INTERNATIONAL STANDARD ISO 2604/II

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Steel products for pressure purposes — Quality requirements — Part II : Wrought seamless tubes

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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.

International Standard ISO 2604/II (originally ISO/DIS 2605) 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	India	South Africa, Rep. of
Austria	Ireland	Spain
Belgium	Italy	Switzerland
Czechoslovakia	Japan	Thailand
Denmark	Korea, Rep. of	Turkey
Egypt, Arab Rep. of	Netherlands	United Kingdom
Finland	New Zealand	U.S.S.R.
Germany	Portugal	
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The Member Bodies of the following countries expressed disapproval of the document on technical grounds :

France
Norway
Sweden
U.S.A.

Printed in Switzerland

Steel products for pressure purposes — Quality requirements — Part II : Wrought seamless tubes

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the quality requirements for plain end wrought seamless tubes for pressure purposes manufactured from the steel types listed in table 3.

NOTE — The word "tube" is synonymous with "pipe".

This International Standard does not cover :

a) casing, tubing, drill pipe and linepipe for use by the oil and natural gas industries, and

b) tubes for the transport of gas, water and sewage.

2 REFERENCES

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

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

ISO/R 165, *Flanging test on steel tubes.*

ISO/R 166, *Drift expanding test on steel tubes.*

ISO/R 202, *Flattening test on steel tubes.*

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

ISO 375, *Steel — Tensile testing of tubes.*

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 2694, *Pressure vessels.* [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 tube dimensions and tolerances (see 3.8);

b) the steel type (see table 3);

c) the test category (see 3.11);

d) the inspection procedures and type of documents (see 3.9, 3.15, 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 :

e) the deoxidation practice (see 3.2.3);

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

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

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

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

j) any special straightness requirements (see 3.7.4);

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

2) At present at the stage of draft.

k) if special protection is required (see 3.7.6);

l) if cast separation is required (see 3.12.1.3);

m) if room temperature impact tests are required and, if so, the number of test pieces (see 3.12.1.6);

n) if the hydraulic test is to be omitted (see 3.12.3);

o) if a drift expanding or flanging test, when appropriate, is required (see 3.13.3);

p) the details of non-destructive tests, if required (see 3.13.6);

q) if elevated temperature proof stress tests are required and, if so, the testing temperature selected from table 5 (see 4.2.2.2);

r) if low temperature V-notch impact tests are required and, if so, the testing temperature selected from table 7 (see 5.2.2);

s) if a maximum copper content is required (see table 3, note 1).

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 3 will be at the option of the steel manufacturer.

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

3.2.3 Deoxidation practice shall be as defined in table 3 for the steel type specified.

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

3.3 Manufacture of the product

The tubes shall be manufactured by a seamless process and may be hot-finished or cold-finished. The terms "hot-finished" and "cold-finished" apply to the condition of the tube before it is heat-treated in accordance with 3.4.

3.4 Heat treatment

3.4.1 The tubes shall be supplied in the hot-finished condition or the heat-treated condition given in table 3 for the particular steel type ordered. Where more than one level of properties is specified in table 3 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 tubes may be delivered in a condition other than the final heat-treated condition according to table 3, in which case they shall be suitable for subsequent manipulation and the purchaser shall be informed of the heat treatment necessary to give the required properties (see also 3.6.1 and 3.12.1.4).

3.5 Chemical composition

3.5.1 *Ladle analysis*

The steel shall show on ladle analysis the composition given in table 3 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 4 shall apply to the ladle analysis specified in table 3 for samples taken from the standard position (see 3.5.2.2).

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 on the product is required, the number of samples to be taken shall be agreed between the interested parties.

The samples shall be taken either from the test pieces used for the verification of the mechanical properties, or from drillings through the whole thickness of the tube at the same location as for the mechanical test samples.

The requirements of 3.2 and 3.3 of ISO/R 377, covering the method of selection and preparation of 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.

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 test pieces selected, prepared and tested in accordance with 3.12.1 and 3.13 are given in table 3.

3.6.1.2 If heat treatments which are different from, or additional to, the normal reference heat treatment are to be carried out after the delivery of the tubes (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

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.

have been given heat treatments different from, or additional to, those in table 3. 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.

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 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 Appearance and soundness

3.7.1 The tubes shall have a workmanlike finish and shall be clean and free from such surface and internal defects as can be established by the test category (see 3.11).

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

3.7.4 The tubes shall be reasonably straight. Complete straightness cannot be guaranteed. Special requirements regarding straightness shall be the subject of agreement.

3.7.5 The ends shall be cut square with the axis of the tube.

3.7.6 The tubes may be supplied uncoated or with the manufacturer's standard mill protective coating, unless otherwise specified.

3.8 Dimensions and tolerances

3.8.1 The dimensions shall be in accordance with the appropriate ISO document.

3.8.2 The tolerances on the outside diameter and thickness of the tubes depend upon the method of manufacture, the steel type and the heat treatment and shall be selected from the appropriate ISO document.

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 Test categories

The tubes shall be subjected to the tests given in table 1 below for the appropriate test category.

TABLE 1 – **Test categories**

Tests[1]	Test categories			
	II	III	IV	V
Visual inspection	X	X	X	X
Hydraulic	X	X	X[2]	X[2]
Tensile	X	X	X	X
Flattening or bend	X	X	X	X
Drift expanding or flanging		X		X
Non-destructive testing			X[2]	X[2]

1) If required, an impact test at room temperature may be carried out for any of the test categories (see 3.12.1.6).

2) See 3.12.3.

3.12 Number, selection and preparation of samples and test pieces

3.12.1 *Mechanical tests at room temperature*

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

3.12.1.2 For test categories II and III, the number of tubes on which mechanical tests at room temperature are to be performed shall be as follows :

a) up to and including 323,9 mm outside diameter : one tube in each 200 tubes as made;

b) over 323,9 mm outside diameter : one tube in each 100 tubes as made.

The samples shall be taken at random from batches containing not more than 200 tubes as presented for inspection. If the number of samples specified in this clause, when applied to a particular order, necessitates a number of tubes which includes a fraction, the fraction shall be treated as unity.

A batch is a convenient quantity of tubes of the same type of steel, diameter and thickness, such that a suitable number of sample tubes taken at random from a batch for purposes of test will adequately represent the whole batch.

3.12.1.3 For test categories IV and V, the number of tubes on which mechanical tests at room temperature are to be performed shall be as follows :

a) not heat-treated : 2 % of the tubes from each batch;

b) heat-treated : 2 % of the tubes from each heat-treatment batch.

For tubes not heat-treated, a batch shall consist only of tubes of the same diameter and thickness and of the same steel type. For tubes which are heat-treated, a batch shall consist only of tubes of the same diameter and thickness, and of the same steel type, subjected to the same finishing treatment in a continuous furnace, or heat-treated in the same furnace charge in a batch-type furnace.

Cast separation may be carried out when specified on the enquiry and order and agreed between the interested parties.

NOTE – Cast separation is required for all tubes having specified elevated or low temperature properties and which are subjected to acceptance tests for these properties.

3.12.1.4 The test sample shall be cut from the tube after final heat-treatment. If the tubes 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 3.

3.12.1.5 From each tube selected for testing, one test piece shall be prepared for each of the mechanical tests required by 3.11.

For the tensile test, the test piece may be taken longitudinally or transversely at the option of the manufacturer. The dimensions of the test piece shall comply with the appropriate ISO document.

For the bend test, the test piece shall consist of a circumferential strip cut from the tube and of full thickness of the tube or, for large tubes, a test piece machined from a circumferential strip to a rectangular cross-section 38 mm × 19 mm. The edges may be rounded to a radius of 1,6 mm.

3.12.1.6 Where the dimensions of the tube permit the taking of a full size (10 mm × 10 mm) test piece, and if agreed between the interested parties, or if required by the application code (see for example ISO 2694) one or, if agreed at the time of enquiry and order, three V-notch impact test pieces shall be taken from one of the tubes selected.

The form and dimensions of the test pieces shall be in accordance with ISO 148.

The test pieces shall be cut so that the longitudinal axes are transverse to the longitudinal axis of the tube. The notch shall be perpendicular to the original surface of the tube.

3.12.2 *Visual inspection*

Every tube shall be inspected.

3.12.3 *Hydraulic test*

A hydraulic test shall be carried out on each tube except that, by agreement between the interested parties, the hydraulic test may be omitted for tubes of test categories IV and V which have been ultrasonically tested for acceptance purposes in accordance with the annex.

3.12.4 *Non-destructive testing*

All tubes to test categories IV and V shall be non-destructive tested for acceptance purposes.

3.13 Test methods and test results

3.13.1 *Tensile test at room temperature*

3.13.1.1 The tensile test shall be carried out in accordance with ISO 375.

3.13.1.2 The tensile strength R_m, the lower yield stress R_{eL} or proof stress R_p, and the elongation A shall be determined. The results obtained shall meet the requirements given in table 3.

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 steels), shall be determined.

