

CERTIFIED French standard	IRON AND STEEL PRODUCTS TENSILE TESTING OF STEEL <i>APPROVED BY AFNOR</i>	NF A 03-151 June 1978
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FOREWORD

At the date of approval, this standard is largely in conformity from the technical standpoint with standard ISO 82 which deals with the same subject. One essential difference is that standard NF A 03-151 defines the apparent elastic limit whereas standard ISO 82 defines the elongation limit and specifies the method to be used for its measurement.

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Certified in O.J. of
19.3.78 to take
effect on 1.6.78

This approved Standard replaces the
standard of the same number, registered
by decision of 2.11.78

Produits siderurgiques
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1 SCOPE AND FIELD OF APPLICATION

This standard describes the tensile test for steel products and defines the mechanical properties determined by that test. It applies to steel products 4 mm or more in diameter or 3 mm or more in thickness. The tensile testing of certain products such as thin sheet, wire and tubes is dealt with in separate documents.

2 PRINCIPLE OF THE TEST

The test consists in straining a test piece by tensile stress, generally to fracture, with a view to determining one or more of the mechanical properties enumerated below.

The test is carried out at ambient temperature unless otherwise specified.

3 DEFINITIONS

3.1 GAUGE LENGTH (*)

Gauge length is the length of the prescribed cylindrical or prismatic portion of the test piece on which elongation is measured at any moment during the test. In particular, a distinction is to be made between the following:

(*) The term "gauge length" derives from the fact that this length is generally the distance delimited by the gauge marks on the test piece.

- Original gauge length (L_0)(*)

Gauge length before the piece is strained.

- Final gauge length (L_u):

Gauge length after the test piece has been fractured and the fractured parts have been carefully fitted together so that their axes lie in a straight line.

3.2 ELONGATION

Elongation is the increase in gauge length at any moment during the test.

Percentage permanent elongation is the increase in the gauge length of a test piece subjected to a prescribed stress (see clause 3.5) and after removal of the stress, expressed as a percentage of the original gauge length. The symbol for this elongation is supplemented by an index indicating the prescribed stress.

Percentage elongation after fracture (A) is the permanent elongation of the gauge length after fracture, $L_u - L_0$, expressed as a percentage of the original gauge length L_0 .

(*) When the elongation to be measured is elongation after fracture, the original gauge length shall satisfy precise conditions (see clause 5.4, page 11). On the other hand, the basis of measurement when an extensometer is used to determine the yield stress, as for example, 0.2% proof stress, is not necessarily the same as gauge length so defined.

3.3 REDUCTION OF AREA

The reduction of area is the local change in cross-sectional dimensions of the test piece occurring during the test under the influence of the stress (*).

The original cross-sectional area (S_0) is the cross-sectional area of the parallel length of the test piece before application of the stress.

The cross-sectional area after fracture (S_u) is the minimum cross-sectional area after fitting together of the test piece.

The percentage reduction of area (Z) is the ratio of the maximum change in cross-sectional area which has occurred during the test, $S_0 - S_u$, to the original cross-sectional area S_0 .

It is expressed as a percentage.

The reduction of area elongation (Z_u) is the ratio of the final change in the cross-sectional area produced by the test, $S_0 - S_u$, to the cross-sectional area after fracture S_u . It is expressed as a percentage.

3.4 LOADS

Maximum load (F_m) is the highest load which the test piece withstands during the test.

Ultimate load (F_u) is the load withstood by the test piece at the instant of fracture.

The load at the apparent yield point (F_e) is the load under which, for the first time, the elongation of the test piece continues to increase without any increase in load, or when the load is decreased

3.5 STRESS (UNIT LOAD)

Stress is, at any moment during the test, load divided by the original cross-sectional area of the test piece S_0 .

(*) If the fractured test piece has a collar, the dimensions of the collar may be greater than the minimum cross-sectional area.

Tensile strength (R_m) is the stress corresponding to the maximum load.

Unit load (stress) at the apparent yield point, also abbreviated to apparent yield point (or sometimes yield stress).

