INTERNATIONAL STANDARD

ISO 9329-3

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Seamless steel tubes for pressure purposes — Technical delivery conditions —

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

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

Partie 3: Aciers non alliés et alliés avec caractéristiques spécifiées à basse température

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 9329-3 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, 2 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)*

Seamless steel tubes for pressure purposes — Technical delivery conditions —

Part 3:
Unalloyed and alloyed steels with specified low 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 low temperature toughness properties.

These tubes are intended for low temperature piping systems.

The requirements of appropriate international application standards and relevant national legal regulations shall be taken into account by the user. For pressure containing equipment, ISO 5730 is 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 2: Unalloyed and alloyed steels with specified elevated temperature properties* (partial revision of ISO 2604-2:1975).

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

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

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 643:1983, *Steels — Micrographic determination of the ferritic or austenitic grain size.*

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/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";

— 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) 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);

— special straightness requirements (see 7.3.3);

— product chemical analysis (see 9.3 and 9.10.1);

— leak-tightness test (see 9.5);

— 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 PL 21 with specified room temperature properties to be submitted to specific inspection and testing to test category II involving the issuing of an inspection certificate 3.1.B according to ISO 10474.

Tube hot-finished ISO 4200 - 168,3 × 4 - 4 to 8 - ISO 9329-3 - PL 21 - II - 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;

— quenching and tempering.

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.

When minima only are specified, the deviations are always negative.

6.2 Mechanical properties

6.2.1 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 Table 4 gives minimum values for the impact energy, as determined on ISO V-notch test pieces, used to characterize the cold-toughness of the various steel grades at low temperature (see also footnote 2 to table 4).

Impact tests shall be carried out at the lowest temperature indicated in table 4 for each steel grade (see also 9.10.7.1), except that higher temperatures shown may be agreed upon between the purchaser and the manufacturer.

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.

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

Steel grade[1]		C	Si	Mn	P max.	S max.	Al (total) min.	Cr	Mo	Ni	V max.	Nb max.
Unalloyed steels	PL 21	⩽ 0,17	⩽ 0,35	0,40 to 1,00	0,030	0,025	0,015 [2]	—	—	—	—	—
	PL 23	⩽ 0,19	⩽ 0,35	0,60 to 1,20	0,030	0,025	0,015 [2]	—	—	—	—	—
	PL 25	⩽ 0,17	⩽ 0,35	0,40 to 1,00	0,030	0,025	0,015 [2]	—	—	—	—	—
	PL 26	⩽ 0,20	⩽ 0,35	0,80 to 1,40	0,030	0,025	0,015 [2]	—	—	—	—	—
Alloyed steels	26 CrMo 4	0,22 to 0,29	⩽ 0,35	0,50 to 0,80	0,030	0,025	—	0,90 to 1,20	0,15 to 0,30	—	—	—
	11 MnNi 5-3	⩽ 0,14	⩽ 0,50	0,70 to 1,50	0,030	0,025	0,020 [3]	—	—	0,30 [4] to 0,80	0,05	0,05
	13 MnNi 6-3	⩽ 0,18	⩽ 0,50	0,85 to 1,65	0,030	0,025	0,020 [3]	—	—	0,30 [4] to 0,85	0,05	0,05
	12 Ni 14	⩽ 0,15	0,15 to 0,35	0,30 to 0,85	0,025	0,020	—	—	—	3,25 to 3,75	0,05	—
	X 12 Ni 5	⩽ 0,15	⩽ 0,35	0,30 to 0,80	0,025	0,020	—	—	—	4,50 to 5,30	0,05	—
	X 10 Ni 9	⩽ 0,13	0,15 to 0,35	0,30 to 0,80	0,025	0,020	—	—	⩽ 0,10	8,50 to 9,50	0,05	—

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) Metallic aluminium content. Where the total aluminium content is determined, the result shall be deemed to meet this requirement, provided the total aluminium content value obtained is not less than 0,018 % (*m/m*). In cases of dispute, the metallic aluminium content shall be determined. Alternatively, an austenitic grain size of 6 or finer, determined in accordance with ISO 643, can be agreed upon. By agreement between the interested parties, aluminium may be replaced by other elements having a similar effect.

