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.

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_m	R_{eH} or $R_{p0,2}$ or $R_{t0,5}$ for wall thicknesses in mm [2]			A min [3]		K											
				$T \leqslant 16$	$16 < T \leqslant 40$	$40 < T \leqslant 60$	l	t			$\leqslant 0,6$	$> 0,6$ $\leqslant 0,8$	$> 0,8$	$\leqslant 0,5$	$> 0,5$ $\leqslant 0,6$	$> 0,6$ $\leqslant 0,8$	$> 0,8$ $\leqslant 0,9$	$> 0,9$		
			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.

Table 4 — Minimum 0,2 % proof stress ($R_{p0,2}$) values at elevated temperature

Steel grade		Reference heat treatment[1]	Wall thickness mm	Minimum proof stress $R_{p0,2}$, N/mm²[2] Temperature, °C									
				150	200	250	300	350	400	450	500	550	600
Unalloyed steels	PH 23	N	⩽ 16	185	165	145	127	116	110	106	—	—	—
			> 16 ⩽ 40	183	164	145	127	116	110	106	—	—	—
			> 40 ⩽ 60	172	159	145	127	116	110	106	—	—	—
	PH 26	N	⩽ 16	216	194	171	152	141	134	130	—	—	—
			> 16 ⩽ 40	213	192	171	152	141	134	130	—	—	—
			> 40 ⩽ 60	204	188	171	152	141	134	130	—	—	—
	PH 29	N	⩽ 16	247	223	198	177	167	158	153	—	—	—
			> 16 ⩽ 40	242	220	198	177	167	158	153	—	—	—
			> 40 ⩽ 60	236	217	198	177	167	158	153	—	—	—
	PH 35	N	⩽ 60	270	255	235	215	200	180	170	—	—	—
Alloyed steels	8 CrMo 4-5	N + T	⩽ 60	186	181	179	174	167	157	151	143	—	—
	8 CrMo 5-5	N + T	⩽ 60	186	181	179	174	167	157	151	143	—	—
	X 11 CrMo 5 TA	A	⩽ 60	—	118	116	115	114	113	111	—	—	—
	X 11 CrMo 5 TN+TT	N + T	⩽ 60	237	230	223	216	206	196	181	167	—	—
	13 CrMo 4-5	N + T	⩽ 60	230	220	210	183	169	164	161	156	150	145
	16 Mo 3	N	⩽ 60	237	224	205	173	159	155	150	145	—	—
	11 CrMo 9-10 TA	A	⩽ 60	187	186	186	186	186	186	181	173	—	—
	11 CrMo 9-10 TN+TT	N + T	⩽ 60	241	233	224	219	212	207	194	180	160	137
	12 MoCrV 6-2	N + T	⩽ 60	—	235	218	196	184	177	167	155	—	—
	X 11 CrMo 9-1 TA	A	⩽ 60	—	118	112	106	102	99	96	94	—	—
	X 11 CrMo 9-1 TN+TT	N + T	⩽ 60	—	334	330	325	322	316	310	290	235	—
	X 10 CrMoVNb 9-1	N + T	⩽ 60	—	380	370	360	350	340	325	300	260	200
	9 NiMnMoNb 5-4-4	N + T	⩽ 60	412	402	392	382	373	343	304	—	—	—
	X 20 CrMoNiV 11-1-1	N + T	⩽ 60	—	349	328	317	310	305	292	272	—	—

1) N = Normalizing; N + T = Normalizing + Tempering; A = Full Annealing

2) The minimum values of $R_{p0,2}$ for tubes with wall thickness above 60 mm are subject to agreement between the purchaser and the manufacturer.

7 Dimensions, masses and tolerances

7.1 Outside diameters, wall thicknesses and masses

The outside diameters, wall thicknesses and masses of the tubes covered by this part of ISO 9329 should be selected from those in ISO 4200 and ISO 1129.

By agreement between the purchaser and the manufacturer, tubes specified by inside diameter and wall thickness can be supplied. In this case, the dimensions and the tolerances required have to be agreed upon at the time of enquiry and order.

7.2 Lengths

7.2.1 It shall be stated in the enquiry and order whether the tubes are to be delivered with random lengths (see 7.2.2) or with exact lengths (see 7.2.3).

7.2.2 If the tubes are to be delivered with random lengths, their lengths shall be within the length range in which they usually fall in normal production. The relevant length ranges are dependent on the diameter and wall thickness of the tube, as well as on the production facilities of the manufacturer. They shall be agreed upon at the time of ordering.

7.2.3 If the tubes are to be delivered with exact lengths, the length tolerances given in 7.3.2 shall apply.

7.3 Tolerances

7.3.1 Tolerances on outside diameter and on wall thickness

The outside diameters and the wall thicknesses of the tubes covered by this part of ISO 9329 shall be within the tolerance limits given in tables 5 and 6 (see 9.6).

