

Australian/New Zealand Standard[®]

Winding wires

Part 5: Test methods

AS/NZS 1194.5:1996

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Department of Defence, Australia
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Part 5: Test methods

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL/3 on Electric Wires and Cables, to supersede in part AS 1194.1—1984, AS 1194.2—1983, AS 1194.3—1984 and AS 1194.4—1985, NZS/AS 1194.1—1984, NZS/AS 1194.2—1983, NZS/AS 1194.3—1984 and NZS/AS 1194.4—1985.

This Standard is part of a series, the other parts being:

AS/NZS

- 1194 Winding wires
- 1194.1 Enamelled round copper winding wires
- 1194.2 Enamelled rectangular copper winding wires
- 1194.3 Enamelled round aluminium winding wires
- 1194.4 Enamelled rectangular aluminium winding wires

This Part 5 of the Standard stipulates the test methods applicable to round and rectangular wires of both copper and aluminium enamelled material and Parts 1, 2, 3 and 4 specify dimensions and material requirements for each of these four conductors.

In preparation of this Standard, consideration was given to IEC 851 Parts 1 to 6* and acknowledgment is made of the assistance received from those sources.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

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- * IEC 851 Methods of test for winding wires
- Part 1: General
 - Part 2: Determination of dimensions
 - Part 3: Mechanical properties
 - Part 4: Chemical properties
 - Part 5: Electrical properties
 - Part 6: Thermal properties

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 AS 1194.3—1984 and AS 1194.4— 1985 in part.
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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard

Winding wires

Part 5: Test methods

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard specifies the test methods for round and rectangular, copper and aluminium enamelled winding wires in AS/NZS 1194 Parts 1 to 4, where relevant.

1.2 REFERENCED DOCUMENTS The following documents are referred to in this Standard:

AS/NZS

1194	Winding wires
1194.1	Part 1: Enamelled round copper winding wires
1194.2	Part 2: Enamelled rectangular copper winding wires
1194.3	Part 3: Enamelled round aluminium winding wires
1194.4	Part 4: Enamelled rectangular aluminium winding wires

IEC

172	Test procedure for the determination of the temperature index of enamelled winding wires
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CGBS

53-GP-14b	Standard for sharpener, pencil
53-GP-27M	Standard for pencil, drawing, black

SECTION 2 TESTS

2.1 GENERAL TEST CONDITIONS Unless otherwise specified, all tests shall be carried out within a range of 15°C to 35°C and a relative humidity of 45 percent to 75 percent. Before measurements are made, the specimens shall be preconditioned under these atmospheric conditions for a period of at least 30 min.

The specimen shall be removed from the packaging in such a way that it will not be subjected to tensions or to unnecessary bends. Before each test, discard sufficient wire to ensure that any damaged wire is not included in the specimens.

NOTE: Some terms used in rectangular winding wire tests are illustrated in Figure 2.1.

2.2 DIMENSIONS

2.2.1 Measuring equipment The equipment used shall have an accuracy better than 2 µm. If a micrometer is used, it shall be ensured that the measuring force is within the range given in Table 2.1. The diameter range of the spindle and anvil is also given in Table 2.1.

TABLE 2.1
SPINDLE/ANVIL DIAMETERS AND MEASURING FORCES

Type of winding wire	Nominal conductor diameter mm	Spindle and anvil diameter mm	Measuring force N
Enamelled round wire	<0.100	2 - 8	0.1 - 1.0
	≥0.100	5 - 8	1 - 8
Enamelled rectangular wire	—	5 - 8	4 - 10

2.2.2 Overall diameter of round wire Three measurements of the overall diameter of wire shall be made at successive 60-degree angular displacements at each of two places 1 m apart on a specimen.

The average of the six results so obtained shall be the overall diameter of wire.

2.2.3 Conductor diameter of round wire At each of two places 1 m apart on a specimen the enamel shall be completely removed for a length sufficient to enable measurements of conductor diameter to be made.

The method used for enamel removal shall have no deleterious effect on the conductor.

NOTE: Recommended methods are described in Appendix A.

