INTERNATIONAL STANDARD

ISO 9329-2

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Seamless steel tubes for pressure purposes — Technical delivery conditions —

Part 2:

Unalloyed and alloyed steels with specified elevated temperature properties

Tubes en acier sans soudure pour service sous pression — Conditions techniques de livraison —

Partie 2: Aciers non alliés et alliés avec caractéristiques spécifiées à température élevée

Reference number
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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

International Standard ISO 9329-2 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 19, *Technical delivery conditions for steel tubes for pressure purposes*.

It cancels and replaces ISO 2604-2:1975, of which it constitutes a technical revision, together with parts 1, 3 and 4 of ISO 9329.

ISO 9329 consists of the following parts, under the general title *Seamless steel tubes for pressure purposes — Technical delivery conditions*:

— *Part 1: Unalloyed steels with specified room temperature properties*

— *Part 2: Unalloyed and alloyed steels with specified elevated temperature properties*

— *Part 3: Unalloyed and alloyed steels with specified low temperature properties*

— *Part 4: Austenitic stainless steels (Partial revision of ISO 2604-2:1975)*

Annex A forms an integral part of this part of ISO 9329.

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Seamless steel tubes for pressure purposes — Technical delivery conditions —

Part 2:
Unalloyed and alloyed steels with specified elevated temperature properties

1 Scope

1.1 This part of ISO 9329 specifies the technical delivery conditions for seamless tubes of circular cross-section, made of unalloyed and alloyed steel with specified elevated temperature properties.

These tubes are intended for pressure purposes in cases when the material is also subjected to elevated temperatures, e.g. for the construction of steam generating equipment and for interconnecting pipework.

The requirements of appropriate international application standards and relevant national legal regulations shall be taken into account by the user. For boilers and pressure vessels, ISO/R 831 and ISO 5730 are available.

The following parts of ISO 9329 are now available or are being prepared:

— *Part 1: Unalloyed steels with specified room temperature properties* (partial revison of ISO 2604-2:1975).

— *Part 3: Unalloyed and alloyed steels with specified low temperature properties* (partial revision of ISO 2604-2:1975).

— *Part 4: Austenitic stainless steels* (partial revision of ISO 2604-2:1975).

NOTES

1 The English words "tube" and "pipe" are synonymous.

2 This part of ISO 9329 can also be used as a basis for the manufacture of tubes of non-circular section. In this case, the values quoted in this part of ISO 9329 for chemical analysis and mechanical properties are applicable, all other requirements are by agreement between the purchaser and the manufacturer.

1.2 For the general technical delivery requirements, see ISO 404.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9329. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9329 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 148:1983, *Steel — Charpy impact test (V-notch).*

ISO 377-1:1989, *Selection and preparation of samples and test pieces of wrought steels — Part 1: Samples and test pieces for mechanical test.*

ISO 377-2:1989, *Selection and preparation of samples and test pieces of wrought steels — Part 2: Samples for the determination of the chemical composition.*

ISO 404:1992, *Steel and steel products — General technical delivery requirements.*

ISO 783:1989, *Metallic materials — Tensile testing at elevated temperature.*

ISO/R 831:1968, *Rules for construction of stationary boilers.*

ISO 1129:1980, *Steel tubes for boilers, superheaters and heat exchangers — Dimensions, tolerances and conventional masses per unit length.*

ISO 2566-1:1984, *Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels.*

ISO 3205:1976, *Preferred test temperatures.*

ISO 4200:1991, *Plain end steel tubes, welded and seamless — General tables of dimensions and masses per unit length.*

ISO 4948-1:1982, *Steels — Classification — Part 1: Classification of steels into unalloyed and alloy steels based on chemical composition.*

ISO/TR 4949:1989, *Steel names based on letter symbols.*

ISO 5252:1991, *Steel tubes — Tolerance systems.*

ISO 5730:1992, *Stationary shell boilers of welded construction (other than water-tube boilers).*

ISO 6761:1981, *Steel tubes — Preparation of ends of tubes and fittings for welding.*