Within areas where the tube surface has been dressed by mechanical machining (such as grinding), it is permissible to exceed the minus deviation on the outside diameter over a length of not more than 1 m, provided that the wall thickness remains within the lower tolerance limits.

The tolerances on ovality and eccentricity are included in the tolerances on outside diameter and wall thickness.

7.3.2 Tolerances on exact lengths

For lengths up to and including 6 m: $^{+10}_{0}$ mm

For lengths above 6 m up to and including 12 m: $^{+15}_{0}$ mm

For lengths greater than 12 m, the applicable tolerances shall be agreed between the purchaser and the manufacturer.

7.3.3 Straightness

All tubes shall be reasonably straight. For tubes over 50 mm in diameter, the deviation from straightness shall not exceed 0,002 L (L = length).

Deviation from straightness over any length of 1 m shall not exceed 3 mm.

Special requirements regarding straightness shall be the subject of an agreement.

Table 5 — Tolerances on outside diameter and on wall thickness of hot-finished tubes

Outside diameter mm	Tolerances on D	Tolerances (see ISO 5252) on T for a T/D ratio			
		⩽ 0,025	> 0,025 ⩽ 0,05	> 0,05 ⩽ 0,10	> 0,10
$D \leqslant 101,6$	± 1 % [1] with a min. ± 0,5 mm	± 12,5 % with a min. ± 0,4 mm			
$D > 101,6$		± 20 %	± 15 %	± 12,5 %	± 10 %
1) ± 1,5 % for hot-expanded tubes.					

Table 6 — Tolerances on outside diameter and on wall thickness of cold-finished tubes

Tolerances (see ISO 5252) on	
D	*T*
± 0,75 % with a min. of ± 0,30 mm	± 10 % with a min. of ± 0,2 mm

8 Technical delivery conditions

8.1 Appearance and soundness

8.1.1 The tubes shall be free from such defects as can be established by visual inspection and testing in accordance with this part of ISO 9329.

8.1.2 The tubes shall have a finish and internal and external surface condition typical of the manufacturing process and the heat-treated condition. The finish and surface condition shall permit surface imperfections or marks requiring dressing to be identified.

8.1.3 It shall be permissible to dress by grinding or machining surface marks and imperfections, provided that the thickness of the tube after dressing does not fall below the minimum permitted wall thickness.

8.1.4 Surface imperfections which encroach on the minimum wall thickness shall be considered defects and shall be deemed not to comply with this part of ISO 9329.

8.1.5 All dressed areas shall blend smoothly into the contour of the tube.

8.1.6 The manufacturer shall explore by grinding a sufficient number of surface marks and imperfections identified during visual inspection, to provide assurance that these have been evaluated to ensure compliance with 8.1.7.

8.1.7 Subject to the limitations given in 8.1.8, the manufacturer shall dress surface marks, and imperfections found by exploration in accordance with 8.1.6, to be deeper than 5 % of the nominal thickness or 3 mm, whichever is the lesser but not less than 0,5 mm.

8.1.8 If surface imperfections that are acceptable according to 8.1.7 are not scattered and appear over a large area in excess of what is considered to be an acceptable surface condition, tubes shall be rejected (or alternatively subjected to dressing) as agreed between the purchaser and the manufacturer.

8.1.9 Repairs to tubes shall only be carried out by grinding or machining; peening or welding are not permitted.

8.2 Preparation of ends

Tubes are normally delivered with square-cut ends; by agreement between the purchaser and manufacturer at the time of ordering they can also be delivered with bevelled ends (see ISO 6761). The ends shall be free from excessive burrs.

8.3 Delivery conditions

The tubes are delivered in the heat-treated condition indicated in table 7.