At each of these two places, three measurements of conductor diameter shall be made at successive 60-degree angular displacements.

The average of the six results so obtained shall be the conductor diameter.

2.2.4 Increase in diameter of round conductor due to enamel or enamel plus bond layer The difference between the overall diameter of wire as obtained from the method described in Clause 2.2.2, and the conductor diameter as obtained from the method described in Clause 2.2.3, shall be the increase in diameter due to enamel or enamel plus bond layer.

2.2.5 Out-of-roundness of round conductor (nominal conductor diameters not less than 0.071 mm) The greatest difference between any two of the three measurements of conductor diameter obtained at each of the two places described in Clause 2.2.3 above shall be the out-of-roundness of the conductor.

2.2.6 Overall dimensions of the rectangular wire The overall width and the overall thickness of the wire shall be measured at three positions not less than 100 mm apart. The measurements shall be made on completely straight parts of the specimen.

The mean values of the results for each dimension shall be reported as the overall width and overall thickness.

2.2.7 Conductor dimensions of the rectangular wire The insulation shall be removed at the three positions used for measurements in Clause 2.2.6 by any method which does not damage the conductor and the conductors shall be measured at these positions.

The mean value of the results for each dimension shall be reported as conductor width and conductor thickness.

2.2.8 Rounding of corners of the rectangular wire The corner radii of conductors shall be measured by optical means at a convenient magnification carried out on wire samples prepared in a manner that presents an undistorted, polished cross-section of the conductor.

The measurements shall be carried out on at least three samples, all cut from the same length of wire, and from positions not less than 200 mm apart.

NOTE: A suitable method for the preparation of wire samples is given in Appendix B.

2.3 ELECTRICAL RESISTANCE

2.3.1 Procedure The d.c. resistance of the specimen shall be measured at 20°C and expressed in ohms. The method used shall be accurate to within ± 0.5 percent.

If the d.c. resistance of the specimen is measured at a temperature other than 20°C then the d.c. resistance at 20°C shall be determined as follows:

$$R_{20} = \frac{R_t}{1 + \alpha(t - 20)}$$

where

R_{20} = the d.c. resistance of the specimen at 20°C, in ohms

R_t = the d.c. resistance of the specimen when measured at a temperature (t), in ohms

α = the temperature coefficient of the conductor materials for copper, taken as $3.96 \times 10^{-3} K^{-1}$ or for aluminium, taken as $4.03 \times 10^{-3} K^{-1}$, for temperature range 15°C to 25°C

t = the actual temperature at which the d.c. resistance of the specimen is measured to obtain R_t , in degrees Celsius.

As an alternative, electronic equipment which automatically corrects temperature to a base of 20°C is permitted, provided the electronics emulate the calculation specified above.