3) Total aluminium content. By agreement between the interested parties, aluminium may be replaced by other elements having a similar effect.

4) The lower limit value for the nickel content may be reduced to not less than 0,15 % (*m/m*) for tubes with wall thickness not exceeding 10 mm.

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

Element	Content specified for the heat analysis % (*m/m*)	Permissible deviation % (*m/m*)
C	⩽ 0,29	± 0,03
Si	⩽ 0,50	± 0,05
Mn	⩽ 1,65	± 0,10
P	⩽ 0,030	+ 0,005
S	⩽ 0,025	+ 0,005
Al	⩾ 0,015	− 0,005
Cr	⩽ 1,20	± 0,10
Mo	⩽ 0,30	± 0,04
Ni	⩽ 0,85 > 0,85 ⩽ 3,75 > 3,75 ⩽ 5,30 > 5,30 ⩽ 9,50	± 0,05 ± 0,07 ± 0,10 ± 0,15
V	⩽ 0,05	+ 0,01
Nb	⩽ 0,05	+ 0,01

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				
			Tensile strength R_m	Upper yield stress or proof stress R_{eH} or $R_{p0,2}$ or $R_{t0,5}$ min. for wall thicknesses in mm 2)			Elongation for wall thicknesses ≤ 40 mm 2) $A_{min.}$	Constant K	Diameter of mandrel	Percentage increase of D for D_i/D			Percentage increase of D for D_i/D				
				$T \leqslant 13$	$13 < T \leqslant 25$	$25 < T \leqslant 40$				≤ 0,6	> 0,6 ≤ 0,8	> 0,8	≤ 0,5	> 0,5 ≤ 0,6	> 0,6 ≤ 0,8	> 0,8 ≤ 0,9	> 0,9
			N/mm²	N/mm²	N/mm²	N/mm²	%		mm								
Unalloyed steels	PL 21	N	360 to 480	215	215	3)	24	0,10	4T	12	15	19	30	25	15	10	8
	PL 23	N	410 to 530	235	235	3)	22	0,08	4T	10	12	17	30	25	15	10	8
	PL 25	Q + T	360 to 490	255	255	235	21	0,09	—	—	—	—	—	—	—	—	—
	PL 26	N	460 to 580	265	275	3)	21	0,07	4T	8	10	15	30	25	15	10	8
Alloyed steels	26 CrMo 4	Q + T	560 to 740	440	440	420	16	0,06	—	—	—	—					
	11 MnNi 5-3	N	410 to 530	285	275	265	22	0,07	—	—	—	—					
	13 MnNi 6-3	N	490 to 610	355	345	335	20	0,07	—	—	—	—					
	12 Ni 14	Q+T	440 to 590	245	245	245	16	0,08	—	6	8	12					
	X 12 Ni 5	Q+T	510 to 710	390	390	380	17	0,06	—	—	—	—					
	X 10 Ni 9	Q+T	690 to 840	510	510	510	15	0,08	—	6	8	12					

1) See 8.3 (N = Normalizing; Q+T = Quenching + Tempering).

2) For wall thicknesses greater than 40 mm, the values to be obtained shall be the subject of agreement between the purchaser and the manufacturer at the time of ordering.

3) To be agreed upon at the time of ordering.