Upper yield stress is the value of stress at the moment when stress is actually observed to fall.

Lower yield stress is the lowest value of stress measured during plastic deformation, ~~at yield~~ ~~initial~~ which might occur ignoring any transient effects (see figure 1).

Permanent set stress (stress at permanent set limit)

is the stress at which, after removal of the load, a prescribed permanent elongation, expressed as a percentage of the original gauge length, occurs. The prescribed value is often 0.2% (see figure 2).

The symbol used for this stress is to be supplemented by an index giving the prescribed percentage of the original gauge length, for example 0.5.

Proof stress (non proportional elongation) is the stress at which a non-proportional elongation, equal to a specified percentage of the original gauge length, occurs. When a proof stress is specified, the non-proportional elongation shall be stated: for example 0.1% or 0.2% proof stress (see figure 3) (**).

The symbol used for this stress is to be supplemented by an index giving the prescribed percentage of the original gauge length, for example 0.1.

(**) The value adopted for steel is 0.2% unless otherwise specified.

TABLE 1

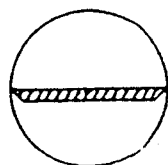
4 UNITS OF MEASUREMENT - SYMBOLS AND DESIGNATIONS

NUMBER (1)	UNIT OF MEASUREMENT	SYMBOL	DESIGNATION
1	mm	d	Diameter of the test section of a test piece of circular cross-section, or diameter of the smallest circle described about the test section for test-pieces of other cross-sections (2).
2	mm	a	Thickness of a flat test piece.
3	mm	b	Width of a flat test piece.
4	mm	L_0	Original gauge length (3).
5	mm	L_c	Parallel length.
6	mm	L_t	Total length of test piece.
7	-	-	Gripped ends.
8	mm ²	S_0	Original cross-sectional area of the gauge length.
9	mm	L_u	Final gauge length.
10	mm ²	S_u	Minimum cross-sectional area after fracture.
11	N	F_e	Load at apparent yield point
12	N/mm ² (6)	R_e	Yield stress
13	N/mm ²	R_{eH}	Upper yield stress. or upper yield point *
14	N/mm ²	R_{eL}	Lower yield stress. or lower yield point *
15	N	F_m	Maximum load
16	N/mm ²	R_m	Tensile strength (4).
17	N	F_u	Final load, or load at fracture.
18	mm	$L_u - L_0$	Permanent elongation after fracture.
19 (5)	%	A	Percentage elongation after fracture: $\frac{L_u - L_0}{L_0} \times 100$
20	%	Z	Percentage reduction of area: $\frac{S_0 - S_u}{S_0} \times 100$
21	%	Z_u	reduction of area elongation $\frac{S_0 - S_u}{S_u} \times 100$
22	N/mm ²	R_r	Permanent set stress.
23	%	-	Permanent elongation limit
24	N/mm ²	R_p	Proof stress. (non proportional elongation) or yield stress (offset) *
25	%	-	Non-proportional elongation limit

* the latter term is used in the USA and in Canada

(1) See Figures 1 to 6.

(2) The smallest circle described is the smallest circle completely encircling the contour of the section but not necessarily running through more than two high points.



(3) In ordinary correspondence, when no confusion is possible, the symbol L_0 may be replaced by L .

(4) In ordinary correspondence, when no confusion is possible, the symbol R_m may be replaced by R .

(5) When proportional test-pieces are used, elongation is expressed by the symbol $A_{5.65}$, expressing the value of the proportionality factor k .

When such proportional test-pieces are not used, elongation is expressed by the symbol A (L_0).

(6) Reminder: $1 \text{ N/mm}^2 = 1 \text{ MPa} = 0.102 \text{ kgf/mm}^2$.

5 TEST PIECES

5.1 GENERAL FORM

There shall be a transition curve between the gripped ends and the parallel length. The gripped ends may be of any shape to suit the holders of the testing machine.

