

ISO

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO RECOMMENDATION R 401

TENSILE TESTING OF COPPER AND COPPER ALLOY TUBES
OF CIRCULAR SECTION

1st EDITION

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BRIEF HISTORY

The ISO Recommendation R 401, *Tensile Testing of Copper and Copper Alloy Tubes of Circular Section*, was drawn up by Technical Committee ISO/TC 26, *Copper and Copper Alloys*, the Secretariat of which is held by the Deutscher Normenausschuss (DNA).

Work on this question by the Technical Committee began in 1958 and led, in 1961, to the adoption of a Draft ISO Recommendation.

In February 1962, this Draft ISO Recommendation (No. 499) was circulated to all the ISO Member Bodies for enquiry. It was approved by the following Member Bodies:

Australia	India	Spain
Bulgaria	Italy	Sweden
Burma	Japan	Switzerland
Canada	Netherlands	Turkey
Denmark	Poland	United Kingdom
Finland	Portugal	U.S.S.R.
Germany	Republic of South Africa	Yugoslavia

Three Member Bodies opposed the approval of the Draft:

Belgium
France
U.S.A.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in November 1964, to accept it as an ISO RECOMMENDATION.

TENSILE TESTING OF COPPER AND COPPER ALLOY TUBES OF CIRCULAR SECTION

1. SCOPE

This ISO Recommendation applies to the tensile testing of copper and copper alloy tubes of circular section.

2. PRINCIPLE OF TEST

The test consists in subjecting a test piece to increasing tensile stress, generally to fracture, with a view to determining one or more of the mechanical properties enumerated hereafter. The test is carried out at ambient temperature, unless otherwise specified.

3. DEFINITIONS

3.1 *Gauge length*. At any moment during the test, the length of the cylindrical or prismatic portion of the test piece on which an increase in length is measured. In particular, a distinction should be made between the following:

- (a) *the original gauge length (L_0)*. Gauge length before the test piece is strained, and
- (b) *the gauge length after fracture (L_u)*. Gauge length after the test piece has been fractured and the fractured parts have been carefully fitted together so that they lie in a straight line.

3.2 Stress (actually "nominal stress"). At any moment during the test, load divided by the original cross-sectional area of the test piece.

3.3 Percentage permanent elongation. Increase in the gauge length of a test piece subjected to a stress after removal of that stress, expressed as a percentage of the original gauge length.

3.4 Stress at specified permanent set (R_r). Stress at which, after removal of load, the specified percentage permanent elongation occurs. (See Fig. 4 (a)).

3.4.1 The symbol used for this stress is supplemented by an index giving the specified percentage elongation.

3.5 Proof stress (R_p)*. Stress at which the specified percentage non-proportional elongation occurs. (See Fig. 4 (b)).

3.5.1 The symbol used for this stress is supplemented by an index giving the specified percentage elongation.

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

3.7 Final load (F_u). Load imposed on the test piece at the moment of fracture.

3.8 Tensile strength (R_m). Maximum load divided by the original cross-sectional area of the test piece, i.e. stress corresponding to the maximum load.

3.9 Percentage elongation after fracture (A). Permanent elongation of the gauge length after fracture $L_u - L_o$, expressed as a percentage of the original gauge length L_o .

3.10 Percentage reduction of area after fracture (Z). Maximum change in cross-sectional area after fracture, $S_o - S_u$, expressed as a percentage of the original cross-sectional area S_o .

3.11 Percentage elongation factor at point of constriction (Z_u). Maximum change in cross-sectional area after fracture, $S_o - S_u$, expressed as a percentage of the minimum cross-sectional area after fracture S_u .

* In the United States of America and Canada this stress is called "yield strength (offset)" in contrast to the stress called "yield strength" which corresponds to a specified total elongation (usually 0.5 per cent) with the test piece under tension.