Table 7 — Heat-trated conditions

Steel grade		Reference heat treatment[1]	Austenitizing temperature °C	Cooling medium for austenitizing	Tempering temperature °C	Cooling medium for tempering
Unalloyed steels	PH 23	N[2]	880 to 940	Air	—	—
	PH 26	N[2]	880 to 940	Air	—	—
	PH 29	N[2]	880 to 940	Air	—	—
	PH 35	N[2]	880 to 940	Air	—	—
Alloyed steels	8 CrMo 4-5	N + T A[3]	900 to 960 900 to 960	Air Furnace	650 to 730 —	Air —
	8 CrMo 5-5	N + T A[3]	900 to 910 900 to 960	Air Furnace	650 to 750 —	Air —
	X 11 CrMo 5 TA	A[3]	890 to 950	Furnace	—	—
	X 11 CrMo 5 TN+TT	N + T	910 to 960	Air	710 to 760	Air
	13 CrMo 4-5	N + T	900 to 960	Air	660 to 730	Air
	16 Mo 3	N	890 to 950	Air	—	—
	11 CrMo 9-10 TA	A[3]	900 to 960	Furnace	—	—
	11 CrMo 9-10 TN+TT	N + T	900 to 960	Air	680 to 750	Air
	12 MoCrV 6-2	N + T	930 to 990	Air	680 to 740	Air
	X 11 CrMo 9-1 TA	A[3]	890 to 950	Furnace	—	—
	X 11 CrMo 9-1 TN + TT	N + T	890 to 950	Air	720 to 800	Air
	X 10 CrMoVNb 9-1	N + T	1 040 to 1 090	Air	730 to 800	Air
	9 NiMnMoNb 5-4-4	N + T	880 to 980	Air	580 to 680	Air
	X 20 CrMoNiV 11-1-1	N + T	1 020 to 1 080	Air	730 to 780	Air

1) N = Normalizing; N + T = Normalizing+Tempering; A = Full Annealing.

2) The hot-finished tubes may be delivered in the non-treated condition at the discretion of the manufacturer, provided that the hot-finishing produces a technically equivalent metallurgical condition. The methods of control to ensure equivalence of structure shall be the subject of a previous agreement between the purchaser and the manufacturer.

3) This heat treatment may be replaced by isothermal annealing at the discretion of the manufacturer.

9 Inspection and testing

9.1 Type of inspection and testing and inspection documents

9.1.1 Tubes manufactured according to this part of ISO 9329 shall be subjected to specific inspections and tests in accordance with ISO 404.

9.1.2 Tubes delivered in accordance with this part of ISO 9329 are provided with an inspection certificate of type 3.1.B according to ISO 10474.

If requested at the time of enquiry and order, the tubes shall be supplied with an inspection certificate of type 3.1.A or 3.1.C or 3.2 according to ISO 10474.

9.1.3 The specific inspections and tests described in 9.3 to 9.8 shall be carried out and the compliance of their results with the requirements shall be stated in the inspection certificate (3.1.A, 3.1.B, 3.1.C or 3.2 according to ISO 10474).

In addition, the document shall include

a) the results of all inspections and tests pertaining to supplementary requirements (see 4.2);

b) the symbols, code letters or code numbers relating the order and the test pieces to the corresponding batches and tested tubes;

c) the actual heat treatment carried out (see 5.4);

d) the results of heat analysis (see 6.1.1).

9.2 Test categories

Unalloyed steel tubes shall be subjected to the inspection and tests indicated in table 8 for the category agreed upon at the time of ordering.

Alloyed steel tubes shall be sujected to the tests indicated in table 8 for category II.

9.3 Testing of chemical composition

9.3.1 A check analysis of chemical composition of the tubes may be agreed upon at the time of ordering (see 9.10.1).

9.3.2 The number of samples to be taken shall be agreed upon by the parties involved at the time of ordering.

9.3.3 The samples shall be taken in accordance with ISO 377-2. The samples may be taken either

a) from the test pieces used for the verification of the mechanical properties,

or

b) from drillings taken through the whole thickness of the tube or from a solid section, at the same location as for the mechanical test pieces.

9.4 Testing of mechanical and technological characteristics

9.4.1 At room temperature

9.4.1.1 Batch

The delivery shall be divided into batches. For tubes which are not heat treated, a batch shall consist only of tubes of the same steel grade, from the same heat and manufacturing process, and having the same nominal outside diameter and wall thickness.

For tubes which are heat treated, a batch shall consist only of tubes of the same steel grade, from the same heat and manufacturing process, and having the same nominal outside diameter and wall thickness, subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch-type furnace.

Each batch shall comprise 100 tubes. The remaining tubes shall be subdivided between the batches if there are 50 or less than 50 tubes; they shall be regarded as a batch if there are more than 50.

If the total number of tubes is less than 100, they constitute one batch.

Table 8 — Test categories

Tests		Test category	
		I	II
Mandatory tests	Heat analysis [see 9.1.3 d)]	X	X
	Visual examination (see 9.7)	X	X
	Dimensional testing (see 9.6)	X	X
	Leak-tightness, hydraulic or non-destructive (see 9.10.5)	X	X
	Tensile test at room temperature (see 9.10.2.1)	X	X
	Flattening or bend or ring tensile test (see 9.10.3)	X	X
	Drift or ring expanding test (see 9.10.4)	X	X
	Non-destructive testing for longitudinal defects (see 9.10.6.1)	—	X
	Material identification of alloyed steels (see 9.9)	—	X
Optional tests[1)]	Check analysis of chemical composition (see 9.10.1)	X	X
	Tensile test at elevated temperature (see 9.10.2.2)	X	X
	Impact test at room temperature (see 9.10.7)	X	X
	Non-destructive testing for transverse defects (see 9.10.6.2)	—	X

1) By agreement at the time of enquiry and order.

