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

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FOREWORD

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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.

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

Norway
Sweden
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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/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 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);

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

2) At present at the stage of draft.

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 parties[1]. 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 $5{,}65\sqrt{S_o}$ 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 $5{,}65\sqrt{S_o}$ 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.

3.12.2 *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 :

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

b) the brand of the manufacturer of the forgings;

c) 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/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 3.11.1, 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 specified for		Mechanical properties at room temperature[11]						Heat treatment				
	C	Si[3]	Mn	P max	S max	Cr	Mo	Ni	Others	low	high	Diameter (or equivalent thickness)	R_{eL} or $R_{t0,2}$ min.[13,17]	$R_{t1,0}$ min.[13]	R_m	A min	KV min	Reference heat treatment[12]	Austenitizing temperature	Cooling condition[16]	Tempering temperature	Cooling condition[16]
	temperature in table											mm	N/mm²	N/mm²	N/mm²	%	J		°C		°C	
F8	≤ 0,20	0,10 – 0,40	0,50 – 1,20	0,040	0,040				Al[15]	–	3,4	≤ 63 63 < ≤ 250	215 205		410 – 530 410 – 530	20 20		A N N + T, Q + T	890 – 930 890 – 930 890 – 930	f a a, o or w	– – 580 – 660[14]	– – a or f
F9	≤ 0,20	0,10 – 0,40	0,50 – 1,20	0,040	0,040				$Al_{mét}$ ≥ 0,015[4,5,6]	5	3,4	≤ 63 63 < ≤ 250	235 220		410 – 530 410 – 530	20 20		A N N + T, Q + T	890 – 930 890 – 930 890 – 930	f a a, o or w	– – 580 – 660[14]	– – a or f
F12	≤ 0,23	0,10 – 0,40	0,60 – 1,40[8]	0,040	0,040				Al[15]	–	3,4[8]	≤ 63 63 < ≤ 250	245 235		460 – 580 460 – 580	18 18		N N + T, Q + T	880 – 920 880 – 920	a a, o or w	– 580 – 660[14]	– a or f
F13	≤ 0,23	0,10 – 0,40	0,60 – 1,40[8]	0,040	0,040				$Al_{mét}$ ≥ 0,015[4,5,6]	5	3,4[8]	≤ 63 63 < ≤ 250	275 255		460 – 580 460 – 580	18 18		N N + T, Q + T	880 – 920 880 – 920	a a, o or w	– 580 – 660[14]	– a or f
F17	≤ 0,25	0,10 – 0,40	0,90 – 1,70	0,040	0,040				Al[15]	–	3,4	≤ 63 63 < ≤ 250	265 255		490 – 610 490 – 610	16 16		N N + T, Q + T	880 – 920 880 – 920	a a, o or w	– 580 – 660[14]	– a or f
F17Q										–	–	≤ 100	285		510 – 630	17		Q + T	880 – 920	o or w	580 – 660	a or f
F18	≤ 0,25	0,10 – 0,40	0,90 – 1,70	0,040	0,040				$Al_{mét}$ ≥ 0,015[4,5,6]	5	3,4	≤ 63 63 < ≤ 250	305 280		490 – 610 490 – 610	16 16		N N + T, Q + T	880 – 920 880 – 920	a a, o or w	– 580 – 660[14]	– a or f
F18Q											–	≤ 100	285	–	510 – 630	17		Q + T	880 – 920	o or w	580 – 660	a or f
F22[7]	≤ 0,30	0,10 – 0,40	0,80 – 1,40	0,050	0,050				Al[15]	–	3,4	≤ 63 63 < ≤ 250	255 235		460 – 580 460 – 580	18 18		N N + T, Q + T	870 – 910 870 – 910	a a, o or w	– 580 – 660[14]	– a or f
F22Q[7]												≤ 100	295	–	530 – 650	18		Q + T	870 – 910	o or w	600 – 660	a or f
F23[7]	≤ 0,35	0,10 – 0,40	0,60 – 1,40	0,040	0,040						3,4	≤ 63 63 < ≤ 250	255 235		460 – 580 460 – 580	18 18		N N + T, Q + T	870 – 910 870 – 910	a a, o or w	– 580 – 660[14]	– a or f
F23Q[7]											–	≤ 100	305		550 – 670	18		Q + T	870 – 910	o or w	600 – 660	a or f
F26	0,12 – 0,20	0,15 – 0,40	0,50 – 0,80	0,040	0,040		0,25 – 0,35		$Al_{mét}$ ≤ 0,012[5]	–	3,4		250		440 – 590	17		N + T, Q + T	880 – 940	a, o or w	600 – 650	a or f
F27	0,18 – 0,25	0,15 – 0,40	0,50 – 0,80	0,040	0,040		0,25 – 0,35		$Al_{mét}$ ≤ 0,012[5]	–	3,4		250		440 – 590	17		N + T, Q + T	880 – 940	a, o or w	600 – 650	a or f
F28	0,12 – 0,20	0,15 – 0,40	0,50 – 0,80	0,040	0,040		0,45 – 0,65		$Al_{mét}$ ≤ 0,012[5]	–	3,4		275		450 – 600	16		N + T, Q + T	900 – 940	a, o or w	600 – 650	a or f
F29	0,18 – 0,25	0,15 – 0,40	0,50 – 0,80	0,040	0,040		0,45 – 0,65		$Al_{mét}$ ≤ 0,012[5]	–	3,4		275	–	450 – 600	16		N + T, Q + T	900 – 940	a, o or w	600 – 650	a or f
F31	0,20 – 0,28	0,15 – 0,40	0,50 – 0,80	0,040	0,040	0,90 – 1,20	0,20 – 0,35		$Al_{mét}$ ≤ 0,020[5]	–	3,4		410	–	640 – 780	15		Q + T	900 – 950	o or w	620 – 720	a or f
F32	≤ 0,20	0,15 – 0,40	0,40 – 0,70	0,040	0,040	0,85 – 1,15	0,45 – 0,65		$Al_{mét}$ ≤ 0,020[5]	–	3,4		255	–	410 – 560	18		N + T, Q + T	900 – 950	a, o or w	620 – 720	a or f
F32Q													375		540 – 690	15		Q + T	900 – 925	o or w	620 – 720	a or f
F33	0,10 – 0,18	0,15 – 0,40	0,40 – 0,70	0,040	0,040	0,30 – 0,60	0,50 – 0,70		$Al_{mét}$ ≤ 0,020[5] V 0,22 – 0,35	–	3,4		275		460 – 610	16		N + T, Q + T	950 – 990	a, o or w	670 – 720	a or f
F34	≤ 0,15	0,15 – 0,40	0,40 – 0,70	0,040	0,040	2,00 – 2,50	0,90 – 1,20		$Al_{mét}$ ≤ 0,020	–	3,4		275	–	490 – 640	18		N + T, Q + T	930 – 1 030	a, o or w	650 – 750	a or f
F34Q													335		540 – 690	15		Q + T	930 – 1 030	o or w		
F35	≤ 0,22	0,15 – 0,40	0,30 – 0,80	0,040	0,040	2,75 – 3,50	0,45 – 0,65				3,4		430		590 – 740	15		N + T, Q + T	890 – 940	a; o	620 – 700	a or f
F36	≤ 0,30	0,15 – 0,40	0,30 – 0,80	0,040	0,040	2,75 – 3,50	0,45 – 0,65				3,4		560		740 – 880	14		N + T, Q + T	890 – 940	a, o or w	620 – 700	a or f
F37	0,18	0,15 – 0,40	0,30 – 0,80	0,040	0,040	4,00 – 6,00	0,45 – 0,65		$Al_{mét}$ ≤ 0,020[5]		3,4		205 420		410 – 510 640 – 780	18 14	VALUES UNDER CONSIDERATION	A N + T, Q + T	850 – 880 925 – 975	f a; o	690 – 750	a or f
F40	0,23[9]	0,15 – 0,40	0,30 – 1,00	0,040	0,040	11,00 – 12,50	0,70 – 1,20	0,30 – 1,0	V 0,20 – 0,35[10]	–	3,4[9]		540		780 – 930	14		Q + T	1 020 – 1 070	o or w	680 – 780	a
F44	0,20	0,15 – 0,40	≤ 0,80	0,040	0,040			3,25 – 3,75	$Al_{mét}$ ≥ 0,015[5]				275		490 – 640	16		N + T, Q + T	840 – 900	a, o or w	580 – 630	a or f
F45	≤ 0,13	0,15 – 0,40	≤ 0,80	0,040	0,040			8,50 – 10,00	$Al_{mét}$ ≥ 0,015[5]	5			490		690 – 830	13		N + Q + T Q + T	880 – 920 780 – 820 780 – 820	a, o or w a, o or w a, o or w	550 – 590 550 – 590	a, o or w min. cooling rate 170 °C/h
F46	≤ 0,03	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00		8,00 – 12,00		–	–		175	205	440 – 640	30		Q	1 000 – 1 100	o, w, a (rapidly)	–	–
F47	≤ 0,07	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00		8,00 – 12,00		–	–		195	235	490 – 690	30		Q	1 000 – 1 100		–	–
F48	0,04 – 0,09	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00		8,00 – 12,00		–	3,4		195	235	490 – 690	30		Q	1 000 – 1 125		–	–
F49	≤ 0,07	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00	≤ 0,50	8,00 – 12,00		5	–		195	235	490 – 690	30		Q	1 000 – 1 100			–
F50	≤ 0,08	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00		9,00 – 13,00	Nb ≥ 10 × C – 1,00	–	–		205	245	490 – 690	30		Q	1 000 – 1 100			–
F51	0,04 – 0,10	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00		9,00 – 13,00	Nb ≥ 10 × C – 1,00	–	3,4		205	245	490 – 690	30		Q	1 050 – 1 125			–
F52	≤ 0,08	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00	≤ 0,50	9,00 – 13,00	Nb ≥ 10 × C – 1,00	5			205	245	490 – 690	30		Q	1 000 – 1 100			–
F53	≤ 0,08	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00		9,00 – 13,00	Ti ≥ 5 × C – 0,80	–			195	235	490 – 690	30		Q	1 000 – 1 100			–
F54A) F54B)	0,04 – 0,10	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00		9,00 – 13,00	Ti ≥ 5 × C – 0,80		3,4		(A)155 (B)195	195 235	490 – 690 510 – 710	30 30		Q	1 020 – 1 140 950 – 1 070			–
F55	≤ 0,08	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00	≤ 0,50	9,00 – 13,00	Ti ≥ 5 × C – 0,80	5			195	235	490 – 690	30		Q	1 000 – 1 100			–
F56	0,04 – 0,10	≤ 1,00	≤ 2,00	0,045	0,030	15,00 – 17,00		12,00 – 14,00	Nb ≥ 10 × C – 1,20		3,4		205	245	490 – 690	30		Q	1 050 – 1 100			–
F59	≤ 0,03	≤ 1,00	≤ 2,00	0,045	0,030	16,00 – 18,00	2,00 – 3,00	11,00 – 15,00		–	–		185	215	440 – 640	30		Q	1 000 – 1 100			–
F62	≤ 0,07	≤ 1,00	≤ 2,00	0,045	0,030	16,00 – 18,00	2,00 – 3,00	10,00 – 14,00		–	–		205	245	490 – 690	30		Q	1 000 – 1 100			–
F64	0,04 – 0,09	≤ 1,00	≤ 2,00	0,045	0,030	16,00 – 17,50	2,00 – 3,00	10,00 – 14,00			3,4		205	245	490 – 690	30		Q	1 050 – 1 125			–
F66	≤ 0,08	≤ 1,00	≤ 2,00	0,045	0,030	16,50 – 18,50	2,00 – 3,00	11,00 – 14,00	Ti ≥ 5 × C – 0,80		3,4		205	245	490 – 690	30		Q	1 000 – 1 100			–
F68	≤ 0,15	≤ 1,50	≤ 2,00	0,045	0,030	24,00 – 26,00		19,00 – 23,00			3,4		205	245	490 – 690	30		Q	1 000 – 1 100			–

