INTERNATIONAL STANDARD

ISO 9330-4

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Welded steel tubes for pressure purposes — Technical delivery conditions —

Part 4: Submerged arc-welded unalloyed and alloyed steel tubes with specified elevated temperature properties

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

Partie 4: Tubes soudés à l'arc immergé en aciers non alliés et alliés avec caractéristiques spécifiées à température élevée

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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.

Attention is drawn to the possibility that some of the elements of this part of ISO 9330 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 9330-4 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 19, *Technical delivery conditions for steel tubes for pressure purposes*.

ISO 9330 consists of the following parts, under the general title *Welded steel tubes for pressure purposes — Technical delivery conditions*:

— *Part 1: Unalloyed steel tubes with specified room temperature properties*

— *Part 2: Electric resistance and induction welded unalloyed and alloyed steel tubes with specified elevated temperature properties*

— *Part 3: Electric resistance and induction welded unalloyed and alloyed steel tubes with specified low temperature properties*

— *Part 4: Submerged arc-welded unalloyed and alloyed steel tubes with specified elevated temperature properties*

— *Part 5: Submerged arc-welded unalloyed and alloyed steel tubes with specified low temperature properties*

— *Part 6: Longitudinally welded austenitic stainless steel tubes*

Annex A of this part of ISO 9330 is for information only.

Welded steel tubes for pressure purposes — Technical delivery conditions —

Part 4: Submerged arc-welded unalloyed and alloyed steel tubes with specified elevated temperature properties

1 Scope

This part of ISO 9330 specifies the technical delivery conditions for submerged arc-welded tubes of circular cross-section, made of unalloyed or 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 International Standards ISO 831, ISO 2604 and ISO 5730 are available.

For the general technical delivery requirements, see ISO 404.

NOTE The English words “tube” and “pipe” are synonymous.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 9330. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 9330 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 148:1983[1)], *Steel — Charpy impact test (V-notch)*.

ISO 377:1997, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing.*

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

ISO 783:1999, *Metallic materials — Tensile testing at elevated temperature.*

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

ISO 3205:1976, *Preferred test temperatures.*

1) This International Standard has been withdrawn and replaced by ISO 148-1:—, ISO 148-2:1998 and ISO 148-3:1998.

ISO 3545-1:1989, *Steel tubes and fittings — Symbols for use in specifications — Part 1: Tubes and tubular accessories with circular cross-section.*

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 5173:1981, *Fusion welded butt joints in steel — Transverse root and face bend test.*

ISO 5177:1981, *Fusion welded butt joints in steel — Transverse side bend test.*

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

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

ISO 6892:1998, *Metallic materials — Tensile testing at ambient temperature.*

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

ISO 9765:1990, *Submerged arc-welded steel tubes for pressure purposes — Ultrasonic testing of the weld seam for the detection of longitudinal and/or transverse imperfections.*

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

ISO 11496:1993, *Seamless and welded steel tubes for pressure purposes — Ultrasonic testing of tube ends for the detection of laminar imperfections.*

ISO 12094:1994, *Welded steel tubes for pressure purposes — Ultrasonic testing for the detection of laminar imperfections in strip/plates used in the manufacture of welded tubes.*

IS0 12096:1996, *Submerged arc-welded steel tubes for pressure purposes — Radiographic testing of the weld seam for the detection of imperfections.*

ISO 14284:1996, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition.*

3 Symbols

3.1 Fundamental symbols

D is the specified outside diameter.

T is the 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 Hydraulic test

p_E is the test pressure.

σ is the 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:

a) the denomination “tube”;

b) reference to the relevant dimensional standard;

c) dimensions (outside diameter × wall thickness), see 7.1;

d) length, see 7.2;

e) tolerances if exact lengths greater than 12 m are ordered, see 7.3.4;

f) reference to this part of ISO 9330, i.e. ISO 9330-4;

g) steel grade, see Table 3;

h) test category for unalloyed steels, see 9.3.1.

4.2 Optional information

Enquiries and orders for tubes in accordance with this part of ISO 9330 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:

a) dimensions (inside diameter × wall thickness) see 7.1;

b) steelmaking process, see 5.1;

c) delivery condition, see 5.4;

d) special straightness requirements, see 7.3.6;

e) tolerances on the height of the weld seam, see 7.3.2;

f) bevelled ends, see 8.2;

g) product analysis, see 10.1.3;

h) tensile testing of weld for tubes over 219 mm but less than 508 mm outside diameter, see 10.1.3;

i) determination of proof stress at elevated temperature $R_{p0,2}$, see 10.1.3;

j) impact test, see 10.1.3;

k) specific marking, see 12.3;

l) protective coating, see 13;

m) type of inspection and testing and corresponding document, see 9.2 and 14.

4.3 Example of an order

Example of an order conforming to the dimensional standard ISO 4200, with an outside diameter of 457 mm, a wall thickness of 10 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 document 3.1 B in accordance with ISO 10474:1991.

Tube ISO 4200 - 457 × 10 - 4 to 8 - ISO 9330-4 - 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 transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

5.2 Deoxidation process

Steels intended for the production of tubes covered by this part of ISO 9330 shall be fully-killed.