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

3.13.2 *Flattening or bend test*

3.13.2.1 At the option of the manufacturer, and as determined by the dimensions of the tube, either a flattening test (see 3.13.2.2) or a bend test (see 3.13.2.3) shall be carried out.

3.13.2.2 The flattening test shall be carried out in accordance with ISO/R 202. The test piece shall show no crack or flaw when the distance between the platens is not greater than the value given by the formula :

$$H = \frac{(1 + C)\, a}{C + a/D}$$

where

H is the distance, in millimetres, between platens;

a is the specified thickness, in millimetres;

D is the specified outside diameter, in millimetres;

C is a constant depending on the steel type (see table 3).

3.13.2.3 The bend test shall be carried out in accordance with ISO/R 85. The test piece shall be doubled over, cold, in the direction of original curvature, round a bar of the diameter specified in table 3 as being appropriate to the steel type specified. It shall show no crack or flaw, but slight premature failure at the edges shall not be considered a cause for rejection.

3.13.3 *Drift expanding or flanging test*

Unless otherwise agreed at the time of enquiry and order, it is at the option of the tube manufacturer whether or not a drift expanding or flanging test is carried out.

3.13.3.1 The drift expanding test shall be carried out in accordance with ISO/R 166. The test piece shall, without cracking, be expanded by a mandrel having an included angle of 30°, 45° or 60° at the option of the manufacturer, to increase the outside diameter by the amount specified in table 3 as being appropriate to the steel type specified.

3.13.3.2 The flanging test shall be carried out in accordance with ISO/R 165. The outside diameter of the flange shall exceed the outside diameter of the tube by the amount shown in table 3 as being appropriate to the steel type specified. After flanging, the tube shall show no crack or flaw.

3.13.4 *Impact test at room temperature*

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

3.13.4.2 If one test piece is used, the value obtained shall meet the requirements given in table 3.

3.13.4.3 If three test pieces are used, the average value obtained shall meet the requirements given in table 3. One individual value may be below the specified value provided that it is not less than 70 % of that value.

3.13.5 *Hydraulic test*

Every tube, except as provided in 3.12.3, shall be hydraulically tested at the manufacturer's works.

The hydraulic pressure for all test categories shall be 1,5 times the design pressure, but not greater than the pressure calculated from the formula :

$$P = \frac{20\, S\, a}{D}$$

where

P is the test pressure, in bars;

D is the specified outside diameter, in millimetres;

a is the specified thickness, in millimetres;

S is the stress, in newtons per square millimetre, which shall be taken as 80 % of the minimum yield stress at room temperature for ferritic steels and 70 % of the minimum 1,0 % proof stress (non-proportional elongation), $R_{p1,0}$, at room temperature for austenitic steels as specified in the order.

The test pressure shall be maintained sufficiently long for proof and inspection. Any tube failing to withstand the hydraulic pressure test shall be deemed not to comply with this International Standard.

3.13.6 *Non-destructive testing*

Non-destructive testing shall be carried out on tubes tested to quality categories IV and V by a method to be agreed between the interested parties. If the tubes are to be ultrasonically tested, the annex shall be used as the basis for agreement.

3.14 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 shall be 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.

3.15 Documents

The purchaser shall state at the time of enquiry and order which of the documents permitted by clause 4 of ISO/R 404 are to be provided (see also 3.9).

3.16 Marking

3.16.1 The tubes shall be legibly marked to show :

a) the identification symbols for the type of steel as given in table 3;

b) the brand of the manufacturer of the tubes;

c) a designation of the method of manufacture;

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

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

3.16.3 On small diameter tubes which are bundled or boxed, the information in 3.16.1 may be marked on a tag securely attached to the bundle or box in which they are shipped.

4 SPECIAL REQUIREMENTS FOR TUBES 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 5.

4.1.2 For the same steel types, average stress rupture properties are given in table 6.

4.2 Verification and testing

4.2.1 All the test categories shown in 3.11 apply.

4.2.2 *Elevated temperature proof stress*

4.2.2.1 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, in ISO 2605/II.

4.2.2.2 VERIFICATION BY ACCEPTANCE TESTS

One test shall be made on each cast using a test sample prepared in accordance with 3.12.1, 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 tubes or more than one thickness are to be supplied from one cast, then the test shall be made on the thickest tube.

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 5 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.

4.2.2.3 VERIFICATION WITHOUT ACCEPTANCE TESTS

The elevated temperature proof stress values shall be verified by the procedure given in clause 3 of ISO 2605/I or, in the case of austenitic steels, ISO 2605/II. The 95 % lower confidence limits of the elevated temperature proof stress values which are necessary for the application of that procedure are given in figures 1 to 13 for the various steel types.

4.2.3 *Stress rupture properties.*

For steel tubes supplied to this International Standard, the average stress rupture properties given in table 6 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 TUBES IN STEEL TYPES HAVING SPECIFIED LOW TEMPERATURE PROPERTIES

5.1 Mechanical properties

For the steel types which have specified low temperature properties, the minimum longitudinal Charpy V-notch impact values are given in table 7 (see also 5.2.6)

5.2 Verification and testing

5.2.1 All the test categories shown in 3.11 shall apply to the tubes covered by this sub-clause.

5.2.2 Tests shall only be carried out if so stated on the enquiry and order and if the thickness of the tube is $\geqslant 6$ mm.

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

5.2.3 If low temperature impact tests are required, the number of tubes on which impact tests are to be carried out shall be :

a) not heat-treated : one tube per batch;

b) heat-treated : one tube per heat-treatment batch where a heat-treatment batch is as defined in 3.12.1.3.

5.2.4 From the sample tube, three longitudinal ISO V-notch test pieces shall be prepared, the form and dimensions of which shall be in accordance with ISO 148.

The test pieces shall be cut so that the longitudinal axes are transverse to the longitudinal axis of the tube. The notch shall be perpendicular to the original surface of the tube.

5.2.5 The tests shall be carried out in accordance with ISO 148 at a temperature selected from table 7 and agreed between the interested parties at the time of enquiry and order.

5.2.6 The average value of the three tests shall meet the requirements given in table 7. One of the three individual values may be below the specified minimum average value of table 7 provided it is not less than 70 % of that value.

5.2.7 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.

ANNEX

ULTRASONIC TESTING OF TUBES FOR LONGITUDINAL DEFECTS

(All dimensions are the nominal specified dimensions.)

A.1 METHOD OF TEST

A.1.1 The tubes shall be tested for defects of a predominantly longitudinal character using an ultrasonic technique.

A.1.2 The tubes to be tested shall be sufficiently straight and the surfaces shall be free from any foreign matter that interferes with the interpretation of the test.

A.1.3 During testing, the tubes or search units shall be moved so that the probes traverse the tube surface in a helix. Unless otherwise agreed between purchaser and manufacturer, the pitch of the helix shall be 25 mm (1 in) maximum per probe.

A.1.4 By agreement between purchaser and manufacturer, the testing shall be in either one or both directions of beam travel.

A.2 CALIBRATION STANDARDS

A.2.1 The ultrasonic equipment shall be calibrated using a longitudinal standard notch on the outside and inside surfaces, or the outside surface, of a tubular test piece according to the specification requirements, usually in the "as supplied" condition. If the test piece is machined, the minimum notch depth may be reduced. (See A.2.2.4.3.)

If the tube is of ferritic steel, the test piece shall be of ferritic steel; if the tube is of austenitic steel, the test piece shall be of austenitic steel. The test piece shall have the same nominal diameter and thickness as the tube to be tested.

External and internal standard notches, where used, need not be further apart than a distance sufficient to make the signals distinguishable.

A.2.2 The dimensions of the standard notches shall be as follows :

A.2.2.1 *Shape and location*

The standard notch shall lie in a longitudinal direction. The sides shall be nominally parallel and the bottom shall be nominally square to the sides.

A.2.2.1.1 Over 15 mm (0.59 in) bore, both external and internal notches shall be used.

From 15 mm (0.59 in) bore to 10 mm (0.4 in) bore inclusive, the internal notch may be used, at the manufacturer's option.

Below 10 mm (0.4 in) bore, the internal notch shall not be used.

A.2.2.1.2 The internal standard notch shall not be used when the D/a ratio is less than 4.

A.2.2.2 *Length*

Standard notch length (at full depth)

50 mm (2 in) minimum

A.2.2.3 *Width*

Standard notch width

1 mm (0.04 in) maximum for tubes up to and including 25 mm (1 in) thick.

1,5 mm (0.06 in) maximum for tubes over 25 mm (1 in) thick.

A.2.2.4 *Depth*

Standard notch depth shall be 5 % of the specified thickness, with the following limitations :

A.2.2.4.1 Tolerance on depth : ± 15 % of standard notch depth with ± 0,05 mm (± 0.002 in) minimum.

A.2.2.4.2 For D/a ratios between 4 and 5 the internal standard notch depth shall be in accordance with table 2.

