	20	-	Yes
X2CrNiMoN29-7-2 [e]	1.4477	+AT	550 [d]	560 [d]	750 [d]	25	25	Yes
X2CrNiMoN22-5-3	1.4462	+AT	450	460	640	22	-	Yes
X2CrNiMoSi18-5-3	1.4424	+AT	480	490	700	30	30	Yes
X2CrNiN23-4 [e]	1.4362	+AT	400	410	600	25	25	Yes
X2CrNiMoN25-7-4 [e]	1.4410	+AT	550	640	800	20	20	Yes
X2CrNiMoCuN26-6-3	1.4507	+AT	500	510	700	20	20	Yes
X2CrNiMoCuWN25-7-4	1.4501	+AT	550	640	800	20	20	Yes

a 1 MPa = 1 N/mm^2

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

c l = longitudinal, t = transverse.

d For thicknesses < 10mm the values for $R_{p0.2}$ and $R_{p1.0}$ are increased by 100 MPa and R_m by 50 MPa.

e Patented steel grade.

Table 9 — Delivery conditions and mechanical properties for tubes made from ferritic and austenitic heat resisting steels

Steel grade		Delivery condition	Proof strength min MPa[a]		Tensile strength min MPa	Elongation A min %	
Steel name	Steel number		$R_{p0,2}$	$R_{p1,0}$	R_m	l [b]	t [b]
Ferritic steels							
X18CrN28	1.4749	+A	280		500	15	15
Austenitic steels							
X8CrNITi18-10	1.4878	+AT	190	230	500	40	40
X9CrNiSiNCe21-11-2	1.4835	+AT	310	350	650	37	40
X12CrNi23-13	1.4833	+AT	210	250	500	33	35
X8CrNi25-21	1.4845	+AT	210	250	500	33	35
X10NiCrAlTi32-21	1.4876	+AT	170	210	450	28	30
X6NiCrSiNCe35-25 [c]	1.4854	+AT	300	340	650	40	40

a 1 MPa = 1 N/mm^2

b l = longitudinal, t = transverse.

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.

8.4.2 Soundness

When Option 3 is specified, tubes supplied with specific inspection and testing shall be subjected to non-destructive testing.

Option 3: *Non-destructive testing for the full length of each tube shall be carried out in accordance with 11.3.*

When Option 4 is specified, tubes supplied with specific inspection and testing shall be subjected to a leak tightness test.

Option 4: *Leak tightness testing of each tube shall be carried out in accordance with 11.2.*

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 5 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 5 *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 random lengths, unless Option 6 is specified. The manufacturer shall inform the purchaser of the random length range at the time of enquiry and order.

Option 6: *Exact lengths shall be supplied. The length required shall be agreed at the time of enquiry and order. For tolerances see 8.7.3.2*

8.7.3 Tolerances

8.7.3.1 Outside diameter and thickness

The tolerances on outside diameter and wall thickness shall be as given in Table 10, unless Option 7 is specified or unless otherwise agreed at the time of enquiry and order.

Table 10 — Tolerances on outside diameter (D) and wall thickness (T) selected from EN ISO 1127

Process route	Tolerance on D		Tolerance on T	
	Tolerance class	Tolerance limits	Tolerance class	Tolerance limits
Hot finished	D_1	± 1,5 % or ± 0,75 mm whichever is the greater	T_1	± 15 % or ± 0,6 mm whichever is the greater.
Cold finished [a]	D_3	± 0,75 % or ± 0,3 mm min whichever is the greater	T_3	± 10 % or ± 0,2 mm whichever is the greater.
[a] Only applies when cold finished is specified				

Option 7: *The tolerances given in Table 11 shall apply, the purchaser to specify if outside diameter, thickness or both shall be to the tighter tolerance.*

Table 11— Optional tolerances on outside diameter (D) and wall thickness (T)

Process route	Tolerance on D		Tolerance on T	
	Tolerance class	Tolerance limits	Tolerance class	Tolerance limits
Hot finished	D_2	± 1 % or ± 0,5 mm whichever is the greater.	T_2	± 12,5 % or ± 0,4 mm whichever is the greater.
Cold finished [a]	D_4	± 0,5 % or ± 0,1 mm whichever is the greater.	T_4	± 7,5 % or ± 0,15 mm whichever is the greater.
[a] Only applies when cold finished is specified				

Ovality is included within the tolerance limits on outside diameter. Eccentricity is included within the tolerance limits on wall thickness.