5.3 Product-making process for tubes

A welded tube is obtained by shaping a flat-rolled product and then welding the edges. The weld may be longitudinal or helical.

Tubes shall be submerged arc-welded (SAW) using at least one run on the inside and one run on the outside of the tube. Unless otherwise agreed, the process of manufacture is left to the discretion of the manufacturer, provided that the welding method and welder/welding operator have been approved in accordance with a qualified procedure.

Tubes covered by this part of ISO 9330 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, if applicable.

5.4 Delivery condition

5.4.1 Tubes covered by this part of ISO 9330 shall be delivered in accordance with Table 1 and when appropriate the heat treatment conditions indicated in Table 2.

5.4.2 By agreement between the purchaser and the manufacturer the tubes may be delivered in a condition other than the final delivery condition in which case they shall be suitable for subsequent manipulation and the purchaser shall be informed of any treatment necessary to obtain the specified properties.

Table 1 — Delivery conditions

Grade	Delivery condition	
	Cold formed	Hot formed
PH 23, PH 26, PH 29, PH 35	As-welded, not heat-treated	Welded, normalized on full tube
	Welded, heat treatment on full tube	
16 Mo 3, 13 CrMo 4-5, 11 CrMo 9-10	Welded, heat treatment on full tube	

Table 2 — Heat treatment conditions

Steel grade		Reference heat treatment [a]	Austenitizing temperature °C	Cooling medium	Tempering temperature °C	Cooling medium
Unalloyed steels	PH 23	N [b]	880-940	Air	—	—
	PH 26	N [b]	880-940	Air	—	—
	PH 29	N [b]	880-940	Air	—	—
	PH 35	N [b]	880-940	Air	—	—
Alloyed steels	16 Mo 3	N	890-950	Air	—	—
	13 CrMo 4-5	N + T	900-960	Air	660-730	Air
	11 CrMo 9-10	N + T	900-960	Air	680-750	Air

[a] N = normalizing; N + T = normalizing + tempering.

[b] 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 manufacturer.

6 Metallurgical properties

6.1 Chemical composition

6.1.1 Heat analysis

The heat analysis reported by the steel producer shall apply and comply with the requirements given in Table 3.

Table 3 — Chemical composition (heat analysis), % (m/m)

Steel grade [a]		C	Si	Mn	P max.	S max.	Cr	Mo	Al (total) max.	Others
Unalloyed steels	PH 23	$\leqslant$ 0,17	0,10-0,30	0,30-0,80	0,035	0,03	—	—	—	[b]
	PH 26	$\leqslant$ 0,21	0,10-0,35	0,40-1,20	0,035	0,03	—	—	—	[b]
	PH 29	$\leqslant$ 0,22	0,10-0,40	0,65-1,40	0,035	0,03	—	—	—	[b]
	PH 35	$\leqslant$ 0,22 [c]	0,15-0,55	1,00-1,50 [c]	0,035	0,03	—	—	—	[b, d]
Alloyed steels	16 Mo 3	0,12-0,20 [e]	0,15-0,35	0,40-0,80	0,035	0,03	—	0,25-0,35	0,02	[b]
	13 CrMo 4-5	0,10-0,17 [e]	0,15-0,35	0,40-0,70	0,035	0,03	0,7-1,1	0,40-0,60	0,02	[b]
	11 CrMo 9-10	0,08-0,15	0,15-0,40	0,30-0,70	0,035	0,03	2,0-2,5	0,90-1,20	0,02	[b]

NOTE Elements not included in this table should 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 should be taken to prevent the addition of elements from scrap or other materials used in the manufacture, but residual elements may be present 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) should be stated in the documents mentioned in clause 14.

[a] Classification in accordance with ISO 4948-1; designation in accordance with ISO/TR 4949.

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

[c] For tubes with wall thickness $>$ 30 mm the upper limit of the carbon content may be increased by 0,02 % but (C + Mn/6) shall never exceed 0,47 % (m/m).

[d] At the discretion of the manufacturer additions of niobium, titanium and vanadium are permitted up to levels permitted for the non-alloyed steels listed in ISO 4948-1:1982, unless otherwise agreed upon between the purchaser and the manufacturer. In such a case the test certificate shall state the level of these elements.

[e] For tubes with wall thickness $>$ 30 mm the upper limit of the carbon content may be increased by 0,02 % (m/m).

6.1.2 Product analysis

If a product analysis is required (see 10.1.3), the permissible deviations given in Table 4 shall apply to the heat analysis specified in Table 3.

The deviations, other than when maxima only are specified, 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 positive only.

Table 4 — Permitted deviations from the specified chemical composition limits given in Table 3

Element	Content specified for the heat analysis % (m/m)	Permissible deviation % (m/m)
C	$\leqslant$ 0,22	$\pm$ 0,03
Si	$\leqslant$ 0,55	$\pm$ 0,05
Mn	$\leqslant$ 1,50	$\pm$ 0,10
P	$\leqslant$ 0,035	+ 0,005
S	$\leqslant$ 0,030	+ 0,005
Cr	$\leqslant$ 2,50	$\pm$ 0,10
Mo	$\leqslant$ 0,35	$\pm$ 0,04
	$>$ 0,30 $\leqslant$ 1,20	$\pm$ 0,05
Al	$\leqslant$ 0,020	+ 0,005

6.2 Mechanical properties

6.2.1 At room temperature

The mechanical and technological properties of the tubes covered by this part of ISO 9330, 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 5.

