INTERNATIONAL STANDARD

ISO 4991

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Steel castings for pressure purposes

Pièces moulées en acier pour service sous pression

Reference number
ISO 4991:1994(E)

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 4991 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 11, *Steel castings*.

Annex A of this International Standard is for information only.

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Introduction

The national standards comparable with this International Standard are different not only in details but also in their basic technical concept, because of different codal requirements. In particular this applies to the following points.

a) Some national standards only specify the verification of mechanical properties for a 28 mm thick standard test block which has been heat treated under the same conditions as the casting, independent of the actual casting thickness. In these cases, the tensile test only checks the quality of the steel and heat treatment and not the actual casting properties. The influence of thickness on mechanical properties or thickness limitations for the use of the steels are considered in the design codes. Other national standards require the verification of mechanical properties on test blocks having the ruling thickness of the casting.

b) Some national standards specify an impact test for room temperature and elevated temperature grades. Others specify only the reduction of area determined by the tensile test.

c) Many national standards specify minimum elevated temperature proof-stress values for the elevated temperature grades. Others consider the influence of the elevated temperature in the design rules.

In order to make this International Standard acceptable for a sufficient number of ISO member bodies, it was necessary to give supplementary or alternative requirements.

It is expected that the attempts to harmonize the codes for boilers and pressure vessels will make a future revision of this International Standard more consistent when considering the material requirements for steel castings.

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Steel castings for pressure purposes

1 Scope

1.1 This International Standard covers steel castings used for pressure purposes. It includes materials which are used for the manufacture of components subject to pressure vessel codes (see ISO/R 831, ISO 2694 and ISO 5730) and for other pressure containing components not subject to codal requirements.

1.2 In cases where castings are produced by welding together component parts, this International Standard does not cover the welding process or the properties of the weldment.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard 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 783:1989, *Metallic materials — Tensile testing at elevated temperature.*

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

ISO 2605-1:1976, *Steel products for pressure purposes — Derivation and verification of elevated temperature properties — Part 1: Yield or proof stress of carbon and low alloy steel products.*

ISO 2605-2:1976, *Steel products for pressure purposes — Derivation and verification of elevated temperature properties — Part 2: Proof stress of austenitic steel products.*

ISO 2694:—[1], *Pressure vessels.*

ISO 4990:1986, *Steel castings — General technical delivery requirements.*

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

3 General delivery requirements

Unless otherwise specified in this International Standard, materials supplied according to this International Standard shall conform to the requirements of ISO 4990.

4 Ordering

In addition to the indications for ordering given in ISO 4990, the following is to be observed.

Alternative delivery conditions are covered by 5.2, 8.2, 9.1.2, 9.2.2.1 and 10.1. If the purchaser cannot leave the choice between the different conditions to the manufacturer, he shall indicate the required conditions in the enquiry and order.

5 Conditions of manufacture

5.1 Steelmaking process

The steel shall be produced by the open hearth or electric process, or one of the basic oxygen processes and this may be followed by separate degassing or refining.

1) To be published.

5.2 Heat treatment

5.2.1 The type of heat treatment shall be as indicated in table 1. Where more than one type of heat treatment is given for the grade ordered, the choice is left to the discretion of the manufacturer, unless otherwise specified by the purchaser.

5.2.2 The heat-treatment temperatures shall be as indicated in table 1.

Unless otherwise agreed, alternative temperatures are permitted, provided that all specified property values are complied with.

5.3 Repairs

Cavities resulting from the removal of unacceptable discontinuities and repair welds (see note 1) shall be inspected according to the same non-destructive testing criteria as the relevant part of the casting.

NOTE 1 Within this International Standard, the term "repair welding" indicates welding operations which are carried out by the founder during the manufacturing process, in order to comply with the quality requirements of the casting.

6 Chemical composition

The steel shall conform to the chemical composition requirements given in table 1. (For check-analysis see footnote 2 to table 1.)

7 Mechanical properties

7.1 The mechanical properties of the 28 mm thick standard test block shall conform to the requirements given in table 1. (See the first note to table 1 and 9.6 of ISO 4990:1986.)

7.2 If material to be used at elevated temperatures is ordered, the proof-stress values given in table 3 apply.

7.3 Annex A gives guidance values for creep properties.

8 Surface quality and internal soundness

8.1 All castings shall be examined visually to verify the absence of feeder heads, adhering sand, scale, cracks and hot tears.