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 $\leqslant$ 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.

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/mm²														
			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 > 63 ⩽ 250	201 189	196 183	192 178	188 175	181 170	168 162	150 150	142 142	138 138	136 136					
F9	N, N + T, Q + T	⩽ 63 > 63 ⩽ 250[4]	226	222	215	204	188	171	152	141	134	130					
F12	N, N + T, Q + T	⩽ 63 > 63 ⩽ 250	232 218	227 212	222 206	218 203	210 197	194 188	176 176	168 168	162 162	158 158					
F13	N, N + T, Q + T	⩽ 63 > 63 ⩽ 250[4]	268	262	251	236	217	198	177	167	158	153					
F17	N, N + T, Q + T	⩽ 63 > 63 ⩽ 250	251 236	245 229	240 222	236 219	227 212	210 203	192 192	183 183	177 177	172 172					
F18	N, N + T, Q + T	⩽ 63 > 63 ⩽ 250[4]	293	286	272	256	234	213	192	182	173	168					
F22	N, N + T, Q + T	⩽ 63 > 63 ⩽ 250	232 218	227 212	222 206	218 203	210 197	194 188	176 176	168 168	162 162	158 158					
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		237	224	210	200	192	180	150	135	130	127	124	120	117		
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		155 195		107 148	103 144	97 139	94 134	90 130	85 124	80 119	76 114	74 111	73 107	72 104	71 101	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/I 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.