2.3.2 Number of tests One measurement shall be made.

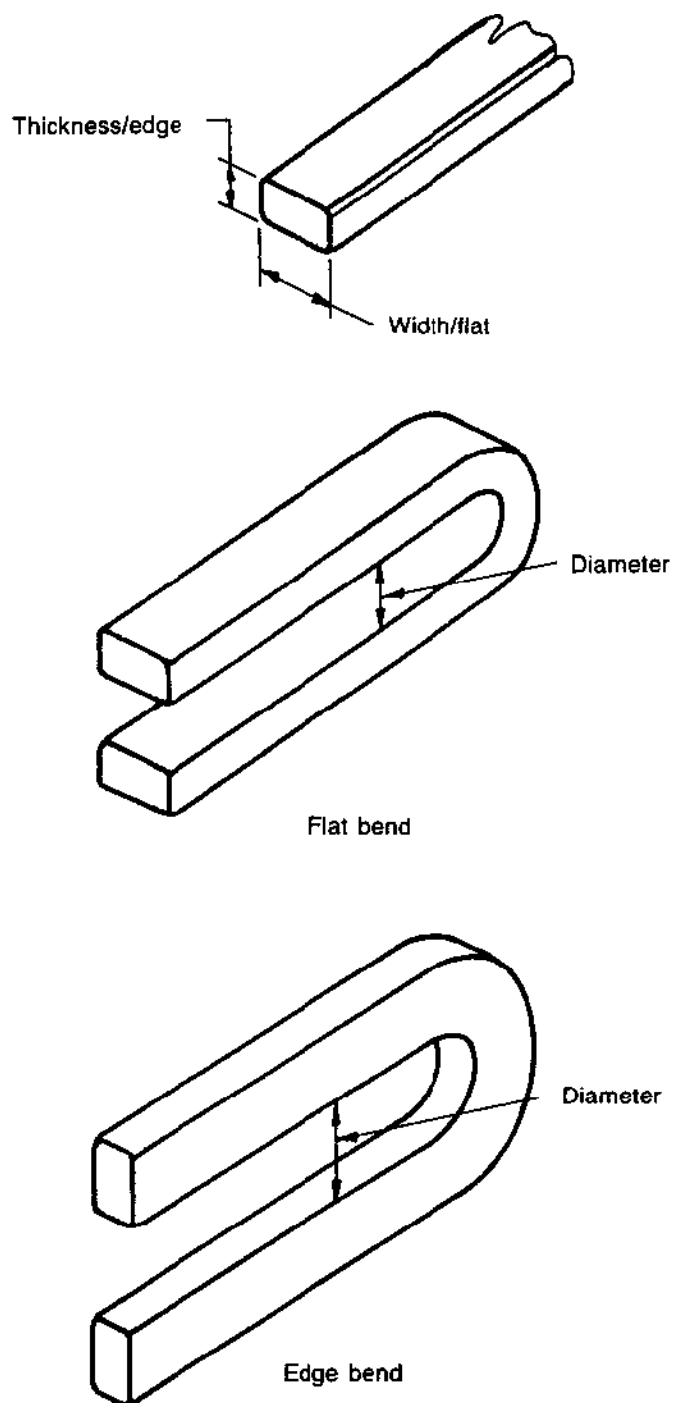


FIGURE 2.1 DEFINITION OF TERMS USED IN RECTANGULAR WINDING WIRE TESTS

2.4 ELONGATION AND TENSILE STRENGTH

2.4.1 Procedure The elongation shall be measured with an elongation tester or a tensile testing-machine. The tensile strength, if required, shall be measured with a tensile testing machine. The free measuring length, i.e. the specimen between the jaws before tension is applied, shall be 200 mm to 250 mm.

The specimen shall be stretched at a rate of 4 mm/s to 5 mm/s for copper specimens or 2 mm/s to 2.5 mm/s for aluminium specimens until fracture occurs. The amount by which the length of the specimen between the jaws exceeds the free measuring length shall be determined, and shall be calculated as a percentage of the free measuring length. The force at which fracture occurs divided by the cross-sectional area shall be the tensile strength.

CAUTION: THE OBJECT OF THIS TEST IS TO DETERMINE THE PROPERTIES OF THE CONDUCTOR AND SHOULD NOT BE CONFUSED WITH SIMILAR TESTS TO DETERMINE ENAMEL CHARACTERISTICS.

2.4.2 Number of tests A total of three tests shall be made but where fracture occurs within 6 mm of a jaw the tests shall be considered invalid and shall be repeated.

The average of the three percentage elongations so obtained shall be the elongation. The average of the three tensile tests shall be the tensile strength.

2.5 SPRINGINESS

2.5.1 For round copper wires of nominal conductor diameters 0.050 mm to 1.60 mm

2.5.1.1 Principle A specimen is wound five times around a mandrel having a diameter and under a tension specified in AS/NZS 1194.1. The amount by which the end of the five turns recoils, is measured and is expressed as the springback.

2.5.1.2 Test apparatus The general arrangement of the test apparatus is shown in Figure 2.2. The details of the mandrel are given in Table 2.2 and in Figure 2.3 (a helical groove, as indicated in Figure 2.3, may be used to facilitate winding but the use of this groove is optional).

The dial is marked at intervals of 5 degrees ± 30 min and marked as shown in Figure 2.2, with 72 equally spaced divisions so that the springback is read directly. The number read corresponds to the number of angular degrees each turn springs back.