8.2 Additional surface and internal quality requirements may be specified by the purchaser. (See 6.2.3.1 and 6.2.3.2 of ISO 4990:1986.)

9 Testing and inspection

9.1 Certificates

9.1.1 Castings delivered according to this International Standard shall be supplied with an inspection certificate and shall consequently be specifically inspected and tested.

9.1.2 Unless an inspection certificate signed by the purchaser or the representative of a body named by him (ICP) is ordered, the inspection certificate signed by the representative of the qualified department of the works (IC) is to be delivered.

9.1.3 The inspection certificate shall include

a) the results of all elements specified in table 1, provided by the manufacturer;

b) the results of the mechanical tests required by 9.2.2;

c) a statement of the results of the visual inspection and dimensional checks;

d) if any additional tests and inspections were agreed upon, the results or statements of the results of these additional tests and inspections.

9.2 Mechanical tests

9.2.1 Formation of lots

9.2.1.1 In the case of castings weighing 1 000 kg or less, the delivery shall be subdivided into lots covering castings of the same type from the same cast having undergone the same heat treatment. (See 9.1 of ISO 4990:1986.)

The weight of a test lot shall not be greater than 5 000 kg.

9.2.1.2 In the case of castings weighing more than 1 000 kg, each individual casting shall be regarded as a test lot.

9.2.2 Test to be carried out

9.2.2.1 Steel used for castings shall conform to the mechanical property requirements given in table 1.

9.2.2.1.1 For the room temperature and elevated temperature grades, either area reduction or impact strength shall be determined and shall conform to the requirements prescribed for the grade in table 1. The

choice of test will be at the discretion of the manufacturer, unless the conditions of 11.3 or 11.5 are specified by the purchaser at the time of the order.

9.2.2.2 For the low temperature grades, three impact tests shall be carried out at the temperature indicated in table 1 and shall be evaluated in accordance with 6.2.2.3.2 of ISO 4990:1986.

9.2.2.3 If a verification of the elevated temperature proof-stress values is required, this may be carried out in accordance with supplementary requirements 11.6 or 11.7.

10 Marking

10.1 If not otherwise agreed at the time of inquiry and order, the castings shall be legibly marked to show

a) the symbols of the manufacturer;

b) symbols, letters or numbers which relate the certificated test, test pieces and products to each other.

10.2 Except as indicated in 10.3, the identification marks shall be stamped or cast on each piece in a location and a manner to be designated by the purchaser.

10.3 Small castings may be batched and the identification marks stamped on the label attached to each batch.

11 Supplementary requirements

11.1 General

Additional supplementary requirements suitable for use with the specifications of this International Standard, at the option of the purchaser, are described below. One or more of the supplementary requirements indicated below may be included in the purchaser's order or contract. When so included, a supplementary requirement shall be as important as the body of the specification. Details of supplementary requirements which are not fully described shall be agreed upon by the purchaser and the supplier.

11.2 List of optional supplementary requirements

A list of standardized supplementary requirements to be used at the option of the purchaser is described in ISO 4990. Those which are considered suitable for use with the specification are listed below, by title only.

From ISO 4990:1986

9.1.2 Reporting of the steel making process

9.1.3 Agreed manufacturing procedure

9.1.4 Dividing up the cast

9.1.6 Mass and tolerance on mass

9.3 Chemical analysis for residual elements

9.4.4.2 Lateral expansion

9.4.4.3 Percentage of shear area

9.6.1 Test blocks representative of the castings

If test blocks with the ruling thickness T of the casting are ordered, instead of the 28 mm thick standard test blocks, or if the test pieces are to be taken from the casting, and if in these cases heat-treatment conditions are, within the limits given in table 1, left to the discretion of the manufacturer, the mechanical properties given in table 1 shall apply up to the ruling thickness given in table 2.

9.7.2 Details of the treatment

9.8.1 Prior agreement relating to major repair welds

9.8.2 Weld maps (sketches)

9.9.1 Liquid penetrant inspection

9.9.2 Magnetic particle inspection

9.9.3 Radiographic inspection

9.9.4 Ultrasonic inspection

9.10.1 Intergranular corrosion test

9.10.3 Pressure-tightness

11.3 Measurement of the reduction in area

The minimum values for the reduction in area given in table 1 are mandatory.