ISO 6892:1984, *Metallic materials — Tensile testing.*

ISO 7438:1985, *Metallic materials — Bend test.*

ISO 8492:1986, *Metallic materials — Tube — Flattening test.*

ISO 8493:1986, *Metallic materials — Tube — Drift expanding test.*

ISO 8495:1986, *Metallic materials — Tube — Ring expanding test.*

ISO 8496:1986, *Metallic materials — Tube — Ring tensile test.*

ISO 9302:1994, *Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes — Electromagnetic testing for verification of hydraulic leak-tightness.*

ISO 9303:1989, *Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes — Full peripheral ultrasonic testing for the detection of longitudinal imperfections.*

ISO 9305:1989, *Seamless steel tubes for pressure purposes — Full peripheral ultrasonic testing for the detection of transverse imperfections.*

ISO/TR 9769:1991, *Steel and iron — Review of available methods of analysis.*

ISO 10332:1994, *Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes — Ultrasonic testing for the verification of hydraulic leak-tightness.*

ISO 10474:1991, *Steel and steel products — Inspection documents.*

3 Symbols and denominations

3.1 Fundamental symbols

D = specified outside diameter

D_i = specified inside diameter

T = specified wall thickness

3.2 Symbols for tolerances

See ISO 5252.

3.3 Symbols for tests

3.3.1 Tensile test

See ISO 6892.

3.3.2 Flattening test

H = distance between platens

K = constant factor of deformation

3.3.3 Hydraulic test

PE = test pressure

S = stress which occurs in the metal during the test

4 Information to be supplied by the purchaser

4.1 Mandatory information

The purchaser shall state on his enquiry and order the following information:

— the denomination "tube";

— the manufacturing process whether tubes are to be supplied hot-finished or cold-finished (see 5.3);

— reference to the relevant dimensional standard;

— dimensions (outside diameter × wall thickness or, by agreement at the time of ordering, inside diameter × wall thickness) in millimetres (see 7.1);

— length (see 7.2);

— tolerances, if exact lengths greater than 12 m are ordered (see 7.3.2);

— reference to this part of ISO 9329;

— steel grade (see table 1);

— test category for unalloyed steels (see 9.2).

4.2 Optional information

Enquiries and orders for tubes in accordance with this part of ISO 9329 shall be supplemented, if it is deemed necessary by the purchaser, with the indication of one or more of the following optional requirements, which shall be the subject of special agreements:

— steelmaking process (see 5.1);

— delivery condition (see 5.4);

— special straightness requirements (see 7.3.3);

— bevelled ends (see 8.2);

— product chemical analysis (see 9.3 and 9.10.1);

— determination of proof stress at elevated temperature, $R_{p0,2}$ (see 9.4.2);

— leak-tightness test (see 9.5);

— impact test (see 9.10.7);

— specific marking (see 10.3);

— protective coating (see clause 11);

— type of inspection and testing and corresponding document (see 9.1 and clause 12).

4.3 Example of an order

Example of an order for a hot-finished seamless tube conforming to the dimensional standard ISO 4200, with an outside diameter of 168,3 mm, a wall thickness of 4 mm and a standard length (random length) of 4 m to 8 m, made of steel grade PH 23 with specified elevated temperature properties to be submitted to specific inspection and testing to test category I involving the issuing of an inspection certificate 3.1.B according to ISO 10474.

Tube hot-finished ISO 4220 - 168,3 × 4 - 4 to 8 - ISO 9329-2 - PH 23 - I - 3.1.B.

5 Manufacturing process

5.1 Steelmaking process

If requested, the purchaser shall be informed of the steelmaking process used.

Steels may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transitional material is required. The producer shall remove the transitional material by an established procedure that efficiently separates the grades.

5.2 Deoxidation process

Steels intended for the production of tubes covered by this part of ISO 9329 shall be fully killed.

5.3 Product-making process for tubes

Tubes covered by this part of ISO 9329 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 5.4.

5.4 Delivery condition

Tubes covered by this part of ISO 9329 shall be supplied suitably heat treated over their full length. The following heat treatments shall be used, depending on the type of steel (see table 7):

— normalizing;

— normalizing and tempering, or isothermal annealing;

— full annealing or isothermal annealing.

Heat treatment is not required for steels PH 23, PH 26, PH 29 and PH 35 if the manufacturing process produces a technically equivalent metallurgical condition[1)].