Unworked portions of sections, bars etc. may be tested if necessary. In such cases, the free length between the machine jaws must be sufficient for the gauge marks to lie at a reasonable distance from the jaws.

5.2 FORM AND DIMENSIONS OF THE MEASURED PORTION

The cross-section of the test piece may be circular, square, rectangular or, in special cases, of other form.

For test pieces of rectangular section, it is recommended that a width/thickness ratio of 8:1 should not be exceeded.

As a general rule, the diameter of the measured portion of machined cylindrical test pieces should not be less than 4 mm.

Tolerances

The tolerances on the cross-sectional dimensions of test pieces shall be as shown in Table II below. An example of the application of these tolerances is given in Note 1 (page 18).

TABLE II

TOLERANCES ON CROSS-SECTIONAL DIMENSIONS OF TEST PIECES

Cross-sectional dimensions of test pieces	Nominal dimensions in mm	Machining tolerance on nominal dimensions (1) in mm	Tolerance on form in mm
Diameter of machined circular-section test pieces	over 3 to 6 over 6 to 10 over 10 to 18 over 18 to 30	± 0.06 ± 0.075 ± 0.09 ± 0.105	0.03 (2) 0.04 (2) 0.04 (2) 0.05 (2)
Cross-sectional dimensions of rectangular-section test pieces machined on all 4 faces		Same tolerances as on the diameter of rectangular section test pieces	
Cross-sectional dimensions of rectangular-section test pieces machined on 2 opposite faces only	over 6 to 10 over 10 to 18 over 18 to 30 over 30 to 50		0.22 (3) 0.27 (3) 0.33 (3) 0.39 (3)
(1) The machining tolerances (js 12) apply when the nominal value of the cross-section is not measured but has to be used in the calculation. (2) Tolerances IT 9) maximum differences between measurements of a given) transverse dimension, over the whole measured (3) Tolerances IT 13) portion of the test piece.			

5.3

PARALLEL LENGTH

The parallel length

 L_c shall be between:

$$L_0 + \frac{d}{2} \text{ and } L_0 + 2d$$

In case of dispute, the length $L_0 + 2d$ is used, provided that there sufficient material.

Case of prismatic test pieces

If rectangular-section prismatic test pieces have to be machined in batches from rolled metal, the parallel length must be uniformly equal to $L_0 + 2d$, with L_0 and d taken from the test piece in the batch with the largest cross-sectional area.

5.4

GAUGE LENGTH

Proportional test pieces

Test pieces which satisfy the condition $L_0 = k \sqrt{S_0}$ where $k = 5.65$ are generally used for the tensile test.

Circular section test pieces should preferably be of the dimensions shown in the table below.

TABLE III

k	GAUGE LENGTH $L_0 = k \sqrt{S_0}$ mm	DIAMETER d mm	CROSS- SECTIONAL AREA S_0 mm ²	PARALLEL LENGTH L_C mm	TOTAL LENGTH L_t
5.65	100 ± 1.0	20 ± 0.105	314	110 to 140	Depends on how the test piece is gripped in the machine. Normally: $L_t > L_C + 2d$ or $4d$
	50 ± 0.5	10 ± 0.075	78.5	55 to 70	

The gauge length corresponding to the actual dimensions of rectangular-section test pieces can be calculated more easily by reference to the scale in the annex.

Non-proportional test pieces

For economic reasons, it is sometimes necessary for the series testing of flat test pieces to adopt an original gauge length independent of the cross-sectional area of the test pieces. Conversion tables can be used to deduce elongation on a proportional test piece from the elongation recorded. In case of dispute, however, elongation measured on the non-proportional test piece will be valid only if so provided explicitly in the product standard.

6 TEST CONDITIONS

6.1 SPEED OF THE MACHINE

6.1.1 YIELD STRESS

When it is intended to determine one of the yield stresses, the rate at which the test piece is strained must not exceed $30 \text{ N/mm}^2/\text{s}$ starting from the specific stress of 50 N/mm^2 , until the yield stress limit is reached.