11.4 Test on samples with additional heat treatment

One additional sample per test lot, selected and prepared as described in 9.2, shall be subjected to an additional heat treatment and to the same tests as the samples which have not undergone the additional

heat treatment. The details of the additional heat treatment and the properties to be obtained shall be agreed upon by the parties concerned at the time of enquiry and order.

11.5 Measurement of the impact energy at room temperature

The minimum values for the impact energy at room temperature given in table 1 are mandatory.

11.6 Verification of the elevated temperature proof-stress properties by specific testing acceptance tests

The proof-stress properties shall be verified by specific tests to be carried out in accordance with ISO 783 at one of the temperatures given in table 1. The relevant temperature and, if 9.2.1 does not apply for these tests, the formation of lots shall be agreed upon by the interested parties.

11.7 Verification of the elevated temperature proof-stress properties by non-specific tests

The elevated temperature proof-stress properties shall be verified by the presentation of statistical assistance, preferably in accordance with ISO 2605-1 or ISO 2605-2.

11.8 Individual testing

Each individual casting shall be regarded as a separate test lot.

Table 1 — Chemical composition (cast analysis), mechanical properties at room temperature of the 28 mm thick reference test block in the heat-treated condition

Steel type designation	Chemical composition [% (m/m)][1), 2)]									Mechanical properties at room temperature[3)]							Heat treatment[5)]				
	C	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others	R_e[6)] min. N/mm²	R_m N/mm²	A min. %	Z[7)] min. %	KV[7), 4)] min. J	KV[3), 4)] at °C	KV[3), 4)] min. J	Symbol[8)]	Austenitizing temperature °C	Cooling condition[9)]	Tempering temperature °C	Cooling condition[9)]
Unalloyed steels																					
C23-45A	< 0,25	< 0,60	< 1,20	0,035	0,035	–	–	–	–	240	450 to 600	22	35	27	–		A N(+T) (Q+T)	890 to 980 890 to 980 890 to 980	f a l	– 600 to 700 600 to 700	–
C23-45AH	< 0,25	< 0,60	< 1,20	0,035	0,035	–	–	–	–	240	450 to 600	22	35	27	–		N(+T)[10)] Q+T	890 to 980 890 to 980	a l	600 to 700 600 to 700	a, f a, f
C23-45B	< 0,20	< 0,60	1,00 to 1,60	0,035	0,035	–	–	–	–	240	450 to 600	22	35	45	–		A N(+T) (Q+T)	890 to 980 890 to 980 890 to 980	f a l	– 600 to 700 600 to 700	– a, f a, f
C23-45BH	< 0,20	< 0,60	1,00 to 1,60	0,035	0,035	–	–	–	–	240	450 to 600	22	35	45	–		N(+T) Q+T	890 to 980 890 to 980	a l	600 to 700 600 to 700	a, f a, f
C23-45BL	< 0,20	< 0,60	1,00 to 1,60	0,030	0,030	–	–	–	–	240	450 to 600	22		–	– 40	27	(N+T) Q+T	890 to 980 890 to 980	a l	600 to 700 600 to 700	a, f a, f
C26-52	< 0,25 [11), 12)]	< 0,60	< 1,20 [11), 12)]	0,035	0,035	–	–	–	–	280	520[13)] to 670	18	30	35	–	–	A N(+T) (Q+T)	890 to 980 890 to 980 890 to 980	f a l	– 600 to 700 600 to 700	– a, f a, f
C26-52H	< 0,25 [11), 12)]	< 0,60	< 1,20 [11), 12)]	0,035	0,035	–	–	–	–	280	520[13)] to 670	18	30	35	–	–	N(+T)[10)] Q+T	890 to 980 890 to 980	a l	600 to 700 600 to 700	a, f a, f
C26-52L	< 0,25 [11)]	< 0,60	< 1,20 [11)]	0,030	0,030	–	–	–	–	280	520[13)] to 670	18		–	– 35	27	(N+T) Q+T	890 to 980 890 to 980	a l	600 to 700 600 to 700	a, f a, f
Alloyed ferritic and martensitic steels																					
C28H	0,15 to 0,23	0,30 to 0,60	0,50 to 1,00	0,035	0,035	< 0,30	0,40 to 0,60	–	–	250	450 to 600	21	35	25	–		N+T Q+T	900 to 960 900 to 960	a l	630 to 710 630 to 710	a, f a, f
C31L	< 0,29	0,30 to 0,60	0,50 to 0,80	0,030	0,030	0,90 to 1,20	0,15 to 0,30	–	–	370	550 to 700	16	30	–	– 45	27	(N+T) Q+T	850 to 910 850 to 910	a l	640 to 690 640 to 690	a, f a, f