TABLE 2 — **Notch depths**

$\frac{\text{Diameter}}{\text{Thickness}}$ ratio D/a	$\frac{\text{Internal standard notch depth}}{\text{External standard notch depth}}$ ratio
5	1
4,75	1,6
4,5	1,9
4,25	2,2
4	2,5

A.2.2.4.3 For all tubes except those in A.2.2.4.4, A.2.2.4.5, and A.2.2.4.6.

Minimum depth : 0,3 mm (0.012 in), except that where the test piece is machined the minimum depth shall be 0,2 mm (0.008 in).

Maximum depth : 1,5 mm (0.06 in).

A.2.2.4.4 Maximum depth for austenitic tubing :

for tubes less than or equal to 50 mm (2 in) thickness : 1,5 mm (0.06 in)

for tubes with thickness greater than 50 mm (2 in) : 3 % of specified thickness.

A.2.2.4.5 For cold-finished austenitic steel tubes, and for ferritic steel tubes containing more than 12 % chromium with thickness less than 3 mm (0.12 in), the minimum depth shall be 0,2 mm (0.008 in).

A.2.2.4.6 Tubes for nuclear application

Minimum depth : 0,2 mm (0.008 in) for normal applications, 0,1 mm (0.004 in) for the most severe applications.

Maximum depth : As in A.2.2.4.3 and A.2.2.4.4.

A.3 CALIBRATION AND CHECKING OF EQUIPMENT

A.3.1 The ultrasonic equipment shall be adjusted so that it detects the signals from both the internal and external standard notches (or the signal from the external standard notch, where only an external standard notch is used). During calibration, the rotational speed of automatic equipment, or the speed of movement of hand-operated equipment, shall be comparable to that used during the test.

A.3.2 If, on checking during production testing, either or both standard notches are not detected, then all tubes tested since the previous check shall be retested after the instrument has been recalibrated.

A.4 ACCEPTANCE

A.4.1 Any tube that does not produce a signal greater than the signal from the standard notch shall be deemed to have passed this test.

A.4.2 Where a signal greater than that from the standard notch is obtained, the imperfection shall be examined for depth which if found to be less than the depth of the standard notch shall be ignored. Its depth shall not be deducted from the thickness.

A.4.3 Imperfections having a depth greater than the standard notch may be removed, provided that the thickness remaining after removal is not less than the permissible minimum. The tube shall then be retested ultrasonically, and if the tube no longer produces a signal greater than the signal from the standard notch, it shall be accepted. Alternatively, the length of tube containing the defect may be cut off, and the remainder shall be deemed to have passed the test.

A.4.4 Acceptance of a tube shall be the subject of a special agreement between the purchaser and the manufacturer if it can be proved that the defect causing the signal greater than the signal from the standard notch does not penetrate the tube surface.

TABLE 3 — Chemical composition, mechanical properties at room temperature and heat treatment

Steel No.	Chemical composition, %[1,2,3]									Mechanical properties specified for		Mechanical properties at room temperature[7]										Heat treatment				
	C	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others	low temperature in Table	high temperature in Table	R_{eL} or $R_{p0,2}$ min.[9,12]	$R_{p1,0}$ min.[9]	R_m	A min	KV min	Flattening test constant C	Bend test D max.	Drift expanding and flanging test (% increase D_o) D_i/D_o ratio ≤ 0,6	> 0,6 ≤ 0,8	> 0,8	Reference heat treatment[8]	Temperature	Cooling condition 10	Temperature	Cooling condition 10
												N/mm²	N/mm²	N/mm²	%	J							°C		°C	
TS 1	≤ 0,16		0,30 – 0,70	0,050	0,050							195		320 – 440	25		0,10	4a	12	15	19	HF,SCA,A,N	HF – SCA 640 – 700 A 880 – 940 N 880 – 940	a f a		
TS 2	≤ 0,16		0,40 – 0,70	0,050	0,050						5,6	195		320 – 440	25		0,10	4a	12	15	19	HF, N				
TS 4	≤ 0,17	≤ 0,35	0,40 – 0,80	0,045	0,045							215		360 – 480	24		0,10	4a	12	15	19	HF,SCA,A,N				
TS 5	≤ 0,17	≤ 0,35	0,40 – 0,80	0,045	0,045						5,6	215		360 – 480	24		0,10	4a	12	15	19	HF, N				
TS 6	≤ 0,17	≤ 0,35	0,40 – 1,00	0,045	0,045				$Al_{met} \geq 0{,}015$[4,5,6]	7		215		360 – 480	24		0,10	4a	12	15	19	HF, A, N				
TS 9	≤ 0,21	≤ 0,35	0,40 – 1,20	0,045	0,045							235		410 – 530	22		0,08	4a	10	12	17	HF, N				
TS 9H	≤ 0,21	≤ 0,35	0,40 – 1,20	0,045	0,045						5,6	235		410 – 530	22		0,08	4a	10	12	17	HF, N				
TS 10	≤ 0,19	≤ 0,35	0,60 – 1,20	0,045	0,045				$Al_{met} \geq 0{,}015$[4,5,6]	7		235		410 – 530	22		0,08	4a	10	12	17	HF, A, N				
TS 13	≤ 0,22	≤ 0,35	0,60 – 1,40	0,045	0,045							265		460 – 580	21		0,07	4a	8	10	15	HF,SCA,A,N				
TS 14	≤ 0,22	≤ 0,35	0,80 – 1,40	0,045	0,045						5,6	265		460 – 580	21		0,07	4a	8	10	15	HF, N				
TS 15	≤ 0,20	≤ 0,35	0,80 – 1,40	0,045	0,045				$Al_{met} \geq 0{,}015$[4,5,6]	7		265		460 – 580	21		0,07	4a	8	10	15	HF, A, N				
TS 18	≤ 0,23	≤ 0,35	0,80 – 1,50	0,045	0,045						5,6	285		490 – 610	21		0,07	4a	8	10	15	HF, N				
TS 26	0,12 – 0,20	0,10 – 0,35	0,40 – 0,80	0,040	0,040		0,25 – 0,35		$Al_{met} \leq 0{,}012$[4]		5,6	250		450 – 600	22		0,07		8	10	15	N, N + T	900 – 940	a	600 – 650	a
TS 32	0,10 – 0,18	0,10 – 0,35	0,40 – 0,70	0,040	0,040	0,70 – 1,10	0,45 – 0,65		$Al_{met} \leq 0{,}024$[4]		5,6	275		440 – 590	22		0,07		8	10	15	N + T	900 – 960	a	640 – 720	a
TS 33	0,10 – 0,18	0,10 – 0,35	0,40 – 0,70	0,040	0,040	0,30 – 0,60	0,50 – 0,70		V 0,22 – 0,32 $Al_{met} \leq 0{,}024$[4]		5,6	275		460 – 610	16		0,07		8	10	15	N + T	930 – 980	a	670 – 720	a
TS 34	0,08 – 0,15	≤ 0,50	0,40 – 0,70	0,040	0,040	2,00 – 2,50	0,90 – 1,20		$Al_{met} < 0{,}024$[4]		5,6	135 275 275		410 – 560 490 – 640 490 – 640	20 16		0,07 0,07		8 8	10 10	15 15	a) A b) N + T c) N + T	900 – 960 900 – 960 900 – 960	f a a	650 – 780 650 – 750	a a
TS 37	≤ 0,15	≤ 0,50	0,30 – 0,60	0,030	0,030	4,00 – 6,00	0,45 – 0,65		$Al_{met} \leq 0{,}024$[4]		5,6	205		410 – 560	20		0,07		8	10	15	A	850 – 880	f		
TS 38	≤ 0,15	0,25 – 1,00	0,30 – 0,60	0,030	0,030	8,00 – 10,00	0,90 – 1,10		$Al_{met} < 0{,}024$[4]		5,6	135 390		410 – 560 590 – 740	20 18		0,07 0,07		8 8	10 10	15 15	a) A b) N + T	850 – 950 900 – 1 000	f a	700 – 800	a
TS 39	≤ 0,08	≤ 1,00	≤ 1,00	0,040	0,030	11,5 – 14,0		≤ 0,50				245 390		440 – 590 590 – 740	20 18		0,08 0,08		6 6	8 8	12 12	a) A b) Q + T	750 – 800 950 – 1 000	a a, o	700 – 750	a
TS 40	0,17 – 0,23	< 0,50	< 1,00	0,030	0,030	10,00 – 12,50	0,80 – 1,20	0,30 – 0,80	V 0,25 – 0,35[11]		5,6	435		690 – 840	15		0,08		6	8	12	N + T	1 020 – 1 070	a	680 – 780	a
TS 43	≤ 0,15	0,15 – 0,35	0,30 – 0,80	0,040	0,040			3,25 – 3,75		7		245		440 – 590	16		0,08		6	8	12	a) N b) N + T	840 – 900	a	580 – 630	a
TS 45	≤ 0,13	0,15 – 0,30	0,30 – 0,80	0,040	0,040			8,50 – 9,50		7		510		690 – 840	15		0,08		6	8	12	Q + T N + N + T	880 – 920 1) 880 – 920 2) 780 min	o, w a	560 – 610	a or w
TS 46	≤ 0,03	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00		9,00 – 13,00		7		175	205	490 – 690	30		0,09		9	15	17	Q	950 – 1 100			
TS 47	≤ 0,07	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00		8,00 – 12,00		7		195	235	490 – 690	30		0,09		9	15	17	Q	950 – 1 100			
TS 48	0,04 – 0,09	≤ 0,75	≤ 2,00	0,045	0,030	17,00 – 20,00		8,00 – 12,00			5,6	195	235	490 – 690	30		0,09		9	15	17	Q	980 – 1 100			
TS 50	≤ 0,08	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00		9,00 – 13,00	Nb ≥ 10 × C ≤ 1,00	7		205	245	510 – 710	30		0,09		9	15	17	Q	950 – 1 100			
TS 53	≤ 0,08	≤ 1,00	≤ 2,00	0,045	0,030	17,00 – 19,00		9,00 – 13,00	Ti ≥ 5 × C ≤ 0,80	7		195	235	510 – 710	30		0,09		9	15	17	Q	950 – 1 100			
TS 54	0,04 – 0,10	0,20 – 0,80	≤ 2,00	0,045	0,030	17,00 – 20,00		9,00 – 13,00	Ti ≥ 4 × C ≤ 0,60		5,6	155 195	195 235	490 – 690 510 – 710	30 30		0,09 0,09		9 9	15 15	17 17	Q Q	1 070 – 1 140 950 – 1 070	a, or w		
TS 56	0,04 – 0,10	0,20 – 0,80	≤ 2,00	0,045	0,030	16,00 – 20,00		11,00 – 14,00	Nb ≥ 10 × C ≤ 1,4		5,6	205	245	510 – 710	30		0,09		9	15	17	Q	950 – 1 100			
TS 57	≤ 0,03	≤ 1,00	≤ 2,00	0,045	0,030	16,00 – 18,50	2,00 – 2,50	11,00 – 14,00		7		185	215	490 – 690	30		0,09		9	15	17	Q	950 – 1 100			
TS 58	≤ 0,03	≤ 1,00	≤ 2,00	0,045	0,030	16,00 – 18,50	2,50 – 3,00	11,50 – 14,50		7		185	215	490 – 690	30		0,09		9	15	17	Q	950 – 1 100			
TS 60	≤ 0,07	≤ 1,00	≤ 2,00	0,045	0,030	16,00 – 18,50	2,00 – 2,50	11,00 – 14,00		7		205	245	510 – 710	30		0,09		9	15	17	Q	950 – 1 100			
TS 61	≤ 0,07	≤ 1,00	≤ 2,00	0,045	0,030	16,00 – 18,50	2,50 – 3,00	11,00 – 14,50		7		205	245	510 – 710	30		0,09		9	15	17	Q	950 – 1 100			
TS 63	0,04 – 0,09	≤ 0,75	1,00 – 2,00	0,045	0,030	16,00 – 18,00	2,00 – 2,75	12,00 – 14,00			5,6	205	245	510 – 710	30		0,09		9	15	17	Q	1 000 – 1 100			
TS 67	0,04 – 0,10	0,30 – 0,60	1,00 – 1,50	0,045	0,030	15,50 – 17,50	1,60 – 2,00	15,50 – 17,50	Nb ≥ 10 × C ≥ 10 × C + 0,4		5,6	215	255	510 – 710	30		0,09		9	15	17	Q				
TS 68	≤ 0,15	≤ 0,75	≤ 2,00	0,045	0,030	24,00 – 26,00		19,00 – 22,00			5,6	205	245	510 – 710	30		0,09		9	15	17	Q				
TS 69	≤ 0,12	≤ 1,00	≤ 1,50	0,045	0,030	19,00 – 23,00		30,00 – 35,00	Ti 0,15 – 0,60 Al 0,15 – 0,60		5,6	165	205	480 – 680	25		0,09		9	15	17	Q				