4. SYMBOLS AND DESIGNATIONS

Number	Symbol	Designation
1	D	External diameter of the tube
2	a	Thickness of tube
3	b	Mean width of longitudinal strip
4	L_o^*	Original gauge length
5	L_c	Parallel length
6	L_t	Total length
7	—	Gripped ends
8	S_o	Original cross-sectional area of the gauge length
9	L_u	Gauge length after fracture
10	S_u	Minimum cross-sectional area of the gauge length after fracture
11	F_m	Maximum load
12	R_m^*	Tensile strength
13	F_u	Final load, i.e. load at moment of fracture
14	$L_u - L_o$	Permanent elongation after fracture
15	A	Percentage elongation after fracture $\frac{L_u - L_o}{L_o} \times 100$
16	Z	Percentage reduction of area after fracture $\frac{S_o - S_u}{S_o} \times 100$
17	Z_u	Percentage elongation factor at point of constriction $\frac{S_o - S_u}{S_u} \times 100$
18	R_r	Stress at specified permanent set
19	—	Specified permanent set
20	R_p	Proof stress
21	—	Specified non-proportional elongation

* In current correspondence and where no misunderstanding is possible, the symbols L_o and R_m may be replaced by L and R respectively.

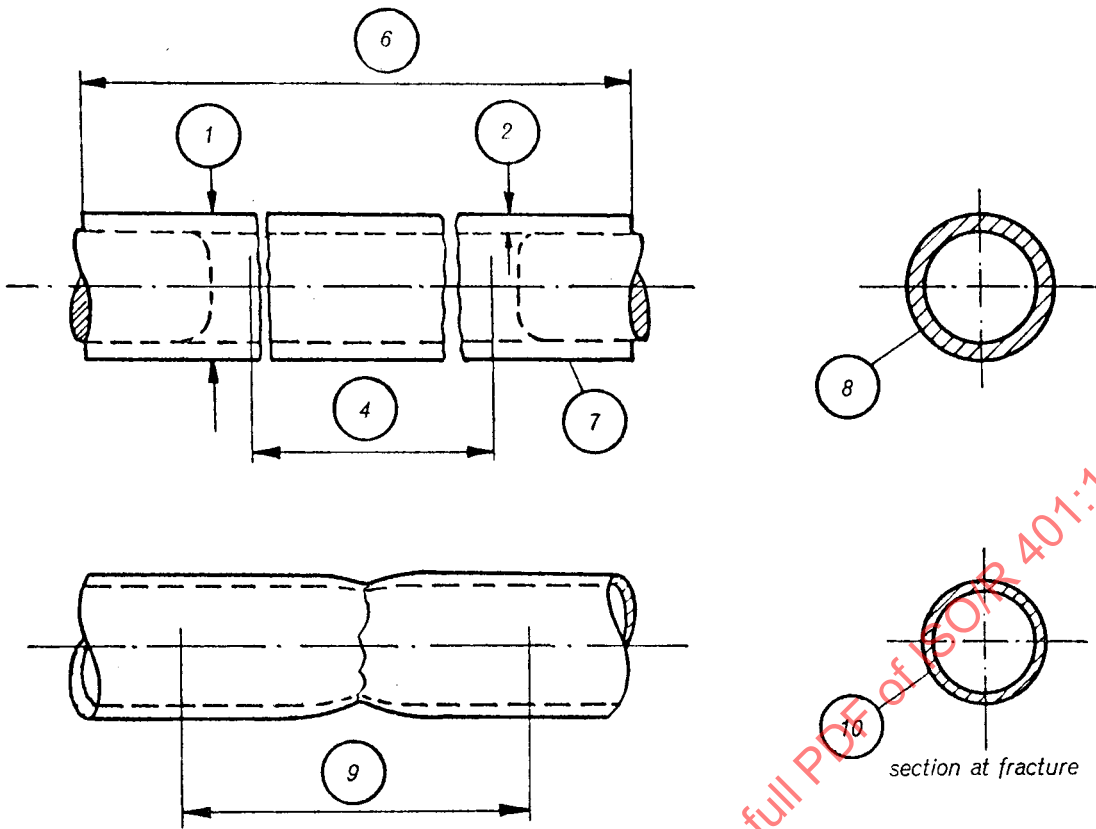


FIG. 1.—Test on full section

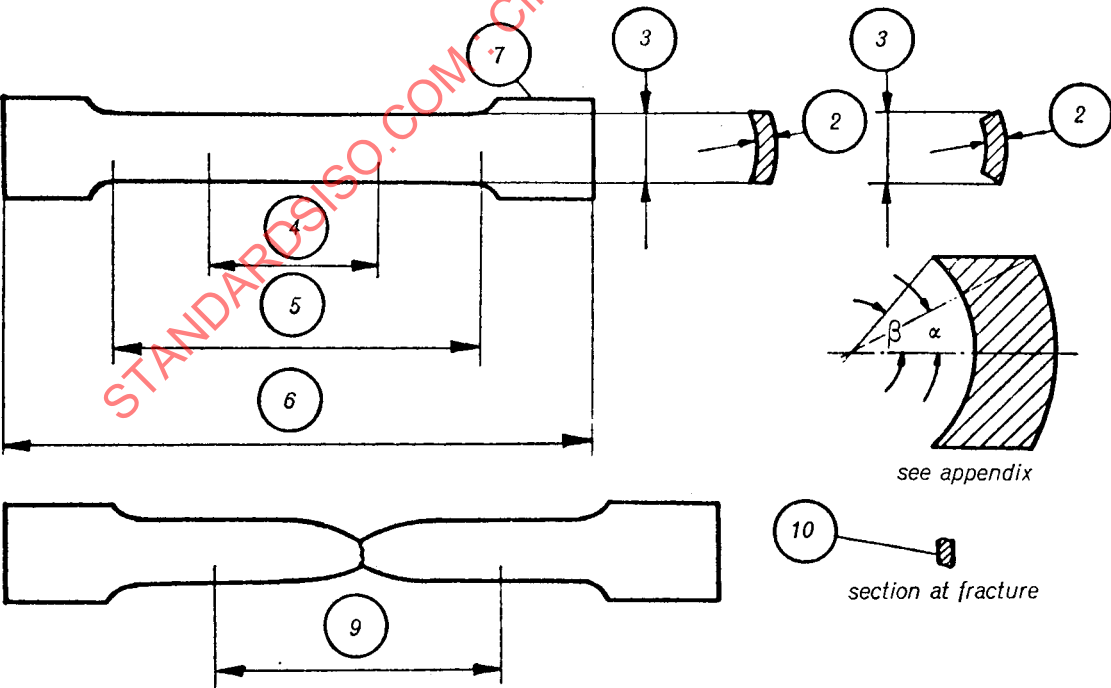


FIG. 2.—Test on longitudinal strip

5. TEST PIECES

5.1 The test piece may consist of a length of the tube tested in full section (see Clause 5.2) or a strip of full thickness cut longitudinally from the tube (see Clause 5.3). Other forms of test pieces may be used by agreement.

5.1.1 Tubes with an external diameter up to approximately 30 mm (1.2 in) should preferably be tested in full section.