Table 5 — Mechanical properties at room temperature

Steel grade		Tensile test						Bend test	Impact test
		Tensile strength	R_{eH} or $R_{p0,2}$ or $R_{t0,5}$ min. for wall thickness [a]			Elongation [b] A min.		Diameter of the mandrel	Transverse [c]
		R_m	< 16 mm	> 16 mm ⩽ 40 mm	> 40 mm ⩽ 60 mm	l	t		
		N/mm^2	N/mm^2			%		mm	J
Unalloyed steels	PH 23	360-480	235	225	215	25	23	$3T$	27
	PH 26	410-530	265	255	245	21	19	$4T$	27
	PH 29	460-580	290	280	270	23	21	$4T$	27
	PH 35	510-640	355	335	315	19	17	$4T$	27
Alloyed steels	16 Mo 31	450-600	270 [d]	270	260	22	20	$4T$	27 [e]
	3 CrMo 4-5	440-590	290 [d]	290	280	22	20	$4T$	27
	11 CrMo 9-10	480-630	280	280	280	20	18	$4T$	27

a For wall thicknesses > 60 mm, the values to be obtained shall be the subject of agreement between the purchaser and the manufacturer at the time of ordering.

b l = longitudinal; t = transversal.

c Applicable for wall thicknesses > 30 mm, unless otherwise indicated.

d For wall thicknesses ⩽ 10 mm the minimum value of yield strength may be increased by I0 N/mm^2.

e Applicable for wall thicknesses > 10 mm.

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 6.

Table 6 — Minimum 0,2 % proof stress ($R_{p0,2}$) values at elevated temperature

Steel grade		Wall thickness [a]	$R_{P0,2}$ N/mm^2									
			Temperature °C									
			150	200	250	300	350	400	450	500	550	600
Un-alloyed steels	PH 23	⩽ 16	185	165	145	127	116	110	106	—	—	—
		> 16 ⩽ 40	183	16.4	145	127	116	110	106	—	—	—
		> 40 ⩽ 60	172	159	145	127	116	110	106	—	—	—
	PH 26	⩽ 16	216	194	171	152	141	134	130	—	—	—
		> 16 ⩽ 40	213	192	171	152	141	134	130	—	—	—
		> 40 ⩽ 60	204	lea	171	152	141	134	130	—	—	—
	PH 29	⩽ 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	⩽ 60	270	255	235	215	200	180	170	—	—	—
Alloyed steels	16Mo3	⩽ 60	237	224	206	173	159	155	150	145	—	—
	13 CrMo 4-5	⩽ 60	230	220	210	183	169	164	161	156	150	145
	11 CrMo 9-10	⩽ 60	241	233	224	219	212	207	194	180	160	137

[a] Values for wall thicknesses > 50 mm are subject to agreement between the purchaser and the manufacturer.

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 9330 are generally 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 significantly, on the condition of preparing and carrying out the welding.

7 Dimensions, masses and tolerances

7.1 Diameters, wall thicknesses and masses

The outside diameters, wall thicknesses and masses of the tubes covered by this part of ISO 9330 should be selected from those given in ISO 4200.

By agreement between the purchaser and the manufacturer tubing specified by inside diameter and wall thickness can be supplied. In such a case the dimensions and the tolerances required should be agreed upon at the time of enquiry and order.

7.2 Lengths

7.2.1 It shall be stated on 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, the length range shall be agreed upon at the time of inquiry and ordering.

7.2.3 If the tubes are to be delivered with exact lengths, the length tolerances given in 7.3.4 shall apply.

7.3 Tolerances

7.3.1 Tolerances on outside diameter and on wall thickness (excluding the weld)

The outside diameters and the wall thicknesses of the tubes covered by this part of ISO 9330 shall be within the tolerance limits given in Table 7, see 9.3.2.2.

Within areas where the tube surface has been dressed by mechanical machining (such as grinding), e.g. as a result of instructions required for the performance of non-destructive testing, it is permissible to exceed the minus deviation on the outside diameter by a small amount over a length of not more than 1 m, provided that wall thickness remains within the lower tolerance limits.

Table 7 — Tolerances on outside diameter and on wall thickness (excluding the weld seam)

Tolerances on (see ISO 5252)	
D	*T*
± 0,75 % with a min. of ± 0,5 mm	±10 % with a min. of ± 0,2 mm

7.3.2 Tolerances on the height of the weld seam

The heights of the external and internal weld seam shall be within the tolerance limits indicated in Table 8 (see 9.3.2.2).

Table 8 — Tolerances on height of weld seam

Wall thickness (T) mm	**Maximum height of external and internal weld seam reinforcement** mm
$T \leqslant 8$	3
$8 < T \leqslant 14{,}2$	3,5
$T > 14{,}2$	4,8

7.3.3 Misalignment of plate edges at the weld

Radial misalignment of the abutting plate or strip edges shall not exceed the following limits:

— for wall thicknesses $\leqslant$ 12,5 mm: 1,6 mm;

— for wall thicknesses > 12,5 mm: 12,5 % of specified wall thickness or 3,2 mm, whichever is the smaller.