VALUES UNDER CONSIDERATION

NOTES TO TABLE 3

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 4.

3) All steels shall be fully killed, except TS1, TS2, TS4 and TS9, which may be semi-killed. See also note in 3.2.3.

4) Where a maximum Al_{met} of 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.

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

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

7) 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

D = maximum diameter of mandrel

a = thickness of test piece

D_o = outside diameter

D_i = inside diameter

8) A = annealed, HF = hot-finished, N = normalized, Q = quenched, SCA = subcritical annealed, T = tempered

9) For acceptance purposes, total elongation proof stress may be used. (See 3.13.1.2.)

10) a = air, f = furnace, o = oil, w = water.

11) W ⩽ 0,70 % may be added, if agreed.

12) For design purposes, the values given in table 5 apply.

TABLE 4a — **Permitted deviation from the specified composition for carbon and carbon-manganese steels**

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

TABLE 4b — **Permitted deviation from the specified composition for low and medium alloy steels excluding manganese steels**

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

TABLE 4c — **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	± 0,005
	> 0,03 – 0,25	± 0,01
Manganese	⩽ 0,40 – 0,70	± 0,03
	> 0,70 – 1,0	± 0,04
	> 1,0 – 2,0	± 0,05
Silicon	⩽ 1,0	± 0,05
Sulphur and Phosphorus specified max.	⩽ 0,030	+ 0,003
	> 0,030 – 0,040	+ 0,004
	> 0,040 – 0,050	+ 0,005
Nickel	⩽ 1,0	± 0,03
	> 1,0 – 2,0	± 0,05
	> 2,0 – 5,0	± 0,07
	> 5,0 – 10,0	± 0,10
	> 10,0 – 20,0	± 0,15
	> 20,0	± 0,20
Chromium	⩽ 10,0	± 0,10
	> 10,0 – 15,0	± 0,15
	> 15,0 – 20,0	± 0,20
	> 20,0	± 0,25
Molybdenum	⩽ 1,0	± 0,04
	> 1,0 – 2,0	± 0,05
	> 2,0 – 3,0	± 0,08
	> 3,0	± 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 3.5.2.2.

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

TABLE 5 — **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]	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
TS 2	HF, N	176	172	168	158	147	125	100	91	88	87					
TS 5		195	192	187	176	165	145	122	111	109	107					
TS 9H		220	217	210	199	188	170	149	137	134	132					
TS 14		245	241	234	223	212	195	177	162	159	156					
TS 18		260	256	249	237	226	210	193	177	174	171					
TS 26	N	247	245	243	237	224	205	173	159	156	150	146				
TS 32	N + T	268	254	240	230	220	210	183	169	164	161	156	151	146		
TS 33	N + T	270	266	259	248	235	218	192	184	177	168	155	148	135		
TS 34	a) A	129	121	108	99	92	85	80	76	72	69	66				
	b) N + T c) N + T	272	268	261	253	245	236	230	224	218	205	189	167	145		
TS 37[4]	A															
TS 38	a) A	130	115	98	88	79	78	77	76	75	74	71				
	b) N + T	398	386	363	348	334	330	326	322	316	311	290	235			
TS 40	N + T	435	425	407	378	349	328	317	310	305	292	272				
TS 48	Q	195		132	120	109	100	93	87	84	81	79	78	76		
TS 54	a) Q 1070/1140	155		107	103	97	94	90	85	80	76	74	73	72	71	70
	b) Q 950/1070	195		148	144	139	134	130	124	119	114	111	107	104	101	99
TS 56	Q	205		171	162	153	149	139	133	129	125	123	122	120		
TS 63	Q	205		155	144	132	121	113	107	101	98	95	92	90	89	88
TS 67[4]		215														
TS 68[4]		205														
TS 69[4]		165														

1) A = annealed, N = normalized, Q = quenched, HF = hot-finished

2) For temperatures and cooling conditions see table 3.