For the determination of upper yield stress, lower yield stress and the apparent yield point, the gauge length shall not increase by more than 15% per minute during plastic deformation.

6.1.2 Tensile strength

When determining tensile strength, the rate of separation of the cross-heads of the testing machine, expressed as a percentage of the parallel length per minute, shall not, in the plastic range, be greater than twice the specified minimum elongation plus 10.

NOTE

When steels with a nominal strength below $1,100 \text{ N/mm}^2$ are tested and the yield stress is not to be determined, the rate within the elastic range may be as high as that specified above for the plastic range.

6.1.3 Regularity

In all cases, the speed of testing shall be as uniform as possible in both the elastic and the plastic range and the change of speed from one to the other shall be made gradually and without shock.

6.2 LOAD

The load shall be measured without interpolation between the graduations, to the accuracy required by the product standard.

6.3 METHOD OF GRIPPING

The machine and the means of gripping shall have attachments allowing the test piece to move freely in the direction of tensile stress without any transverse bending stress being generated.

7 DETERMINATION OF MECHANICAL PROPERTIES

7.1 DETERMINATION OF ELONGATION

Elongation is generally measured on the gauge length $k \sqrt{S_0}$ which is marked prior to testing to within $\pm 1\%$. For this purpose, the two fractured parts of the test piece are carefully fitted together so that their axes lie in a straight line. The change of gauge length is measured to within 0.25 mm (*).

(*) See Notes 2a and 2b on pages 21.22

This method of determination is valid only if the distance from the fractured section to the nearer gauge mark is not less than $1/3$ of the gauge length after fracture, in the case of proportional test pieces ($L_0 = 5.65 \sqrt{S_0}$).

The measurement shall still be valid however, whatever the position of the fracture section, if elongation reaches the specified value.

7.1.2 Special case

In order to avoid the possibility of rejecting test pieces due to the fracture being outside the limits specified in clause 7.1.1.1. the following method may be used (*)

Before testing, sub-divide the gauge length L_0 into N equal parts.

After testing designate by A the end mark on the shorter piece and designate by B the graduation mark on the longer piece, the distance from which to the fracture is close to the distance from the fracture to the end mark A.

If n is the number of intervals between A and B, the elongation after fracture is determined as follows, after the two broken parts have been fitted together as described in clause 7.1.1:

If $N - n$ is an even number (see figure 8),

measure the distance between A and B and the distance from B to the graduation mark C at:

$$\frac{N - n}{2} \text{ intervals from B}$$

(*) This method is of course laborious and adds considerably to the length of the test. It should be used strictly as an exception and would be justified for example in the case of a very large piece from which no additional or test-check specimen could be taken.

The following formula is used to calculate percentage elongation after fracture:

$$A\% = \frac{AB + 2BC - L_0}{L_0} \times 100\%$$

If $N - n$ is an odd number (see figure 9),

measure the distance between A and B and the distance from B to the graduation marks C' and C'' at:

$$\frac{N - n - 1}{2} \text{ and } \frac{N - n + 1}{2} \text{ intervals from B.}$$

Then use the following formula to calculate percentage elongation after fracture:

$$A\% = \frac{AB + BC' + BC'' - L_0}{L_0} \times 100\%$$

7.2 DETERMINATION OF PERMANENT SET STRESS AND PROOF STRESS

- 7.2.1 For the precise determination of 0.2% permanent set stress (or any other specified value), permanent elongation is measured at increasing loads applied successively (return-to-zero load method) (clause 7.2.2). As this determination takes a fairly long time, the intersecting graph method may be used, unless otherwise specified; this method is based on plotting the load/extension curve to determine a proof stress (clause 7.2.3). By special agreement, this measurement may be replaced by the straightforward verification of elongation by measurement under a given load (clause 7.2.4).

