

12

INTERNATIONAL STANDARD



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Steel products for pressure purposes – Quality requirements – Part I : Forgings

Produits en acier pour appareils à pression – Spécifications de qualité – Partie I : Pièces forgées

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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 2604/1 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	Germany	Romania
Austria	Hungary	South Africa, Rep. of
Belgium	India	Spain
Bulgaria	Israel	Switzerland
Canada	Italy	Thailand
Czechoslovakia	Japan	Turkey
Denmark	Korea, Rep. of	United Kingdom
Egypt, Arab Rep. of	Netherlands	U.S.S.R.
Finland	New Zealand	
France	Portugal	

ISO 2604-1:1975

Romania

South Africa, Rep. of

Spain

Switzerland

Thailand

Turkey

United Kingdom

U.S.S.R.

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

Norway
Sweden
U.S.A.

Steel products for pressure purposes – Quality requirements – Part I : Forgings

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the quality requirements for solid steel forgings up to 250 mm diameter or equivalent cross-section and hollow forgings with up to 200 mm wall thickness manufactured from the steel types listed in table 1, for pressure purposes.

NOTE – The term “forgings” used in this International Standard shall be understood to include flanges, fittings, covers, heads, component sections, or complete vessels intended for the containment of gaseous or liquid material under pressure.

2 REFERENCES

ISO 82, *Steel – Tensile testing.*

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 2566/1, *Steel – Conversion of elongation values – Part I : Carbon and low alloy steels.*

ISO 2605/1, *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 2605/11, *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.*

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

2) At present at the stage of draft.

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 forging dimensions, tolerances and surface finishes (see 3.7 and 3.8);

b) the steel type (see table 1);

c) the inspection procedures and type of documents (see 3.9, 3.14, 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 3.2.1);

e) heat-treatment condition of supply (see 3.4);

f) if a product (check) analysis is required (see 3.5.2);

g) if additional mechanical tests are required (see 3.6.1.2);

h) any special requirements for freedom from defects (see 3.7.2);

i) any special requirements regarding the method of providing samples and test pieces (see 3.11.1.2);

j) the number of room temperature impact tests (1 or 3) required (see 3.11.1.4 b));

k) details of non-destructive tests, if required (see 3.12.4);

l) any special marking requirements (see 3.15.2);

m) if elevated temperature proof stress tests are required and, if so, the testing temperature selected from table 3 (see 4.2.1.2);

- n) if low temperature V-notch impact tests are required and, if so, the testing temperature selected from table 5 (see 5.2.3);
- o) if a maximum copper content is required (see table 1, note 1);
- p) if a hydraulic test is required (see 3.11.3 and 3.12.3);
- q) if sectioning and etching for flow lines is required (see 3.11.5 and 3.12.5).

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 parties¹⁾. If he so requests, the purchaser shall be informed of the steelmaking process used.

3.2.3 The steel shall be fully killed.

3.3 Manufacture of the product

3.3.1 The steel shall be forged by hammering, drop-forging, pressing, extruding, ring rolling, upsetting or by any combination of these processes. The reduction shall be accomplished under a tool of sufficient power and shall be carried out to an extent to ensure ample working of the metal throughout its section. The forgings shall be brought as nearly as practicable to the finished shape and size by hot working.

3.3.2 After hot working and before heating for the heat treatment cycle prescribed in table 1, forgings of steels F8 to F45 shall be allowed to cool to a temperature below the transformation range in such a manner that no injury will result to the forging.

3.4 Heat treatment

3.4.1 The forgings shall be supplied in the heat-treated condition given in table 1 for the particular steel type ordered. Where more than one level of properties is specified in table 1 for a given steel type, the level required shall be stated on the enquiry and order.

3.4.2 By agreement between the interested parties, the forgings may be delivered in a condition other than the final heat-treated condition according to table 1. Test samples shall be given a heat treatment conforming with the requirements of table 1 (see 3.11.1.3) and the purchaser shall be informed of the test results and the actual heat treatment used. Additionally, see 3.6.1.2.

3.5 Chemical composition

3.5.1 Ladle analysis

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

3.5.2 Product analysis

3.5.2.1 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 3.5.2.3).

