INTERNATIONAL STANDARD 2604/IV

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Steel products for pressure purposes — Quality requirements — Part IV : Plates

Produits en acier pour appareils à pression — Spécifications de qualité
Partie IV : Tôles

First edition — 1975-05-01

UDC 669.14.018.452-41

Ref. No. ISO 2604/IV-1975 (E)

Descriptors : pressure equipment, metal plates, steels, specifications, chemical composition, mechanical properties, heat treatment, testing conditions.

Price based on 30 pages

FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up 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.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2604/IV (originally ISO/DIS 2607) was drawn up by Technical Committee ISO/TC 17, *Steel,* and circulated to the Member Bodies in October 1971.

It has been approved by the Member Bodies of the following countries :

Australia	France	Romania
Austria	Germany	South Africa, Rep. of
Belgium	Hungary	Spain
Bulgaria	India	Switzerland
Canada	Japan	Thailand
Czechoslovakia	Korea, Rep. of	Turkey
Denmark	Netherlands	United Kingdom
Egypt, Arab Rep. of	New Zealand	U.S.S.R.
Finland	Portugal	

The Member Bodies of the following countries expressed disapproval of the document on technical grounds :

Norway
Sweden
U.S.A.

Printed in Switzerland

Steel products for pressure purposes — Quality requirements — Part IV : Plates

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the quality requirements for plates of 3 to 100 mm thickness manufactured from the steel types listed in table 1, for pressure purposes.

2 REFERENCES

ISO 82, *Steel — Tensile testing.*

ISO/R 83, *Charpy impact test (U-notch) for steel.*

ISO/R 85, *Bend test for steel.*

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

ISO/R 205, *Determination of proof stress and proving test for steel at elevated temperatures.*

ISO/R 377, *Selection and preparation of samples and test pieces for wrought steel.*

ISO/R 404, *General technical delivery requirements for steel.*

ISO/R 643, *Micrographic determination of the austenitic grain size of steels.*

ISO/R 783, *Mechanical testing of steel at elevated temperatures — Determination of lower yield stress and proof stress and proving test.*

ISO 2566/I, *Steel — Conversion of elongation values — Part I : Carbon and low alloy steels.*

ISO 2605/I, *Steel products for pressure purposes — Derivation and verification of elevated temperature properties — Part I : Yield or proof stress of carbon and low alloy steel products.*[2]

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

ISO/DATA No. 1, *Summary of average stress rupture properties for wrought boiler and pressure vessel steels for times of 10 000 hours to 250 000 hours and master curves.*

3 GENERAL REQUIREMENTS

3.1 Information to be supplied by the purchaser

3.1.1 The purchaser shall state on his enquiry and order the requirements given below :

a) the plate dimensions and tolerances (see 3.7);

b) the steel type (see table 1);

c) the inspection procedures and type of documents (see 3.8, 3.13, 4.2 and 5.2).

3.1.2 Certain alternatives are permitted by this International Standard and the purchaser may also state on his enquiry and order his requirements as follows, but if no such statement is made supply will be at the option of the manufacturer :

d) the deoxidation practice (see 3.2.3);

e) if plates for hot-forming are required, the heat-treatment condition of supply (see 3.3.2 and 3.5.1.2);

f) if a product (check) analysis is required (see 3.4.2);

g) if additional mechanical tests are required (see 3.5.1.2);

h) any special requirements for freedom from defects (see 3.6.2);

i) the number of room temperature impact tests (1 or 3) required (see 3.10.1.6);

j) the details of non-destructive tests, if required (see 3.10.3 and 3.11.4);

k) if elevated temperature proof stress tests are required and if so, the testing temperature selected from table 3 (see 4.2.1);

l) if low temperature V-notch impact tests are required and, if so, the testing temperature selected from table 5 (see 5.2.3);

m) if a maximum copper content is required (see table 1, note 1).

1) At present at the stage of draft. (Revision of ISO/R 148.)

2) At present at the stage of draft.

3.2 Manufacture of the steel

3.2.1 Unless otherwise stated on the enquiry and order, the steelmaking process and the deoxidation practice within the provisions of 3.2.2, 3.2.3 and table 1 will be at the option of the steel manufacturer.

3.2.2 The steel shall be produced by the open hearth, electric or one of the basic oxygen processes. Other processes may be used by agreement between the interested parties[1]. If he so requests, the purchaser shall be informed of the steelmaking process used.

3.2.3 Deoxidation practice shall be as defined in table 1 for the steel type specified.

NOTE – ISO documents covering the use of plates for pressure purposes place additional limitations on deoxidation practice for certain applications. For such applications, the purchaser shall ensure that these limitations are stated on the enquiry and order.

3.3 Heat treatment

3.3.1 The plates shall be supplied in the heat-treated condition given in table 1 for the particular steel type ordered.

For the steel types P3 to P18, the application of controlled temperatures during and after rolling or forming may take the place of normalizing provided the specified properties are obtained.

3.3.2 By agreement between the interested parties the plates may be delivered in a condition other than the final heat-treated condition according to table 1, for example for hot-forming. Test samples shall be given a heat treatment complying with the requirements of table 1 (see 3.10.1.5) and the purchaser shall be informed of the actual heat treatment. Alternatively, see 3.5.1.2.