TABLE 4 — Stress rupture properties at elevated temperatures

Steel No.	Reference heat treatment 1,2)	Rupture time h	Estimated average stresses, for rupture[3], N/mm²												
			Temperature, °C												
			380	390	400	410	420	430	440	450	460	470	480	490	500
F8[7]	N, N + T[4] Q + T[4]	10 000	285	263	240	218	196	176	155	135	117	101	86	75	64
		30 000	251	228	205	181	160	139	120	103	88	76	64	53	(44)
		50 000	234	211	183	165	143	124	105	89	76	65	54	(45)	(36)
		100 000	211*	186*	164*	141*	122*	103	88	75	63	51	(42)*	–	–
		150 000	196*	173*	150*	127*	108*	91*	78*	66*	54*	(44)*	(36)*	–	–
		200 000	185*	163*	139*	118*	99*	85*	72*	60*	49*	(39)*	(31)*	–	–
		250 000	177*	155*	131*	111*	90*	80*	67*	55*	(45)*	(36)*	–	–	–
F9	N, N + T[4] Q + T[4]	10 000	221	201	181	164	148	132	118	104	91	79	69	59	51
		30 000	192	175	157	140	124	108	94	81	70	60	51*	43*	(36)*
		50 000	181*	163*	145*	128*	112*	97*	82*	70*	59*	50*	43*	(36)*	(30)*
		100 000	164*	145*	127*	110*	94*	79*	68*	56*	46*	39*	(33)*	–	–
		150 000	153*	135*	119*	101*	84*	71*	59*	49*	40*	(34)*	(28)*	–	–
		200 000	146*	128*	111*	93*	77*	64*	53*	44*	(36)*	(30)*	–	–	–
		250 000	140*	123*	104*	86*	72*	59*	49*	40*	(33)*	(27)*	–	–	–
F12[5,7]	N + T[4] Q + T[4]	10 000	293	270	247	226	204	182	162	143	127	111	97	84	74
		30 000	259	235	214	191	170	150	132	116	101	87	75	64	(54)
		50 000	243	221	197	176	155	135	119	104	89	76	65	(54)	–
		100 000	221	198	176	154	134	117	102	87	75	63	(53)	–	–
		150 000	206*	183*	162*	142*	125*	107*	91*	77*	66*	(55)*	(46)*	–	–
		200 000	196*	174*	153*	134*	116*	99*	84*	72*	60*	(50)*	(42)*	–	–
		250 000	189*	167*	146*	128*	110*	93*	79*	67*	56*	(47)*	–	–	–
F13	N + T[4] Q + T[4]	10 000	279	254	229	206	183	163	145	127	113	100	88	78	71
		30 000	251	224	197	174	152	133	117	101	88	77	68	60	(52)
		50 000	237	206	179	158	137	119	103	88	76	67	59	(52)	(45)
		100 000	211*	182*	157*	135*	117*	100*	85*	73*	62*	(53)*	(47)*	–	–
		150 000	196*	168*	144*	124*	104*	87*	75*	65*	56*	(48)*	–	–	–
		200 000	185*	157*	135*	114*	95*	79*	69*	59*	(51)*	–	–	–	–
		250 000	177*	150*	127*	106*	88*	75*	64*	(55)*	(46)*	–	–	–	–
F17[7]	N + T[4] Q + T[4]	10 000	293	270	247	226	204	182	162	143	127	111	97	84	74
		30 000	259	235	214	191	170	150	132	116	101	87	75	64	(54)
		50 000	243	221	197	176	155	135	119	104	89	76	65	(54)	–
		100 000	221	198	176	154	134	117	102	87	75	63	(53)	–	–
		150 000	206*	183*	162*	142*	125*	107*	91*	77*	66*	(55)*	(46)*	–	–
		200 000	196*	174*	153*	134*	116*	99*	84*	72*	60*	(50)*	(42)*	–	–
		250 000	189*	167*	146*	128*	110*	93*	79*	67*	56*	(47)*	–	–	–
F18	N + T[4] Q + T[4]	10 000	279	254	229	206	183	163	145	127	113	100	88	78	71
		30 000	251	224	197	174	152	133	117	101	88	77	68	60	(52)
		50 000	237	206	179	158	137	119	103	88	76	67	59	(52)	(45)
		100 000	211*	182*	157*	135*	117*	100*	85*	73*	62*	(53)*	(47)*	–	–
		150 000	196*	168*	144*	124*	104*	87*	75*	65*	56*	(48)*	–	–	–
		200 000	185*	157*	135*	114*	95*	79*	69*	59*	(51)*	–	–	–	–
		250 000	177*	150*	127*	106*	88*	75*	64*	(55)*	(46)*	–	–	–	–
F22[7]	N + T[4] Q + T[4]	10 000	293	270	247	226	204	182	162	143	127	111	97	84	74
		30 000	259	235	214	191	170	150	132	116	101	87	75	64	(54)
		50 000	243	221	197	176	155	135	119	104	89	76	65	(54)	–
		100 000	221	198	176	154	134	117	102	87	75	63	(53)	–	–
		150 000	206*	183*	162*	142*	125*	107*	91*	77*	66*	(55)*	(46)*	–	–
		200 000	196*	174*	153*	134*	116*	99*	84*	72*	60*	(50)*	(42)*	–	–
		250 000	189*	167*	146*	128*	110*	93*	79*	67*	56*	(47)*	–	–	–

TABLE 4 (*continued*)

Steel No.	Reference heat treatment 1,2)	Rupture time h	Estimated average stresses for rupture[3], N/mm²															
			Temperature, °C															
			450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600
F26	N + T Q + T	10 000	298	273	247	222	196	171	147	125	102	82	64	–	–	–	–	–
		30 000	273	244	216	187	159	134	113	93	76	61	49	–	–	–	–	–
		50 000	260*	229*	200*	172	144	119	99	80	66	53	(42)	–	–	–	–	–
		100 000	239*	208*	178*	148	123	101	81	66	53*	(42)*	(34)*	–	–	–	–	–
		150 000	226*	197*	168*	139*	114*	91*	74*	60*	48*	(39)*	–	–	–	–	–	–
		200 000	217*	188*	159*	130*	105*	84*	69*	55*	45*	(36)*	–	–	–	–	–	–
		250 000	210*	180*	151*	124*	100*	80*	65*	52*	(42)*	(33)*	–	–	–	–	–	–
F27	N + T Q + T	10 000	298	273	247	222	196	171	147	125	102	82	64	–	–	–	–	–
		30 000	273	244	216	187	159	134	113	93	76	61	49	–	–	–	–	–
		50 000	260*	229*	200*	172	144	119	99	80	66	53	(42)	–	–	–	–	–
		100 000	239*	208*	178*	148	123	101	81	66	53*	(42)*	(34)*	–	–	–	–	–
		150 000	226*	197*	168*	139*	114*	91*	74*	60*	48*	(39)*	–	–	–	–	–	–
		200 000	217*	188*	159*	130*	105*	84*	69*	55*	45*	(36)*	–	–	–	–	–	–
		250 000	210*	180*	151*	124*	100*	80*	65*	52*	(42)*	(33)*	–	–	–	–	–	–
F28[6]	N + T Q + T	10 000																
		30 000																
		50 000																
		100 000																
		150 000																
		200 000																
		250 000																
F29[6]	N + T Q + T	10 000																
		30 000																
		50 000																
		100 000																
		150 000																
		200 000																
		250 000																
F31[6]	Q + T	10 000																
		30 000																
		50 000																
		100 000																
		150 000																
		200 000																
		250 000																
F32	N, Q + T	10 000	–	–	–	304	273	239	209	179	154	129	109	91	76	64	53	44
		30 000	–	–	–	267	233	200	169	140	116	96	79	66	54	44	36	(29)
		50 000	–	–	–	239	207	177	149	124	101	82	68	55	45	–	–	–
		100 000	–	–	–	210	177	146	121	99	81	67	54	43	35	–	–	–
		150 000	–	–	–	194*	161*	132*	108*	87*	71	57	46	38	(31)	–	–	–
		200 000	–	–	–	180*	148*	122*	99*	79*	64*	52*	42*	34*	(28)*	–	–	–
		250 000	–	–	–	170*	139*	114*	91*	74*	59*	48*	39*	32*	(26)*	–	–	–
F33	N + T Q + T	10 000	–	–	–	299	268	241	219	198	179	164	148	134	121	108	95	78
		30 000	–	–	–	261	232	209	187	168	152	135	121	107	93	80	67	(50)
		50 000	–	–	–	243	217	193	172	153	136	121	107	92	78	66	–	–
		100 000	–	–	–	218	191	170	150	131	116	100	85	72	59	(46)*	–	–
		150 000	–	–	–	205	179	156	136	119	101*	85*	70*	57*	(45)*	(35)*	–	–
		200 000	–	–	–	194*	169*	146*	127*	109*	91*	76*	61*	(48)*	(37)*	(28)*	–	–
		250 000	–	–	–	185*	160*	138*	119*	101*	83*	68*	54*	(42)*	(32)*	–	–	–
F34	N + T Q + T	10 000	(309)*	(285)*	(263)*	240	219	196	176	155	137	122	108	96	85	76	68	61
		30 000	(276)*	(254)*	233*	213	192	172	152	134	118	103	90	79	70	61	54	48
		50 000	(257)*	236*	217*	197*	177*	158*	139*	123*	107	93	80	71	62	54	47	42
		100 000	221*	204*	186*	170*	153*	137*	122*	107*	93	79	69	59	51	44	(38)	(34)
		150 000	209*	192*	175*	158*	141*	126*	110*	95*	82*	73*	63*	54*	47	40	(35)	(30)
		200 000	203*	186*	169*	152*	135*	119*	103*	89*	77*	68*	58*	50*	43*	(37)*	(32)*	(28)*
		250 000	198*	181*	164*	147*	130*	113*	98*	84*	74*	64*	55*	47*	41*	(35)*	(30)*	(26)*

TABLE 4 (*continued*)