Where the manufacturing process produces a technically equivalent metallurgical conditon, tempering only, instead of normalizing and tempering, is adequate for steels 13 CrMo 4-5 and 11 CrMo 9-10 TN+TT. Other steels shall be supplied in the heat-treated conditions given in table 7.

6 Metallurgical properties

6.1 Chemical composition

6.1.1 Heat analysis

On heat analysis, the steel shall show the composition given in table 1 appropriate to the steel grade specified.

6.1.2 Product analysis

If a check analysis on the product is required (see 9.3), the permissible deviations given in table 2 shall apply to the heat analysis specified in table 1.

Other than when maxima only are specified, the deviations apply either above or below the specified limits of the range, but not both above and below, for the same element from different sample products from the same heat.

When maxima only are specified, the deviations are always positive.

6.2 Mechanical properties

6.2.1 At room temperature

The mechanical and technological properties of the tubes covered by this part of ISO 9329, measured at room temperature (23 °C ± 5 °C, see ISO 3205), to be obtained on test pieces selected, prepared and tested in accordance with clause 9, shall comply with the requirements of table 3.

6.2.2 At elevated temperature

6.2.2.1 Proof stress

The minimum proof stress ($R_{p0,2}$) values at elevated temperatures are indicated in table 4.

6.2.2.2 Stress rupture properties

The long-term stress rupture property (σ_R) values at elevated temperatures are indicated in annex A. It is stressed that they are given for information only.

6.3 Weldability

Steels intended for the production of tubes covered by this part of ISO 9329 are regarded as being weldable. However, 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 essentially on the conditions of preparing and carrying out the welding.

NOTE 3 Certain of the ferritic steels covered by this part of ISO 9329 will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures, particularly the 4 % (*m/m*) to 6 % (*m/m*) chromium steels. Therefore, operations that involve heating such steels above their critical temperatures, such as welding, flanging and hot bending, should be followed by suitable heat treatment.

1) The methods of control used to ensure the equivalence of structure shall be the subject of a previous agreement between the purchaser and manufacturer.

Table 1 — Chemical composition (heat analysis) % (*m/m*)

Steel grade[1]		C	Si	Mn	P max.	S max.	Cr	Mo	Ni	V	Nb	Al max.	Others
Unalloyed steels	PH 23	⩽ 0,17	0,10 to 0,35	0,30 to 0,80	0,035	0,035	—	—	—	—	—	—	2)
	PH 26	⩽ 0,21	0,10 to 0,35	0,40 to 1,20	0,035	0,035	—	—	—	—	—	—	2)
	PH 29	⩽ 0,22	0,10 to 0,40	0,65 to 1,40	0,035	0,035	—	—	—	—	—	—	2)
	PH 35	⩽ 0,22 3)	0,15 to 0,55	1,00 to 1,50 3)	0,035	0,035	—	—	—	4)	4)	—	2) 4)
Alloyed steels	8 CrMo 4-5	⩽ 0,15	⩽ 0,50	0,30 to 0,60	0,035	0,035	0,80 to 1,25	0,45 to 0,65	—	—	—	0,020	2)
	8 CrMo 5-5	⩽ 0,15	0,50 to 1,00	0,30 to 0,60	0,030	0,030	1,00 to 1,50	0,45 to 0,65	—	—	—	0,020	2)
	X11 CrMo 5 TA	0,08 to 0,15	0,15 to 0,50	0,30 to 0,60	0,030	0,030	4,00 to 6,00	0,45 to 0,65	—	—	—	0,020	2)
	X11 CrMo 5 TN+TT	0,08 to 0,15	0,15 to 0,50	0,30 to 0,60	0,030	0,030	4,00 to 6,00	0,45 to 0,65	—	—	—	0,020	2)
	13 CrMo 4-5	0,10 to 0,17 5)	0,15 to 0,35	0,40 to 0,70	0,035	0,035	0,70 to 1,10	0,45 to 0,65	—	—	—	0,020	2)
	16 Mo 3	0,12 to 0,20 5)	0,15 to 0,35	0,40 to 0,80	0,035	0,035	—	0,25 to 0,35	—	—	—	0,020	2)
	11 CrMo 9-10 TA	0,08 to 0,15	0,15 to 0,40	0,30 to 0,70	0,035	0,035	2,00 to 2,50	0,90 to 1,20	—	—	—	0,020	2)
	11 CrMo 9-10 TN+TT	0,08 to 0,15	0,15 to 0,40	0,30 to 0,70	0,035	0,035	2,00 to 2,50	0,90 to 1,20	—	—	—	0,020	2)
	12 MoCr 6-2	0,10 to 0,15	0,15 to 0,35	0,40 to 0,70	0,035	0,035	0,30 to 0,60	0,50 to 0,70	—	0,22 to 0,28	—	0,020	2)
	X11 CrMo 9-1 TA	0,08 to 0,15	0,25 to 1,00	0,30 to 0,60	0,030	0,030	8,00 to 10,00	0,90 to 1,10	—	—	—	0,020	2)
	X11 CrMo 9-1 TN+TT	0,08 to 0,15	0,25 to 1,00	0,30 to 0,60	0,030	0,030	8,00 to 10,00	0,90 to 1,10	—	—	—	0,020	2)
	X10 CrMoVNb 9-1	0,08 to 0,12	0,20 to 0,50	0,30 to 0,60	0,020	0,020	8,00 to 9,50	0,85 to 1,05	⩽ 0,40	0,18 to 0,25	0,06 to 0,10	0,020	2) 6)
	9 NiMnMoNb 5-4-4	⩽ 0,17	0,25 to 0,50	0,80 to 1,20	0,030	0,030	⩽ 0,30	0,25 to 0,40	1,00 to 1,30	—	0,015 to 0,045	0,020	Cu 0,05 to 0,80
	X20 CrMoNiV 11-1-1	0,17 to 0,23	0,15 to 0,50	⩽ 1,00	0,030	0,030	10,00 to 12,50	0,80 to 1,20	0,30 to 0,80	0,25 to 0,35	—	0,020	2)