8.7.3.2 Exact length

The tolerances on exact length shall be as given in Table 12.

Table 12 — Tolerances on exact lengths

Dimensions in millimetres

Length L	Tolerance
$L \leq 6\,000$	$^{+5}_{0}$
$6\,000 < L \leq 12\,000$	$^{+10}_{0}$
$L > 12\,000$	$^{0}_{+}$ 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 8 is specified.

Option 8: *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 9 is specified.

Option 9: *A test report 2.2 shall be supplied.*

— for tubes supplied with specific inspection and testing, an inspection certificate, 3.1, unless Option 10 is specified.

Option 10: *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 organisation 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;

C71-C92 - Chemical composition;

D01 - Marking and identification, the surface appearance, the shape and the dimensions;

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 tests;

C71-C92 - Chemical composition;

D01 - Marking and identification, the surface appearance, the shape and the dimensions;

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 13.

Table 13 — Requirements for Inspection and testing

Types of inspection or test		Non-specific inspection and testing	Specific inspection and testing	Reference paragraph
Mandatory tests	Cast Analysis	Manufacturers procedure	1/cast	8.2
	Tensile Test	Manufacturers procedure	1/test unit	8.3; 11.1
	Dimensional inspection	See 11.4		
	Visual examination	See 11.5		
	Material identification	individual	individual	11.6
Optional tests	Leak tightness test (Option 4)	Not applicable	individual	8.4.2; 11.2
	Non-destructive test for imperfections (Option 3)	Not applicable	individual	8.4.2; 11.3

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.

For extruded tubes, 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.

The maximum quantity of tubes, in random manufacturing lengths [1)], per test unit shall be in accordance with Table 14.

Table 14 — Test unit

Outside Diameter D mm	Maximum number of tubes per test unit
$D \leq 114{,}3$	400
$114{,}3 > D \leq 323{,}9$	200
$D > 323{,}9$	100

1) The random manufacturing length may differ from the actual delivered length.

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 or a machined circular cross section (T>10mm) 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.

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 $5{,}65\sqrt{S_o}$.

If a non-proportional test piece is used, the percentage elongation value shall be converted to the value for a gauge length $L_0 = 5{,}65\sqrt{S_o}$ using the conversion Tables given in EN ISO 2566-2.

11.2 Leak tightness test

11.2.1 General

Tubes shall be leak tightness tested in accordance with 11.2.2 or 11.2.3. The choice of test method shall be at the discretion of the manufacturer unless Option 11 is specified.

Option 11: *The test method for verification of the leak tightness of tubes according to 11.2.2 or 11.2.3 shall be chosen by the purchaser.*

11.2.2 Electromagnetic test

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

11.2.3 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 6, 7, 8 and 9) 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.

11.3 Non-destructive testing

When Option 5 is specified testing shall 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 E4 or E4H;

EN 10246-5 - acceptance level F4;

EN 10246-7 - acceptance level U4.

The choice of test method is at the discretion of the manufacturer.

11.4 Dimensional inspection

Specified dimensions shall be verified.

The outside diameter is normally measured using a gauge, however, for tubes of D ≥ 406,4 mm, a circumference tape may be used. The wall thickness shall be measured within 100 mm of the tube ends.

11.5 Visual examination

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

11.6 Material identification

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

11.7 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, where two possibilities are given;

— 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.