9.4.1.2 Number of products sampled per test unit

Each test unit consists of

— one tube per batch for test category I;

— two tubes per batch for test category II.

9.4.1.3 Number of tests

For each test unit, the following tests shall be carried out:

— one tensile test on each tube (see 9.10.2.1);

— one flattening test or bend test or ring tensile test on each tube (see 9.10.3);

— one drift or ring expanding test on each tube where appropriate (see 9.10.4).

9.4.1.4 Selection of samples and test pieces

Samples and test pieces shall be taken at the tube ends and in accordance with the requirements of ISO 377-1.

9.4.1.5 Location and orientation of the test pieces

9.4.1.5.1 The test piece for the tensile test is either a full tube section or a test piece taken in a direction either longitudinal or transverse to the axis of the tube in accordance with the requirements of ISO 6892.

At the manufacturer's option

— for tubes with an outside diameter equal to or less than 219,1 mm, the test is carried out either on a tube section or on a test piece taken in a direction longitudinal to the axis of the tube;

— for tubes with an outside diameter greater than 219,1 mm, the test is taken in a direction either longitudinal or transverse to the axis of the tube.

9.4.1.5.2 The test piece for the bend test consists of a section cut in the tube in accordance with the requirements of ISO 7438. For tubes with a wall thickness greater than 20 mm, the test piece may consist of a segment in a transverse direction, with rectangular section having a width of 38 mm and a thickness of 19 mm.

9.4.1.5.3 The test piece for the flattening test consists of a tube section, in conformity with ISO 8492.

9.4.1.5.4 The test piece for the drift or ring expanding test or ring tensile test consists of a tube section, in conformity with ISO 8493 or ISO 8495 or ISO 8496, respectively.

9.4.1.5.5 Impact testing (see ISO 148) may be agreed upon the time of ordering. For the impact test, a set of three ISO V-notch test pieces shall be taken from each sample tube transverse to the tube axis, provided that the dimension of the tube permits this without flattening of the test piece; otherwise the test pieces shall be taken longitudinal to the tube axis.

The test pieces shall be taken and prepared in such a way that the axis of the notch is perpendicular to the surface of the tube.

9.4.2 At elevated temperature

Determination of the proof stress ($R_{p0,2}$) may be agreed upon at the time of ordering. The temperature and number of test pieces (see 9.10.2.2) shall also be established at this time.

9.5 Leak-thightness test

9.5.1 All the tubes shall be submitted to a leak-thigtness test.

9.5.2 Unless otherwise specified by the purchaser, the hydraulic leak-tightness test may be replaced, at the discretion of the manufacturer, by a non-destructive test (see 9.10.5.2).

9.6 Dimensional testing

The tubes shall be checked with respect to dimensions by suitable methods.

The tolerance on diameter is normally measured across the diameter; however, for tubes where $D > 457$ mm, this tolerance may be measured by a circumference tape. In the case of dispute, the tolerance shall be that measured across the diameter.

Unless otherwise specified at the time of enquiry and order, the wall thickness shall be measured at the tube ends.

The ovality shall be measured across the diameter at the pipe ends, for a distance of 100 mm.

9.7 Visual examination

The tubes shall be submitted to a visual examination to confirm, in particular, their conformity with the requirements of 8.1 and 8.2.

9.8 Non-destructive testing

The tubes of test category II shall all be submitted to a non-destructive inspection for longitudinal defects (see 9.10.6.1).

If agreed at the time of enquiry and order, tubes of test category II may also be submitted to non-destructive testing for transverse defects (see 9.10.6.2).

9.9 Material identification of alloyed steels

Each alloyed steel tube shall be tested by an appropriate method to ensure that the correct grade has been supplied.

9.10 Test methods and results

9.10.1 Chemical analysis

9.10.1.1 If agreed at the time of ordering, a check analysis shall be carried out (see 9.3.1 and 9.3.2).

9.10.1.2 The elements shall be determined in conformity with the methods considered in the corresponding International Standards. Spectrographic analysis is permitted.

9.10.1.3 The results shall comply with the values in table 1, taking into account the permissible deviations given in table 2.

In the case of dispute about analytical methods, the chemical composition shall be determined in accordance with a reference method in one of the International Standards listed in ISO/TR 9769.

9.10.2 Tensile test

9.10.2.1 At room temperature

9.10.2.1.1 The tensile test shall be carried out at room temperature in conformity with ISO 6892 (see 9.4.1.3 and 9.4.1.5.1).