7.3.4 Tolerances on exact lengths

— for lengths $\leqslant$ 6 m: $^{+10\ \text{mm}}_{0}$

— for lengths > 6 m $\leqslant$ 12 m: $^{+15\ \text{mm}}_{0}$

For lengths > 12 m, the applicable tolerance shall be agreed upon between the purchaser and the manufacturer.

7.3.5 Ovality

The ovality shall be determined as a percentage using the following formula, see ISO 3545-1:

$$\text{Ovality} = 100\,\frac{D_{\max} - D_{\min}}{D}$$

Where $D_{\max}$ and $D_{\min}$ are respectively the maximum and the minimum outside diameters measured in the same cross-section.

For tubes having D < 406 mm ovality is included in the limits of the diameter tolerances.

For tubes having $D \geqslant 406$ mm the ovality shall not exceed 2 % if the D/T ratio is < 100. If the D/T ratio is $\geqslant$ 100 the tolerance on ovality shall be agreed upon between the purchaser and manufacturer.

7.3.6 Straightness

All tubes shall be reasonably straight. The deviation from straightness shall not exceed $0{,}002 \times L$ where L is the length. Deviation from straightness over any one metre length shall not exceed 3 mm.

Special requirements regarding straightness shall be the subject of an agreement between the purchaser and the manufacturer.

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 9330.

8.1.2 The tubes shall have a finish and internal and external surface condition typical of the manufacturing process and, when applicable, 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 9330.

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 The manufacturer shall, subject to the limitations given in 8.1.8, dress surface marks and imperfections found by exploration in accordance with 8.1.6 to be deeper than 5 % of the specified thickness but not less than 0,5 mm.

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

8.1.9 Repairs to the parent metal of the tubes shall only be carried out by grinding or machining. Peening or welding are not permitted.

NOTE Repairs to the weld seam are permitted, in accordance with an established procedure.

8.2 Preparation of ends

Tubes are normally delivered with square cut ends. By agreement between the purchaser and the 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

When the tubes are delivered in the heat-treated condition the parameters given in Table 2 shall apply.

9 Inspection and testing

9.1 Type of inspection and testing

The inspection and testing procedure for deliveries in accordance with this part of ISO 9330 shall be as specified in ISO 404.

9.2 Types of the inspection document

Tubes delivered in accordance with this part of ISO 9330 shall be provided with an inspection certificate, 3.1.B, in accordance with ISO 10474, see 4.2.

NOTE If inspection document 3.1.C or 3.2 is specified the purchaser should notify the manufacturer of the address of the organization or person nominated by him to carry out the inspection and to produce the certificate of conformity.

The inspection documents supplied shall contain at least the following information:

a) reference to the order;

b) description of products to which the inspection document applies;

c) information on tests as follows:

   1) location of sample, direction of test pieces and test temperature;

   2) tensile test — test piece shape and test results;

   3) bend test — test piece shape and test results;

   4) chemical composition — the heat analysis and if applicable the product analysis;

   5) NDT — type of test and result;

   6) impact test — test piece size and result if applicable;

   7) leak tightness test — requirements of the order;

d) the heat treatment carried out;

e) authentication that the products comply with the requirements of the order.

9.3 Product inspection and testing

9.3.1 General

Unalloyed steel tubes shall be subjected to the tests for category I in Table 9 unless category II is specified at the time of enquiry and order, see 4.1.

Alloy steel tubes shall be subjected to the test for category II in Table 9.

Table 9 — Test categories

Tests		Reference	Test category	
			I	II
Mandatory tests	Heat analysis	6.1.1	×	×
	Visual inspection	9.3.2.1	×	×
	Dimensional testing	9.3.2.2	×	×
	Leak tightness	9.3.3	×	×
	Tensile test on tube body at room temperature	10.1.3	×	×
	Tensile test on weld at room temperature	10.1.3	×	×
	Bend test	10.1.3	×	×
	Non-destructive testing of the weld	9.3.4	×	×
	Non-destructive testing of the body of the tube for laminations	9.3.4	–	×
	Non-destructive testing of tube ends for laminations	9.3.4	–	×
	Material identification for alloy steels	9.4	–	×
Optional tests (see 4.2)	Product analysis	10.1.3	×	×
	Tensile test at elevated temperature	10.1.3	×	×
	Impact test of the tube body at room temperature	10.1.3	×	×

9.3.2 Visual inspection and dimensional check

9.3.2.1 Visual inspection

Every tube shall be visually inspected for compliance with the requirements of 8.1 and 8.2.

9.3.2.2 Dimensional testing

The dimensions of the tube shall be checked for compliance with the requirements of clause 7.

The tolerance on diameter is normally measured across the diameter but, for a tube where $D \geqslant 406$ mm, this tolerance may be measured by a circumference tape. 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 on the tube ends.

9.3.3 Leak tightness testing

Every tube shall be submitted to a leak tightness test.

9.3.4 Non-destructive testing

Every tube shall be subjected to a non-destructive test of the weld seam, see 11.8.1. All tubes of test category II shall be submitted to a non-destructive test for the detection of laminations in the tube body and at the tube ends, see 11.8.2.