Steel type designation	Chemical composition [% (m/m)][1), 2)]									Mechanical properties at room temperature[3)]							Heat treatment[5)]				
	C	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others	R_c[6)] min. N/mm²	R_m N/mm²	A min. %	Z[7)] min. %	KV[7), 4)] min. J	KV[3), 4)] at °C	KV[3), 4)] min. J	Symbol[8)]	Austenitizing temperature °C	Cooling condition[9)]	Tempering temperature °C	Cooling condition[9)]
Alloyed ferritic and martensitic steels																					
C32H	0,10 to 0,20[10)]	0,30 to 0,60	0,50 to 0,80	0,035	0,035	1,00 to 1,50	0,45 to 0,65	—	—	290	490 to 640	18	35	27	—	—	N+T Q+T	900 to 960 900 to 960	a l	650 to 720 650 to 720	a, f a, f
C33H	0,10 to 0,17	0,30 to 0,60	0,40 to 0,70	0,035	0,035	0,30 to 0,60	0,40 to 0,60	≤ 0,40	V: 0,22 to 0,32	320	500 to 650	17	30	13	—	—	N+T	950 to 1 000	a	680 to 750	a, f
C34AH	0,08 to 0,15	0,30 to 0,60	0,50 to 0,80	0,035	0,035	2,00 to 2,50	0,90 to 1,20	—	—	280	510 to 660	18	35	25	—	—	N+T	930 to 970	a	680 to 750	a, f
C34BH	0,13 to 0,20	0,30 to 0,60	0,50 to 0,80	0,035	0,035	2,00 to 2,50	0,90 to 1,20	—	—	390	600 to 750	18	35	40	—	—	(N+T) N_{ac}+T Q+T	930 to 970 930 to 970 930 to 970	a ac l	680 to 750 680 to 750 680 to 750	a, f a, f a, f
C34BL	≤ 0,20	0,30 to 0,60	0,50 to 0,80	0,030	0,030	2,00 to 2,50	0,90 to 1,20	—	—	390	600 to 750	18	—	—	50	27	(N+T) (N_{ac}+T) Q+T	930 to 970 930 to 970 930 to 970	a ac l	680 to 750 680 to 750 680 to 750	a, f a, f a, f
C35BH	0,13 to 0,20	0,30 to 0,60	0,50 to 0,80	0,035	0,035	1,20 to 1,60[14)]	0,90 to 1,20	[15)]	V: 0,15 to 0,35	420	590 to 740	15	35	24	—	—	N_{ac}+T Q+T	940 to 980 940 to 980	ac l	680 to 750 680 to 750	a, f a, f
C37H	0,12 to 0,19	≤ 0,80	0,50 to 0,80	0,035	0,035	4,00 to 6,00	0,45 to 0,65	—	—	420	630 to 780	16	35	25	—	—	N+T	930 to 990	a	620 to 750	a, f
C38H	0,10 to 0,17	≤ 0,80	0,50 to 0,80	0,035	0,035	8,00 to 10,0	1,00 to 1,30	—	—	420	630 to 780	16	35	20	—	—	N+T	930 to 990	a	620 to 750	a, f
C39CH	0,10 to 0,17	≤ 0,80	≤ 1,00	0,035	0,035	11,5 to 13,5	≤ 0,50	≤ 1,00	—	450	620 to 770	14	30	20	—	—	N+T	950 to 1 050	a	620 to 750	a
C39CNiH	0,05 to 0,10	≤ 0,80	0,40 to 0,80	0,035	0,035	11,5 to 13,0	0,20 to 0,50	0,80 to 1,80	—	360	540 to 690	18	35	35	—	—	N+T	1000 to 1050[16)]	a	650 to 720	a, f
C39NiH	≤ 0,08	≤ 1,00	≤ 1,50	0,035	0,035	11,5 to 13,5	≤ 1,00	3,50 to 5,00	—	550	750 to 900	15	35	45	—	—	N+T	950 to 1 050	a	570 to 620	a, f