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 6 – **Stress rupture properties**

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	510	520	530	540	550	560	570	580	590	600
TS 2 TS 5 TS 9H	N HF	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)*	–	–	–	–	–	–	–	–	–	–	–	–	–
TS 14 TS 18	N HF	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)*	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TS 26	N N + 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)*	–	–	–	–	–	–
TS 32	N + T	10 000	–	–	–	–	–	–	–	–	–	–	304	273	239	209	179	154	129	109	91	76	64	53	44
		30 000	–	–	–	–	–	–	–	–	–	–	267	233	200	169	140	116	96	79	66	54	44	36	(29)
		50 000	–	–	–	–	–	–	–	–	–	–	239	207	177	149	124	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)*	–	–	–

TABLE 6 (*continued*)

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	510	520	530	540	550	560	570	580	590	600
TS 33	N + 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)*	–	–	–
TS 34	a) A c) N + T	10 000								(251)*	(236)*	221*	206	191	177	162	147	133	121	108	96	85	76	68	61
		30 000								(226)*	211*	196*	181	168	153	139	126	113	101	89	78	70	61	54	48
		50 000								211*	197*	183*	170*	156*	142*	128*	116*	104	92	81	71	62	54	47	42
		100 000								196*	182*	168*	154*	141*	127*	115*	102*	90	78	69	59	51	44*	(38)*	(34)*
		150 000								193*	177*	161*	145*	129*	116*	103*	91*	79*	71*	62*	54*	46*	40*	(35)*	(30)*
		200 000								186*	170*	154*	138*	123*	110*	97*	85*	75*	66*	58*	50*	43*	(37)*	(32)*	(28)*
		250 000								181*	165*	149*	132*	118*	105*	93*	81*	72*	63*	54*	47*	40*	(35)*	(30)*	(26)*
	b) N + 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 6 (*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	660
TS 37[4]	A																		
TS 38	A	10 000	181	161	142	127	112	99	86	76	67	58	50	44	38	33	28	25	–
		30 000	159*	137*	121*	104*	90*	79*	69*	60*	52*	45*	38*	33*	28*	25*	22*	19*	–
		50 000	147*	127*	111*	95*	82*	73*	62*	53*	46*	39*	33*	28*	25*	21*	18*	(16)*	–
		100 000	131*	113*	96*	83*	72*	62*	53*	45*	38*	32*	27*	24*	20*	(17)*	(14)*	(11)*	–
		150 000	123*	105*	90*	76*	65*	56*	47*	40*	33*	28*	24*	21*	(17)*	(15)*	(13)*	–	–
		200 000	116*	99*	84*	72*	61*	52*	44*	37*	31*	25*	22*	19*	(16)*	(14)*	–	–	–
		250 000	111*	95*	80*	68*	58*	49*	41*	34*	28*	25*	21*	(17)*	(15)*	–	–	–	–
	N + T	10 000	224	199	177	157	138	121	104	91	79	69	60	51	44	38	33	28	25
		30 000	197*	174*	152*	133	116	100	85	74	63	54	46	39	34	29*	25*	22*	(18)*
		50 000	185*	162*	141*	123*	106*	90*	77*	67*	57*	47*	41*	35*	29*	25*	22*	(18)*	(16)*
		100 000	167*	144*	124*	106*	91*	78*	66*	57*	47*	40*	34*	28*	24*	21*	(17)*	(15)*	(12)*
		150 000	156*	136*	117*	100*	85*	74*	62*	52*	43*	36*	30*	25*	22*	(18)*	(16)*	(13)*	–
		200 000	150*	129*	111*	94*	80*	69*	57*	48*	40*	33*	27*	24*	20*	(17)*	(14)*	–	–
		250 000	145*	125*	106*	90*	76*	65*	54*	45*	37*	31*	26*	22*	19*	(16)*	(13)*	–	–
TS 40	N + T	10 000	294	274	253	232	213	192	173	154	136	119	101	87	74	63	53	46	–
		30 000	271	250	228	208	187	168	148	130	113	97	81	70	58	49*	(41)*	(36)*	–
		50 000	261	238	217	195	175	155	136	119	102	87	74	62	51	(42)*	(35)*	(30)*	–
		100 000	248	225	202	180	159	139	121	104	88	75	63	52	(43)	–	–	–	–
		150 000	239*	219*	197*	175*	150*	128*	110*	94*	80*	68*	57*	48*	(39)*	–	–	–	–
		200 000	234*	213*	190*	167*	143*	122*	104*	89*	76*	64*	53*	(44)*	(36)*	–	–	–	–
		250 000	229*	208*	185*	161*	137*	117*	100*	84*	72*	60*	50*	(41)*	(33)*	–	–	–	–

TABLE 6 (*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
TS 48	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)*	–	–					
TS 54A	Q(a)	10 000	–	–	–	197	182	170	157	145	134	124	114	104	95	86	77	(70)	(63)					
	1 070 – 1 140	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)*	–	–					
TS 54B	Q(b)	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)*					
	950 – 1 070	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)*	–	–	–	–					

TABLE 6 (*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	760	770	780	790	800	810	820	830	840	850
TS 56	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)*	–	–														
TS 63	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)*	–											
TS 67	Q	10 000							220	203	186	171	157	143	131	120	109	99	90	82	75	68	61	55	50	45	40								
		30 000							187	170	154	140	127	114	103	92	83	75	67	59	53	47*	41*	37*	32*	29*	(25)*								
		50 000							173	154	138	125	112	101	90	81	73	65	57	50	44	39*	33*	29*	26*	(23)*	(20)*								
		100 000							150	133	119	105	93	83	74	65	58	50	44	38	33	28*	(25)*	(22)*	–	–									
		150 000							134*	118*	103*	90*	78*	69*	60*	52*	45	39	34	30	26	(23)*	(20)*	(17)*	–	–	–								
		200 000							124*	108*	94*	81*	71*	61*	53*	46*	40*	34*	30*	(25)*	(23)*	(20)*	(17)*	–	–	–									
		250 000							116*	100*	86*	75*	65*	56*	48*	41*	36*	31*	26*	(23)*	(20)*	(17)*	(15)*	–	–	–									
TS 68[4]	Q																																		
TS 69	Q	10 000		223	207	192	177	164	152	141	130	121	112	103	95	87	80	74	68	62	57	53	48	44	40	37	34	32	30	27	25	23	21	19	
		30 000		197*	182*	168*	155	143	132	122	113	104*	95*	88*	80*	74*	68	62	57	52	48	43	40	36	34	31	29	26	24	22	20	18*	16*	(14)*	
		50 000		185*	171*	158*	146	135	124	114	105	97*	89*	81*	75*	68*	63	57	52	48	43	40*	36*	34*	31*	29*	26*	24*	22*	20*	18*	16*	(14)*		
		100 000		171*	157*	145*	134*	123*	114*	104*	96*	88*	80*	73*	67*	61*	56*	51*	47*	42*	39*	36*	33*	30*	28*	25*	23*	21*	19*	17*	15*				
		150 000		163*	150*	138*	127*	117*	108*	99*	90*	83*	76*	69*	63*	58*	53*	48*	43*	40*	36*	34*	31*	28*	26*	24*	21*	19*	17*	15*	(14)*				
		200 000		158*	145*	134*	123*	113*	104*	95*	87*	79*	72*	66*	60*	55*	50*	46*	41*	38*	35*	32*	30*	27*	25*	22*	20*	18*	16*	(14)*					
		250 000		154*	141*	130*	120*	110*	101*	92*	84*	77*	70*	64*	58*	53*	48*	44*	40*	37*	34*	31*	29*	26*	24*	21*	19*	17*	15*						

NOTES TO TABLE 6

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

2) For temperatures and cooling conditions see table 3.

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) Until values of stresses for rupture derived by ISO/TC 17/SC 10/ETP Subgroup 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.

GENERAL NOTE – 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 Subgroup, 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 7 – **Impact properties at low temperature**

Steel No.	Reference heat treatment[1, 2]	Thickness mm	Provisional minimum impact test value $KV^{3,4,5)}$, in joules, average of three tests									
			Temperature, °C									
			0	– 20	– 40	– 50	– 80	100	– 120	150	– 170	– 195
TS 6	A, N, HF	⩽ 25	55	47	27							
TS 10	A, N, HF		55	47	31	27						
TS 15	A, N, HF											
TS 43	N, N + T	⩽ 25	59	55	51	47	39	27				
TS 45	N + N + T, Q + T		71	67	63	63	55	55	51	47	43	39
TS 46	Q	⩽ 16	86	86	82	82	78	78	74	74	71	71
TS 47	Q											
TS 50	Q		78	78	74	74	71	71	67	67	63	63
TS 53	Q											
TS 57	Q											
TS 58	Q											
TS 60	Q											
TS 61	Q											

1) A = annealed, N = normalized, Q = quenched, T = tempered, HF = hot-finished.

2) For temperatures and cooling conditions see table 3.

3) V-notch test pieces, longitudinal.

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

5) The values apply to standard 10 mm × 10 mm test pieces. Where it is necessary to use subsidiary standard test pieces, the values shall be agreed between the interested parties.