5.2 Test on lengths of tube in full section

5.2.1 Tubes to be tested may be plugged at each end. The length of the plug projecting beyond the grip in the direction of the gauge length should not exceed the external diameter of the tube, and its shape should be such that it does not interfere with the free elongation of the gauge length.

5.2.2 The free length between the end of each plug and the nearest gauge mark on a test piece consisting of the full section of the tube should be between $\frac{D}{4}$ and D , except that, provided there is sufficient material, D should always be approached for arbitration purposes.

5.3 Test on strips cut longitudinally from tubes

5.3.1 The test piece should have a parallel length, and may have enlarged ends, in which case there should be a transition radius between the gripped ends and the parallel length. The parallel length should not be flattened, but the gripped ends may be flattened for gripping in the testing machine.

5.3.2 The parallel length L_c for test pieces consisting of a strip cut longitudinally from the tube should be between $L_c + \frac{b}{2}$ and $L_o + 2b$, except that, provided there is sufficient material, $L_o + 2b$ should always be used for arbitration purposes.

5.3.3 The parallel length L_c should be parallel within ± 0.05 mm (0.002 in) of the mean value of the width.

5.4 In general, only test pieces complying with the requirement that $L_o = k \sqrt{S_o}$, where k may be equal to 4, 4.5, 5.65, 8.16 or 11.3, are used for the tensile test; these test pieces are known as proportional test pieces.