Steel type designation	Chemical composition [% (m/m)][1), 2)]									Mechanical properties at room temperature[3)]							Heat treatment[5)]				
	C	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others	R_e[6)] min. N/mm²	R_m N/mm²	A min. %	Z[7)] min. %	KV[7),4)] min. J	KV[3),4)] at °C	KV[3),4)] min. J	Symbol[8)]	Austenitizing temperature °C	Cooling condition[9)]	Tempering temperature °C	Cooling condition[9)]
Alloyed ferritic and martensitic steels																					
C39NiL	≤ 0,08	≤ 1,00	≤ 1,50	0,030	0,030	11,5 to 13,5	≤ 1,00	3,50 to 5,00	—	550	750 to 900	15	—	—	−80	27	N_{ac} + T (N + T)	950 to 1 050 950 to 1 050	ac a	570 to 620 570 to 620	a, f a, f
C40H	0,20 to 0,26	0,20 to 0,40	0,50 to 0,70	0,035	0,035	11,3 to 12,3	1,00 to 1,20	0,70 to 1,00	V: 0,25 to 0,35	540	740 to 880	15	20	21[17)]	—	—	N + T	1 020 to 1 070	a	680 to 750	a, f
C43L	≤ 0,14	0,30 to 0,60	0,50 to 0,80	0,030	0,030	—	—	3,00 to 4,00	—	300	460 to 610	20	—	—	−70	27	Q + T	820 to 870	l	590 to 660	a[18)]
C43C1L	≤ 0,24	0,30 to 0,60	0,80 to 1,20	0,030	0,030	—	0,15 to 0,30	1,50 to 2,00	—	380	520 to 670	20	—	—	−35	27	Q + T	900 to 950	l	600 to 670	a[18)]
C43E2aL	≤ 0,22	≤ 0,60	0,40 to 0,80	0,030	0,030	1,35 to 2,00	0,35 to 0,60	2,50 to 3,50	—	450	620 to 800	16	—	—	−80	27	(N + T) N_{ac} + T Q + T	900 to 950 900 to 950 900 to 950	a ac l	580 to 650 580 to 650 580 to 650	a[18)] a[18)] a[18)]
C43E2bL	≤ 0,22	≤ 0,60	0,40 to 0,80	0,030	0,030	1,50 to 2,00	0,35 to 0,60	2,75 to 3,90	—	655	800 to 950	13	—	—	−60	27	(N + T) N_{ac} + T Q + T	900 to 950 900 to 950 900 to 950	a ac l	580 to 650 580 to 650 580 to 650	a[18)] a[18)] a[18)]
Austenitic stainless steels																					
C46	≤ 0,03	≤ 2,00	≤ 2,00	0,045	0,035	17,0 to 19,0	—	9,0 to 12,0	—	210	440 to 640	30	—	[19)]	—	—	S	1 040 to 1 100	l[20)]	—	—
C47	≤ 0,07	≤ 2,00	≤ 2,00	0,045	0,035	18,0 to 21,0	—	8,0 to 11,0	—	210	440 to 640	30	—	[19)]	—	—	S	1 040 to 1 100	l[20)]	—	—
C47H	0,04 to 0,10	≤ 2,00	≤ 2,00	0,045	0,035	18,0 to 21,0	—	8,0 to 12,0	—	230	470 to 670	30	—	[19)]	—	—	S	1 040 to 1 100	l[20)]	—	—
C47L	≤ 0,07	≤ 2,00	≤ 2,00	0,045	0,035	17,0 to 20,0	—	9,0 to 12,0	—	210	440 to 640	30	—	—	−195[21)]	45	S	1 040 to 1 100	l[20)]	—	—
C50	≤ 0,08	≤ 2,00	≤ 2,00	0,045	0,035	18,0 to 21,0	—	9,0 to 12,0	Nb: 8 × %C ≤ 1,0	210	440 to 640	25	—	[19)]	—	—	S	1 040 to 1 100	l[20)]	—	—
C57	≤ 0,03	≤ 2,00	≤ 2,00	0,045	0,035	17,0 to 21,0	2,0 to 2,5	9,0 to 13,0	—	210	440 to 620	30	—	[19)]	—	—	S	≥ 1 050	l[20)]		