9.10.2.1.2 The tensile strength (R_m), the proof stress ($R_{p0,2}$), or the upper yield stress (R_{eH}) and the percentage elongation after fracture (A) shall be determined during the tensile test. For unalloyed steel tubes, the proof stress, total elongation ($R_{t0,5}$) can be determined instead of the proof stress ($R_{p0,2}$).

The percentage elongation after fracture shall be reported with reference to a gauge length of $5{,}65\sqrt{S_o}$, where S_o is the original cross-sectional area of the test piece. If other gauge lengths are used, the corresponding elongation referred to a gauge length of $5{,}65\sqrt{S_o}$ shall be obtained in accordance with ISO 2566-1.

9.10.2.1.3 The results of the tensile test shall comply with the values in table 3 for the steel grade concerned.

9.10.2.2 At elevated temperature

9.10.2.2.1 If agreed at the time of ordering, a tensile test at elevated temperature shall be carried out (see 9.4.2) in accordance with ISO 783.

9.10.2.2.2 The proof stress ($R_{p0,2}$) shall be determined during the tensile test.

9.10.2.2.3 The result of the tensile test shall comply with the value in table 4 at the selected temperature.

9.10.3 Flattening or bend test or ring tensile test

9.10.3.1 General

At the option of the manufacturer, either a flattening test or a bend test or a ring tensile test shall be carried out at room temperature (see 9.4.1.3) for tubes with an outside diameter above or equal to 200 mm; for tubes with an outside diameter below 200 mm and above or equal to 152,4 mm, the flattening test or the ring tensile test is usually carried out; for tubes with an outside diameter below 152,4 mm, only the flattening test is usually carried out.

9.10.3.2 Flattening test

9.10.3.2.1 The flattening test shall be carried out in conformity with ISO 8492.

The tube section or the tube end shall be flattened in a press, up to the moment when the distance H between the platens reaches the value given by the following formula:

$$H = \frac{1+K}{K+\frac{T}{D}} \times T$$

where

H is the distance between platens, in millimetres, to be measured under load;

D is the specified outside diameter, in millimetres;

T is the specified wall thickness, in millimetres;

K is the constant factor of deformation (see table 3).

9.10.3.2.2 After testing, the test piece shall be free from cracks or breaks; however, a slight incipient crack at the edges shall not be regarded as a justification for rejection.

When low D/δ ratio tubes are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 h and 12 h locations, cracks at these locations shall not be a cause for rejection if the D/δ ratio is less than 10.

9.10.3.3 Bend test

9.10.3.3.1 The bend test (see 9.4.1.3) shall be carried out in accordance with ISO 7438. The tube section shall be doubled over, cold, in the direction of initial curvature around a mandrel with a diameter as specified in table 3 for the steel grade concerned.

9.10.3.3.2 After testing, the test piece shall show no crack or flaw, but slight premature failure at the edges shall not be considered a cause for rejection.

9.10.3.4 Ring tensile test

9.10.3.4.1 The ring tensile test is only applicable for tubes with an outside diameter equal to or greater than 152,4 mm.

The test shall be carried out in accordance with ISO 8496.

9.10.3.4.2 The tube section (see 9.4.1.5.4) shall be subjected to strain in the circumferential direction until fracture occurs.

9.10.3.4.3 After testing, the test piece shall show no cracks visible without the use of magnifying aids.

9.10.4 Drift expanding test or ring expanding test

9.10.4.1 General

At the option of the manufacturer, either a drift expanding test or a ring expanding test shall be carried out at room temperature (see 9.4.1.3).

9.10.4.2 Drift expanding test

9.10.4.2.1 The drift expanding test shall be carried out in accordance with ISO 8493.

It is carried out on tubes with outside diameter up to 150 mm and wall thickness up to 9 mm.

The end of the tube section (see 9.4.1.5.4) shall be expanded on a conical mandrel until the increase in the outside diameter of the expanded tube reaches the value indicated in table 3 for the steel grade concerned.

9.10.4.2.2 After testing, the test piece shall show no crack or flaw, but slight premature failure at the edges shall not be considered a cause for rejection.

9.10.4.3 Ring expanding test

9.10.4.3.1 The ring expanding test shall be carried out in accordance with ISO 8495.

The tube section (see 9.4.1.5.4) shall be expanded until the increase in the outside diameter reaches the value indicated in table 3 for the steel grade concerned.

9.10.4.3.2 After testing, the test piece shall show no crack or flaw, but slight premature failure at the edges shall not be considered a cause for rejection.