3.4 Chemical composition

3.4.1 *Ladle analysis*

The steel shall show on ladle analysis the composition given in table 1 appropriate to the steel types specified.

3.4.2 *Product analysis*

3.4.2.1 If a check analysis on the product is required, the permissible deviations given in table 2 shall apply to the ladle analysis specified in table 1 for samples taken from the standard position (see 3.4.2.2).

If a check analysis for acceptance purposes is required, this shall be stated on the enquiry and order.

3.4.2.2 If a check analysis on the product is required, the number of samples to be taken shall be agreed between the interested parties.

The samples shall be taken either from the test pieces used for the verification of the mechanical properties, or from drillings through the whole thickness of the plate at the same location, as for the mechanical test samples. The requirements of 3.2 and 3.3 of ISO/R 377, covering the method of selection and preparation of the samples for chemical analysis, shall apply.

3.4.3 *Cases of dispute*

In cases of dispute, the methods for chemical analysis shall be in accordance with the relevant ISO documents. If no ISO document is available, the method to be used shall be agreed between the interested parties.

3.5 Mechanical and technological properties

3.5.1 *Mechanical properties*

3.5.1.1 The mechanical properties at room temperature to be obtained on test pieces selected, prepared and tested in accordance with 3.10.1 and 3.11 are given in table 1.

3.5.1.2 If heat treatments different from, or additional to, the normal reference heat treatment are to be carried out after the delivery of the plates (which may have an adverse effect on the mechanical properties), the purchaser may require, at the time of enquiry and order, additional mechanical tests on additional samples which have been given heat treatments different from, or additional to, those in table 1. In this case the heat treatment of the samples and the mechanical properties to be obtained on them shall be agreed between the interested parties at the time of enquiry and order.

NOTES

1 The mechanical properties can be affected by heating or reheating during fabrication. Purchasers who intend to heat or reheat any of the steels are advised to discuss the application and proposed heating or reheating treatment with the supplier.

2 If the plates are hot-formed, they shall have the same mechanical properties as specified in this International Standard provided the steel has not been heated to more than 1 100 °C, and that, after forming, it has been cooled to a temperature below the transformation temperature and then normalized at the specified temperature.

However, the final normalizing may be omitted provided :

a) the hot-forming is done in one operation at the normalizing temperature;

b) if hot-forming is done in more than one operation, the plate is cooled to a temperature below the transformation temperature before the last operation, and this operation is then carried out at the normalizing temperature.

3.5.2 *Weldability*

The steels covered by this International Standard are generally regarded as being weldable. However, the general weldability of any of the steels, but especially of the steels with relatively high carbon content or relatively high alloy content, cannot be guaranteed as the behaviour of the steel

1) Such as the user, purchaser, and manufacturer of the equipment, the producer of the supplied construction material and the inspection and/or certifying authority.

during and after welding is dependent not only on the steel, but also on the welding conditions and the final use for which the steel is employed. Therefore, where appropriate, the welding procedure shall be agreed between the interested parties at the time of enquiry and order.

3.6 Surface condition and soundness

3.6.1 The plates shall have a workmanlike finish and shall be clean and free from surface and internal defects likely to have an adverse effect.

3.6.2 Any special requirements for freedom from defects shall be agreed between the interested parties at the time of the enquiry and order.

3.6.3 The requirements for surface defects, rectification and internal defects given in 8.1, 8.2 and 8.3 of ISO/R 404 shall apply.

3.6.4 Before delivery or submission for acceptance, the surface defects shall be removed by the supplier by grinding, provided that the final thickness complies with the minimum tolerance and that the resulting depression is properly smoothed off in relation to the remainder of the surface. If the thickness has to be reduced below the minimum accepted value, this repair shall be carried out only with the agreement of the user or his representative. Larger surface defects may, by agreement with the user or his representative, be repaired by grinding (possibly by chiselling), followed by welding and levelling of the weld. This operation shall be carried out under the following conditions :

a) The defects shall be completely eliminated before any filler metal is applied.

b) The total surface to be repaired shall not exceed 2 % of the surface area of the face of the plate in question.

c) The complete removal of the defects shall not reduce the thickness of the plate by more than 20 % of the nominal thickness.

d) It shall be verified that, after the total elimination of the defect, the two above conditions are complied with. Every facility shall be given to the accepting agent (or to the representative of the user) to enable him if necessary to carry out the same verification.

e) The repair shall be carried out by qualified welders accepted by the user or his delegate, using covered electrodes and following a procedure suitable for the composition of the steel used for the plate and further heat treatments. His procedure shall be accepted by the user (or his representative). The welds shall be sound, without discontinuity or break. The filler metal, which shall be completely melted and joined throughout to the base metal shall finally present an excess thickness of at least 1,5 mm. This excess shall then be levelled by grinding (possibly preceded by chiselling) to give the repaired plate a technically smooth and uniform surface.

f) An examination of the quality of the repair shall be carried out ultrasonically, magnetoscopically, by dye penetration or, where applicable, by radiography. The technique used for the examination and the qualification of the operator shall be agreed by the user or his representative.

g) For plate which has to be delivered in a heat-treated condition, the repair of the defects shall be carried out before the final test treatment.

h) In cases where plates are delivered untreated, repair by means of welding shall be followed by a post-weld heat treatment.