NOTE — Elements not included in this table may not be intentionally added without the agreement of the purchaser, except for elements which may be added for deoxidation and finishing of the heat. All reasonable precautions shall be taken to prevent the addition of elements from scrap or other materials used in the manufacture; however residual elements may be tolerated, provided that the mechanical properties and applicability are not adversely affected.

If the amount of residual elements is likely to affect the weldability of the steel, the content of such elements (heat analysis) shall be stated in the documents mentioned in clause 12.

1) Designation according to ISO/TR 4949.

2) A maximum copper content of 0,25 % (*m/m*) may be requested by the purchaser in order to facilitate subsequent operations of forming.

3) For tubes with wall thickness greater than 30 mm, the upper limit of the carbon content may be increased by 0,02 % (*m/m*) but $\left(C + \frac{Mn}{6}\right)$ shall never exceed 0,47 % (*m/m*).

4) Additions of niobium, titanium and vanadium are permitted at the discretion of the manufacturer, unless otherwise agreed between the purchaser and the manufacturer, up to the levels permitted for non-alloyed steels in ISO 4948-1. In this case, the test certificate shall state the level of these elements.

5) For tubes with wall thickness greater than 30 mm, the upper limit of the carbon content may be increased by 0,02 % (*m/m*).

6) N: 0,030 % (*m/m*) to 0,070 % (*m/m*).

Table 2 — Permissible deviations from the specified chemical composition limits given in table 1

Element	Content specified for the test analysis % (*m/m*)	Permissible deviation % (*m/m*)
C	⩽ 0,23	± 0,03
Si	⩽ 1,00	± 0,05
Mn	⩽ 1,50	± 0,10
P	⩽ 0,035	+ 0,005
S	⩽ 0,035	+ 0,005
Cr	⩽ 10,0 > 10 ⩽ 12,5	± 0,10 ± 0,15
Mo	⩽ 0,35 > 0,35 ⩽ 1,20	± 0,04 ± 0,05
Ni	⩽ 1,30	± 0,07
V	⩽ 0,35	± 0,03
Nb	⩽ 0,10	± 0,01
Al	⩽ 0,020	+ 0,005
Cu	⩽ 0,80	+ 0,07 − 0,05