Steel type designation	Chemical composition [% (m/m)][1), 2)]									Mechanical properties at room temperature[3)]								Heat treatment[5)]				
	C	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others	R_e[6)] min. N/mm²	R_m N/mm²	A min. %	Z[7)] min. %	KV[7), 4)] min. J	KV[3), 4)] at °C	KV[3), 4)] min. J		Symbol[8)]	Austenitizing temperature °C	Cooling condition[9)]	Tempering temperature °C	Cooling condition[9)]
Austenitic stainless steels																						
C60	< 0,07	< 2,00	< 2,00	0,045	0,035	17,0 to 21,0	2,0 to 2,5	9,0 to 13,0	—	210	440 to 640	30	—	[19)]	—	—		S	⩾ 1 050	[20)]	—	—
C60H	0,04 to 0,10	< 2,00	< 2,00	0,045	0,035	17,0 to 21,0	2,0 to 2,5	9,0 to 13,0	—	230	470 to 670	30	—	[19)]	—	—		S	⩾ 1 050	[20)]	—	—
C60Nb	< 0,08	< 2,00	< 2,00	0,045	0,035	17,0 to 21,0	2,0 to 2,5	9,0 to 13,0	Nb: 8 × %C ⩽ 1,0	210	440 to 640	25	—	[19)]	—	—		S	⩾ 1 050	[20)]	—	—
C61LC	< 0,03	< 2,00	< 2,00	0,045	0,035	17,0 to 21,0	2,5 to 3,0	9,0 to 13,0	—	210	440 to 640	30	—	[19)]	—	—		S	⩾ 1 050	[20)]	—	—
C61	< 0,07	< 2,00	< 2,00	0,045	0,035	17,0 to 21,0	2,5 to 3,0	9,0 to 13,0	—	210	440 to 640	30	—	[19)]		—		S	⩾ 1 050	[20)]	—	—

NOTES: See next page.

NOTES

The mechanical properties required are obtained from 28 mm thick standard test blocks, cast either separately, or attached to the casting that they represent. The test values so exhibited therefore represent the quality of steel from which the castings have been poured; they do not necessarily represent the properties of the casting themselves, which may be affected by solidification conditions and rate of cooling during heat treatment, which in turn are influenced by casting thickness, size and shape. If the thickness of the casting is considerably greater than 28 mm, the application of the supplementary requirement 9.6 of ISO 4990:1986 should be taken into consideration.

(See 11.2: text following 9.6.1 of ISO 4990:1986.)

1) Elements not quoted in this table shall not be intentionally added without the purchaser's agreement, other than for the purpose of finishing the heat treatment. For unalloyed steels, if not otherwise agreed, the following maximum values, in percentage, are applicable:

Cr	Mo	Ni	V	Cu	$\frac{Cr + Mo + Ni + V\ Cu}{100}$
0,40	0,15	0,40	0,03	0,40	

2) The permissible deviations for the results of check-analysis on test blocks shall be as specified in ISO 4990.

3) R_e: yield strength (see footnote 5);

R_m: tensile strength;

A: percentage elongation after fracture on original gauge-length

$L_o = 5{,}65\sqrt{S_o}$ (where S_o is the original cross-sectional area);

Z: reduction of area;

KV: ISO V-notch impact strength.

4) The given minimum values apply for the average of three individual test results. One of the three individual values may be below the specified minimum average value, provided it is not less than 70 % of that value.

5) See 5.2.

6) The values of R_e shall be regarded as complied with if, in the case of non-austenitic steels, the upper yield stress (R_{eH}), the 0,5 % total elongation proof stress ($R_{t0,5}$) or the 0,2 % proof stress ($R_{p0,2}$) satisfy the specified values.

For the austenitic steels, the value of R_e shall be regarded as complied with if the 0,2 % proof stress ($R_{p0,2}$) is not more than 30 N/mm^2 lower than the specified value.

7) The minimum values for either Z or KV apply. Unless otherwise specified, the choice is left to the manufacturer. However, the purchaser shall note that some national or ISO codes require the testing of impact specimens.

8) A: annealed (heated above Ac_3, furnace cool);
N: normalized (heated above Ac_3, cooled in air);
Q: quenched (heated above Ac_3, quenched in liquid);
T: tempered;
N_{ac}: (heated above Ac_3, accelerated air cooling);
S: solution treated;
Brackets indicate that the relevant treatment is only applied in special cases.

9) a: air; f: furnace; l: liquid quenching; ac: accelerated cooling in air.

10) For steels C23-45AH and C26-52H, the creep properties in annex A were only derived from test pieces in the condition N + T or Q + T.

For steel C32H, the creep properties annex A stem from casts with a specified carbon content of 0,15 % (m/m) to 0,20 % (m/m).