3.6.5 The position of repairs of defects shall be carefully marked and pointed out to the user. These marks shall be mentioned in the acceptance report.

3.7 Dimensions and tolerances

3.7.1 The dimensions of the plates shall be stated on the enquiry and order.

3.7.2 Until the relevant ISO documents are available, the tolerances on dimensions and mass shall be agreed between the interested parties and stated on the enquiry and order.

3.7.3 The requirements of 8.4 of ISO/R 404 shall apply.

3.8 Inspection procedures

The purchaser shall indicate on his enquiry and order which of the five inspection procedures listed in clause 4 of ISO/R 404 is to be followed.

NOTE – The inspection procedure selected shall, if appropriate, be compatible with the requirements of the ISO document covering the use of the product.

3.9 General rules for carrying out acceptance tests

The requirements of clause 5 of ISO/R 404 covering the following shall apply :

a) place of acceptance;

b) submission for inspection;

c) rights of the inspector;

d) acceptance.

3.10 Number, selection and preparation of samples and testpieces

3.10.1 *Mechanical tests at room temperature*

3.10.1.1 The requirements of 2.3 and 2.4 of ISO/R 377, covering the identification and preparation of samples and test pieces shall apply.

3.10.1.2 For plates not exceeding 5 000 kg in mass and 15 m in length, one test sample sufficient for the required test pieces shall be taken from one end of each plate as rolled[1] (see 3.10.1.6, 4.2 and 5.2).

3.10.1.3 For plates exceeding 5 000 kg in mass or 15 m in length, one test sample sufficient for the required test pieces (see 3.10.1.6, 4.2 and 5.2) shall be taken from each end of each plate as rolled[1].

3.10.1.4 The test samples shall be selected from a position halfway between the edge and the axis of the plate.

3.10.1.5 The test samples shall be cut from the plate after the final heat treatment. If the plates are to be delivered in a condition different from the specified final heat-treatment condition, the test samples shall be in the reference heat-treatment condition required by table 1

3.10.1.6 From each test sample, the following test pieces shall be prepared, with the axis of the test pieces at right angles to the direction of final rolling :

a) One tensile test piece – this shall be a rectangular-section test piece, with dimensions in accordance with the requirements of ISO 82. The width of the parallel portion shall not exceed 40 mm. The thickness shall be that of the plate, except that for plates over 30 mm thick, the thickness of the test piece may be reduced to 30 mm by planing or milling of one face only.

Alternatively, for plates over 30 mm thick, and by agreement between the interested parties, a proportional round test piece, having dimensions in accordance with the requirements of ISO 82 and with the axis located one-sixth of the thickness from the outer surface, may be used.

b) One bend test piece – this shall be of the dimensions specified in 4.1 and 4.2.2 of ISO/R 85, except that the test piece shall be of the full thickness of the plate for plates up to 30 mm thick. For plates over 30 mm thick, the thickness of the test piece may be reduced to 30 mm by machining on one face only.

c) One or, if specified on the order, three transverse ISO V-notch test pieces – these shall be of the dimensions specified in ISO 148 and shall be taken from a position close to one of the rolled surfaces. For plates thicker than 40 mm the axis of the test piece shall be one-quarter of the thickness from one of the rolled surfaces. The test piece shall not be closer than 25 mm from any flame-cut or sheared edge.

The axis of the notch shall be perpendicular to the rolled surface.

For plates with a thickness between 5 and 10 mm, the impact test pieces shall be reduced to test pieces of a width equal to the thickness of the plate. The impact strength values to be obtained, increased in proportion to the difference in cross-sectional area between the test piece used and a normal test piece, are the same as for normal test pieces.

NOTE – Until 31st December 1975, U-notch test pieces with dimensions as specified in ISO/R 83 may be used instead of V-notch specimens.

3.10.2 *Visual inspection*

Every plate shall be inspected.

3.10.3 *Non-destructive testing*

If non-destructive testing is required by the order, every plate shall be tested unless otherwise agreed between the interested parties.

3.11 Test methods and test results

3.11.1 *Tensile test at room temperature*

3.11.1.1 The tensile test shall be carried out in accordance with ISO 82.

3.11.1.2 The tensile strength R_m, the lower yield stress R_{eL} or proof stress R_p, and elongation A shall be determined. The results obtained shall meet the requirements given in table 1.

For acceptance purposes, the proof stress (total elongation) R_t may be determined. The 0,5 % proof stress (total elongation) $R_{t0,5}$ shall be used for ferritic steels having a specified lower yield stress R_{eL} or 0,2 % proof stress (non-proportional elongation) $R_{p0,2}$. The 1,0 % proof stress (total elongation) $R_{t1,0}$ should be used for austenitic steels having a specified 1,0 % proof stress (non-proportional elongation). However, in cases of dispute, the lower yield stress R_{eL}, or proof stress (non-proportional elongation) $R_{p0,2}$ ($R_{p1,0}$ for austenitic steels), shall be determined.

The percentage elongation shall be reported with reference to a $5{,}65\sqrt{S_o}$ gauge length. If other gauge lengths are used, the corresponding elongation on $5{,}65\sqrt{S_o}$ shall be obtained by reference to ISO 2566/I. In cases of dispute, a gauge length of $5{,}65\sqrt{S_o}$ shall be used.