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

3.5.2.2 If a check analysis from a location other than the standard position is required, this shall be stated at the time of enquiry and order and the permissible deviations to be applied shall be agreed between the interested parties.

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

Unless otherwise agreed (see 3.5.2.2) the samples shall be taken either from the test pieces used for the verification of the mechanical properties or from drillings from the same location.

The requirements of 3.2 and 3.3 of ISO/R 377, covering the method of selection and preparation of samples for chemical analysis, shall apply.

3.5.3 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.

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.

3.6 Mechanical and technological properties

3.6.1 Mechanical properties

3.6.1.1 The mechanical properties at room temperature to be obtained on the test pieces selected, prepared and tested in accordance with 3.11.1 and 3.12 are given in table 1.

3.6.1.2 If heat treatments different from, or additional to, the normal reference heat treatment are to be carried out after the delivery of the forgings (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. In the case of stress rupture properties, of steels F8 to F22, see note 4 to table 4.

NOTE — 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.

3.6.2 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 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.

3.7 Surface condition and soundness

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

Surface scale shall be removed in order to permit the required inspection.

The purchaser's drawing shall indicate the surface finishes required on the forging.

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

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

3.8 Dimensions and tolerances

3.8.1 Forgings shall conform to the sizes and shapes specified by the purchaser.

3.8.2 The purchaser's drawing which shall accompany and form part of the enquiry and order shall indicate the dimensions and the dimensional tolerances required on the forgings.

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

3.9 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.

3.10 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.

3.11 Number, selection and preparation of samples and test pieces

3.11.1 Mechanical tests at room temperature

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

3.11.1.2 The minimum number of samples are given below. These samples shall be sufficient for the required test pieces to be taken as far as possible in the direction of the principal grain flow, except where otherwise stated (for example the periphery of an upset-forging) or as agreed between the interested parties.

- a) Forgings of mass less than 1 000 kg (2 200 lb) may be tested in batches not exceeding 10 000 kg which shall consist of forgings of similar size made from the same

cast of steel heat-treated together in the same furnace charge. From each batch, one set of samples sufficient for the required tests shall be taken. This also applies to forgings made as multiples whose mass may be more than 1 000 kg (2 200 lb) but which are to be parted after heat treatment into individual forgings each of mass less than 1 000 kg (2 200 lb).

b) For forgings of mass between 1 000 kg (2 200 lb) and 3 500 kg (7 700 lb), samples sufficient for the required test pieces shall be taken from one end, or from one position on the periphery of an upset-forging.

c) For forgings of mass more than 3 500 kg (7 700 lb), samples sufficient for the required test pieces shall be taken from each end.

However, in the case of forgings where the diameter exceeds the length of the axis, the two sets of test samples may be taken 180° apart on one end of the forging or from the periphery. Also, in the case of hollow forgings having a solid end, test pieces shall be taken from the open end of the forging at one position on the periphery.

d) In the case of closed hollow vessels the test samples shall be cut off before closing and they shall be subjected to the same heat treatment as the vessels themselves. In the case of open hollow vessels the samples shall be cut off after completion of the heat treatment.

A sufficient number of forgings shall have prolongations or integral surplus material in order to provide the test samples.

Unless otherwise specified, the axis of the test pieces shall lie approximately 12,5 mm (0.50 in) from the surface of the forging.

If the above requirements are not appropriate or if mechanical tests are required at special locations, for example transversely adjacent to the bore surface, the type of test taken and the properties required shall be agreed between the interested parties before manufacture commences, and allowance shall be made with regard to the effects of mass, grain flow and segregation in determining the minimum property requirements.

3.11.1.3 The test samples shall be cut from the forgings after the final heat treatment. If the forgings 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 (see 3.6.1.2).

3.11.1.4 From each test sample, the following test pieces shall be prepared :

a) One tensile test piece — this shall be a proportional round test piece having a gauge length of $5,65\sqrt{S_0}$ and dimensions in accordance with the requirements of ISO 82;

b) One or, if specified on the order, three Charpy V-notch test pieces — these shall be of the dimensions specified in ISO 148. The axis of the notch shall be perpendicular to the nearest surface of the forging.

3.11.2 Visual inspection

Every forging shall be inspected.

3.11.3 Hydraulic test

If a hydraulic test is required by the order, every forging shall be tested unless otherwise agreed by the interested parties.