Steel No.	Reference heat treatment 1,2)	Rupture time h	Estimated average stresses for rupture[3], N/mm²														
			Temperature, °C														
			500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650
F35[6]	N + T Q + T	10 000 30 000 50 000 100 000 150 000 200 000 250 000															
F36[6]	N + T Q + T	10 000 30 000 50 000 100 000 150 000 200 000 250 000															
F37[6]	A N + T Q + T	10 000 30 000 50 000 100 000 150 000 200 000 250 000															
F40	Q + T	10 000	362	331	303	274	246	221	197	174	152	132	113	97	81	68	57	48
		30 000	333*	301•	272*	242	215	190	168	146	127	107	90	75	60	48*	(38)*	(32)*
		50 000	322*	287*	256*	226	199	175	153	132	113*	95*	78*	63*	49*	–	–	–
		100 000	301•	265*	231•	201	176	152	132	113	95*	79*	66•	52*	–	–	–	–
		150 000	286*	249*	218*	190*	166*	142*	122*	104*	87*	72*	58•	46*	–	–	–	–
		200 000	276*	239*	208•	182*	158*	134*	115*	97*	80*	66*	52*	41*	–	–	–	–
		250 000	268*	231•	201•	176*	151*	128*	109*	92*	76*	61*	48*	(38)•	–	–	–	–

TABLE 4 (*continued*)

Steel No.	Reference heat treatment 1,2)	Rupture time h	Estimated average stresses for rupture[3], N/mm² — Temperature, °C																				
			540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	710	720	730	740	750
F48	Q	10 000	–	176	164	152	142	131	122 ,	113	104	95	87	79	73	67	61	55	48	–	–	–	–	–
		30 000	–	147*	135*	126*	115*	105*	96*	,88*	80*	74	67	61	55	50	44*	(40)*	(35)*	–	–	–	–	–
		50 000	–	134*	123*	113*	103*	94*	85*	78*	72*	65*	58*	52*	47*	41*	(36)*	(32)*	(27)*	–	–	–	–	–
		100 000	–	115*	105*	98*	89*	81*	74*	68*	61*	55*	50*	45*	(40)*	(35)*	(30)*	(26)*	(23)*	–	–	–	–	–
		150 000	–	108*	99*	,89*	81*	74*	67*	60*	54*	49*	43*	(39)*	(34)*	(30)*	(26)*	(23)*	(20)*	–	–	–	–	–
		200 000	–	102*	93*	84*	76*	69*	62*	56*	50*	45*	(40)*	(35)*	(31)*	(27)*	(24)*	(21)*	–	–	–	–	–	–
		250 000	–	97*	88*	79*	73*	66*	59*	53*	47*	42*	(37)*	(33)*	(29)*	(25)*	(22)*	–	–	–	–	–	–	–
F51, F56	Q	10 000	243	228	215	200	186	173	159	146	134	124	114	104	95	86	77	69	61	54	46	–	–	–
		,30 000	210*	197	184	172	159	146	133	123	112	102	92	83	74	66	58	51	44	38	(33)	–	–	–
		50 000	198*	185*	172*	159*	146	133	123	111	101	91	82	74	66	58	51	44	39	(33)	(28)	–	–	–
		100 000	181*	168*	154*	142*	129	118	106	96	86	77	69	61	53	46	40*	35*	(30)*	(25)*	(22)*	–	–	–
		150 000	171*	158*	145*	132*	121	109	98	88	79	71*	63*	55*	48*	42*	36*	(32)*	(28)*	(24)*	–	–	–	
		200 000	164*	151*	138*	127*	114*	103*	93*	83*	75*	66*	58*	51*	44*	38*	(33)*	(29)*	(25)*	(22)*	–	–	–	–
		250 000	159*	146*	133*	122*	110*	99*	88*	79*	71*	63*	55*	48*	41*	36*	(31)*	(27)*	(25)*	–	–	–	–	–
F54 A)	Q	10 000	–	–	–	197	182	170	157	145	134	124	114	104	95	86	77	(70)	(63)	–	–	–	–	–
		30 000	–	–	–	167*	154	142	130	120	109	99	90	82	75	(67)	(60)*	(53)*	(47)*	–	–	–	–	–
		50 000	–	–	–	154*	142*	130*	120*	110*	100*	91*	82*	75*	(67)*	(60)*	(54)*	(47)*	(42)*	–	–	–	–	–
		100 000	–	–	–	137*	126*	116*	106*	97*	88*	78*	71*	(64)*	(57)*	(50)*	(44)*	(39)*	(34)*	–	–	–	–	–
		150 000	–	–	–	130*	119*	109*	99*	89*	80*	73*	(65)*	(57)*	(50)*	(44)*	(38)*	(33)*	–	–	–	–	–	–
		200 000	–	–	–	125*	113*	103*	93*	84*	76*	(68)*	(60)*	(53)*	(46)*	(40)*	(35)*	(30)*	–	–	–	–	–	–
		250 000	–	–	–	120*	109*	99*	,89*	80*	72*	(64)*	(57)*	(50)*	(43)*	(37)*	(32)*	–	–	–	–	–	–	–
F54 B)	Q	10 000	–	–	–	185	170	156	142	130	120	110	101	92	82	74	65	(57)	(48)	–	–	–	–	–
		30 000	–	–	–	154*	141	128	118	107	98	88	79	71	61	(53)	(46)*	(40)*	(34)*	–	–	–	–	–
		50 000	–	–	–	139*	127*	117*	107*	97*	87*	77*	,69*	,60*	(52)*	(44)*	(37)*	(32)*	(27)*	–	–	–	–	–
		100 000	–	–	–	123*	112*	102*	92*	82*	74*	64*	(55)*	(47)*	(40)*	(36)*	(31)*	(27)*	(23)*	–	–	–	–	–
		150 000	–	–	–	112*	102*	93*	83*	73*	64*	(55)*	(47)*	,(41)*	(35)*	(30)*	–	–	–	–	–	–	–	–
		200 000	–	–	–	106*	96*	86*	76*	67*	58*	(50)*	(43)*	(37)*	(32)*	(27)*	–	–	–	–	–	–	–	–
		250 000	–	–	–	101*	92*	81*	72*	62*	(54)*	(46)*	(40)*	(34)*	(29)*	–	–	–	–	–	–	–	–	–
F64	Q	10 000	–	260	245	228	211	195	179	164	149	136	123	111	99	89	80	74	65	59	53	48	44	39
		30 000	–	243*	224*	204*	187	171	155	139	125	112	100	89	79	72	64	57	51	46	41	37*	33*	30*
		50 000	–	226*	208*	192*	175	158	142	128	115	103	91	80	72	63	56*	50*	45*	40*	36*	32*	29*	(26)*
		100 000	–	196*	180*	160*	147*	132*	118*	106*	96*	86*	76*	69*	60*	53*	46*	41*	37*	33*	30*	27*	(25)*	(23)*
		150 000	–	187*	171*	152*	139*	124*	110*	97*	86*	76*	68*	60*	53*	47*	41*	36*	32*	28*	(25)*	(24)*	(21)*	–
		200 000	–	181*	165*	146*	133*	116*	103*	91*	80*	71*	63*	56*	49*	43*	38*	33*	29*	(26)*	(24)*	(22)*	(20)*	–
		250 000	–	176*	159*	140*	127*	110*	97*	86*	76*	67*	59*	52*	46*	40*	35*	31*	28*	(25)*	(23)*	(21)*	(19)*	–

TABLE 4 (*concluded*)

Steel No.	Reference heat treatment 1,2)	Rupture time h	Estimated average stresses for rupture[3], N/mm² — Temperature, °C																				
			540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	710	720	730	740	750
F66[6]	Q	10 000 30 000 50 000 100 000 150 000 200 000 250 000																						
F68[6]	Q	10 000 30 000 50 000 100 000 150 000 200 000 250 000																						

NOTES TO TABLE 4

1) A = annealed N = normalized Q = quenched T = tempered.

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

3) Values given in parentheses were obtained by extrapolation beyond the stress range covered by the test data and are thus subject to greater uncertainty.