9.10.5 Leak-tightness test

9.10.5.1 Hydraulic test

If the leak-thigtness test is carried out by a hydraulic test, the test pressure is defined, up to a maximum of 80 bar, by the following equation:

$$\mathrm{PE} = 20\,\frac{S \times T}{D}$$

where

PE is the test pressure, in bars;

D is the specified outside diameter, in millimetres;

T is the specified wall thickness, in millimetres;

S is the stress, in newtons per square millimetre, corresponding to 80 % of the specified minimum value of R_{eH} or $R_{p0,2}$ or $R_{t0,5}$ (see table 3) for the steel grade concerned.

The test pressure shall be maintained for at least 5 s.

The tube shall withstand the test without showing leaks or deformation beyond the limits of the dimensional tolerances.

9.10.5.2 Non-destructive test

If the tube is not submitted to the hydraulic test defined in 9.10.5.1, it shall be submitted to a non-destructive test (see 9.5.2), namely:

a) an electromagnetic test in accordance with ISO 9302;

or

b) an ultrasonic test in accordance with ISO 10332.

9.10.6 Non-destructive testing

9.10.6.1 Tubes of test category II shall be submitted to ultrasonic testing for the detection of longitudinal defects in accordance with ISO 9303, with acceptance level L2.

9.10.6.2 If agreed at the time of enquiry and order, tubes of test category II may also be submitted to ultrasonic testing for the detection of transverse defects in accordance with ISO 9305, with acceptance level L2.

9.10.7 Impact testing

9.10.7.1 If agreed at the time of ordering, impact testing at room temperature shall be carried out (see 9.4.1.5.5) in accordance with ISO 148. The mean value of the three test pieces shall be taken.

9.10.7.2 The test is regarded as having fulfilled the requirements of this part of ISO 9329 if the mean value of the three test pieces corresponds to the minimum value given in table 3 for the relevant steel grade; only one individual value may fall short of this minimum value by up to 30 %.

9.10.7.3 If the mean value of the three test pieces is below the minimum value, or if one individual value is less than the minimum value by more than 30 %, the three further test pieces shall be taken from the sample tube and shall be tested in accordance with ISO 148.

9.10.7.4 The mean value of all six tests shall correspond to the minimum value given in table 3 for the relevant steel grade; of the six individual values, only two may fall below this minimum value, and of these two, only one by more than 30 %.

9.11 Invalidation of the tests

See ISO 404.

9.12 Retests

See ISO 404.

9.13 Sorting or reprocessing

See ISO 404.

10 Marking

10.1 Marking to be applied

The following marking shall, according to the size of the tubes, either be applied on a label attached to the bundle or the box of tubes, or be marked indelibly on each tube at one end.

The marking shall include the following information:

— the mark of the manufacturer of the tubes;

— the designation of the steel grade;

— the heat number of a code number;

— the designation of the test category;

— the inspector's mark;

— a number or mark by which the tubes can be identified with the inspection certificate or inspection report;

— reference to this part of ISO 9329.

10.2 Methods

10.2.1 Tubes with outside diameter up to and including 76,1 mm

The symbols indicated in 10.1 shall be indelibly marked on a label attached firmly to each bundle or box.

10.2.2 Tubes with outside diameter larger than 76,1 mm

The symbols indicated in 10.1 shall be marked on each tube, at a distance of approximately 300 mm from one end.

10.2.3 Paints used for marking

If paints are used for marking, they shall be as free as practicable from lead, copper, zinc and tin.

10.3 Specific marking

Other marking may be applied if specifically requested in the order.

11 Protection

The tubes are normally delivered without protection or with the manufacturer's normal mill protection.

If special protection is to be applied, this shall be specified in the enquiry and order.

12 Documents

Documents issued shall conform with 9.1.

13 Claims after delivery

See ISO 404.

Annex A
(normative)