9.4 Material identification

Each alloy steel tube shall be tested using an appropriate method in order to ensure that the correct grade has been supplied.

10 Samples

10.1 Frequency of tests

10.1.1 General

For products supplied according to this part of ISO 9330 the verification of mechanical properties and product analysis, if applicable, shall be carried out by test units. A test unit is defined as tubes of the same steel grade, the same cast, the same manufacturing process (using the same type of filler wires), the same nominal dimensions and, if applicable, subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch-type furnace.

The number of tubes per test unit shall comply with the parameters given in Table 10.

Table 10 — Number of tubes per test unit

Outside diameter range	Number of tubes per test unit [a]	
	Category I	Category II
$D \leqslant 114{,}3$	400	200
$114{,}3 < D \leqslant 323{,}9$	200	100
$323{,}9 < D$	100	50

[a] Any residual fraction of the test unit is considered as a test unit.

10.1.2 Number of samples per test unit

The number of samples sufficient for the preparation of the tests specified in 10.1.3 shall be:

— one sample tube per test unit for test category I;

— two samples tube per test unit for test category II;

— for test units with less than 20 tubes only one sample is required.

10.1.3 Type and number of tests

The following tests shall be carried on each sample:

a) one tensile test on the tube body, see 11.2;

b) one tensile test on the weld for tubes with outside diameter $\geqslant$ 508 mm. Weld tensile tests are not carried out on tubes of outside diameter $\leqslant$ 219 mm. Tests for tubes of diameter > 219 mm but < 508 mm shall be agreed at the time of enquiry and order, see 11.3;

c) two weld bend tests, see 11.5;

d) one set of three impact tests on the tube body when required, see 11.6;

e) one product analysis when required, see 11.1;

f) one elevated temperature tensile test on the tube body when required, see 11.4.

10.2 Preparation of samples and test pieces

10.2.1 Selection and preparation of samples for chemical analysis

Samples for product analysis shall be taken from the test pieces or samples for mechanical testing or from the whole thickness of the tube at the same location as for the mechanical test samples, in accordance with ISO 14284.

10.2.2 Location, orientation and preparation of samples for mechanical tests

10.2.2.1 General

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

10.2.2.2 Tensile test pieces on the tube body

The test pieces shall be taken at a distance from the weld and heat affected zone in a direction transverse to the axis of the tube in accordance with the requirements of ISO 6892. At the discretion of the manufacturer the test pieces may be taken in the longitudinal direction.

10.2.2.3 Tensile test pieces on the weld

The test piece shall be a strip section taken transverse to the weld with weld at the centre of the test piece and shall represent the full wall thickness of the pipe from which the specimen was cut. Weld reinforcement may be removed at the discretion of the manufacturer.

10.2.2.4 Elevated temperature tensile lest

The test piece shall be taken adjacent to the test piece used for the tensile test at room temperature and prepared in accordance with ISO 783.

10.2.2.5 Bend test pieces on the weld

The test pieces shall be in accordance with ISO 5173 for root and face bend tests and ISO 5177 for transverse side bend tests with the weld at the centre of the test piece.

For tubes having a thickness $\leqslant$ 20 mm, one face bend and one root bend shall be carried out on test pieces not less than 40 mm wide.

For tubes having a thickness $>$ 20 mm, one face bend and one root bend test or alternatively, and at the manufacturer's discretion, two side bend tests shall be carried out.

The face and root bend test pieces shall be machined from a circumferential strip to a rectangular section nominally 40 mm wide $\times$ 20 mm thick. The side bend test pieces shall be machined to a rectangular section nominally 10 mm wide $\times$ 20 mm thick.

10.2.2.6 Impact test pieces

The test pieces shall be taken from the tube body transverse to the tube axis and shall be V-notch test pieces in accordance with ISO 148. The axis of the notch shall be perpendicular to the surface of the tube.

Flattening of the tube to provide the test piece is not permitted.

11 Test methods and results

11.1 Chemical analysis

The elements to be determined and reported shall be those given in Table 3. The choice of a suitable physical or chemical analytical method for the analysis shall be at the discretion of the manufacturer. In case of dispute the method used shall be agreed upon taking into account the relevant existing ISO standards.

11.2 Tensile test pieces on the tube body

The tests shall be carried out at room temperature in accordance with ISO 6892 in order to determine the following:

a) tensile strength (R_m);

b) upper yield strength (R_{eH}) for the specified yield strength in Table 5;

c) if a yield phenomenon is not present, the 0,2 % proof strength ($R_{p0,2}$) or the 0,5 % total extension ($R_{t0,5}$) shall be determined. In cases of dispute, the 0,2 % proof strength ($R_{p0,2}$) shall apply;

d) percentage elongation after fracture, with reference to a gauge length of 5,65 S_o. If other gauge lengths are used, the percentage elongation value for a length L_o = 5,65 S_o using the conversion tables given in ISO 2566-1;

where

L_o is the original gauge length;

S_o is the original crosss-sectional area of the parallel test piece.

See clause 4 of ISO 6892:1998.

11.3 Tensile tests on the tube weld

The test shall be carried out at room temperature in accordance with ISO 6892 in order to determine the following:

a) tensile strength (R_m).