3.11.2 *Bend test*

3.11.2.1 The bend test shall be carried out in accordance with ISO/R 85.

The test piece shall be bent through 180° to an internal diameter not exceeding that given in table 1.

If the test piece is reduced in thickness by machining (see 3.10.1.6), the remaining original rolled surface shall be placed in tension.

1) The term "plate as rolled" refers to the unit plate from a slab, or rolled directly from an ingot, in its relation to the location and number of specimens; not to its condition. If the plate is sheared or otherwise cut into smaller pieces after rolling, the tests made on test samples taken from the original plate shall govern.

3.11.2.2 The outer surface of the bent test piece shall not show any cracks or splits.

3.11.3 *Impact test at room temperature*

3.11.3.1 The V-notch impact test shall be carried out in accordance with ISO 148 and the U-notch impact test in accordance with ISO/R 83.

3.11.3.2 If one test piece is used, the value obtained shall meet the requirements given in table 1.

3.11.3.3 If three test pieces are used, the average value obtained shall meet the requirements given in table 1. One individual value may be below the specified value provided that it is not less than 70 % of that value.

3.11.4 *Non-destructive testing*

If non-destructive tests for internal soundness, by methods such as radiography, ultrasonics, magnetic particle detection, or dye penetrants, are required by the purchaser, this shall be the subject of agreement at the time of the enquiry and order. Any such agreement shall include details of the test procedure.

3.12 Retests

The requirements of 6.5 and 7.6 of ISO/R 404 shall apply except in the case of impact tests, where the average of the results on three test pieces is taken. In this latter case, the following procedure shall be used :

If the average of three impact values is lower than the specified value, or if any one value is lower than 70 % of this specified value, three additional test pieces shall be taken from the same sample and tested. The average value of the six tests shall be not less than the specified value. Not more than two of the individual values may be lower than the specified value and not more than one may be lower than 70 % of this value.

3.13 Documents

The purchaser shall state at the time of the enquiry and order which of the documents permitted by clause 4 of ISO/R 404 are to be provided (see also 3.8).

3.14 Marking

3.14.1 The plates shall be legibly marked to show :

a) the identification symbols for the type of steel, as given in table 1;

b) the brand of the manufacturer of the plates;

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

3.14.2 Unless the provisions of 3.14.4 are valid, the symbols, letters or numbers shall be stamped or painted on a corner of each plate such that they read in the direction of rolling.

3.14.3 If paint is used for marking, it shall be free of lead, copper, zinc and tin.

3.14.4 On plates which are bundled or boxed, the information in 3.14.1 may be marked on the box, or on a tag securely attached to the bundle or box in which they are shipped.

4 SPECIAL REQUIREMENTS FOR PLATES IN STEEL TYPES HAVING SPECIFIED ELEVATED TEMPERATURE PROPERTIES

4.1 Mechanical properties

4.1.1 For the steel types which have specified elevated temperature properties, the minimum elevated temperature proof stress values, derived in accordance with clause 2 of ISO 2605/I (in the case of austenitic steels, ISO 2605/II) are given in table 3.

4.1.2 For the same steel types, average stress rupture properties are given in table 4.

4.2 Verification and testing

4.2.1 *Elevated temperature proof stress*

4.2.1.1 The elevated temperature proof stress values shall be verified either by elevated temperature acceptance testing or by the procedure given in clause 3 of ISO 2605/I or, in the case of austenitic steels ISO 2605/II.

4.2.1.2 VERIFICATION BY ACCEPTANCE TESTS

One test shall be made on each cast using a test sample prepared in accordance with 3.10.1, and with the test piece taken at a position adjacent to one of the test pieces used for the tensile test at room temperature. If plates of more than one thickness are to be supplied from one cast, then the test shall be made on the thickest plate.

The proof stress tests at elevated temperature shall be carried out in accordance with ISO/R 205 or ISO/R 783 at a temperature selected from table 3 and agreed between the interested parties at the time of enquiry and order.

For retests, the requirements of 6.5 of ISO/R 404 shall apply.

4.2.1.3 VERIFICATION WITHOUT ACCEPTANCE TESTS

The elevated temperature proof stress values shall be verified by the procedure given in clause 3 of ISO 2605/I or, in the case of austenitic steels, ISO 2605/II. The 95 % lower confidence limits of the elevated temperature proof stress values which are necessary for the application of that procedure are given in figures 1 to 14 for the various steel types.

4.2.2 *Stress rupture properties*

For steel plates supplied to this International Standard, the average stress rupture properties at elevated temperatures given in table 4 are valid provided that :

a) the product has been manufactured strictly in accordance with the technical requirements of this International Standard, to ensure that the stress rupture requirements are complied with;

b) the producer of the steel supplies a statement to this effect, which shall be agreed by the interested parties.

5 SPECIAL REQUIREMENTS FOR PLATES IN STEEL TYPES HAVING SPECIFIED LOW TEMPERATURE PROPERTIES

5.1 Mechanical properties

For the steel types which have specified low temperature properties, the minimum longitudinal Charpy V-notch impact values are given in table 5 (see also 5.2.4).