Table 4 — Impact properties at low temperature

Steel grade		Wall thickness, T [1] mm	Orientation of test pieces with respect to tube axis	Minimum impact test value, KV [2] [3] (J) (average of three test pieces)									
				Temperature, °C									
				−196	−120	−110	−100	−90	−60	−50	−40	−20	+20
Unalloyed steels	PL 21	⩽ 10	Longitudinal	—	—	—	—	—	—	—	40	45	55
	PL 23	< 25	Longitudinal	—	—	—	—	—	—	27	40	45	50
			Transverse [4]	—	—	—	—	—	—	—	27	30	35
	PL 25	< 25	Longitudinal	—	—	—	—	—	—	40	45	50	60
			Transverse [4]	—	—	—	—	—	—	27	30	35	40
		> 25 ⩽ 40	Longitudinal	—	—	—	—	—	—	—	40	45	55
			Transverse [4]	—	—	—	—	—	—	—	27	30	35
	PL 26	< 25	Longitudinal	—	—	—	—	—	—	27	40	45	50
			Transverse [4]	—	—	—	—	—	—	—	27	30	35
Alloyed steels	26 CrMo 4	⩽ 40	Longitudinal	—	—	—	—	—	40	40	45	50	60
			Transverse [4]	—	—	—	—	—	27	27	30	35	40
	11 MnNi 5-3 13 MnNi 6-3	⩽ 40	Longitudinal	—	—	—	—	—	40	45	50	55	70
			Transverse [4]	—	—	—	—	—	27	30	35	40	45
	12 Ni 14	⩽ 25	Longitudinal	—	—	—	40	45	50	55	55	60	65
			Transverse [4]	—	—	—	27	30	35	35	40	45	45
		> 25 ⩽ 40	Longitudinal	—	—	—	—	40	45	50	50	55	65
			Transverse [4]	—	—	—	—	27	30	30	35	40	45
	X 12 Ni 5	⩽ 25	Longitudinal	—	40	45	50	55	65	65	65	70	70
			Transverse [4]	—	27	30	30	35	45	45	45	50	50
		> 25 ⩽ 40	Longitudinal	—	—	40	45	50	60	65	65	65	70
			Transverse [4]	—	—	27	30	30	40	45	45	45	50
	X 10 Ni 9	⩽ 40	Longitudinal	40	50	50	60	60	70	70	70	70	70
			Transverse [4]	27	35	35	40	40	50	50	50	50	50

1) Values for tubes with wall thicknesses exceeding the maximum value shown in this table may be agreed upon at the time of enquiry and order.

2) Single values not less than 70 % of the average value.

3) The values apply to standard 10 mm × 10 mm test pieces. For different sizes of test pieces, see 9.10.7.1.

4) Transverse test pieces shall be used only by agreement.

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.

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			
		$\leqslant$ 0,025	> 0,025 $\leqslant$ 0,05	> 0,05 $\leqslant$ 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.

9 Inspection and testing

9.1 Type of inspection and testing and type of 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;

Table 7 — Heat-treated conditions

Steel grade		Reference heat treatment[1]	Normalizing temperature °C	Tempering temperature °C	Quenching and tempering		
					Hardening temperature °C	Cooling medium[2]	Tempering temperature °C
Unalloyed steels	PL 21	N	900 to 940	—	—	—	—
	PL 23	N	890 to 930	—	—	—	—
	PL 25	Q + T	—	—	890 to 930	Water or oil	600 to 680
	PL 26	N	890 to 930	—	—	—	—
Alloyed steels	26 CrMo 4	Q + T	—	—	830 to 860	Water or oil	600 to 680
	11 MnNi 5-3	N[3]	890 to 940	(580 to 640)	—	—	—
	13 MnNi 6-3	N[3]	890 to 940	(580 to 640)	—	—	—
	12 Ni 14	Q + T[4]	830 to 880	580 to 640	820 to 880	Water or oil	580 to 660
	X 12 Ni 5	Q + T[4]	800 to 850	580 to 640	800 to 850	Water or oil	580 to 660
	X 10 Ni 9	Q + T	880 to 930	—	770 to 820	Water or oil	540 to 600
		N + N + T	880 to 915 + 775 to 805	565 to 605			

1) N = Normalizing; Q + T = Quenching + Tempering; N + T = Normalizing + Tempering.

2) When choosing the cooling medium, the influence of other parameters, such as dimensions and quenching temperature, on properties and crack susceptibility should be taken into account. Other cooling media, such as synthetic quenchants, may also be used.

3) Tempering can occasionally be necessary after normalizing. In this case, the manufacturer shall inform the purchaser accordingly and shall state the tempering temperature.