4) The properties quoted apply only if the tempering temperature does not exceed 620 °C and the tempering time does not exceed 3 h. If the conditions are exceeded during fabrication, the following stress rupture properties are valid for times up to 250 000 h :

For steels F8 and F9

Rupture time h	Estimated average stresses, for rupture[3], N/mm² — Temperature, °C												
	380	390	400	410	420	430	440	450	460	470	480	490	500
10 000	199	181	164	147	143	120	106	93	82	71	61	53	46
30 000	172	157	141	126	111	97	84	73	63	54	46	39	(32)
50 000	164	146	130	116	101	87	74	63	53	45	39	(32)	(27)
100 000	147	130	115	99	84	72	61	50	41	35	(30)	–	–
150 000	138	121	107	91	76	64	53	44	36	(31)	(25)	–	–
200 000	131	115	100	84	69	58	48	40	(32)	(27)	–	–	–
250 000	126	111	94	77	65	53	44	36	(30)	(24)	–	–	–

For steels F12, F13, F17, F18 and F22

Rupture time h	Estimated average stresses, for rupture[3], N/mm² — Temperature, °C												
	380	390	400	410	420	430	440	450	460	470	480	490	500
10 000	251	229	207	185	165	146	130	115	102	90	79	70	62
30 000	225	201	177	156	136	120	105	91	79	69	61	54	(47)
50 000	214	185	162	142	123	106	92	79	69	60	53	(47)	(40)
100 000	189	164	141	121	105	90	76	66	56	(48)	(42)	–	–
150 000	176	151	130	112	94	78	67	58	51	(43)	–	–	–
200 000	166	141	121	103	85	71	62	53	(46)	–	–	–	–
250 000	159	135	114	95	79	67	58	(50)	(41)	–	–	–	–

5) The stress rupture properties are valid only if the manganese content is ⩾ 0,80 %.

6) Until values of stresses for rupture derived by ISO/TC 17/SC 10/ETP Sub-Group are available, the values provided by national or similar standards, or by the quality control of the interested parties, shall, if necessary, be agreed at the time of enquiry and order.

7) The stress rupture properties are valid only if the Al_{met} content is ⩽ 0,010 %.

GENERAL NOTES – Values are subject to revision when more data become available.

Values for the longer times have been extrapolated by the method approved by TC 17/SC 10/ETP Sub-Group, to a greater or lesser degree depending upon the duration of the tests from which the values have been derived.

In analysing the data on austenitic steels, no differentiation has been made between boron-containing and boron-free casts.

The derivation of the values marked with an asterisk may have involved extended extrapolation. The values are recommended values, but their use should take account of the extent and duration of the test data on which they were based (see ISO/DATA No. 1).

TABLE 5 – **Impact properties at low temperature**

Steel No.	Reference heat treatment[1,2]	Diameter	Thickness	Provisional minimum impact test value, KV[3,4] in joules, average of three tests									
				Temperature, °C									
		mm	mm	0	− 20	− 40	− 50	− 80	−100	− 120	−150	−170	−195
F9[5]	N, N + T	⩽ 250	⩽ 100										
F13[5]	N, N + T Q + T												
F18[5]	N, N + T												
F18Q[5]	Q + T	⩽ 100	⩽ 40										
F44	N + T, Q + T	⩽ 150	⩽ 50	59	55	51	47	39	27				
F45	N + Q + T			63	59	55	55	47	47	43	39	35	31
F49	Q	⩽ 50	⩽ 16	86	86	82	82	78	78	74	74	71	71
F52[5]	Q												
F55	Q			78	78	74	74	71	71	67	67	63	63

1) N = normalized Q = quenched T = tempered

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

3) V-notch test pieces as far as possible in the direction of principal grain-flow (see 5.2.2 and 3.11.1).

4) Single values not less than 70 % of the average value (see 5.2.4).

5) Until impact values are agreed for these steels, the values provided by national standards shall, if necessary, be agreed between the interested parties at the time of enquiry and order.

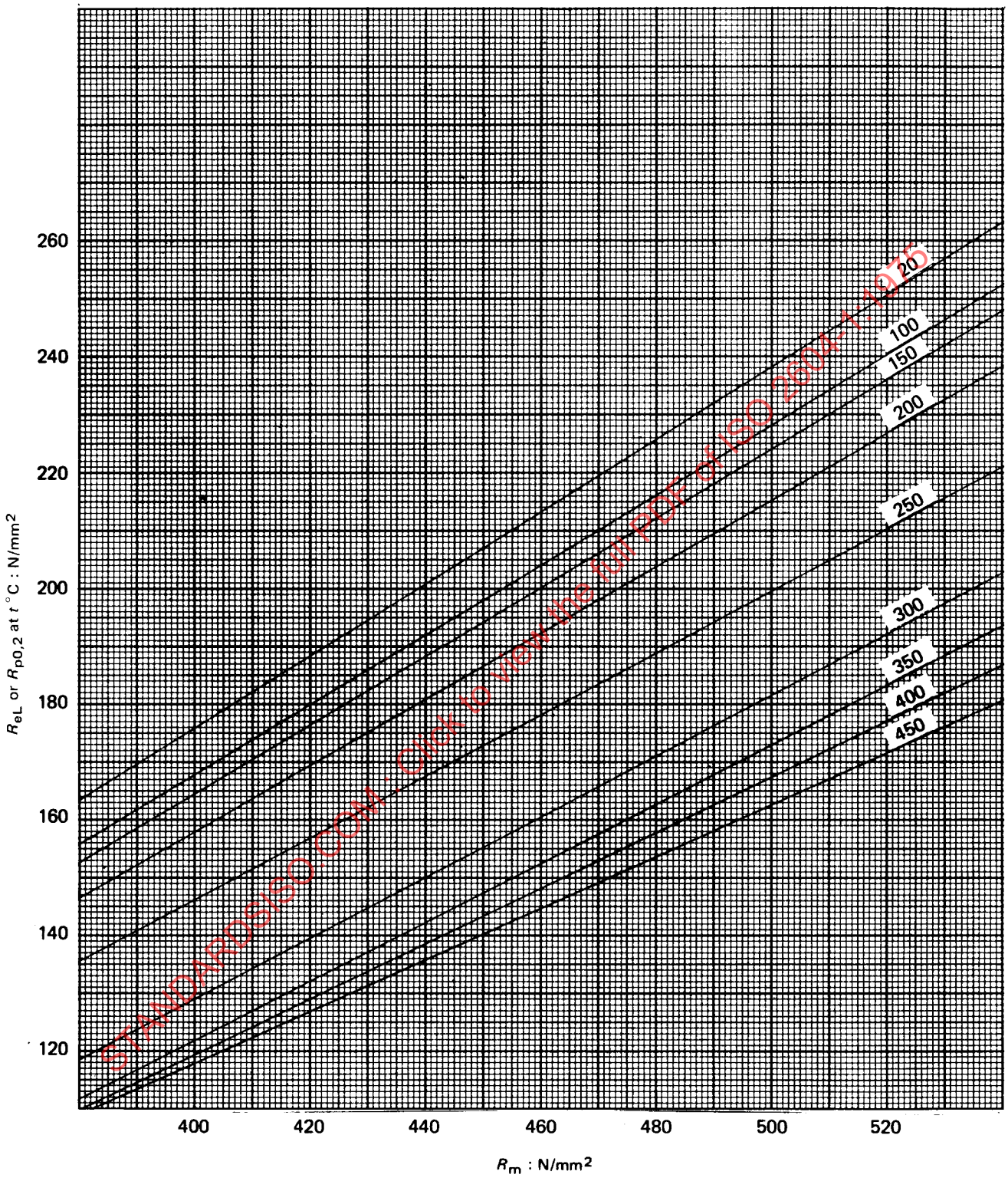

FIGURE 1 — **95 % LCL lines for** :

Steels : F8, F12, F17, F22 (C and CMn; coarse grained)

Heat treatment : Normalized, Normalized and tempered, Quenched and tempered.