11.4 Elevated temperature tensile tests

If specified at the time of enquiry and order the test shall be carried out in accordance with ISO 783 at a temperature selected by the purchaser from Table 6 and which is also specified at the time of enquiry and order. The following is determined:

a) 0,2 % proof strength ($R_{p0,2}$).

11.5 Bend tests

The tests shall be carried out in accordance with ISO 7438 using a mandrel of a diameter in accordance with the parameters given in Table 5. Tests shall be carried out to an angle of 120° and after testing the following requirement shall be met:

a) the test piece shall show no cracks or flaws, but slight premature failure at the edges shall not be considered cause for rejection.

11.6 Impact tests

If specified at the time of enquiry and order the test shall be carried out at room temperature in accordance with ISO 148. The mean value of the three test pieces shall be taken, and shall meet the minimum average value given in Table 5 subject to the following:

a) only one individual value may be below the specified minimum average value and then only up to a maximum of 30 % below;

b) if the above criteria are not met the second set of test pieces shall be prepared and tested in accordance with ISO 148 and the six tests shall meet the following requirements:

   1) the mean value of the six tests shall meet the specified minimum average value given in Table 5;

   2) two of the six values may fall below the specified minimum value but only one by more than 30 %.

11.7 Leak tightness test

The leak tightness tests are carried out hydraulically and the test pressure is defined by the following equation:

$$p_E = 20\frac{\sigma \times T}{D}$$

where:

p_E is the test pressure in bar;

D is the specified outside diameter in millimetres;

T is the specified thickness in millimetres;

σ is the the stress, in newtons per square millimetre, corresponding to 80 % of the specified minimum value of the yield strength, see Table 5.

The test shall be carried out at the pressure p_E or 80 bar whichever is the lower.

The test pressure shall be maintained for not less than 10 s for any leakage to be observed.

11.8 Non-destructive testing

11.8.1 Non-destructive testing of the weld

The ultrasonic testing shall be carried out to acceptance level 3 in accordance with ISO 9765:1990 or, at the manufacturer's discretion, radiographic testing to image quality class R2 in accordance with ISO 12096:1996 shall be used. Acceptance limits are given in 11.9.

11.8.2 Non destructive test for laminations

11.8.2.1 Ultrasonic non-destructive testing for laminations in the tube body shall be carried out in accordance with ISO 12094. The acceptance level shall be agreed at the time of enquiry and order.

11.8.2.2 Ultrasonic non-destructive testing for laminations at the tube ends shall be carried out in accordance with ISO 11496.

11.9 Radiographic acceptance limits

Any one of the following imperfections shall be judged unacceptable:

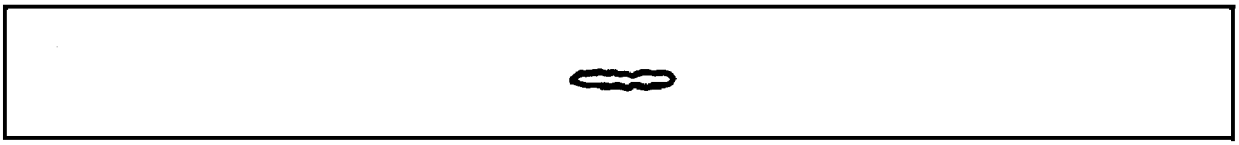
a) cracks, lack of penetration, lack of fusion as indicated by radiographic examination;

b) slag inclusions or gas pocket discontinuities of a size and distribution that exceed those given in Tables 11 and 12.

Table 11 — Elongated slag inclusion type discontinuities (see Figure 1)

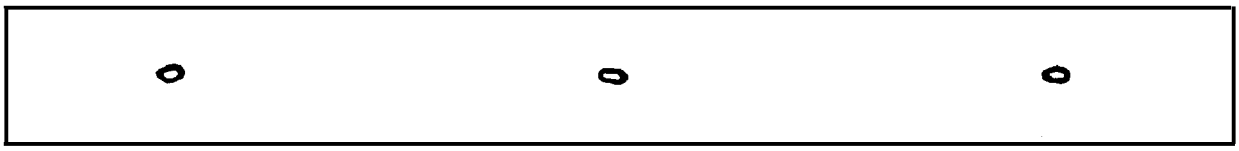
Maximum dimensions mm	**Minimum separation** mm	**Maximum number in any 150 mm** [a]
1,5 × 10	150	1
1,5 × 5	75	2
1,5 × 3	50	3

[a] The maximum accumulated length of elongated slag discontinuities in any 150 mm shall not exceed 10 mm.