11) For each 0,01 % (m/m) C below the maximum carbon content, an increase of 0,04 % (m/m) Mn will be permitted up to a maximum manganese content of 1,40 % (m/m).

12) For certain applications and upon agreement at the time of enquiry and order, this grade of steel can be supplied with a maximum carbon content of 0,30 % (m/m) and a maximum manganese content of 0,90 % (m/m).

13) If the minimum yield strength R_e is met, tensile strength (R_m) values down to 500 N/mm^2 should be regarded as acceptable.

14) For castings with thin sections, a minimum value of 1,00 % (m/m) Cr may be agreed upon.

15) Depending on the wall thickness, a nickel content of less than 1,00 % (m/m) is permitted.

16) After cooling to less than 100 °C, intercritical heat treatment at 820 °C to 870 °C with subsequent cooling in air may be appropriate.

17) This type of steel is usually applied only at temperatures above 525 °C.

18) Liquid cooling is permitted, unless otherwise specified by the purchaser at the time of enquiry and order.

19) Austenitic steels normally have a high toughness because of their structure.

20) Depending on the thickness, accelerated air cooling may also be applicable.

21) Valid for an impact value of 45 J. Normally, this value is also to be expected for the room temperature grade. If, however, the low temperature grade is ordered, the value has to be verified by testing.

Table 2 — Maximum ruling thickness for table 1 when an alternative test block is used

Values in millimetres

Steel type designation	Ruling thickness
Unalloyed steels	
C23-45A	40
C23-45AH	40
C23-45B	40
C23-45BH	40
C23-45BL	40
C26-52	40
C26-52H	40
C26-52L	40
Alloyed ferritic and martensitic steels	
C28H	100
C31L	75
C32H	150
C33H	150
C34AH	150
C34BH	150
C34BL	100
C35BH	150
C37H	150
C38H	150
C39CH	300
C39CNiH	300
C39NiH	300
C39NiL	300
C40H	300
C43L	40
C43C1L	100
C43E2aL	100
C43E2bL	100
Austenitic steels	
C46	150
C47	150
C47H	150
C47L	150
C50	150
C57	150
C60	150
C60H	150
C60Nb	150
C61	150
C61LC	150

NOTES

1 It is not necessary to test a 28 mm thick test block, if a thicker test block is tested.

2 As the ruling thickness of a casting increases, it may be necessary to use a higher alloyed steel to attain the desired mechanical properties.

3 All the mechanical properties specified in table 1 apply to test blocks with a ruling thickness up to the value listed in this table. In addition, the R_e and R_m values and low temperature impact values for the low temperature grades, apply to test pieces taken from the actual casting, if this is agreed upon by the purchaser and manufacturer at the time of enquiry and order.

Table 3 — Minimum 0,2 % or 1,0 % proof stress ($R_{p0,2}$ or $R_{p1,0}$) values at elevated temperatures

Steel type designation	Reference heat treatment[1) 2)]	$R_{p0,2}$ or $R_{p1,0\ min.}$ [3)] (N/mm^2) Temperature (°C)											
		20	50[4)]	100	150	200	250	300	350	400	450	500	550
C23-45AH	N(+T), Q+T	240	235	215	195	175	160	145	140	135	130	—	—
C23-45BH	N(+T), Q+T	240	235	215	195	175	160	145	140	135	130	—	—
C26-52H	N(+T), Q+T	280	265	250	230	215	200	190	180	170	155	—	—
C28H	N+T, Q+T	250	240	230	215	205	185	170	160	155	150	140	—
C32H	N+T, Q+T	290	285	275	260	250	240	230	220	205	195	180	160
C34AH	N+T, (Q+T)	280	275	270	260	255	245	240	235	230	220	205	180
C34BH	N+T, (N_{ac} +T), Q+T	390	380	375	365	355	345	340	330	315	300	280	240
C35BH	N_{ac} +T, Q+T	420	410	400	395	385	375	365	350	335	320	300	260
C37H	N+T												
C38H	N+T	420	410	395	385	375	365	355	335	320	295	265	—
C39CH	N+T												
C39CNiH	N+T	360	335	305	285	275	270	265	260	255	—	—	—
C39NiH	N+T	550	535	515	500	485	470	455	440	—	—	—	—
C40H	N+T	540	510	480	460	450	440	430	410	390	370	340	290
C47H	Q	230	195	170	155	145	135	130	125	120	116	113	10
C60H	Q												

NOTE — Values are subject to revision when more data become available.