3.11.4 Non-destructive testing

Every forging with a thickness of 100 mm or more shall be non-destructively tested.

3.11.5 Etching for flow lines

If agreed between purchaser and supplier, a sample forging may be sectioned and etched to show flow lines. In such cases, the question of acceptable and unacceptable character of metal flow shall be a subject of agreement between the manufacturer and the purchaser.

3.12 Test methods and test results

3.12.1 Tensile test at room temperature

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

3.12.1.2 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) $R_{t1,0}$ shall 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 steel) shall be determined.

The percentage elongation shall be reported with reference to a $5,65\sqrt{S_0}$ gauge length. If other gauge lengths are used, the corresponding elongation on $5,65\sqrt{S_0}$ shall be obtained by reference to ISO 2566/1. In cases of dispute, a gauge length of $5,65\sqrt{S_0}$ shall be used.

3.12.2 *Impact test at room temperature*

3.12.2.1 The impact test shall be carried out in accordance with ISO 148.

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

3.12.2.3 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 it is not less than 70 % of that value.

3.12.3 *Hydraulic test*

Details of the test procedure shall be agreed between the interested parties at the time of the enquiry and order. In no case shall the nominal stress produced by the hydraulic test exceed 90 % of the specified minimum room temperature yield or proof stress. The test pressure shall be maintained for sufficient time for proofing and inspection.

3.12.4 *Non-destructive testing*

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

3.12.5 *Etching for flow lines*

If etch tests for flow lines are required by the purchaser, this shall be the subject of agreement at the time of enquiry and order. Any such agreement shall include details of the test procedure.

3.13 **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.

3.14 **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 3.9).

3.15 **Marking**

3.15.1 The forgings shall be legibly marked to show :

- the identification symbols for the type of steel, as given in table 1;
- the brand of the manufacturer of the forgings;
- symbols, letters or numbers which relate the test certificates, test pieces and products to each other.

3.15.2 Unless the provisions of 3.15.3 are valid, the identification marks shall be stamped on each piece in such a location and in such a manner as may be designated by the purchaser such that it will not be detrimental to the end use of the forging.

3.15.3 On forgings which are boxed, the information in 3.15.1 may be marked on the box or on a tag securely attached to the box in which they are shipped.

4 SPECIAL REQUIREMENTS FOR FORGINGS 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 2605/1 (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 2605/1 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 3.11.1, 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 forgings of more than one thickness are to be supplied from one cast, then the test shall be made on the thickest forging.

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 2608 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 12 for the various steel types.

4.2.2 Stress rupture properties

For forgings 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 FORGINGS IN STEEL TYPES HAVING SPECIFIED LOW TEMPERATURE PROPERTIES

5.1 Mechanical properties

For the steel types which have specified low temperature properties, the minimum Charpy V-notch impact values are given in table 5 for tests taken in the direction of principal grain flow (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.

NOTE – International Standards covering the use of forgings 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 3.11.1.2 and 3.11.1.3, three ISO V-notch test pieces shall be prepared under the same provisions as given in 3.11.1.4 b).