Example 1: one 10 mm discontinuity

Example 2: two 5 mm discontinuities



Example 3: three 3 mm discontinuities

Figure 1 — Examples of maximum distribution patterns of indicated elongated slag inclusion type discontinuities

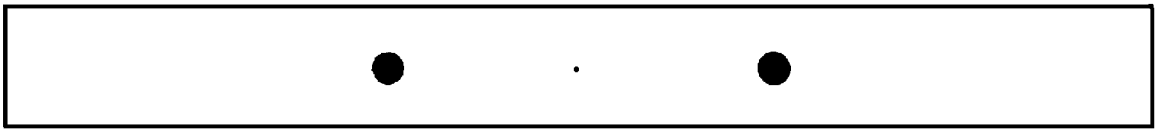
Table 12 — Circular slag inclusion and gas pocket type discontinuities (see Figure 2)

Size of discontinuity mm	Adjacent size mm	Minimum separation [a] mm
3[b]	3	50
3[b]	1,5	25
3[b]	1	12
3[b]	0,5	10
1,5	1,5	12
1,5	1	10
1,5	0,5	5
1	1	5[c]
1	0,5	5[c]
0,5	0,5	3[c]

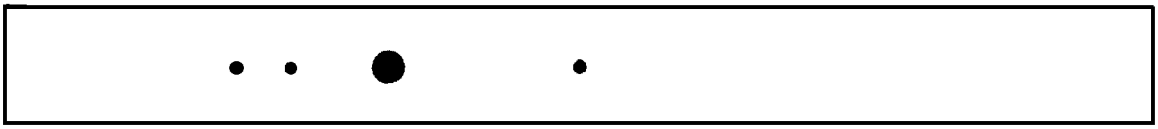
[a] The sum of the diameters of all discontinuities in any 150 mm shall not exceed 6,5 mm.

[b] The maximum size of circular slag discontinuity for thicknesses of 6,5 mm and smaller shall be 2,5 mm.

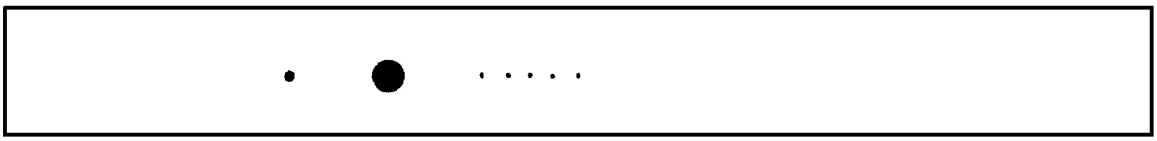
[c] Two discontinuities 1 mm or smaller may be as close as one diameter apart provided that they are separated from any other discontinuity by at least 10 mm.



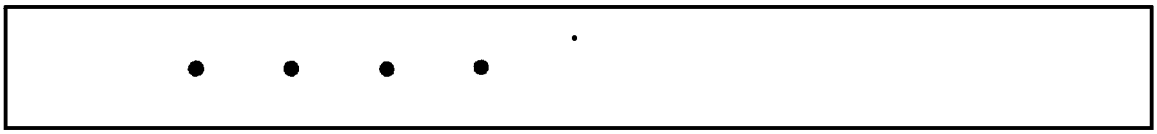
Example 1: two 3 mm, one 0,5 mm discontinuities



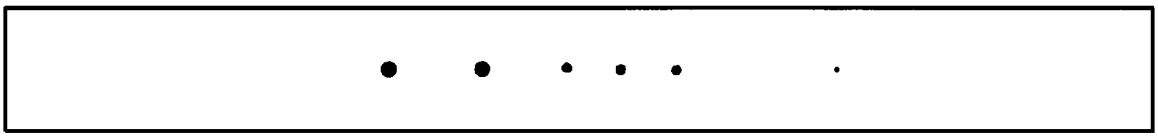
Example 2: one 3 mm, one 1,5 mm, two 1,0 mm discontinuities



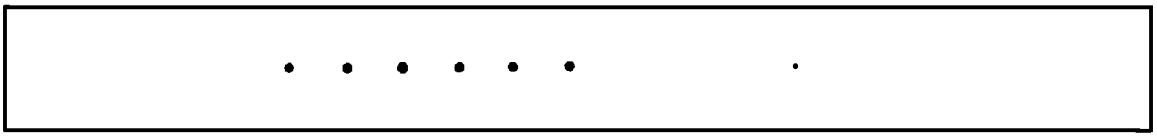
Example 3: one 3 mm, one 1 mm, five 0,5 mm discontinuities



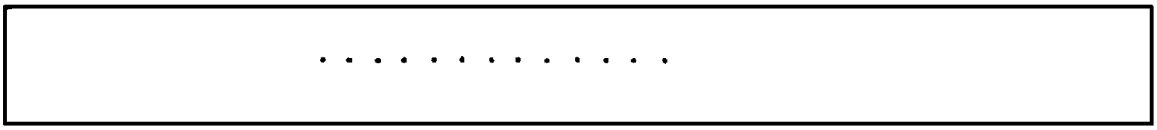
Example 4: four 1,5 mm, one 0,5 mm discontinuities



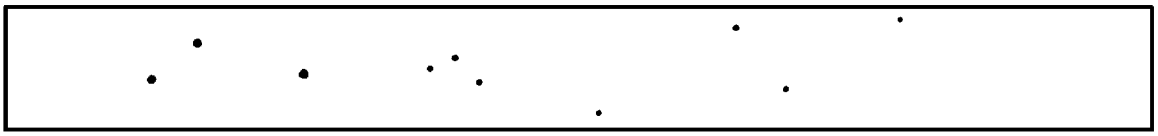
Example 5: two 1,5 mm, three 1 mm, one 0,5 mm discontinuities



Example 6: six 1 mm, one 0,5 mm discontinuities



Example 7: thirteen 0,5 mm discontinuities



Example 8: three 1 mm, seven 0,5 mm discontinuities (scattered)

Figure 2 — Examples of maximum distribution patterns of indicated circular slag inclusion and gas pocket type discontinuities

11.10 Invalidation of the tests

See ISO 404.