5.2 Verification and testing

5.2.1 Tests shall only be carried out if so stated on the enquiry and order, and if the thickness of the plate is greater than or equal to 5 mm.

NOTE – International Standards covering the use of plates in the construction of pressure vessels include mandatory low temperature test requirements.

5.2.2 If low temperature impact tests are required, from one sample of each acceptance unit as specified in 3.10.1.2 and 3.10.1.3, three ISO V-notch test pieces shall be prepared in accordance with 3.10.1.6, except that longitudinal test pieces shall be taken.

5.2.3 The tests shall be carried out in accordance with ISO 148 at a temperature selected from table 5 and agreed between the interested parties at the time of enquiry and order.

5.2.4 The average value of the three tests shall meet the requirements given in table 5. One of the three individual values may be below the specified minimum average value of table 5 provided it is not less than 70 % of that value.

5.2.5 For retests the following procedure shall be used :

If the average of three impact values is lower than the specified value, or if any one value is lower than 70 % of this specified value, three additional test pieces shall be taken from the same sample and tested. The average value of the six tests shall be not less than the specified value. Not more than two of the individual values may be lower than the specified value, and not more than one may be lower than 70 % of this value.

TABLE 1 — **Chemical composition, mechanical properties at room temperature and heat treatments**

Steel No.	Chemical composition %[1,2]									Mechanical properties specified for		Mechanical properties at room temperature[11]								Heat treatment				
	C	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others[7]	low	high	Thickness	R_{eL} or $R_{p0,2}$[14] min.[18]	$R_{p1,0}$[14] min.	R_m	A min.	KCU min.	KV min.	Bend test D max.	Reference[12] heat treatment	Austenitizing or solution temperature	Cooling condition[17]	Tempering temperature	Cooling condition[17]
										temperature in table		mm	N/mm²	N/mm²	N/mm²	%	J	J			°C		°C	
P3R[3]	⩽ 0,17	–	0,40 – 1,00	0,050	0,050	–	–	–	N ⩽ 0,009		–	> 3 ⩽ 16	205		360 – 480	26	30		1*a*	N	900 – 940	a	–	–
P3[3]	⩽ 0,17	⩽ 0,35	0,40 – 1,00[5]	0,050	0,050				N⩽ 0,009[4] Al[16]	–	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	205 195 185 175	– – – –	360 – 480	26 26 25 24	30		1*a*	N	900 – 940	a		
P5	⩽ 0,17	⩽ 0,35	0,40 – 1,00[5]	0,040	0,040	–	–	–	Al_{met} ⩾ 0,015[6,7,8]	5	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	235 215 195 Note[13]	– – – –	360 – 480	26 26 25 24	30		1*a*	N	900 – 940	a	–	–
P7[3]	⩽ 0,20	⩽ 0,35	0,50 – 1,30	0,050	0,050	–	–	–	N ⩽ 0,009[4] Al[16]	–	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	235 225 215 205	– – – –	410 – 530	24 24 23 22	25		2*a*	N	890 – 930	a	–	–
P9	⩽ 0,20	⩽ 0,35	0,50 – 1,30	0,040	0,040	–	–	–	Al_{met} ⩾ 0,015[6,7,8]	5	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	265 245 235 Note[13]	– – – –	410 – 530	24 24 23 22	25		2*a*	N	890 – 930	a	–	–
P11	⩽ 0,20	⩽ 0,40	0,60 – 1,40[10]	0,050	0,050	–	–	–	N ⩽ 0,009[4] Al[16]	–	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	285 255 245 235	– – – –	460 – 580	22 22 21 20	20		2,5*a*	N	880 – 920	a	–	–
P13	⩽ 0,20[9]	⩽ 0,40	0,60 – 1,40[10]	0,040	0,040		–		Al_{met} ⩾ 0,015[6,7,8]	–	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	295 285 275 Note[13]	– – – –	460 – 580	22 22 21 20	20	VALUES UNDER CONSIDERATION	2,5*a*	N	880 – 920	a	–	–
P15	⩽ 0,20[9]	⩽ 0,40	0,60 – 1,50	0,040	0,040	–	–	–	Al_{met} ⩾ 0,015[6,7,8]	5		> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	295 285 275 Note[13]	– – – –	460 – 580	22 22 21 20	20		2,5*a*	N	880 – 920	a	–	–
P16	⩽ 0,20[9]	0,10 – 0,50	0,90 – 1,60	0,050	0,050	–	–	–	N ⩽ 0,009[4] Al[16]	–	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	305 275 265 255	– – – –	490 – 610	21 21 20 19	20		3*a*	N	880 – 920	a	–	–
P18	⩽ 0,20[9]	0,10 – 0,50	0,90 – 1,60	0,040	0,040	–	–		Al_{met} ⩾ 0,015[6,7,8]	5	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	315 315 305 Note[13]	– – – –	490 – 610	21 21 20 19	20		3*a*	N	880 – 920	a	–	–
P26	0,12 – 0,20	0,15 – 0,35	0,50 – 0,80	0,030	0,040	⩽ 0,30	0,25 – 0,35	–	Al_{met} ⩽ 0,012[7]	–	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	260 250 250 Note[13]	– – – –	440 – 590	24 24 23 22	30		3*a*	N (+ T)	900 – 940	a	(600 – 650)	(a)
P28	0,12 – 0,20	0,15 – 0,35	0,50 – 0,80	0,035	0,035	⩽ 0,30	0,40 – 0,60	–	Al_{met} ⩽ 0,012[7]	–	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	285 275 275 Note[13]	– – – –	450 – 600	23 23 22 21	30		3*a*	N (+ T)	900 – 940	a	(600 – 650)	(a)
P30	0,12 – 0,20	0,15 – 0,35	0,90 – 1,40	0,040	0,040	⩽ 0,30	0,40 – 0,60	–	Al_{met} ⩽ 0,012[7]	–	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	355 345 345 Note[13]	– – – –	510 – 660	21 21 20 19	30		3*a*	N (+ T)	880 – 930	a	(600 – 720)	(a)
P32	0,10 – 0,18	0,15 – 0,35	0,40 – 0,80	0,040	0,040	0,70 – 1,30	0,40 – 0,60	–	Al_{met} ⩽ 0,020[7]	–	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	305 305 305 Note[13]	– – – –	470 – 620	20 20 19 18	30		3*a*	N + T	900 – 950	a	630 – 700	a
P33	0,08 – 0,18	0,15 – 0,35	0,40 – 0,70	0,040	0,040	0,30 – 0,60	0,50 – 0,70		V = 0,22 – 0,35 Al_{met} ⩽ 0,020[7]	–	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	285 285 285 Note[13]	– – – –	460 – 610	19 19 19 19	30 30 30 25		3,5*a*	N + T	930 – 980	a	670 – 720	a
P34	0,08 – 0,18	0,15 – 0,50	0,40 – 0,80	0,040	0,040	2,00 – 2,50	0,90 – 1,10	–	Al_{met} ⩽ 0,020[7]	–	3, 4	> 3 ⩽ 16 > 16 ⩽ 40 > 40 ⩽ 63 > 63 ⩽ 100	275 265 265 Note[13]	– – – –	480 – 630	18 18 17 16	30 30 30 25		3*a*	N + T	900 – 950	a	650 – 720	a