Table 3 — Mechanical properties at room temperature

Steel grade		Reference heat treatment [1]	Tensile test						Flattening test	Bend test	Drift expanding test			Ring expanding test					Impact test	
			Tensile strength	Upper yield stress or proof stress			Elongation [3]		Constant	Diameter of mandrel	Percentage increase of D for D_i/D			Percentage increase of D for D_i/D					Transverse [4]	Longitudinal [5]
				R_{eH} or $R_{p0,2}$ or $R_{t0,5}$ for wall thicknesses in mm [2]			A min [3]												
				$T \leqslant 16$	$16 < T \leqslant 40$	$40 < T \leqslant 60$	l	t			$\leqslant 0,6$	$> 0,6$ $\leqslant 0,8$	$> 0,8$	$\leqslant 0,5$	$> 0,5$ $\leqslant 0,6$	$> 0,6$ $\leqslant 0,8$	$> 0,8$ $\leqslant 0,9$	$> 0,9$		
			R_m						K											
			N/mm²	N/mm²	N/mm²	N/mm²	%			mm									J	J
Unalloyed steels	PH 23	N	360 to 480	235	225	215	25	23	0,09	3T	12	15	19	30	25	15	10	8	27	35
	PH 26	N	410 to 530	265	255	245	21	19	0,07	4T	10	12	17	30	25	15	10	8	27	35
	PH 29	N	460 to 580	290	280	270	23	21	0,07	4T	8	10	15	30	25	15	10	8	27	35
	PH 35	N	510 to 640	355	335	315	19	17	0,07	4T	8	10	15	30	25	15	10	8	27	35
Alloyed steels	8 CrMo 4-5	N + T	410 to 560	205	205	205	22	20	0,08	4T	8	10	15	—	—	—	—	—	27	35
	8 CrMo 5-5	N + T	410 to 560	205	205	205	22	20	0,08	4T	8	10	15	—	—	—	—	—	27	35
	X 11 CrMo 5 TA	A	430 to 580	175	175	175	22	18	0,07	4T	8	10	15	30	20	10	8	6	27	35
	X 11 CrMo 5 TN+TT	N + T	480 to 640	280	280	280	20	18	0,07	4T	8	10	15	30	10	10	8	6	27	35
	13 CrMo 4-5	N + T	440 to 590	290[6]	290	280	22	20	0,07	4T	8	10	15	30	20	10	8	6	27	35
	16 Mo 3	N	450 to 600	270[6]	270	260	22	20	0,07	4T	8	10	15	30	20	10	8	6	27[7]	35[7]
	11 CrMo 9-10 TA	A	410 to 560	205	205	205	22	20	0,08	4T	8	10	15	—	—	—	—	—	27	35
	11 CrMo 9-10 TN+TT	N + T	480 to 630	280	280	280	20	18	0,07	4T	8	10	15	30	20	10	8	6	27	35
	12 MoCrV 6-2	N + T	460 to 610	320	320	310	20	18	0,05	4T	8	10	15	30	20	10	8	6	27[8]	35[8]
	X 11 CrMo 9-1 TA	A	440 to 620	205	205	205	20	18	0,07	4T	8	10	15	30	20	10	8	6	27	35
	X 11 CrMo 9-1 TN+TT	N + T	590 to 740	390	390	390	18	16	0,07	4T	8	10	15	30	20	10	8	6	27	35
	X 10 CrMoVNb 9-1	N + T	590 to 770	415	415	415	20	16	0,07	4T	8	10	15	30	20	10	8	6	27	35
	9 NiMnMoNb 5-4-4	N + T	610 to 780	440	440	440	19	17	0,05	4T	8	10	15	30	20	10	8	6	27	35
	X 20 CrMoNiV 11-1-1	N + T	690 to 840	490	490	490	17	14	0,05	4T	6	8	12	30	20	10	8	6	27[8]	35[8]

1) See 8.3 (N = Normalizing; N + T = Normalizing + Tempering; A = Full Annealing).
2) For wall thicknesses greater than 60 mm, the values to be obtained shall be the subject of agreement between the purchaser and the manufacturer at the time of ordering.
3) l = longitudinal; t = transverse.
4) Applicable for wall thicknesses > 30 mm, unless otherwise indicated.
5) Applicable only in cases where transverse test pieces cannot be taken (see 9.4.1.5.5).
6) For wall thicknesses ⩽ 10 mm, the minimum value of yield strength is increased by 10 N/mm².
7) Applicable for wall thicknesses > 20 mm.
8) Applicable for wall thicknesses > 10 mm.