5.4.1 The value of L_o thus calculated should be rounded off to the nearest 5 mm (0.2 in).

5.4.2 It is recommended that the value of k should be 5.65 for general purposes except for material of small section if the calculated gauge length L_o with $k = 5.65$ is less than 25 mm. In this case k should normally be 11.3.

The use of the other values, namely $k = 4, 4.5$ and 8.16 should be regarded as an interim measure, and these should only be used in connection with existing specifications. These values of k may be deleted after a period to be determined later.

5.5 Exceptionally, test pieces other than proportional test pieces may be used by agreement. The gauge length used should be stated in the test report.

5.6 Determination of the original cross-sectional area of test piece

The cross-sectional area of the test piece should be determined to an accuracy of 1 per cent, unless otherwise agreed.

The cross-sectional area of a test piece consisting of a strip with parallel sides cut longitudinally from a tube should be determined by the formulae in the Appendix.

6. DETERMINATION OF ELONGATION AFTER FRACTURE

6.1 The gauge length is marked on the specimen before the test to a suitable accuracy. The marking is performed in such a manner that it does not cause fracture at the gauge marks.

6.1.1 The fractured parts of the test piece are carefully fitted together so that they lie in a straight line. The increase in gauge length after test is measured to the nearest 0.25 mm (0.01 in).

6.1.2 This type of determination is valid only if the distance between the fracture and the nearest gauge mark is greater than or equal to $0.25 L_0$.

6.1.3 The measurement is valid in any case if the elongation reaches the specified value, whatever the position of the fracture.

6.2 To avoid the possibility of rejection of test pieces due to the fracture being outside the limits specified in Clause 6.1.2, the following method may be employed:

6.2.1 Before testing, subdivide the gauge length L_0 into N equal parts.

6.2.2 After testing, designate by A the end mark on the shorter piece. On the larger piece, designate by B the graduation mark, the distance from which to the fracture is most nearly equal to the distance from the fracture to the end mark A .

6.2.3 If n be the number of intervals between A and B , the elongation after fracture is determined as follows:

(a) If $N - n$ is an even number (see Fig. 5 (a)), measure the distance between A and B and the distance from B to a graduation mark C

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

then calculate the elongation after fracture from the formula:

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

- (b) If $N - n$ is an uneven number (see Fig. 5 (b)), measure the distance between A and B and the distance from B to the graduation marks C' and C''

at $\frac{N - n - 1}{2}$ and $\frac{N - n + 1}{2}$ intervals from B ;

then calculate the elongation after fracture from the formula:

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

7. RATE OF LOADING

If the rate of loading is considered to be of importance, it should be the subject of special agreement. For the determination of the proof stress, it should in no case exceed 1 kgf/mm² (0.6 tonf/in²) per second.

8. MEASUREMENT OF LOAD

Loads corresponding to specified stresses should be determined on a testing machine compatible in accuracy with Class 1.0 of ISO Recommendation R 147 – *Load calibration of testing machines for tensile testing of steel*.

9. DETERMINATION OF STRESS AT SPECIFIED PERMANENT SET

9.1 The unloading method of determining this stress is as follows: Increasing loads are successively applied to the test piece and maintained in each case for about 10 seconds. After removal of each load, the permanent elongation which the test piece has taken is measured, using a suitable extensometer. The test is stopped when this elongation exceeds the specified percentage. The stress corresponding to the specified permanent elongation is then obtained by interpolation.

9.2 Special agreement may be made for the substitution for this method of the proving test (Clause 11.1).

10. DETERMINATION OF PROOF STRESS

10.1 This stress is determined as follows: Using a suitable extensometer, a curve is plotted, taking the loads as ordinates and the corresponding elongations as abscissae. A straight line is drawn on the graph parallel to the straight part of the curve, at a distance from the straight part, measured along the axis of the abscissae, equal to the specified percentage of the original gauge length. (See Fig. 4 (b)). The desired stress corresponds to the point of intersection of the straight line and the curve.