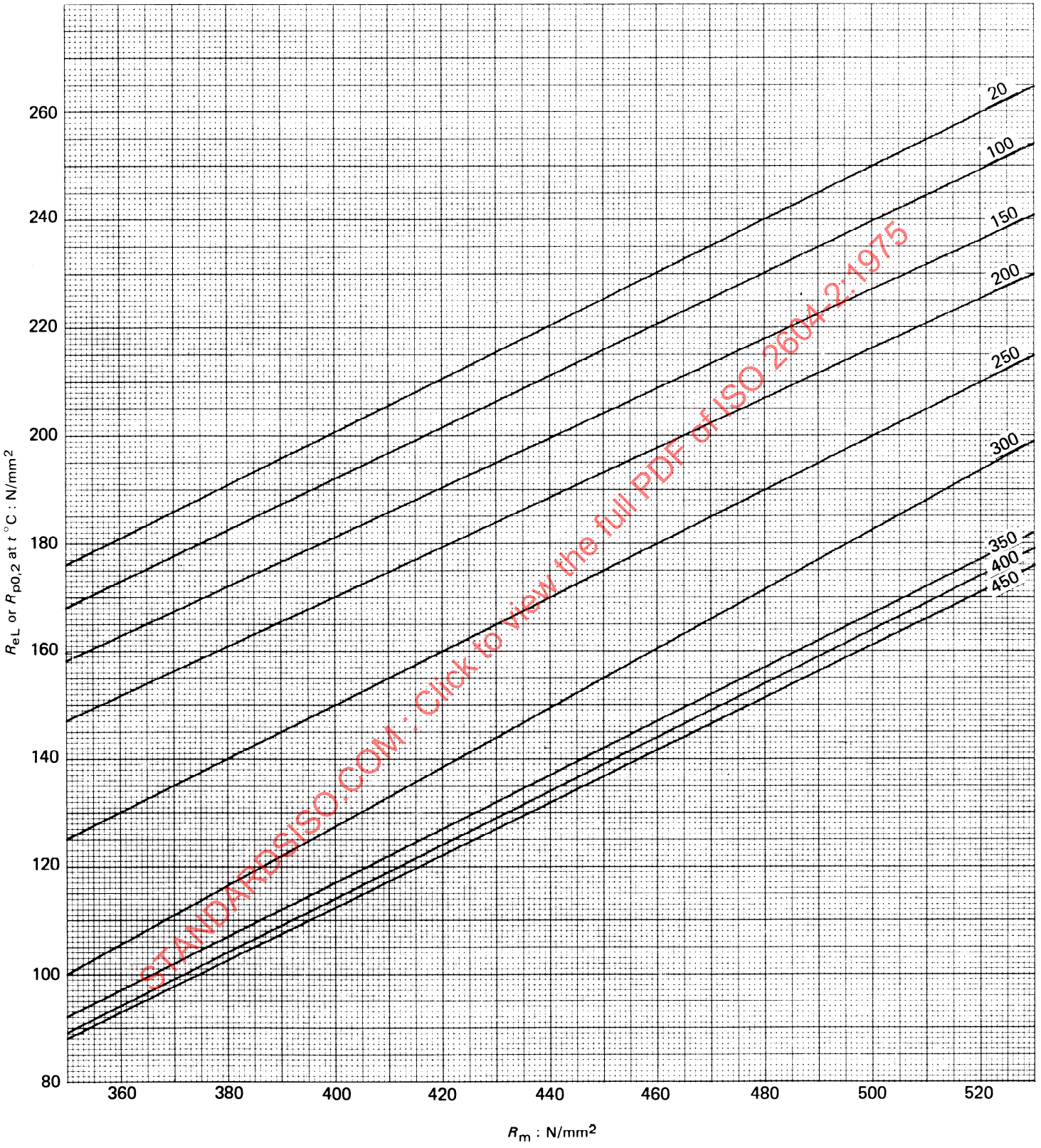

FIGURE 1 – **95 % LCL lines for :**

Steels : TS2, TS5, TS9H, TS14, TS18 (C and CMn)

Heat treatment : Normalized, hot finished

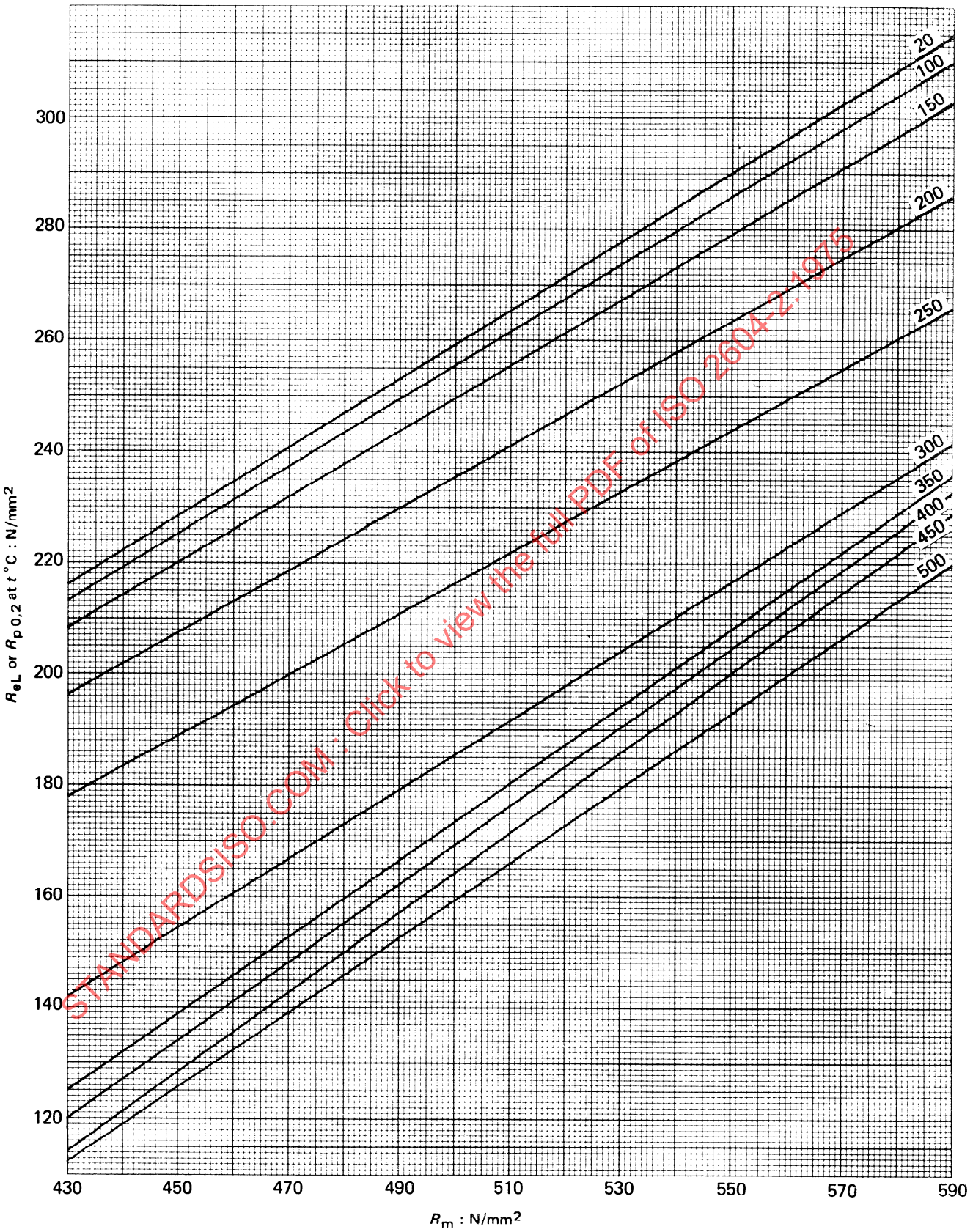

FIGURE 2 – **95 % LCL lines for :**

Steel : TS 26 (0,3 % Mo)