EXAMPLE OF MARKING

X - 60,3 x 3,6 - EN 10297-2 - 1.4016 - C - - Y - Z

X = manufacturer's name or trademark;

C = cast number or code number;

Y = mark of inspection representative;

Z = 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 [a]

Symbol [b]	Process route	Surface condition
HFD	Hot finished heat treated, descaled	Metallically clean
CFD	Cold finished heat treated, descaled	Metallically clean
CFA	Cold finished bright annealed	Metallically bright
CFG	Cold finished heat treated, ground	Metallically bright-ground, the type of grinding and degree of roughness shall be agreed at the time of enquiry and order[c]
CFP	Cold finished heat treated, polished	Metallically bright-polished, the type of polishing and degree of roughness shall be agreed at the time of enquiry and order[c]

[a] Combinations of the different conditions may be agreed at the time of enquiry and order.

[b] The symbols are abbreviations for type of condition. Example: CFD = Cold Finished Descaled.

[c] The enquiry and order shall indicate whether the requirement 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 and martensitic 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	Annealing or solution annealing temperature	Type of cooling	Temperature °C	Type of cooling
Ferritic steels [a]					
X2CrTi12	1.4512	750 to 850	Air, water or gas	1 100 to 800	Air or gas
X6CrAl13	1.4002	750 to 850	Air, water, or gas	1 100 to 800	Air or gas
X6Cr17	1.4016	750 to 850	Air, water, or gas	1 100 to 800	Air or gas
X3CrTi17	1.4510	750 to 850	Air, water, or gas	1 100 to 800	Air or gas
Martensitic steels					
X12Cr13	1.4006	950 to 1 010	quenching in oil or air [b]	1 100 to 800	Air or gas

[a] In special cases furnace cooling is also permitted.

[b] QT 550 tempering carried out at 680 °C to 780 °C, QT 650 tempering carried out at 620 °C to 700 °C.

Table B.2 — Guideline data for austenitic 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
X2CrNi18-9	1.4307	1 000 to 1 100	Quenching in water or air or gas	1 150 to 750	Air or gas
X2CrNi19-11	1.4306	1 000 to 1 080	Quenching in water or air or gas	1 150 to 750	Air or gas
X2CrNiN18-10	1.4311	1 000 to 1 080	Quenching in water or air or gas	1 150 to 750	Air or gas
X5CrNi18-10	1.4301	1 000 to 1 080	Quenching in water or air or gas	1 150 to 750	Air or gas
X8CrNiS18-9	1.4305	1 000 to 1 100	Quenching in water or air or gas	1 150 to 750	Air or gas
X6CrNiTi18-10	1.4541	1 020 to 1 100	Quenching in water or air or gas	1 150 to 750	Air or gas
X6CrNiNb18-10	1.4550	1 020 to 1 100	Quenching in water or air or gas	1 150 to 750	Air or gas
X1CrNi25-21	1.4335	1 030 to 1 110	Quenching in water or air or gas	1 150 to 850	Air or gas
X2CrNiMo17-12-2	1.4404	1 020 to 1 100	Quenching in water or air or gas	1 150 to 850	Air or gas
X5CrNiMo17-12-2	1.4401	1 020 to 1 100	Quenching in water or air or gas	1 150 to 850	Air or gas
X1CrNiMoN25-22-2	1.4466	1 070 to 1 150	Quenching in water or air or gas	1 150 to 850	Air or gas
X6CrNiMoTi17-12-2	1.4571	1 020 to 1 100	Quenching in water or air or gas	1 150 to 850	Air or gas
X6CrNiMoNb17-12-22	1.4580	1 020 to 1 100	Quenching in water or air or gas	1 150 to 850	Air or gas
X2CrNiMoN17-13-3	1.4429	1 040 to 1 120	Quenching in water or air or gas	1 150 to 850	Air or gas
X3CrNiMo17-3-3	1.4436	1 020 to 1 100	Quenching in water or air or gas	1 150 to 850	Air or gas
X2CrNiMo18-14-3	1.4435	1 020 to 1 100	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
X2CrNiMoN17-13-5	1.4439	1 060 to 1 140	Quenching in water or air or gas	1 150 to 850	Air or gas
X1NiCrMoCu31-27-4	1.4563	1 070 to 1 150	Quenching in water or air or gas	1 150 to 850	Air or gas
X1NiCrMoCu25-20-5	1.4539	1 060 to 1 140	Quenching in water or air or gas	1 150 to 850	Air or gas