11.11 Retest

See ISO 404.

11.12 Sorting or reprocessing

See ISO 404.

12 Marking

12.1 Marking to be applied

The following shall be marked indelibly on each tube at one end:

a) reference to this part of ISO 9330, i.e. ISO 9330-4;

b) the mark of the manufacturer of the tubes;

c) the designation of the steel grade;

d) the heat number or a code number (only for test category II);

e) the designation of the test category for unalloyed steels;

f) the mark of the inspector;

g) a number or mark by which the tubes can be identified with the inspection document.

12.2 Methods

The symbols indicated in 12.1 shall be marked on each tube, at a distance of approximately 300 mm from one end.

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

12.3 Specific marking

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

13 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 on the enquiry and order.

14 Documents

Documents issued shall be in accordance with 9.2.

Annex A
(informative)

Long term rupture values

Table A.1 — Long term stress rupture values at elevated temperatures

Steel grade		Heat treatment	Rupture time [a] *h*	Estimated average long term stresses for rupture [b] R (N/mm^2)																							
				Temperature °C																							
				380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610
Unalloyed steel	PH 23 PH 26	N	10 000	213	197	181	166	151	138	125	112	100	19	78	67	67											
			30 000	192	176	161	147	133	120	107	95	84	73	63	52	42											
			50 000	183	167	152	138	125	112	100	88	77	66	56	46	(35)											
			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)	(4)	29												
			200 000	(159)	(144)	(130)	(116)	(104)	(92)	(80)	(69)	(58)	(48)	(37)	23												
			250 000	(155)	(140)	(126)	(113)	(101)	(891	(77)	(66)	(55)	(45)	(34)													
	PH 29 PH 35	N	10 000	291	266	243	221	200	180	161	143	126	110	96	84	74											
			30 000	262	237	214	192	171	151	132	115	99	86	74	65	57											
			50 000	248	223	200	177	156	136	118	102	87	75	65	57	50											
			100 000	227	203	179	157	136	117	100	85	73	63	55	(47)	(41)											
			150 000	215	190	167	144	124	105	89	76	65	56	(49)	(42)	(34)											
			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)												

[a] N = Normalizing; N+T = Normalizing + tempering.

[b] Values which involved extrapolation are indicated in parentheses.

Table A.1 — Long term stress rupture values at elevated temperatures *(continued)*

Steel grade		Heat treatment	Rupture time [a] *h*	Estimated average long term stresses for rupture [b] R (N/mm^2)																							
				Temperature °C																							
				380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610
Alloyed steel	16MO3	N	10 000								298	273	247	222	196	171	147	125	102	82	64						
			30 000								273	244	216	187	159	134	113	93	76	61	49						
			50 000								260	229	200	172	144	119	99	80	66	53	(42)						
			100 000								(239)	(208)	(170)	148	123	101	81	66	(53)	(42)							
			150 000								(226)	(197)	(168)	(139)	(114)	(91)	(74)	(60)	(48)								
			200 000								(217)	(188)	(159)	(130)	(105)	(84)	(69)	(55)	(45)								
			250 000								(210)	(180)	(151)	(124)	(100)	(80)	(65)	(52)	(42)								
	13CRrMo4-5	N + T	10 000											304	273	239	209	179	154	129	109	91	76	64	53	44	
			30 000											267	233	200	169	140	116	96	79	66	54	44	36	(29)	
			50 000											239	207	177	149	124	10)	82	68	55	45				
			100 000											210	177	146	121	99	81	67	54	43	35				
			150 000											(194)	(161)	(132)	(108)	(81)	71	57	46	38	(38)				
			200 000											(180)	(148)	(122)	(99)	(79)	(64)	(52)	(42)	(34)	(28)				
			250 000											(170)	(139)	(114)	(91)	(74)	(59)	(48)	(39)	(32)	(26)				
	11CrMo9-10	N + T	10 000								(309)	(285)	(263)	240	219	196	176	156	137	122	108	96	85	76	68	61	
			30 000								(276)	(254)	(233)	213	192	172	152	134	118	103	90	79	70	61	54	48	
			50 000								(257)	(236)	(217)	(197)	(177)	158	(139)	(123)	107	93	80	71	62	54	47	42	
			100 000								(221)	(204)	(186)	(170)	(153)	(137)	(122)	(107)	93	79	69	59	51	44	(38)	(34)	
			150 000								(209)	(192)	(175)	(159)	(141)	(126)	(110)	(95)	(82)	(73)	(63)	(54)	47	40	(35)	(30)	
			200 000								(203)	(186)	(169)	(152)	(135)	(119)	(103)	(89)	(77)	(68)	(58)	(50)	(43)	(37)	(32)	(28)	
			250 000								(198)	(181)	(164)	(147)	(130)	(113)	(98)	(84)	(74)	(64)	(55)	(47)	(41)	(35)	(30)	(26)	

[a] N = Normalizing; N+T = Normalizing + tempering.

[b] Values which involved extrapolation are indicated in parentheses.

ICS 23.040.10; 77.140.75

Price based on 25 pages