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 at room temperature (1)		Heat treatment							
	C	Si(3)	Mn	P max	S max	Cr	Mo	Ni	Others	Mechanical properties specified for low temperature in table	Diameter (or equivalent thickness) mm	R _{eL} or R _{m0.2} min(1,7)	R _{p0.01} min(1,3)	A min	KV min	Reference heat treatment(2)	Austenitizing temperature °C	Cooling condition(6)	Tempering temperature °C	Cooling condition(6)
F8	0.20	0.10-0.40	0.50-1.20	0.040	0.040				A1(5)	3.4	63-250	215	410-530	20		A	880-930	f		
F9	0.20	0.10-0.40	0.50-1.20	0.040	0.040			A ₁ met, 0.015A, 5.6(1)	5	63-250	235	410-530	20		N, N.T.O.T	880-930	a	580-660(14)	a or f	
F12	0.23	0.10-0.40	0.60-1.40(8)	0.040	0.040			A1(5)	—	63-250	245	460-580	18		N, N.T.O.T	880-930	f			
F13	0.23	0.10-0.40	0.60-1.40(8)	0.040	0.040			A ₁ met, 0.015A, 5.6(1)	5	63-250	255	460-580	18		N, N.T.O.T	880-930	a	580-660(14)	a or f	
F17	0.25	0.10-0.40	0.90-1.70	0.040	0.040			A1(5)	—	63-250	265	490-610	16		N, N.T.O.T	880-930	a	580-660(14)	a or f	
F170									—	100	265	510-630	17		O, T	880-930	a or w	580-660	a or f	
F18	0.25	0.10-0.40	0.90-1.70	0.040	0.040			A ₁ met, 0.015A, 5.6(1)	5	63-250	280	490-610	16		N, N.T.O.T	880-930	a	580-660(14)	a or f	
F18Q									—	100	280	510-630	17		O, T	880-930	a or w	580-660	a or f	
F22(7)	0.30	0.10-0.40	0.80-1.40	0.050	0.050			A1(5)	—	63-250	255	460-580	18		N, N.T.O.T	870-910	a	580-660(14)	a or f	
F220(7)									—	100	255	460-580	18		O, T	870-910	a or w	600-680	a or f	
F23(7)	0.35	0.10-0.40	0.60-1.40	0.040	0.040				—	63-250	255	460-580	18		N, N.T.O.T	870-910	a	580-660(14)	a or f	
F230(7)									—	100	255	460-580	18		O, T	870-910	a or w	600-680	a or f	
F26	0.17-0.20	0.15-0.40	0.50-0.80	0.040	0.040			A ₁ met, 0.0125(1)	—	63-250	250	440-580	17		N, T.O.T	880-940	a or w	600-650	a or f	
F27	0.18-0.25	0.15-0.40	0.50-0.80	0.040	0.040			A ₁ met, 0.0125(1)	—	63-250	250	440-580	17		N, T.O.T	880-940	a or w	600-650	a or f	
F28	0.17-0.20	0.15-0.40	0.50-0.80	0.040	0.040			A ₁ met, 0.0125(1)	—	63-250	270	450-600	16		N, T.O.T	900-940	a or w	600-650	a or f	
F29	0.18-0.25	0.15-0.40	0.50-0.80	0.040	0.040			A ₁ met, 0.0125(1)	—	63-250	270	450-600	16		N, T.O.T	900-940	a or w	600-650	a or f	
F31	0.20-0.26	0.15-0.40	0.50-0.80	0.040	0.040			A ₁ met, 0.020(5)	—	63-250	410	640-780	15		O, T	900-950	a or w	620-720	a or f	
F32	0.20	0.15-0.40	0.40-0.70	0.040	0.040			A ₁ met, 0.020(5)	—	63-250	375	540-680	15		O, T	900-950	a or w	620-720	a or f	
F32Q									—	100	375	540-680	15		O, T	900-950	a or w	620-720	a or f	
F33	0.10-0.18	0.15-0.40	0.40-0.70	0.040	0.040			A ₁ met, 0.020(5)	—	63-250	460	610-760	16		N, T.O.T	950-990	a or w	670-720	a or f	
F34	0.15	0.15-0.40	0.40-0.70	0.040	0.040			A ₁ met, 0.020	—	63-250	460	610-760	16		N, T.O.T	930-1030	a or w	650-750	a or f	
F34Q									—	100	460	610-760	16		O, T	930-1030	a or w	650-750	a or f	
F35	0.22	0.15-0.40	0.30-0.80	0.040	0.040			A ₁ met, 0.020	—	63-250	430	590-740	15		N, T.O.T	880-940	a or w	620-700	a or f	
F36	0.30	0.15-0.40	0.30-0.80	0.040	0.040			A ₁ met, 0.020	—	63-250	560	740-880	14		N, T.O.T	880-940	a or w	620-700	a or f	
F37	0.18	0.15-0.40	0.30-0.80	0.040	0.040			A ₁ met, 0.020(5)	—	63-250	420	640-780	14		N, T.O.T	925-975	a or w	680-750	a or f	
F40	0.23(9)	0.15-0.40	0.30-1.00	0.040	0.040			V 0.20 - 0.35(9)	—	63-250	640	780-930	14		O, T	1020-1070	a or w	680-780	a	
F44	0.20	0.15-0.40	0.80	0.040	0.040			A ₁ met, 0.015(5)	—	63-250	575	480-640	16		N, T.O.T	840-900	a or w	580-630	a or w	
F45	0.13	0.15-0.40	0.80	0.040	0.040			A ₁ met, 0.015(5)	5	63-250	480	600-830	15		N, O, T	880-920	a or w	560-590	min. 1000 ing. max. 170 C/h	
F46	0.03	1.00	2.00	0.045	0.030	17.00-19.00		8.50-10.00	—	63-250	175	205-440	30		O	1000-1100				
F47	0.07	1.00	2.00	0.045	0.030	17.00-19.00		8.00-12.00	—	63-250	195	235-490	30		O	1000-1100				
F48	0.04-0.09	1.00	2.00	0.045	0.030	17.00-19.00		11.00-15.00	3.4	63-250	195	235-490	30		O	1000-1100				
F49	0.07	1.00	2.00	0.045	0.030	17.00-19.00		8.00-12.00	—	63-250	195	235-490	30		O	1000-1100				
F50	0.08	1.00	2.00	0.045	0.030	17.00-19.00		9.00-13.00	—	63-250	205	245-490	30		O	1000-1100				
F51	0.04-0.10	1.00	2.00	0.045	0.030	17.00-19.00		9.00-13.00	3.4	63-250	205	245-490	30		O	1050-1175				
F52	0.08	1.00	2.00	0.045	0.030	17.00-19.00		8.00-12.00	—	63-250	205	245-490	30		O	1000-1100				
F53	0.08	1.00	2.00	0.045	0.030	17.00-19.00		9.00-13.00	—	63-250	195	235-490	30		O	1000-1100				
F54(A)	0.04-0.10	1.00	2.00	0.045	0.030	17.00-19.00		9.00-13.00	3.4	63-250	195	235-490	30		O	1000-1100				
F55	0.08	1.00	2.00	0.045	0.030	17.00-19.00		9.00-13.00	—	63-250	195	235-490	30		O	1000-1100				
F56	0.04-0.10	1.00	2.00	0.045	0.030	15.00-17.00		12.00-14.00	—	63-250	205	245-490	30		O	1060-1100				
F59	0.03	1.00	2.00	0.045	0.030	16.00-18.00		11.00-15.00	—	63-250	185	245-490	30		O	1000-1100				
F62	0.07	1.00	2.00	0.045	0.030	16.00-18.00		10.00-14.00	—	63-250	205	245-490	30		O	1060-1125				
F64	0.04-0.09	1.00	2.00	0.045	0.030	16.00-17.50		10.00-14.00	—	63-250	205	245-490	30		O	1000-1100				
F66	0.08	1.00	2.00	0.045	0.030	16.50-18.50		11.00-14.00	—	63-250	205	245-490	30		O	1000-1100				
F68	0.15	1.50	2.00	0.045	0.030	24.00-26.00		19.00-23.00	—	63-250	205	245-490	30		O	1000-1100				