TABLE 1 (*concluded*)

Steel No.	Chemical composition %[1,2]									Mechanical properties specified for		Mechanical properties at room temperature[11]								Heat treatment				
	C	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others[7]	low / high temperature in table		Thickness	R_{eL} or $R_{p0,2}$[14] min.[18]	$R_{p1,0}$[14] min.	R_m	A min.	KCU min.	KV min.	Bend test D max.	Reference[12] heat treatment	Austenitizing or solution temperature	Cooling condition [17]	Tempering temperature	Cooling condition [17]
												mm	N/mm²	N/mm²	N/mm²	%	J	J			°C		°C	
P41	≤ 0,18	0,15 – 0,35	≤ 0,80	0,035	0,035	–	–	1,30 – 1,70	–	5	–	≥ 3 ≤ 30 > 30 ≤ 50	275 265	–	490 – 640	22 21	25		2a	N N + T Q + T	850 – 880 850 – 880 850 – 880	a a o or w	– 600 – 690 600 – 690	– a or w a or w
P42	≤ 0,18	0,15 – 0,35	≤ 1,50	0 035	0,035	–	–	1,30 – 1,70	–	5	–	≥ 3 ≤ 30 > 30 ≤ 50	345 335	– –	490 – 640	22 21	25		2a	N	850 – 880	a	–	–
P43	≤ 0,15	0,15 – 0,35	≤ 0,80	0,035	0,035	–	–	3,25 – 3,75	–	5	–	≥ 3 ≤ 30 > 30 ≤ 50	275 265	– –	450 – 600	23 22	25		2a	N N + T	820 – 850 820 – 850	a a	– 580 – 630	– a or w
P44	≤ 0,18	0,15 – 0,35	≤ 0,80	0,035	0,035	–	–	3,25 – 3,75	–	5	–	≥ 3 ≤ 30 > 30 ≤ 50	345 335		460 – 610	22 21	30		2a	N + T Q + T	810 – 840 810 – 840	a o or w	580 – 630 580 – 630	a or w a or w
P45	≤ 0,10	0,15 – 0,35	≤ 0,80	0,035	0,035	–	–	8,50 – 10,0	–	5	–	≥ 3 ≤ 30 > 30 ≤ 50	495 485		690 – 840	19 18	30		3a	N + N + T Q + T	770 – 800[15] 770 – 800	a o or w	540 – 580 540 – 560	a or w a or w
P46	≤ 0,03	≤ 1,00	≤ 2,00	0,045	0 030	17,0 – 19,0	–	9,0 – 12,0	–	–	–	≥ 3 ≤ 30 > 30 ≤ 50	175 175	205 205	440 – 640	50 45	40		–	Q	1 000 – 1 050		–	–
P47	≤ 0,07	≤ 1,00	≤ 2,00	0,045	0,030	17,0 – 19,0	–	8,0 – 11,0	–	–	–	≥ 3 ≤ 30 > 30 ≤ 50	195 195	235 235	490 – 690	50 45	40		–	Q	1 000 – 1 050		–	–
P48	0,03 – 0,07	≤ 1,00	≤ 2,00	0,045	0,030	17,0 – 19,0	–	8,0 – 11,0	–	–	3, 4	≥ 3 ≤ 40 > 40 ≤ 63	195 195	235 235	490 – 690	50 45	40		–	Q	1 000 – 1 050		–	–
P49	≤ 0,07	≤ 1,00	≤ 2,00	0,045	0,030	17,0 – 19,0	≤ 0,50	9,0 – 11,5	–	5	–	≥ 3 ≤ 16	185	225	490 – 690	45	40	VALUES UNDER CONSIDERATION	–	Q	1 050 – 1 100		–	–
P50	≤ 0,08	≤ 1,00	≤ 2,00	0,045	0,030	17,0 – 19,0	–	9,0 – 12,0	Nb ≥ 10 % C ≤ 1,0	–	–	≥ 3 ≤ 40 > 40 ≤ 63	205 205	245 245	490 – 690	40 35	35		–	Q	1 020 – 1 070		–	–