1) N: cooling in still air; Q: quenched; T: tempered; N_{ac}: accelerated air cooling. Brackets indicate that the relevant treatment is only applied in special cases.

2) For temperatures and cooling conditions, see table 1.

3) The values given for the steels C23-45AH to C40H are $R_{p0,2\ min.}$-values. The values for the austenitic steels C47H and C60H represent $R_{p1,0\ min.}$-values. The $R_{p0,2\ min.}$-values of the austenitic steels are 30 N/mm^2 lower than the $R_{p1,0\ min.}$-values.

4) Values at 50 °C have been obtained by interpolation and are included for design purposes only. They are not subject to verification.

Annex A
(informative)

Stress rupture properties at elevated temperatures

Steel type designation	Reference heat treatment[1), 2)]	Rupture time	Estimated average stresses for rupture[3)] (N/mm²) Temperature (°C)																							
		h	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600
C23-45AH and C23-45BH C26-52H	N + T Q + T	10 000	225	208	191	175	160	145	130	117	105	94	84	—	—	—	—	—	—	—	—	—	—
		30 000												—	—	—	—	—	—	—	—	—	—
		50 000												—	—	—	—	—	—	—	—	—	—
		100 000	177	157	138	121	105	90	78	68	59	53	50	—	—	—	—	—	—	—	—	—	—
		150 000												—	—	—	—	—	—	—	—	—	—
		200 000	(163)	(142)	(123)	(105)	(88)	(74)	(63)	(55)	(50)	(45)	(41)	—	—	—	—	—	—	—	—	—	—
		250 000												—	—	—	—	—	—	—	—	—	—
C28H	N + T Q + T	10 000	(360)	(346)	(330)	(312)	(293)	275	250	228	205	182	160	134	110	90	74	66	—	—	—	—	—
		30 000																	—	—	—	—	—
		50 000																	—	—	—	—	—
		100 000	(310)	(292)	(273)	(252)	(229)	205	180	157	132	108	85	68	54	43	35	30	—	—	—	—	—
		150 000																	—	—	—	—	—
		200 000	(290)	(271)	(251)	(229)	(206)	(180)	(156)	(131)	(109)	(88)	(70)	(54)	(41)	(32)	(26)	(23)	—	—	—	—	—
		250 000																	—	—	—	—	—
C32H[4)]	N + T Q + T	10 000	—	—	—	—	—	321	292	265	238	212	187	165	145	127	112	98	—	—	—	—	—
		30 000	—	—	—	—	—												—	—	—	—	—
		50 000	—	—	—	—	—												—	—	—	—	—
		100 000	—	—	—	—	—	244	214	186	160	137	117	98	83	70	61	55	—	—	—	—	—
		150 000	—	—	—	—	—												—	—	—	—	—
		200 000	—	—	—	—	—	222	191	163	138	116	96	80	67	56	49	44	—	—	—	—	—
		250 000	—	—	—	—	—												—	—	—	—	—
C33H	N + T	10 000																					
		30 000																					
		50 000																					
		100 000											[5)]										
		150 000																					
		200 000																					
		250 000																					
C34AH	N + T	10 000	—	—	—	—	—	281	261	241	221	201	182	163	147	133	121	110	96	85	76	68	61
		30 000	—	—	—	—	—	255	234	212	191	171	153	137	123	111	100	(88)	79	70	61	54	48
		50 000	—	—	—	—	—	242	220	198	176	157	140	125	113	101	89	80	71	62	54	47	42
		100 000	—	—	—	—	—	222	199	177	156	139	124	111	99	(85)	(79)	69	59	51	44	(38)	(34)
		150 000	—	—	—	—	—																
		200 000	—	—	—	—	—																
		250 000	—	—	—	—	—																
C34BH	N + T N_{ac} + T Q + T	10 000	404	374	348	324	302	282	262	242	224	206	188	170	152	136	120	106	93	81	72	63	58
		30 000																					
		50 000																					
		100 000	324	298	274	254	236	218	201	184	166	150	136	120	106	92	79	66	56	46	38	32	28
		150 000																					
		200 000	(304)	(278)	(256)	(236)	(218)	(200)	(183)	(166)	(151)	(134)	(120)	(104)	(90)	(76)	(64)	(52)	(42)	(34)	(28)	(24)	(22)
		250 000																					