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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) If the steel is vacuum-deoxidized, the lower limit of the silicon range may be removed.

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

5) Where a maximum Al_{met} of 0,010 %, 0,012 % or 0,020 % is specified, determination of the total aluminium content, provided 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.

6) Alternatively, an austenitic grain size of 6 or finer, determined according to ISO/R 643, can be agreed.

7) Special reference to be made to 3.6.2.

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

9) If the elevated temperature properties of tables 3 and 4 are specified, the carbon content shall be 0,20 to 0,26 %.

10) 0,40 to 0,70 % W may be added, if so agreed.

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, $L_o = 5,65 \sqrt{S_o}$.

KV = ISO V-notch impact strength

12) A = annealed N = normalized Q = quenched T = tempered

13) For acceptance purposes, total elongation proof stress may be used (see 3.12.1.2).

14) Where the steel is to be used at elevated temperatures and the requirements of table 4 are required to apply, the tempering temperature must not exceed 620 °C and tempering times shall not exceed 3 h.

15) If the elevated temperature properties of table 3 are specified, the Al_{met} content shall be $\leq 0,010$ %, and in this case see also note 5.

16) a = air f = furnace o = oil w = water

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

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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	≤ 0,35	± 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	≤ 0,35	± 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	≤ 10,0	± 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 ± 0,25
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 3.5.2.3.