Long-term rupture values

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Steel grade	Heat treatment[1]	Rupture time	Estimated average long-term stresses for rupture (R)[2], (N/mm^2)											
			Temperature, (°C)											
		h	380	390	400	410	420	430	440	450	460	470	480	490
Unalloyed steels														
		10 000	213	197	181	166	151	138	125	112	100	89	78	67
PH 23		30 000	192	176	161	147	133	120	107	95	84	73	63	52
		50 000	183	167	152	138	125	112	100	88	77	66	56	46
	N	100 000	171	155	141	127	114	102	90	78	67	57	47	36
		150 000	164	149	134	121	108	96	84	73	62	52	41	29
PH 26		200 000	159	144	130	116	104	92	80	69	58	48	37	23
		250 000	155	140	126	113	101	89	77	66	55	45	34	
		10 000	291	266	243	221	200	180	161	143	126	110	96	84
PH 29		30 000	262	237	214	192	171	151	132	115	99	86	74	65
		50 000	248	223	200	177	156	136	118	102	87	75	65	57
	N	100 000	227	203	179	157	136	117	100	85	73	63	55	(47)
		150 000	215	190	167	144	124	105	89	76	65	56	(49)	(42)
PH 35		200 000	206	181	157	135	115	97	82	70	60	52	(44)	(37)
		250 000	199	174	150	128	108	91	77	66	56	(48)	(41)	(32)
Alloyed steels														
		10 000											304	273
		30 000											267	233
8 CrMo 4-5		50 000											239	207
	N + T	100 000											210	177
		150 000											194	161
8 CrMo 5-5		200 000											180	148
		250 000											170	139
X11 CrMo 5 TA		10 000								196	170	166	151	137
		30 000								172	158	142	120	117
		50 000								162	146	131	120	110
	A	100 000								146	131	119	109	97
		150 000								136	123	112	101	89
		200 000								130	118	107	95	84
		250 000								126	114	103	91	81
X11 CrMo 5 TN + TT		10 000	296	286	275	264	250	235	220	205	190	175	160	145
	N + T	100 000	266	252	237	221	205	189	173	158	143	128	113	100
		200 000	254	240	225	209	193	177	161	145	129	119	102	89
13 CrMo 4-5		10 000											304	273
		30 000											267	233
		50 000											239	207
	N + T	100 000											210	177
		150 000											194	161
		200 000											180	148
		250 000											170	139
16 Mo 3		10 000								298	273	247	222	196
		30 000								273	244	216	187	159
		50 000								260	229	200	172	144
	N	100 000								239	208	178	148	123
		150 000								226	197	168	139	114
		200 000								217	188	159	130	105
		250 000								210	180	151	124	100
11 CrMo 9-10 TA		10 000								(251)	(236)	221	206	191
		30 000								(226)	211	196	181	168
		50 000								211	197	183	170	156
	A	100 000								190	182	168	134	141
		150 000								193	177	161	145	129
		200 000								186	170	154	138	123
		250 000								181	165	149	132	118

Estimated average long-term stresses for rupture (R)[2], (N/mm^2)																	
Temperature, (°C)																	
500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670
57 42 35																	
74 57 50 (41) (34)																	
239 200 177 146 132 122 114	209 169 149 121 108 99 91	179 140 124 99 87 79 74	154 116 101 81 71 64 59	129 96 82 67 57 52 48	109 79 68 54 46 42 39	91 66 55 43 38 34 32	76 54 45 35 (31) (28) (26)	64 44	53 36	44 (29)							
125 108 99 86 79 75 72	115 97 88 77 71 67 63	105 86 79 68 63 59 56	95 78 70 61 56 52 56	85 70 63 54 49 46 49	77 62 56 48 43 40 43	69 56 50 42 38 35 38	62 50 44 37 34 31 33	56 44 39 33 30 28 30	50 39 35 29 27 (25) 27	45 35 31 (26)	40 31 28	36 28 (25) (25)	32 (25)	29	(26)		
130 90 79	119 81 70	108 73 63	98 65 56	88 57 49	79 50 42	71 44 35	64 38 30	57 33 26	50 28 23	43 24 20	38 21 17	33 18 15	29 16 13	25 14 11	22 12 10		
239 200 177 146 132 122 114	209 169 149 121 108 99 91	179 140 124 99 87 79 74	154 116 101 81 71 64 59	129 96 82 67 57 52 48	109 79 68 54 46 42 39	91 66 55 43 38 34 32	76 54 45 35 (31) (28) (26)	64 44	53 36	44 (29)							
171 134 119 101 91 84 80	147 113 99 81 74 69 65	125 93 80 66 60 55 52	102 76 66 53 48 45 (42)	82 61 53 (42)	64 49 (42)												
177 153 142 137 116 110 105	102 159 128 115 103 97 93	147 120 116 102 91 85 81	133 113 104 90 79 75 72	121 101 92 78 71 66 63	108 89 81 69 62 58 54	96 78 71 59 54 50 47	85 70 62 51 46 43 40	76 61 54 44 40 (37) (35)	68 54 47 (38) (35)	61 48 42							