7.2.2 Method of determining permanent set stress

The return-to-zero load method of determining permanent set stress is as follows: two increasing loads are applied successively to the test piece and each held for ten to twelve seconds; when each of these loads is removed, the permanent elongation of the test piece is measured. The test is stopped when this elongation goes beyond 0.2% (or any other specified value) of the original length. The load corresponding to the prescribed permanent set stress is then determined by interpolation between the results obtained.

7.2.3 Method of determining proof stress

The load curve (Y-axes) is accurately plotted in terms of percentage elongation (X-axes). On this diagram, a line is drawn parallel to the straight section of the curve and distant from it, on the extension axis, by the prescribed percentage of the original gauge length. Proof stress is represented by the point at which this line cuts the curve.

When the straight section of the load/extension diagram is not clearly defined so that the parallel line cannot be drawn with sufficient certainty, the following procedure is recommended (see figure 10).

When the presumed proof stress is exceeded, reduce the load to about 10% of the load reached. Then increase the load again until it exceeds the value first reached. The required proof stress is then determined by drawing a line through the hysteresis loop. Then draw a line parallel to the first one at a distance from the origin of the curve measured on the X-axis, equal to the prescribed non-proportional elongation. The required proof stress is represented by the point at which this parallel cuts the load/extension curve.

7.2.4 Method of verification by measuring elongation at set load

The test piece is strained for ten to twelve seconds at the load corresponding to the specified yield stress. The load is then removed and the tester verifies that the permanent set is not more than the prescribed percentage of the original gauge length.

APPENDIX

SCALE FOR CALCULATING THE GAUGE LENGTH OF RECTANGULAR
SECTION TEST PIECES

This scale is constructed by the alignment method.

METHOD OF USE

- On the side scales, find points a and b which represent the width and thickness of the rectangular test piece.
- Join these two points by a straight line (taut string or edge of a ruler).
- Read off the corresponding gauge length on the left-hand graduation at the point where this line cuts the middle scale.

Example of application

$$a = 21 \text{ mm}$$

$$b = 15.5 \text{ mm}$$

$$L_0 = 102 \text{ mm}$$

NOTES:

- 1) With less than 1% reading error on L_0 , this scale can be used in all cases without further calculation.
- 2) The reading error may exceed 1% on the areas, and this may in some cases not provide the required degree of accuracy; in such cases, it is better to calculate the product of a and b directly.
- 3) Construction of the scale