Heat treatment : Normalized and normalized + tempered

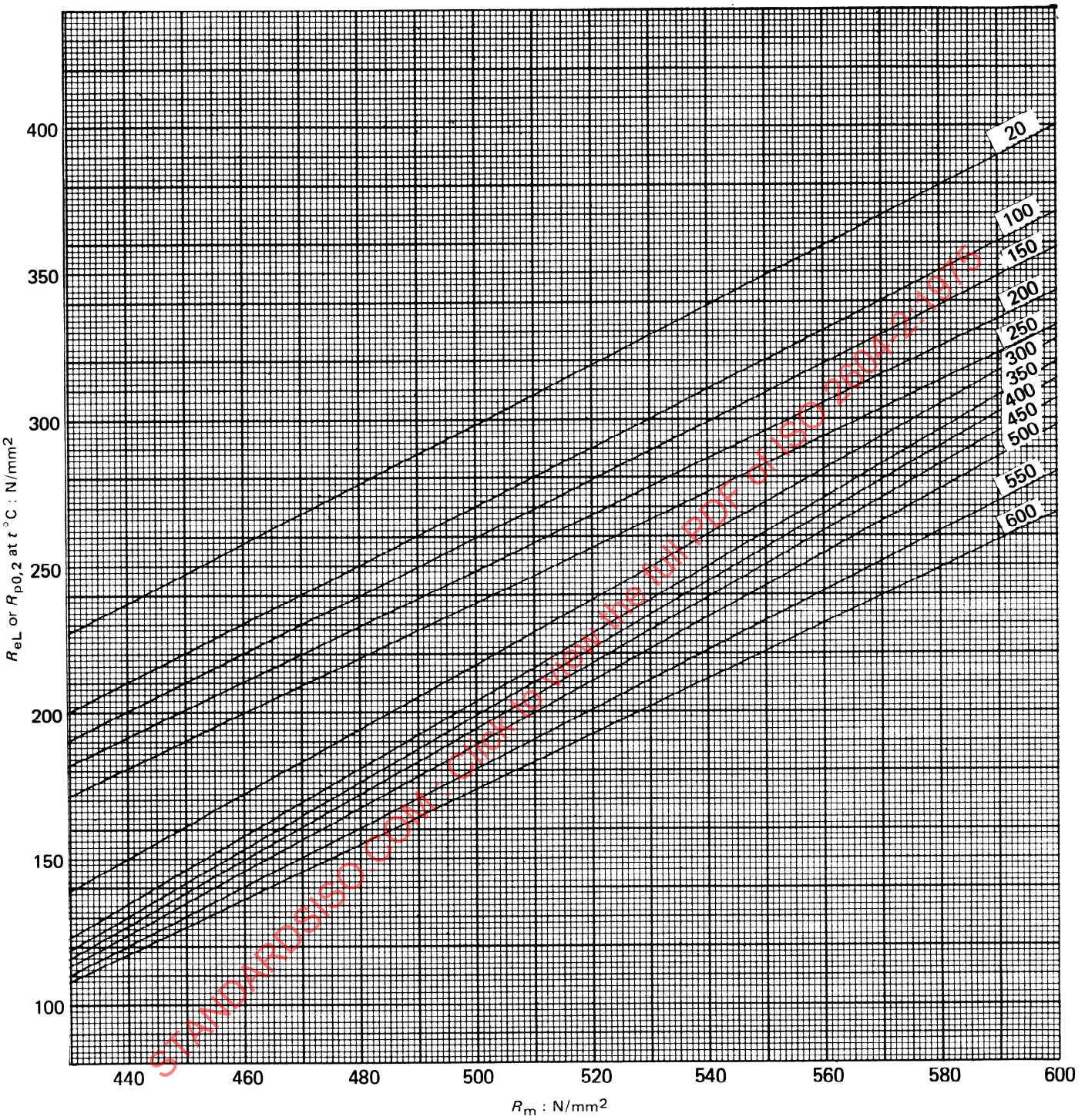

FIGURE 3 — **95 % LCL lines for :**

Steel : TS32 (1 Cr 0,5 Mo)

Heat treatment : Normalized and tempered

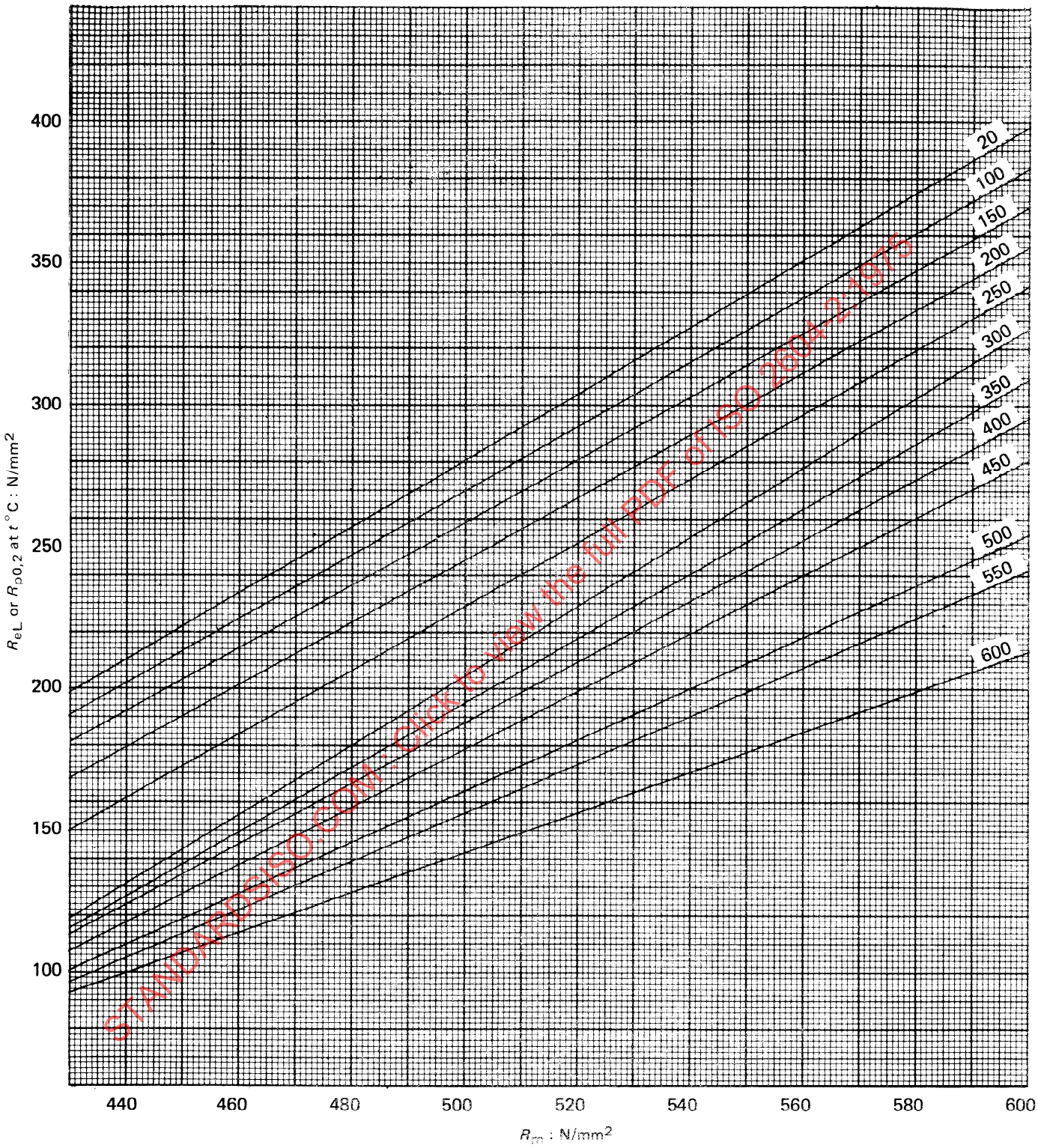

FIGURE 4 – 95 % LCL lines for :

Steel : TS33 (0,5 Cr Mo V)

Heat treatment : Normalized and tempered

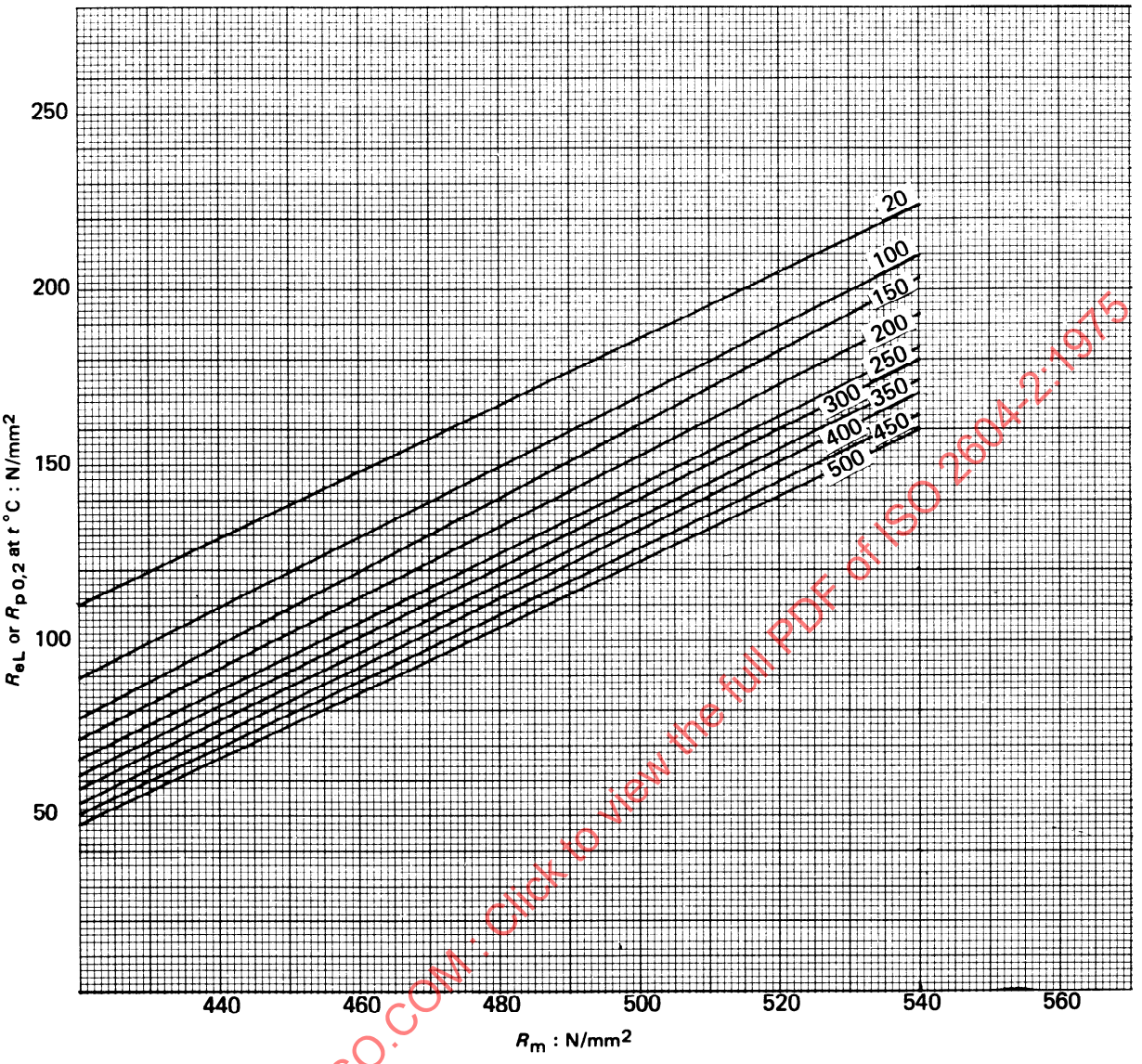

FIGURE 5 — **95 % LCL lines for :**

Steel : TS 34 (2,25 Cr 1 Mo)