Steel grade	Heat treatment[1]	Rupture time	Estimated average long-term stresses for rupture (R)[2], (N/mm^2)											
			Temperature, (°C)											
		h	380	390	400	410	420	430	440	450	460	470	480	490
Alloyed steels *(concluded)*														
11 CrMo 9-10 TN + TT	N + T	10 000								(309)	(285)	(263)	240	219
		30 000								(276)	(254)	233	213	192
		50 000								(257)	236	217	197	177
		100 000								(221)	204	186	170	153
		150 000								209	192	175	153	141
		200 000								203	186	169	152	135
		250 000								198	181	164	147	130
12 MoCrV 6-2	N + T	10 000											299	268
		30 000											261	232
		50 000											243	217
		100 000											218	191
		150 000											205	179
		200 000											194	169
		250 000											185	160
X11 CrMo 9-1 TA	A	10 000								278	250	226	203	182
		30 000								255	228	204	182	161
		50 000								245	218	194	172	151
		100 000								229	203	179	157	138
		150 000								220	194	171	149	130
		200 000								214	188	164	143	124
		250 000								209	182	160	138	119
X11 CrMo 9-1 TN + TT	N + T	10 000					(463)	(416)	(375)	(340)	(308)	281	256	233
		30 000					(428)	(384)	(345)	(312)	282	256	232	211
		50 000					(412)	(369)	(331)	299	270	245	222	201
		100 000					(390)	(349)	(313)	282	254	229	207	187
		150 000					(377)	(337)	302	272	245	220	198	178
		200 000					(368)	(329)	295	265	238	214	192	172
		250 000					(361)	(322)	289	259	233	209	187	168
X10 CrMoVNb 9-1	N + T	10 000												
		100 000												
9 NiMnMoNb 5-4-4	N + T	10 000			402	385	368	348	328	304	274	242	212	179
		30 000												
		50 000												
		100 000			373	349	325	300	273	245	210	175	139	104
		150 000												
		200 000												
		250 000												
X20 CrMoNiV 11-1-1	N + T	10 000											350	319
		30 000											324	293
		50 000											311	281
		100 000											294	265
		150 000											284	255
		200 000											277	247
		250 000											371	242

[1] N = Normalizing; N + T = Normalizing + Tempering; A = Full Annealing.

[2] Values which have involved extrapolation are indicated in brackets.

Estimated average long-term stresses for rupture (R)[2], (N/mm^2)																	
Temperature, (°C)																	
500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670
196	176	155	137	122	108	16	85	76	68	61							
172	152	134	118	103	90	79	70	61	54	48							
158	139	123	107	93	80	71	62	54	47	42							
137	122	107	93	79	69	59	51	44	(38)	(34)							
126	110	95	82	73	63	54	47	40	(35)	(30)							
119	103	89	77	68	58	50	43	(37)	(32)	(28)							
113	98	84	74	64	55	47	41	(35)	(30)	(26)							
241	219	198	179	164	148	134	121	108	95	78							
209	187	168	152	135	121	107	93	80	87	(50)							
193	172	153	136	121	107	92	78	66									
170	150	131	116	100	85	72	59	(46)									
156	136	119	101	85	70	57											
146	127	109	91	76	61	(48)											
138	119	101	83	68	54												
163	145	129	114	101	81	79	71	63	57	52	47	43	39	35			
143	126	110	97	85	75	67	60	54	48	43	39	35					
133	116	102	89	78	69	61	55	49	44	40	35	(31)					
120	104	90	79	69	61	55	49	44	39	(34)							
112	97	84	73	64	57	51	45	40	36	(31)							
107	92	80	70	61	54	48	43	38									
103	88	77	67	59	52	46	41	36									
213	194	176	160	145	130	117	103	90	78	66	54	45	37	32	28	25	23
191	173	156	141	126	111	98	84	71	59	48	39	33	29	26	24	(22)	
181	164	147	131	116	102	88	75	62	50	41	34	30	26	24	(22)		
168	150	134	118	104	89	75	62	50	40	34	29	26	23	(22)			
160	143	126	111	96	81	68	55	44	36	30	27	24	(22)	(21)			
154	137	121	105	90	76	62	50	40	33	29	25	23	(21)				
149	132	116	101	86	71	58	46	37	31	27	24	(22)					
			(222)	(206)	190	175	160	147	136	125	114	103	91	78	65		
			182	167	152	141	130	119	108	98	86	74	63	53	43		
147																	
69																	
290	264	240	217	196	176	157	139	123	107	93	81	71	62	54	48	42	37
265	240	216	194	173	153	135	117	102	88	75	65	57	50	44	38	33	29
254	228	205	183	162	142	124	107	92	79	68	59	51	45	39	34	29	
237	212	189	167	146	127	109	93	80	68	59	51	44	38	33	28		
228	203	179	157	137	118	101	86	73	62	54	46	40	35	30			
221	196	172	151	130	112	95	80	68	58	50	44	38	32				
215	190	167	145	125	107	90	76	65	56	48	41	36	30				

ICS 23.040.10; 77.140.30; 77.140.75

Descriptors: pipes (tubes), pressure pipes, metal tubes, heat resistant steels, steel tubes, seamless tubes, specifications, delivery condition, dimensions, dimensional tolerances, mechanical properties, chemical composition, tests, marking.

Price based on 22 pages