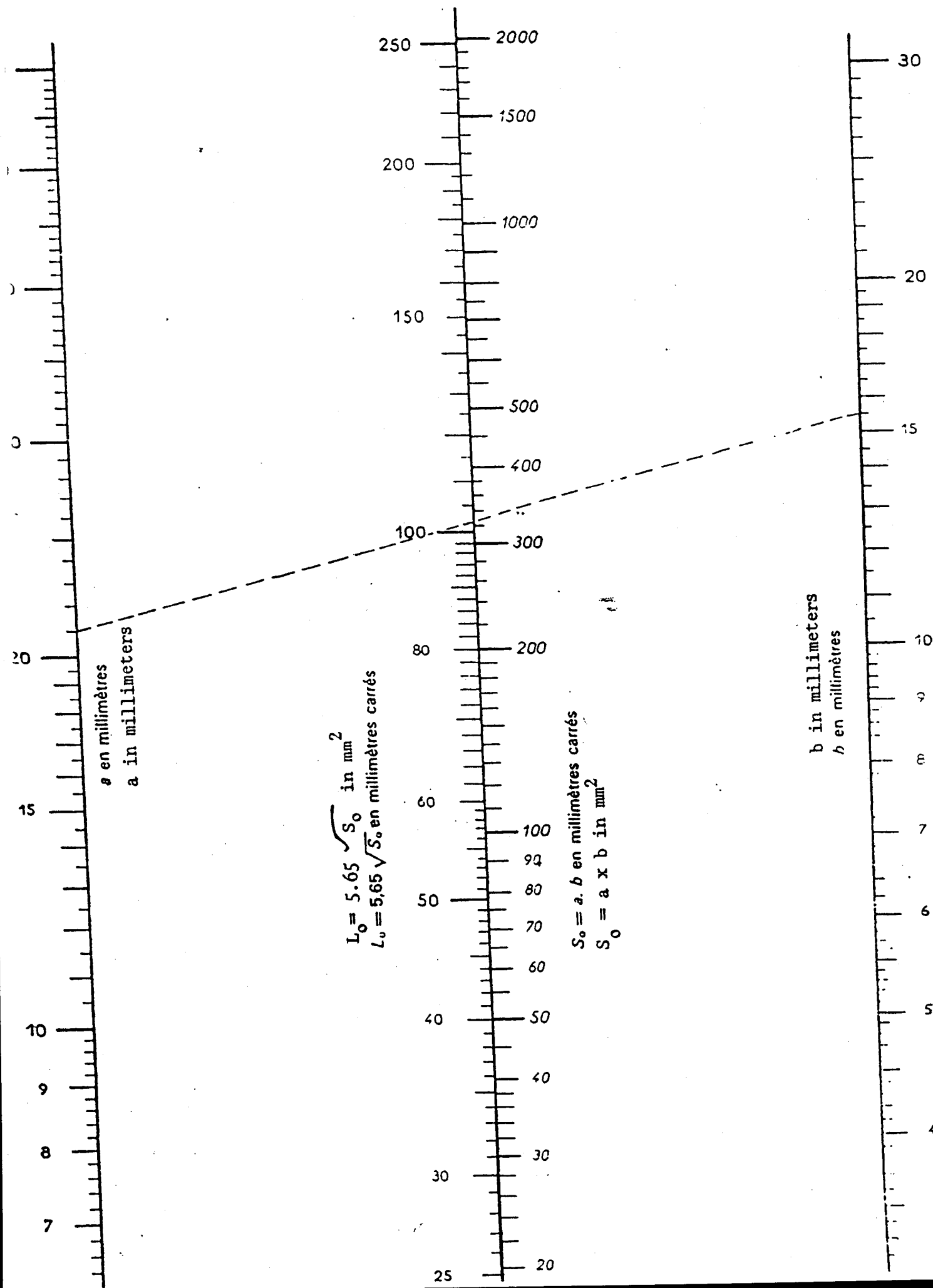
Draw three equidistant straight lines to carry the logarithmic graduations. These lines are graduated with a modulus such that log 10 is represented by 250 mm; the values on the three scales rise

towards the top of the sheet. Points (20) and (10) are set approximately in the middle of the sheet on the two side scales.

Join the two points (10) on the side scales.

The point at which this line cuts the middle scale gives the 56.5 point on the left hand centre graduation L_0 .

The area scale S_0 (right hand graduation on the centre scale). This same 56.5 point is the 100 point on the area scale. Complete the graduation with a modulus half the previous one, i.e. $\log 10 = 125$ mm.



COMMENTS

1 EXAMPLES OF THE APPLICATION OF TOLERANCES

(see clause 5.2)

a) Machining tolerances

The value specified in Table II in clause 5.2.1, i.e. ± 0.075 mm on a nominal diameter of 10 mm means that if the nominal cross-section is to be used for calculation, no test piece should have a diameter outside the following two values:

$$10 + 0.075 = 10.075 \text{ mm}$$

$$10 - 0.075 = 9.925 \text{ mm}$$

b) Tolerance on form

The value specified in Table II in clause 5.2.1 means that for a given test piece having a nominal diameter of 10 mm complying with the condition of machining specified above, the difference between the smallest and the largest measured diameter shall not exceed 0.04 mm.

Consequently, if the minimum diameter of such a test piece is 9.99 mm, its maximum diameter shall not exceed:

$$9.99 + 0.04 = 10.03 \text{ mm}$$

2 ELONGATION

(see clause 7)

- 2 a In some cases (such as skew fracture), the conventional rule laid down in clause 7.1.1. is not easy to apply because of difficulty in fitting together the two broken parts of the test piece. The determination of elongation after fracture then becomes uncertain.