4) If the product's dimensions so permit, normalizing (with subsequent tempering if necessary) may be carried out at the manufacturer's discretion instead of quenching and tempering. In this case, the manufacturer shall inform the purchaser accordingly.

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 Batch

The delivery shall be divided into batches. 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.

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 (see 9.10.2)	X	X
	Impact test (see 9.10.7)	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
	Non-destructive testing for transverse defects (see 9.10.6.2)	—	X

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

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

9.4.2 Number of products sampled per test unit

Each test unit consists of

a) one tube per batch for test category I;

b) two tubes per batch for test category II.

9.4.3 Number of tests

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

— one tensile test on each tube (see 9.10.2);

— one series of three impact tests on each sample tube (see 9.4.5.5), if the wall thickness permits the preparation of test pieces with widths of at least 5 mm (see 9.10.7);

— 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).

9.4.4 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.

9.4.5 Location and orientation of the test pieces

9.4.5.1 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.

9.4.5.2 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.

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

9.4.5.4 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 with ISO 8495 or ISO 8496, respectively.

9.4.5.5 For the impact test (see ISO 148), a set of three ISO V-notch test pieces shall be taken from each sample tube longitudinal to the tube axis.

By agreement at the time of ordering, test pieces can be taken transverse to the tube axis, provided that the dimension of the tube permits this without flattening of the test piece.

The minimum outside diameter of the pipe necessary to take transversal test pieces may be calculated D_{min}, in millimetres, as a function of the wall thickness T by

$$D_{min} = (T - 5) + \frac{756{,}25}{T - 5}$$

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.

9.4.5.5.1 The dimensions of the test piece should preferably be 10 mm × 10 mm. Test pieces having a width of less than 10 mm, but not below 5 mm, are also permitted.

9.4.5.5.2 In the case of test pieces less than 10 mm wide, the two faces perpendicular to the notch shall only be machined by the amount necessary to obtain a minimum dimension of 5 mm.

9.4.5.5.3 In the case of tubes with a wall thickness exceeding 30 mm, the centreline of the test piece shall have a distance from the external surface equal to one quarter of the wall thickness or shall be positioned as close as possible to this location.

9.5 Leak-tightness test

9.5.1 All the tubes shall be submitted to a leak-tightness 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 $D \geqslant 457$ 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.

9.10.1.4 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 The tensile test shall be carried out at room temperature in conformity with ISO 6892 (see 9.4.3 and 9.4.5.1).

9.10.2.2 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 of 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 accodance with ISO 2566-1.

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

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 9.4.3) 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 cract at the edges shall not be regarded as a justification for rejection.

When low D/T 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/T ratio is less than 10.

9.10.3.3 Bend test

9.10.3.3.1 The bend test (see 9.4.3) 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 9.4.5.4) 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 9.4.3).

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 9.4.5.4) 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 9.4.5.4) 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-tightness test is carried out by a hydraulic test, the test pressure is defined, up to a maximum of 80 bar, by the following equation:

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

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 Impact testing shall be carried out (see 9.4.5.5) in accordance with ISO 148.

The impact energy shall always be determined at the lowest test temperature specified for the steel grade and wall thickness concerned in table 4; the values of impact energy at higher test temperatures shall be considered to have been demonstrated by the same determination.

The mean value of the three test pieces (see 9.4.5.5) shall be taken.

If the width of the test piece is less than 10 mm, the impact energy A_v, in joules, shall be calculated from the specified energy A'_v using the formula

$$A_v = A'_v \cdot \frac{B}{10}$$

where B is the width, in millimetres, of the test piece.

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 4 for the relevant steel

grade and wall thickness; 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 specified value, or if one individual value is less than the minimum specified value by more than 30 %, then 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 test shall correspond to the minimum value given in table 4 for the relevant steel grade and wall thickness; 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 inlcude the following information:

— the mark of the manufacturer of the tubes;

— the designation of the steel grade;

— the heat number or 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.

ICS 23.040.10; 77.140.30; 77.140.75

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

Price based on 16 pages