2.5.1.3 Procedure The procedure shall be as follows:

- (a) *Mounting* The apparatus shall be mounted with the specified mandrel locked in position and with its axis within 2° from the horizontal, so that the slot (or hole) for fastening the wire (and the commencement of the helical groove, if used) corresponds with the 'zero' of the dial.

The mandrel may be dusted with powdered talc (French chalk) to prevent the specimen from clinging to the mandrel.

- (b) *Application of tension* A mass to produce a tension within $\pm 5\%$ of that specified in AS/NZS 1194.1 Table 2.6 shall be attached to one end of the specimen having a length of about 1 m. The handle of the apparatus shall be unlatched for free rotation. The other end of the specimen shall be inserted into the slot or hole so that sufficient projects on to the other side of the mandrel, and the end shall be bent over to enable it to be held firmly to the mandrel. The mass shall be lowered carefully to apply tension. The specimen is then hanging vertically below the mandrel with the dial set at zero and the slot or hole pointing vertically downward.

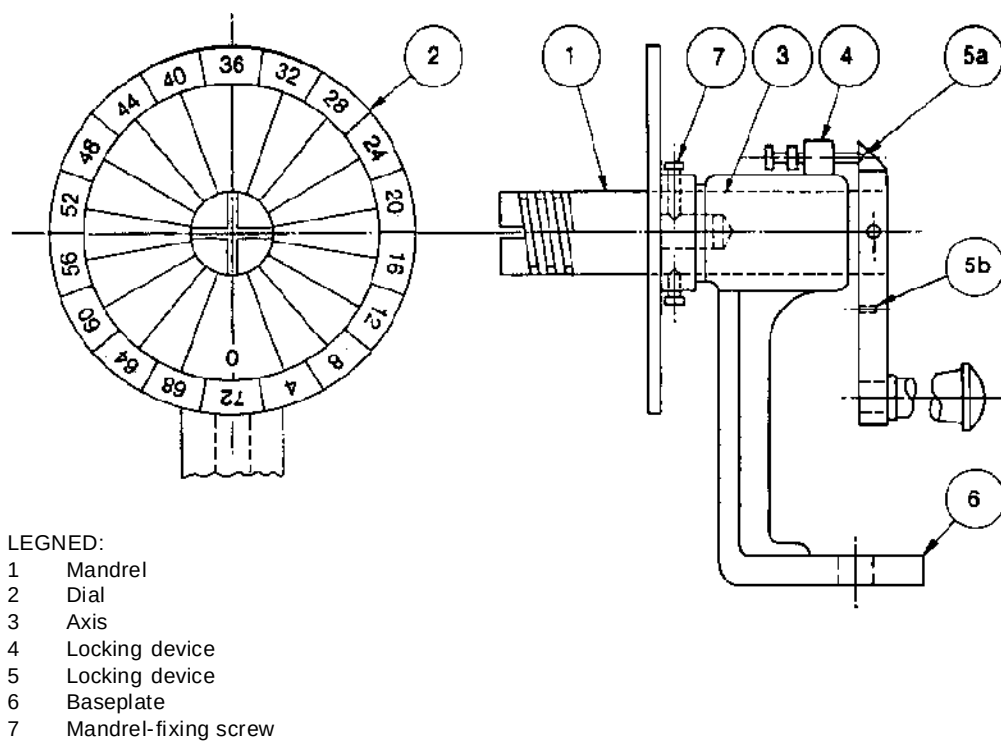


FIGURE 2.2 TEST APPARATUS FOR SPRINGBACK TEST

TABLE 2.2
DETAILS OF OPTIONAL GROOVED MANDREL—SPRINGBACK TEST

Winding diameter mm	Dimension*				Depth of groove e mm	Width of groove f mm
	a mm	b mm	c mm	d mm		
3.0	6.0	6.0	30	0.25	0.04	0.15
5.0	6.0	7.5	32	0.25	0.08	0.30
7.0	6.0	9.0	34	0.40	0.12	0.50
10.0	6.0	9.0	34	0.60	0.16	0.70
12.5	6.0	9.0	40	0.80	0.20	0.80
19.0	10.0	11.0	45	1.20	0.30	1.20
25.0	12.5	12.5	45	2.00	0.15	0.75
37.5	12.5	14.5	47	2.40	0.25	1.25
50.0	12.5	17.5	50	2.80	0.40	2.00
Tolerances	±0.1	±0.1	±0.5	±0.05	±0.005	±0.01

* See Figure 2.3.