Heat treatment : Annealed

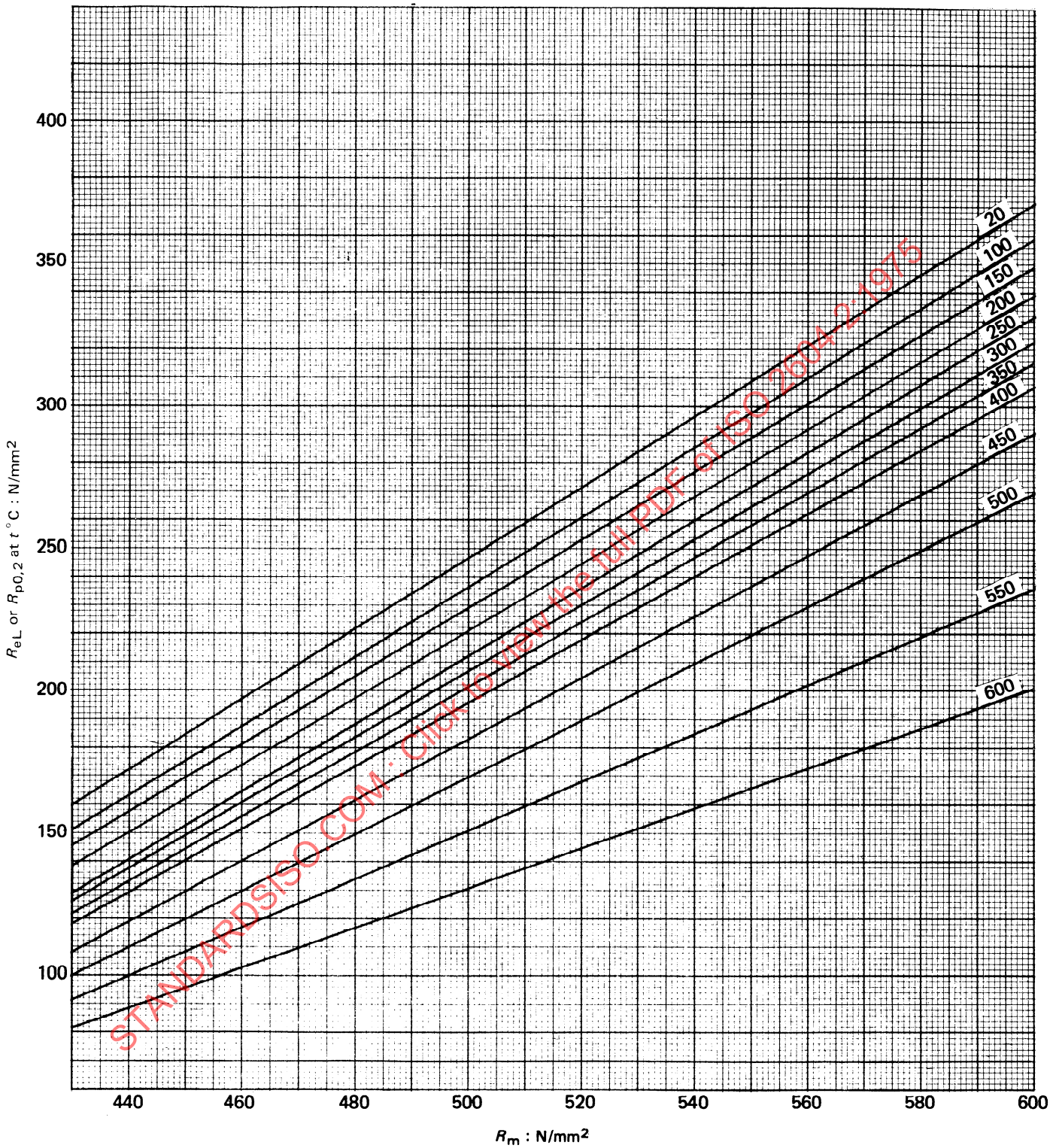

FIGURE 6 — **95 % LCL lines for :**

Steel : TS 34 (2,25 Cr 1 Mo)

Heat treatment : Normalized and tempered

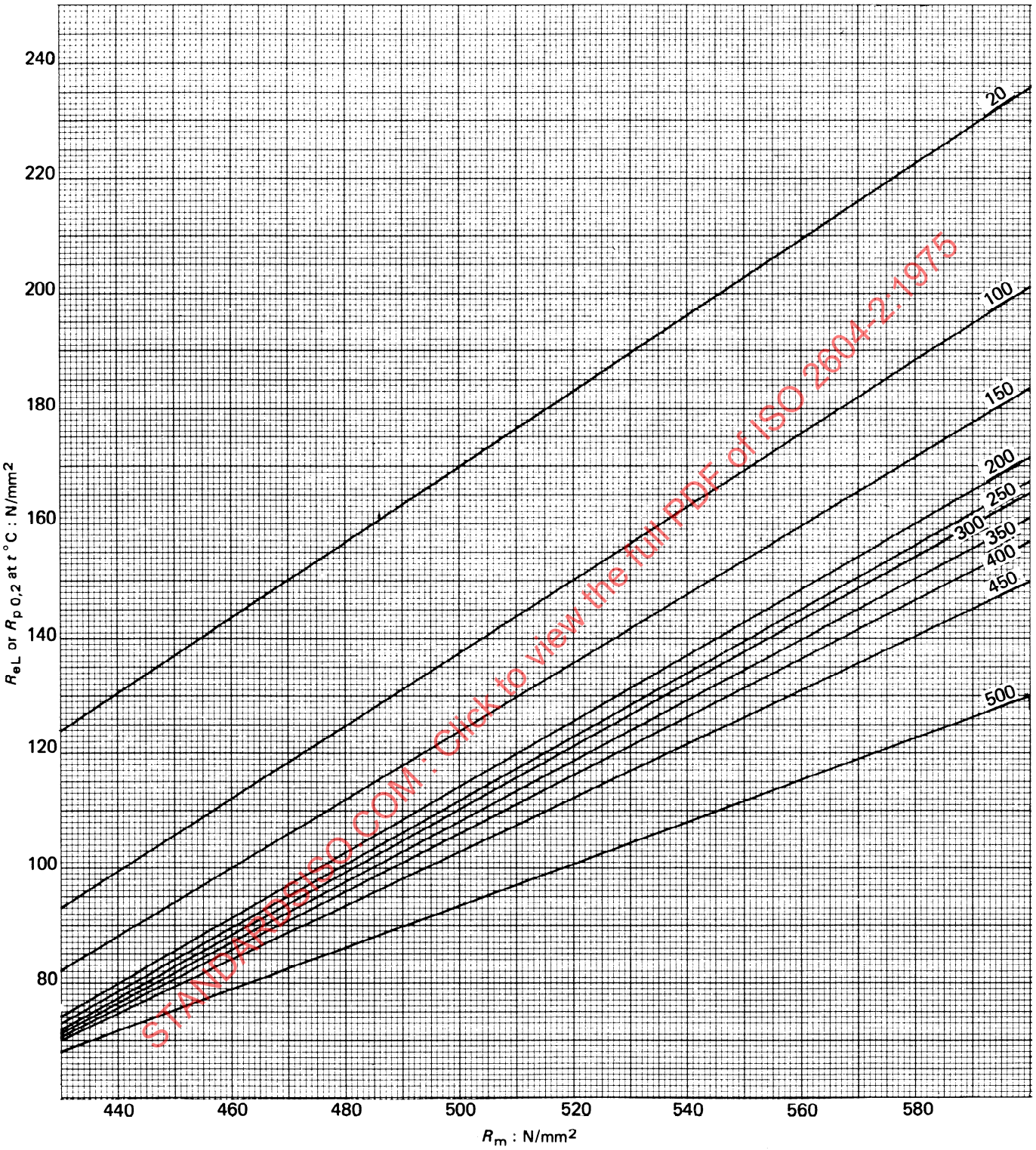

FIGURE 7 – **95 % LCL lines for :**

Steel : TS38 (9 Cr 1 Mo)

Heat treatment : Annealed