P52	≤ 0,10	≤ 1,00	≤ 2,00	0,045	0,030	17,0 – 19,0	≤ 0,50	10,0 – 12,0	Nb ≥ 8 % C ≤ 1,0	5	–	≥ 3 ≤ 16	205	245	490 – 690	35	35		–	Q	1 020 – 1 070		–	–
P53	≤ 0,08	≤ 1,00	≤ 2,00	0,045	0,030	17,0 – 19,0	–	9,0 – 12,0	Ti ≥ 5 % C ≤ 0,80	–	–	≥ 3 ≤ 40 > 40 ≤ 63	195 195	235 235	490 – 690	40 35	35		–	Q	1 020 – 1 070		–	–
P55	≤ 0,10	≤ 1,00	≤ 2,00	0,045	0 030	17,0 – 19,0	≤ 0,50	10,0 – 12,0	Ti ≥ 5 % C ≤ 0,80	5	–	≥ 3 ≤ 16	195	235	490 – 690	35	35		–	Q	1 020 – 1 070		–	–
P56	0,04 – 0,10	0,30 – 0,60	≤ 1,50	0,045	0,030	15,0 – 17,0	–	12,0 – 14,0	Nb ≥ 10 % C ≤ 1,20	–	3, 4	≥ 3 ≤ 40 > 40 ≤ 63	205 205	245 245	490 – 690	35 30	35		–	Q	1 050 – 1 100	o, w, or rapidly in a	–	–
P57	≤ 0,03	≤ 1,00	≤ 2,00	0,045	0,030	16,0 – 18,5	2,0 – 2,5	11,0 – 14,0	–	–	–	≥ 3 ≤ 40 > 40 ≤ 63	185 185	215 215	440 – 640	45 40	40		–	Q	1 050 – 1 100		–	–
P58	≤ 0,03	≤ 1,00	≤ 2,00	0,045	0,030	16,0 – 18,5	2,5 – 3,0	11,5 – 14,5	–	–	–	≥ 3 ≤ 40 > 40 ≤ 63	185 185	215 215	440 – 640	45 40	40		–	Q	1 050 – 1 100		–	–
P60	≤ 0,07	≤ 1,00	≤ 2,00	0,045	0 030	16,0 – 18,5	2,0 – 2,5	10,5 – 14,0	–	–	–	≥ 3 ≤ 40 > 40 ≤ 63	205 205	245 245	490 – 690	45 40	40		–	Q	1 050 – 1 100		–	–
P61	≤ 0,07	≤ 1,00	≤ 2,00	0,045	0 030	16,0 – 18,5	2,5 – 3,0	11,0 – 14,5	–	–	–	≥ 3 ≤ 40 > 40 ≤ 63	205 205	245 245	490 – 690	45 40	40		–	Q	1 050 – 1 100		–	–
P63	0,03 – 0,07	≤ 1,00	≤ 2,00	0,045	0,030	16,0 – 18,5	2,0 – 2,5	10,5 – 14,0	–	–	3, 4	≥ 3 ≤ 40 > 40 ≤ 63	205 205	245 245	490 – 690	40 35	40		–	Q	1 020 – 1 070		–	–
P67	0,04 – 0,10	0,20 – 0,60	≤ 1,50	0,045	0,030	15,5 – 17,5	1,6 – 2,0	15,5 – 17,5	Nb ≥ 10 % C ≤ 1,20	–	3, 4	≥ 3 ≤ 40 > 40 ≤ 63	215 215	255 255	530 – 730	35 30	35		–	Q	1 050 – 1 100		–	–
P69	≤ 0,12	≤ 1,00	≤ 2,00	0,045	0 030	19,0 – 23,0	–	30,0 – 35,0	Al = 0,15 – 0,60 Ti = 0,15 – 0,50	–	3, 4	≥ 3 ≤ 40 > 40 ≤ 63	165 165	205 205	430 – 680	25 20	35		–	Q	1 050 – 1 150		–	–

NOTES TO TABLE 1

1) Elements not quoted in the table shall not be intentionally added without the agreement of the purchaser, other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition of such elements from scrap or other materials used in the manufacture, but residual elements may be present provided the mechanical properties and applicability are not adversely affected.

If the level of residual elements is important in relation to the properties or weldability of the steel, the cast (ladle) analysis for such elements shall be reported.