2) These values shall be considered as provisional until more confident data are available.

TABLE 3 – Minimum lower yield stress (R_{eL}) or 0,2 % proof stress ($R_{p0,2}$) values at elevated temperature

Steel No.	Reference heat treatment 1,2)	Diameter (or equivalent thickness) mm	R_{eL} min. or $R_{p0,2}$ min. ³⁾ , N/mm ²														
			Temperature, °C														
			20 ⁵⁾	50 ^{5,6)}	100	150	200	250	300	350	400	450	500	550	600	650	700
F8	N, N + T, Q + T	≤ 63	201	196	192	188	181	168	150	142	138	136					
		> 63 ≤ 250	189	183	178	175	170	162	150	142	138	136					
F9	N, N + T, Q + T	≤ 63	226	222	215	204	188	171	152	141	134	130					
		> 63 ≤ 250 ⁴⁾															
F12	N, N + T, Q + T	≤ 63	232	227	222	218	210	194	176	168	162	158					
		> 63 ≤ 250	218	212	206	203	197	188	176	168	162	158					
F13	N, N + T, Q + T	≤ 63	268	262	251	236	217	198	177	167	158	153					
		> 63 ≤ 250 ⁴⁾															
F17	N, N + T, Q + T	≤ 63	251	245	240	236	227	210	192	183	177	172					
		> 63 ≤ 250	236	229	222	219	212	203	192	183	177	172					
F18	N, N + T, Q + T	≤ 63	293	286	272	256	234	213	192	182	173	168					
		> 63 ≤ 250 ⁴⁾															
F22	N, N + T, Q + T	≤ 63	232	227	222	218	210	194	176	168	162	158					
		> 63 ≤ 250	218	212	206	203	197	188	176	168	162	158					
F26	N + T, Q + T		241	239	237	232	218	200	167	153	148	143	139				
F27	N + T, Q + T		241	239	237	232	218	200	167	153	148	143	139				
F28 ⁴⁾	N + T, Q + T																
F29 ⁴⁾	N + T, Q + T																
F31 ⁴⁾	Q + T																
F32	N + T, Q + T	≤ 63	237	224	210	200	192	180	150	135	130	127	124	120	117		
		> 63 ≤ 250	369	356	340	328	315	303	294	284	279	273	265	251	240		
F32Q	Q + T		369	356	340	328	315	303	294	284	279	273	265	251	240		
F33	N + T, Q + T		270	266	259	248	235	218	192	184	177	168	155	148	135		
F34	N + T, Q + T		272	268	261	253	245	236	230	224	218	205	189	167	145		
F34Q	Q + T		334	329	322	313	304	296	288	281	273	258	239	210	179		
F35 ⁴⁾	N + T, Q + T																
F36 ⁴⁾	N + T, Q + T																
F37 ⁴⁾	N + T, Q + T																
F40	Q + T		537	527	508	484	457	434	423	416	408	383	344				
F48	Q		195		132	120	109	100	93	87	84	81	79	78	76		
F51, F56	Q		205		171	162	153	147	139	133	129	125	123	122	120		
F54 A) F54 B)	Q	≤ 63	155		107	103	97	94	90	85	80	76	74	73	72	71	
		> 63 ≤ 250	195		148	144	139	134	130	124	119	114	111	107	104	101	99
F64	Q		205		155	144	132	121	113	107	101	98	95	92	90	89	88
F66 ⁴⁾	Q		205														
F68 ⁴⁾	Q		205														

1) N = normalized Q = quenched T = tempered
 2) For temperatures and cooling conditions, see table 1.
 3) If a yield phenomenon is pronounced, R_{eL} is valid. If a yield phenomenon is not pronounced, $R_{p0,2}$ is valid.
 4) Until values for lower yield stress and proof stress, derived in accordance with clause 2 of ISO 2605/1 or, in the case of austenitic steels, ISO 2605/II, are available for these steels, the values shall be

agreed between the interested parties at the time of enquiry and order.
 5) Values at 20 °C and 50 °C are included for design purposes only, and are not subject to verification.
 6) Values at 50 °C have been obtained by interpolation.
GENERAL NOTE – Values are subject to revision when more data become available.