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
X1CrNiMoCuN20-18-7	1.4547	1 140 to 1 200	Quenching in water or air or gas	1 150 to 850	Air or gas
X1NiCrMoCuN25-20-7	1.4529	1 120 to 1 180	Quenching in water or air or gas	1 150 to 850	Air or gas
X2NiCrAlTi32-20	1.4558	950 to 1 050	Quenching in water or 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-ferritic corrosion resistant steels

Steel grade		Heat treatment during fabrication and further processing [a]		Hot working during further processing e.g. hot bending	
Steel name	Steel number	Solution annealing temperature °C	Type of cooling [b]	Temperature °C	Type of cooling
X2CrNiN23-4	1.4362	950 to 1 050	Quenching in water or air or gas	1 100 to 950	Air or gas
X3CrNiMoN27-5-2	1.4460	1 040 to 1 120	Quenching in water or air or gas	1 200 to 950	Air or gas
X2CrNiMoN29-7-2	1.4477	1 040 to 1 120	Quenching in water or air or gas	1 125 to 1 025	Air or gas
X2CrNiMoN22-5-3	1.4462	1 020 to 1 100	Quenching in water or air or gas	1 200 to 950	Air or gas
X2CrNiMoCuN26-6-3	1.4507	1 040 to 1 120	Quenching in water or air or gas	1 200 to 1 000	Air or gas
X2CrNiMoN25-7-4	1.4410	1 040 to 1 120	Quenching in water or air or gas	1 200 to 1 000	Air or gas
X2CrNiMoCuWN25-7-4	1.4501	1 040 to 1 120	Quenching in water or air or gas	1 200 to 1 000	Air or gas
X2CrNiMoSi18-5-3	1.4424	975 to 1 050	Quenching in water or air or gas	1 100 to 950	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 stipulated lower limit for solution annealing

[b] Cooling should be sufficiently rapid.

Table B.4 — Guideline data for ferritic and austenitic heat resisting steels

Steel grade		Heat treatment during fabrication and further processing [a]		Hot working during further processing e.g. hot bending	
Steel name	**Steel number**	**Annealing or solution annealing temperature °C**	**Type of cooling**	**Temperature °C**	**Type of cooling**
Ferritic steel					
X18CrN28	1.4749	800 to 860	Water or air or gas	1 100 to 800	Air or gas
Austenitic steels [a b]					
X8CrNiTi18-10	1.4878	1 020 to 1 120	Quenching in water or air or gas	1 100 to 850	Air or gas
X9CrNiSiNCe21-11-2	1.4835	1 020 to 1 120	Quenching in water or air or gas	1 100 to 850	Air or gas
X12CrNi23-13	1.4833	1 050 to 1 150	Quenching in water or air or gas	1 100 to 850	Air or gas
X8CrNi25-21	1.4845	1 050 to 1 150	Quenching in water or air or gas	1 100 to 850	Air or gas
X10NiCrAlTi32-21	1.4876	1 050 to 1 150	Quenching in water or air or gas	1 100 to 850	Air or gas
X6NiCrSiNCe35-25 [c]	1.4854	1 100 1 150	Quenching in water or air or gas	1 100 to 850	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 stipulated lower limit for solution annealing.

[b] Cooling should be sufficiently rapid.

[c] Patented steel grade.

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	$A = \frac{\pi(D^2 - d^2)}{4\times10^2}$	(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	$I = \frac{\pi(D^4 - d^4)}{64\times10^4}$	(cm^4)
Radius of gyration	$i = \sqrt{\frac{I}{A}}$	(cm)
Elastic section modulus	$W_{el} = \frac{2I\times10}{D}$	(cm^3)
Plastic section modulus	$W_{pl} = \frac{D^3 - d^3}{6\times10^3}$	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*

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