2 b

On proportional test pieces, there is an error of under-measurement if the distance between the fracture section to the nearer gauge mark is less than $1/3$ of the gauge length after fracture. In the much less frequent case where there is more than one neck, there will be an error of over-measurement.

3 MISCELLANEOUS TEST CONDITIONS

The ends of circular-section test pieces may either have the whole of their circumference held by the grips, or may be gripped by means of clamping wedges over a length at least equal to twice the diameter of the section, or may be threaded over a length at least equal to their own diameter (*).

The ends of prismatic test pieces may be gripped either by pegs or by clamping wedges. The cross-sectional area of the pegs shall be at least twice the original cross sectional area S_0 of the measured portion; they fit into holes drilled in each of the ends. Clamping wedges grip a length of the end at least twice the longer side of the test piece cross section.

Lengths of sections, bars, etc without heads are gripped in clamping wedges over a length at least three times the diameter d of the smallest circle circumscribed by the section.

(*)

The ISO metric thread is recommended.

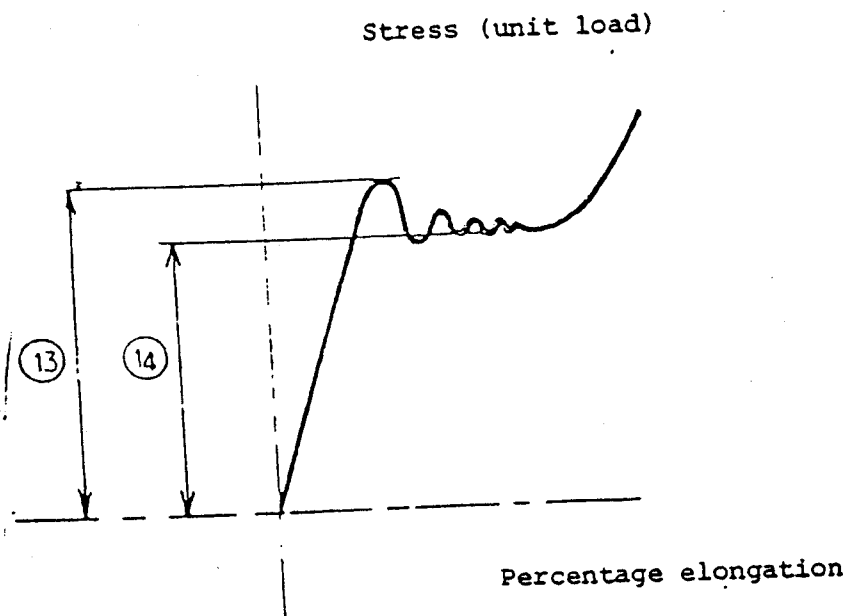


Figure 1 - Lower and upper yield stress

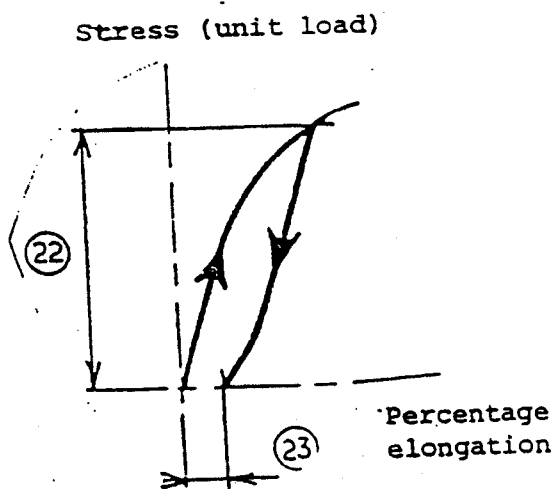


Figure 2
Permanent set stress

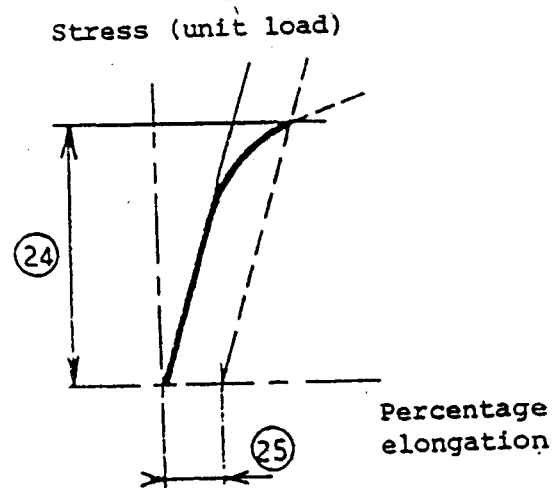


Figure 3
Proof stress

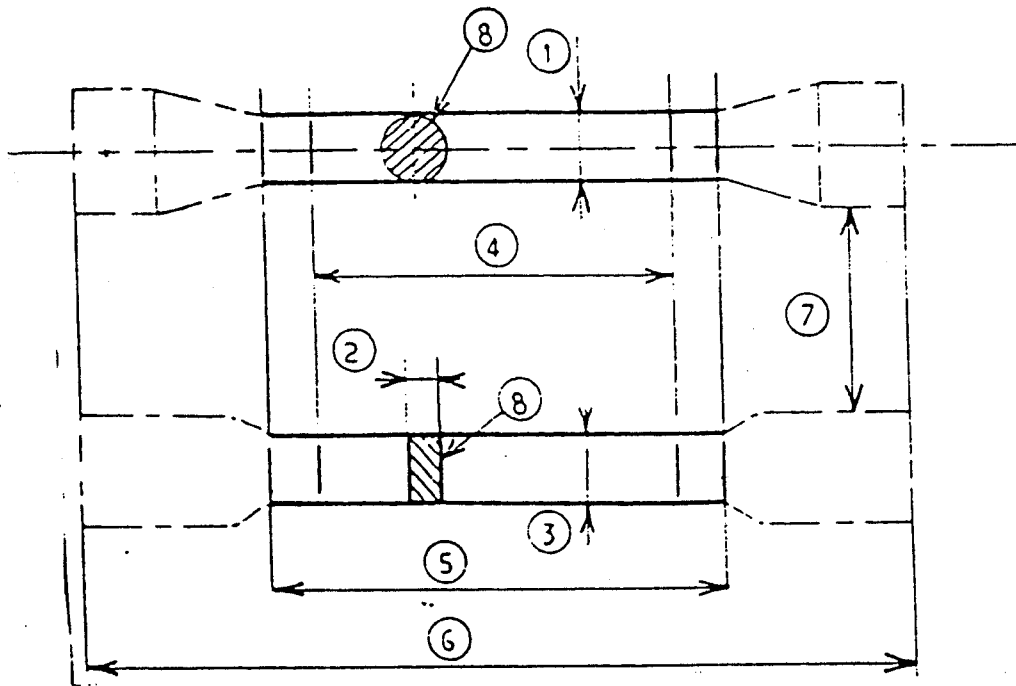


Figure 4

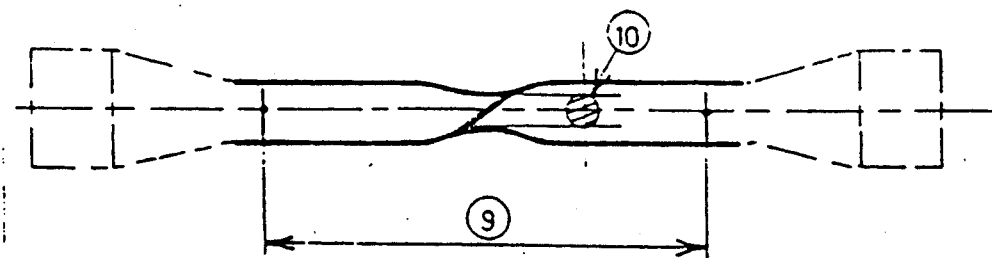


Figure 5 - The form of end of test pieces is intended as a guide only