If the purchaser so requires, for reasons of formability etc., a maximum Cu content of 0,25 % may be imposed.

2) For permissible deviations on product (check) analysis, see table 2.

3) Steel P3R shall be rimmed, steels P3, P7 and P11 semi-killed or fully killed. All other steels shall be fully killed. See also note in 3.2.3.

4) For electric furnace steel, N ⩽ 0,012 %.

5) For steels P3 and P5, in thicknesses exceeding 40 mm, Mn = 0,40 to 1,20 %.

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

7) Where a maximum Al_{met} of 0,010 %, 0,012 % or 0,020 % is specified, determination of the total aluminium content, provided that it does not exceed the specified value, shall be deemed to meet this requirement.

Where a minimum Al_{met} of 0,015 % is specified, determination of the total aluminium content shall be deemed to meet this requirement, provided the total aluminium content value obtained is not less than 0,018 %.

In cases of dispute, the metallic aluminium content shall be determined.

8) Alternatively, an austenitic grain size of 6 or finer, determined in accordance with ISO/R 643, can be agreed.

9) For thicknesses > 30 mm but ⩽ 100 mm, C = 0,22 % max.

10) If the elevated temperature properties of table 4 are specified, the manganese content shall be 0,80 to 1,40 %.

11) R_{eL} = lower yield stress

$R_{p0,2}$ = 0,2 % proof stress (non-proportional elongation)

$R_{p1,0}$ = 1,0 % proof stress (non-proportional elongation)

R_m = tensile strength

A = percentage elongation after fracture on gauge length, $L_o = 5{,}65\sqrt{S_o}$

KCU = ISO U-notch impact strength

KV = ISO V-notch impact strength

D = maximum diameter of mandrel

a = thickness of test piece.

12) N = normalized, Q = quenched, T = tempered.

13) For thickness > 63 mm but ⩽ 100 mm, the values specified for the thickness range > 40 mm but ⩽ 63 mm are lowered by 1 % for each 5 mm of thickness over 63 mm.

14) For acceptance purposes, total elongation proof stress may be used (see 3.11.1.2).

15) Before this treatment, the material should be normalized as follows : 800 to 920 °C, air cooled.

16) If the elevated temperature properties of table 4 are specified, the Al_{met} content shall be ⩽ 0,010 %.

17) a = air, o = oil, w = water.

18) For design purposes, the values given in table 3 apply.

TABLE 2a) — **Permitted deviation from the specified composition for carbon and carbon-manganese steels**

Element	Maximum of specification range	Permissible deviation[1,2] from the specified composition
Carbon	⩽ 0,25	± 0,03
Silicon	⩽ 0,50	± 0,05
Manganese	⩽ 2,0	± 0,10
Sulphur specified max.	⩽ 0,050	+ 0,005
Phosphorus specified max.	⩽ 0,050	+ 0,005

TABLE 2b) — **Permitted deviation from the specified composition for low and medium alloy steels excluding manganese steels**

Element	Maximum of specification range	Permissible deviation[1,2] from the specified composition
Carbon	⩽ 0,25	± 0,03
Silicon	⩽ 0,50	± 0,05
Manganese	⩽ 2,0	± 0,10
Sulphur and Phosphorus specified max.	⩽ 0,050	+ 0,005
Nickel	⩽ 5,0 > 5,0 – 10,0	± 0,07 ± 0,10
Chromium	⩽ 2,5	± 0,10
Molybdenum	⩽ 0,35 > 0,35 – 1,5	± 0,04 ± 0,05
Vanadium	⩽ 0,35	± 0,03

TABLE 2c) — **Permitted deviation from the specified composition for high alloy and austenitic steels**

Element	Maximum of specification range	Permissible deviation[1,2] from the specified composition
Carbon	⩽ 0,03 > 0,03 – 0,25	± 0,005 ± 0,01
Manganese	⩽ 0,40 – 0,70 > 0,70 – 1,0 > 1,0 – 2,0	± 0,03 ± 0,04 ± 0,05
Silicon	⩽ 1,0	± 0,05
Sulphur and Phosphorus specified max.	⩽ 0,030 > 0,030 – 0,040 > 0,040 – 0,050	+ 0,003 + 0,004 + 0,005
Nickel	⩽ 1,0 > 1,0 – 2,0 > 2,0 – 5,0 > 5,0 – 10,0 > 10,0 – 20,0 > 20,0	± 0,03 ± 0,05 ± 0,07 ± 0,10 ± 0,15 ± 0,20
Chromium	⩽ 10,0 > 10,0 – 15,0 > 15,0 – 20,0 > 20,0	± 0,10 ± 0,15 ± 0,20 ± 0,20
Molybdenum	⩽ 1,0 > 1,0 – 2,0 > 2,0 – 3,0 > 3,0	± 0,04 ± 0,05 ± 0,08 ± 0,10
Titanium and Niobium	All ranges	± 0,05
Vanadium	⩽ 0,35	± 0,03

1) 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 cast. When maxima only are specified the deviations are positive only. The values are valid only if the samples were selected according to 3.4.2.2.

2) These values apply only to fully killed and semi-killed steels and shall be considered as provisional until more confident data are available.