Diameter (or equivalent thickness) : ⩽ 63 mm

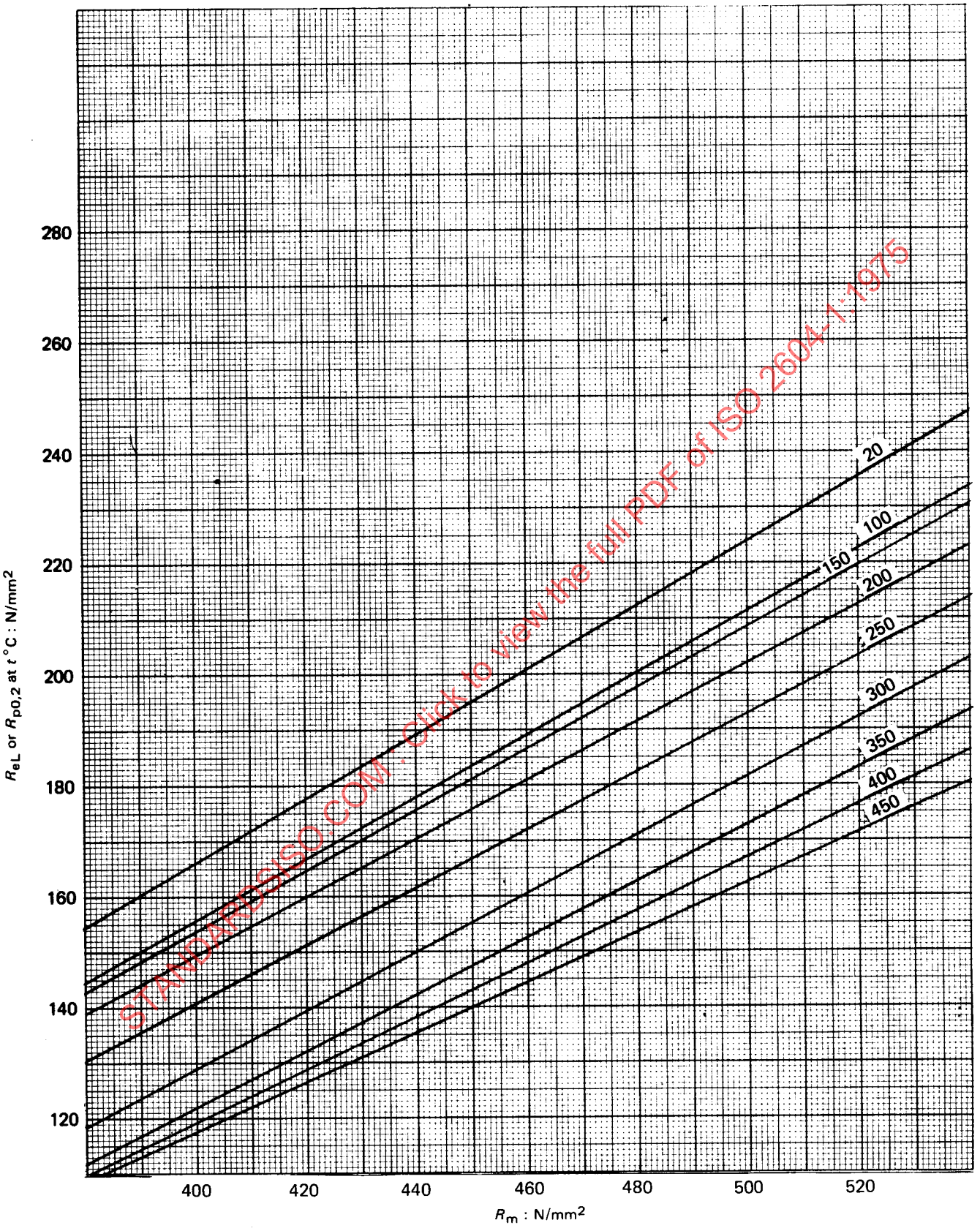

FIGURE 2 – **95 % LCL lines for :**

Steels : F8, F12, F17, F22 (C and CMn; coarse grained)

Heat treatment : Normalized, Normalized and tempered, Quenched and tempered

Diameter (or equivalent thickness) : > 63 but ⩽ 250 mm

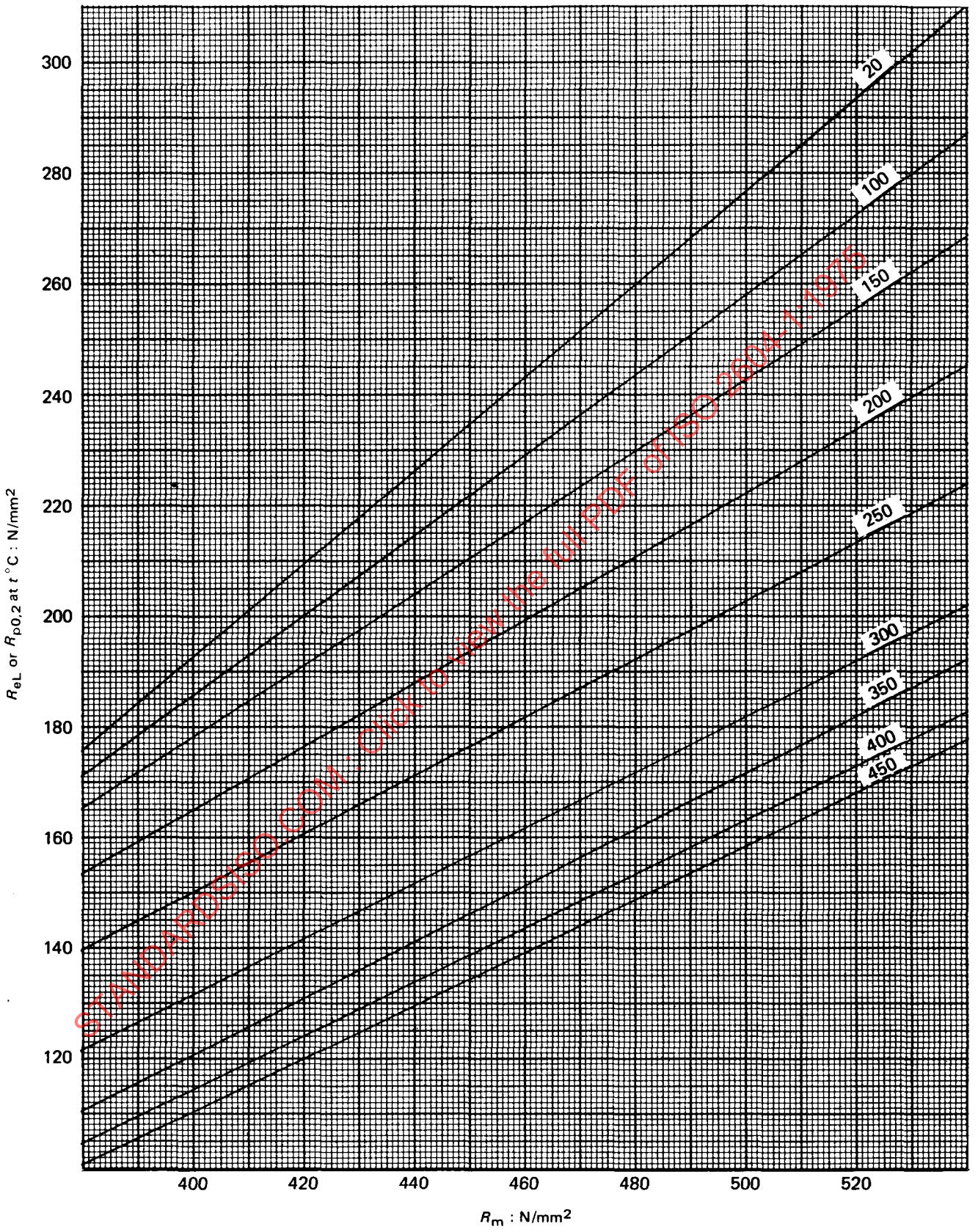

FIGURE 3 – **95 % LCL lines for :**

Steels : F9, F13, F18 (C and CMn; fine grained)

Heat treatment : Normalized, Normalized and tempered, Quenched and tempered

Diameter (or equivalent thickness) : ⩽ 63 mm

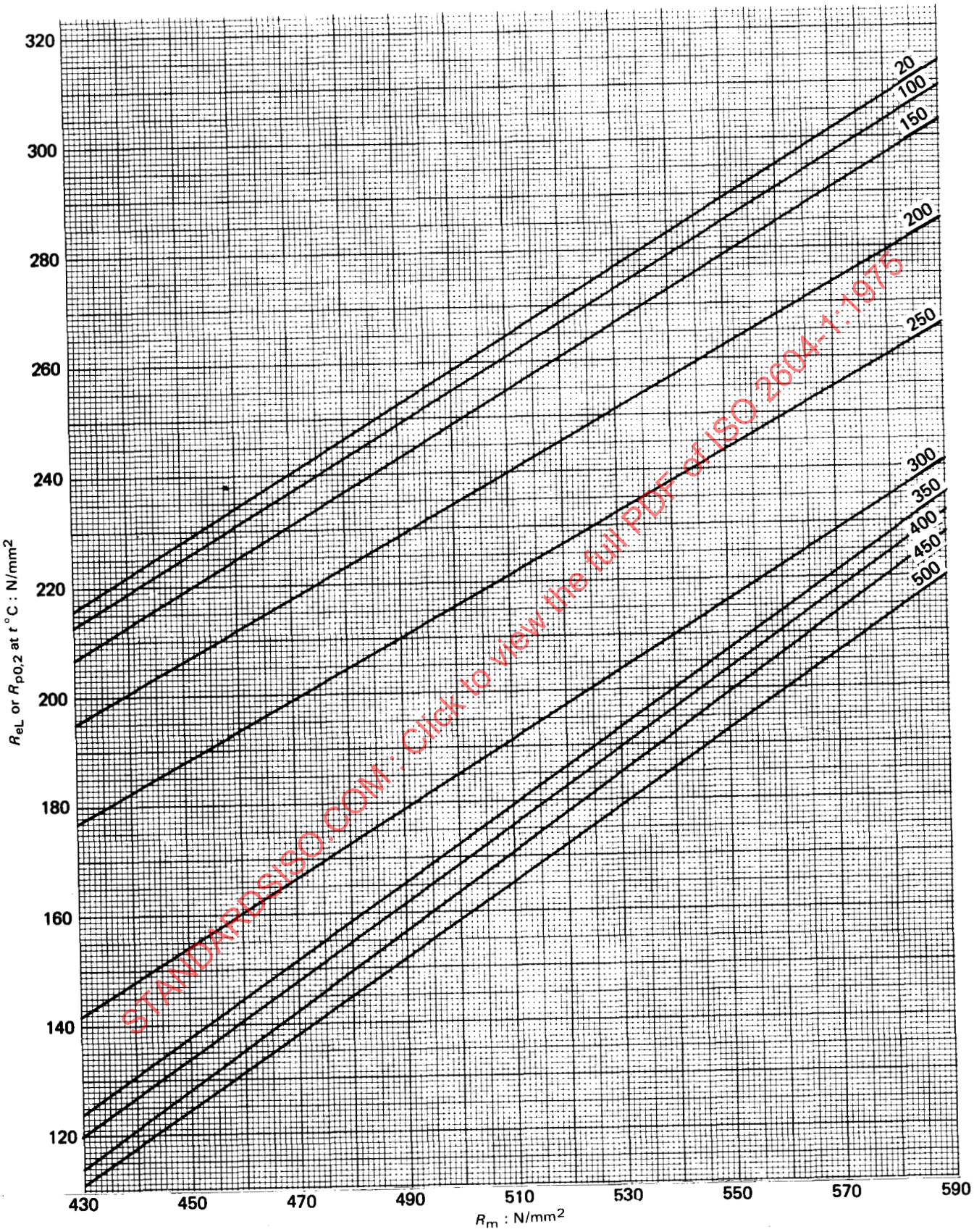

FIGURE 4 – **95 % LCL lines for :**

Steels : F26, F27 (0,3 Mo)

Heat treatment : Normalized, Normalized and tempered

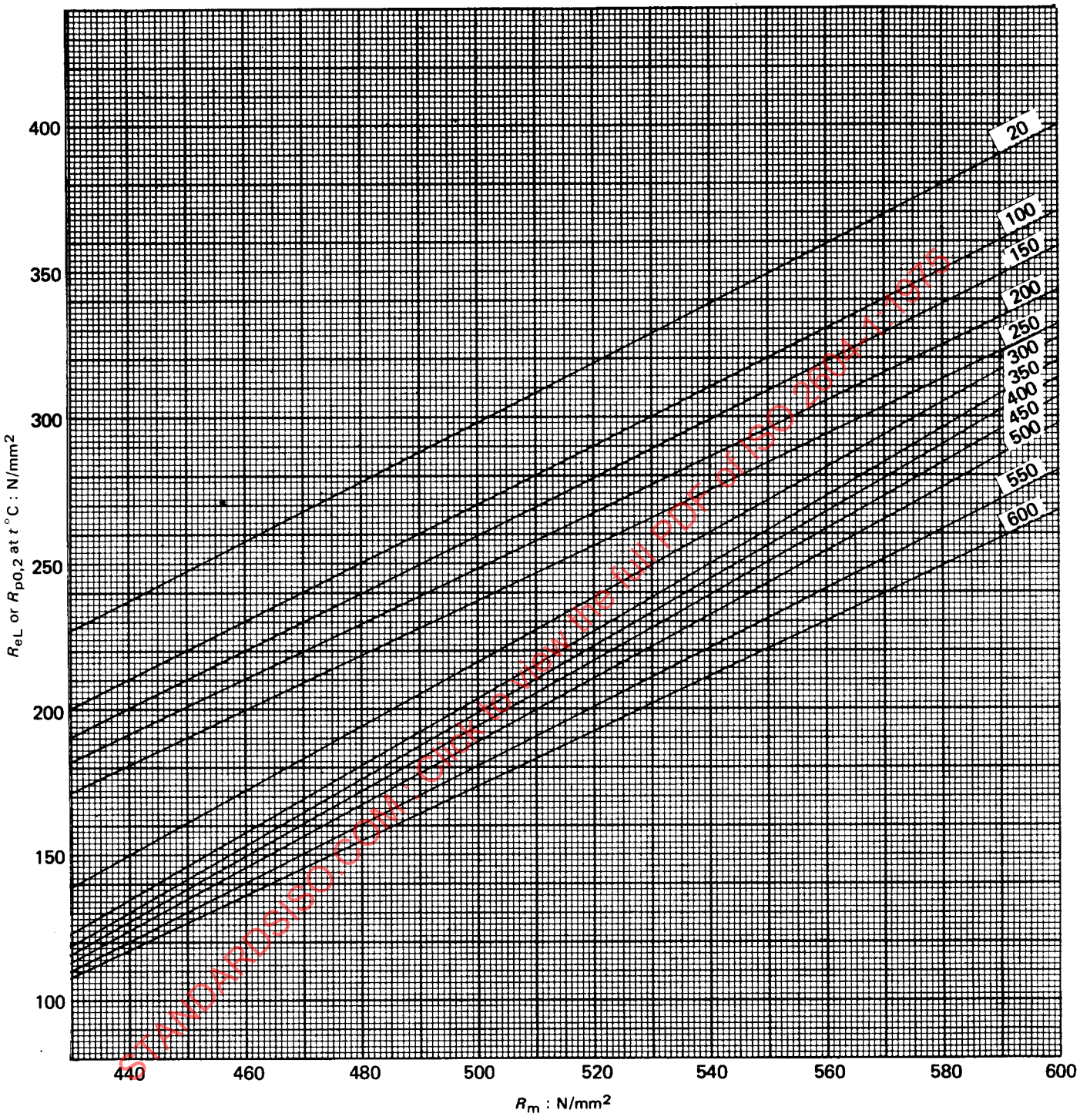

FIGURE 5 — **95 % LCL lines for :**

Steels : F32 (1 Cr 0,5 Mo)

Heat treatment : Normalized and tempered, Quenched and tempered

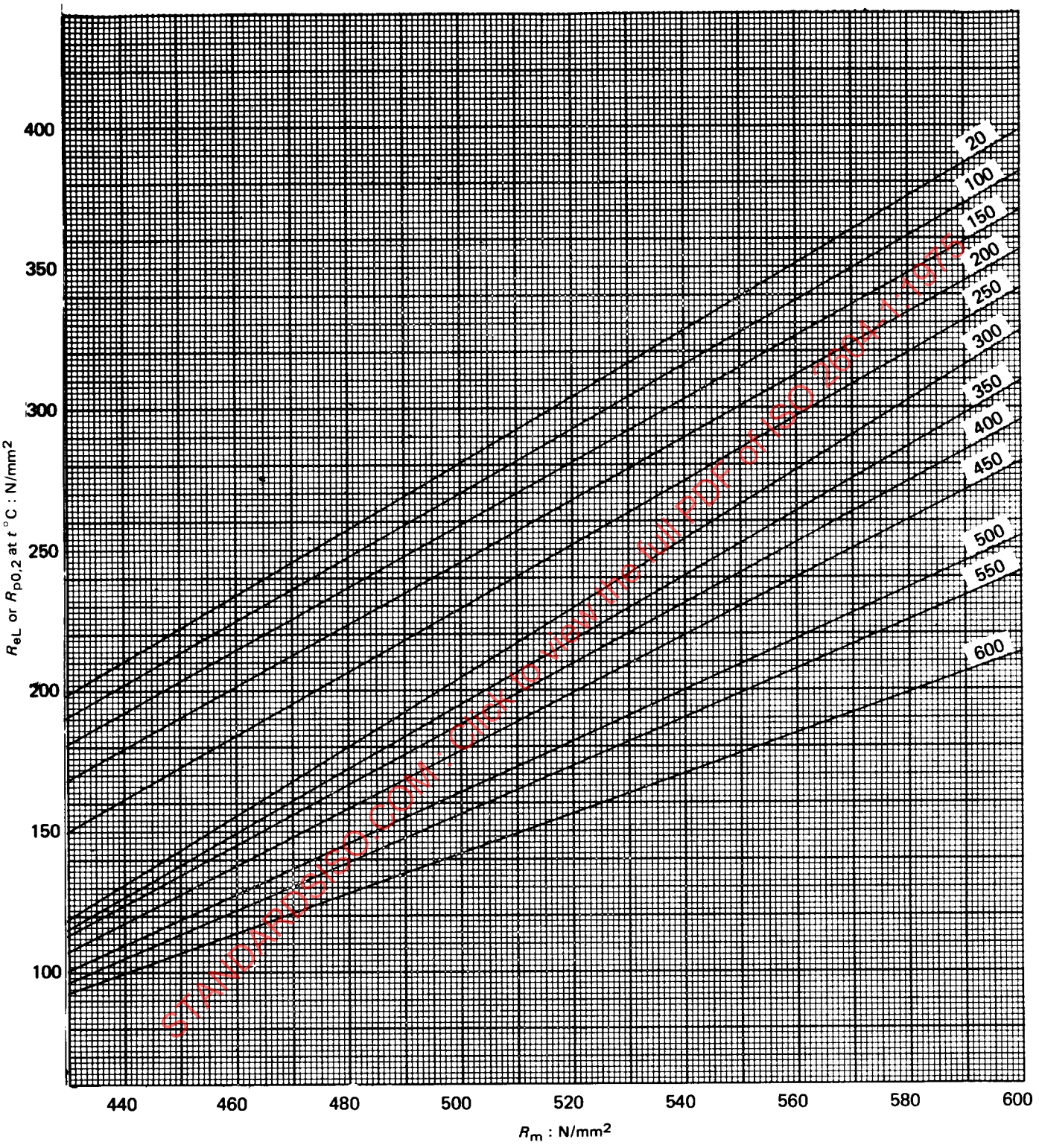

FIGURE 6 — **95 % LCL lines for :**

Steel : F33 (0,5 Cr Mo V)

Heat treatment : Normalized and tempered

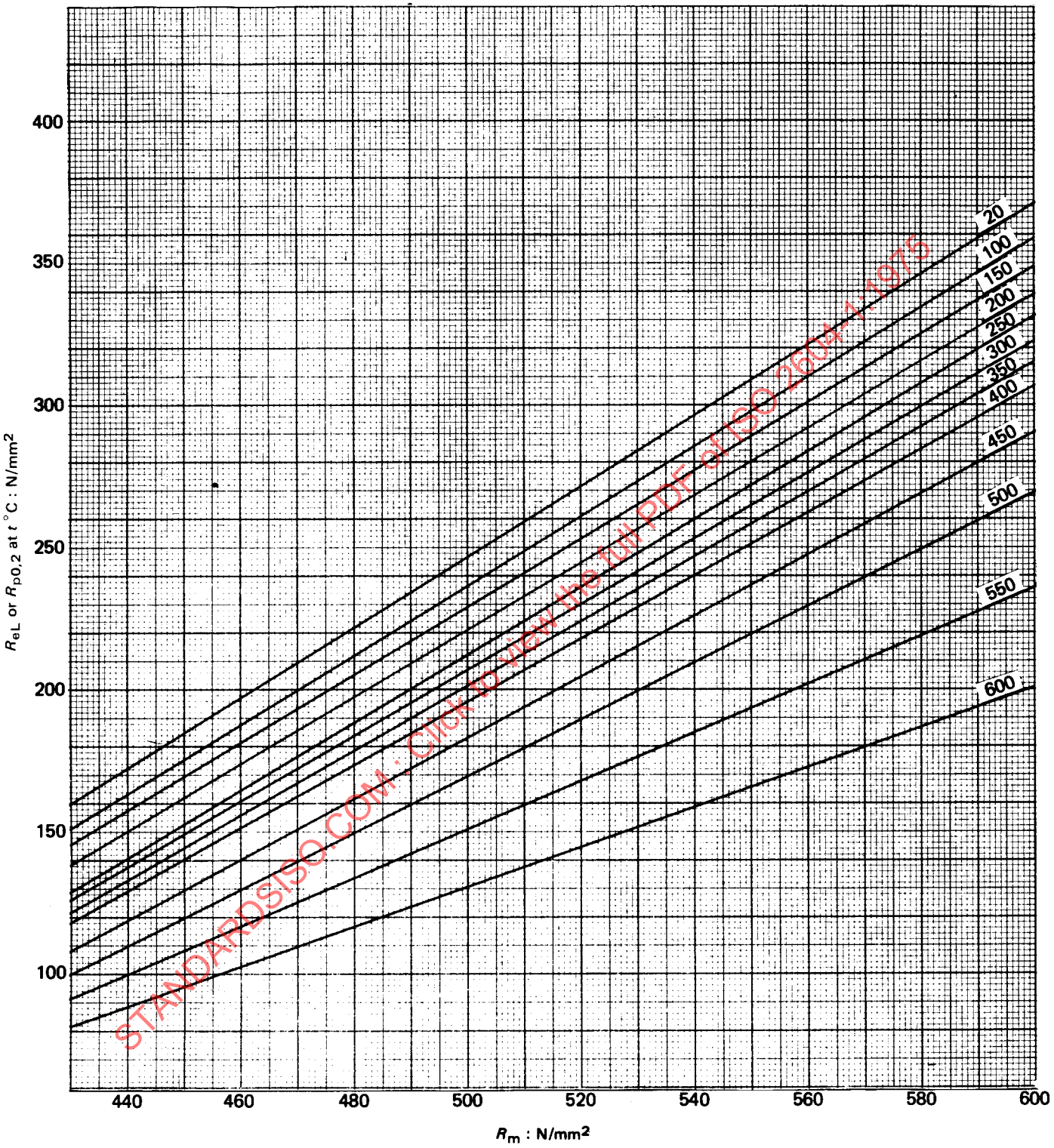

FIGURE 7 – **95 % LCL lines for :**

Steel : F34 (2,25 Cr 1 Mo)

Heat treatment : Normalized and tempered, Quenched and tempered