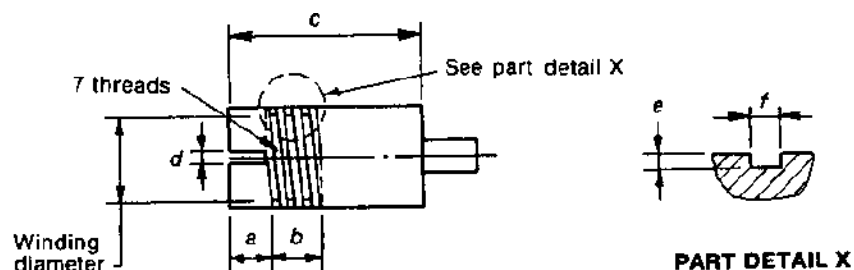


FIGURE 2.3 CONSTRUCTION AND DETAILS OF THE MANDREL

- (c) *Winding on to mandrel* With the free end of the specimen being held securely, the mandrel shall be rotated anti-clockwise (looking at the face of the dial) by means of the handle, until five complete turns have been wound onto the mandrel (or into the groove, if used). The speed of rotation shall be 0.26 ± 0.026 r/s (5 ± 0.5 rpm).

The mandrel shall be rotated further until the dial zero is vertically upwards and shall then be latched in this position. The specimen shall be held in place on the mandrel, the weight shall be removed and the specimen shall be cut 25 mm beyond the end of the fifth turn. This piece at the end of the fifth turn shall be bent into a vertical position in line with the dial zero to act as a pointer.

- (d) *Reading of springback* A pencil or similar object shall be placed to the left of the vertical piece of the specimen to prevent any sudden springback. The coil shall then be allowed to unwind slowly without jerking. If the specimen springs back suddenly, erroneous results are obtained.

The mandrel and the dial shall then be unlatched and rotated to bring the pointer vertically upright again. The bottom of the coil may be gently lifted once or twice with a finger to ensure springback is complete.

The reading on the dial in line with the pointer indicates the springback of the wire.

For very springy wires, the pointer may recoil more than one complete revolution. It is then necessary to add 72 to the dial reading for each completed revolution of recoil.

2.5.1.4 Number of tests One test shall be made.

2.5.2 For round copper wires with nominal conductor diameter over 1.6 mm and rectangular copper wires

2.5.2.1 Principle of test The test consists of bending a specimen over a 30° angle, then removing the load and measuring the springback in degrees.

2.5.2.2 Specimen The sample shall be at least 1200 mm long and shall be removed from the spool with as little bending as possible. It shall be carefully straightened by hand and cut into 400 mm specimens. Work-hardening should be minimized. Elongation by machine should not be used for straightening.

2.5.2.3 Test apparatus The springback is determined by means of the apparatus in Figure 2.4 consisting essentially of two smooth jaws, one fixed, the other movable and a sector graduated in degrees with the 0° to 10° sector of the scale graduated in 0.5° increments.

The test apparatus shall be placed in a horizontal position on the test table. The graduated sector is an arc placed in a plane at 90° to the clamp faces. Its centre is located at the outer edge of the fixed jaw. The lever arm whose fulcrum is placed at the centre of the arc can move over the graduated sector in the horizontal plane. The lever arm shall have a sharp pointer or marker to measure clearly the springback. On the lever arm, which has approximately 305 mm length scaled off in millimetres, whose origin is at the fulcrum, there is a movable slider with edged knife.

2.5.2.4 Test procedure The test shall be made by bending the wire specimens in the same direction in which the wire was bent when wound on the spool. The bare wire thickness (or round wire diameter) shall be measured for determining the actual position of the slider. This thickness (or diameter) multiplied by 40 locates the slider to a specific dimension along the lever arm.

The specimen is moderately tightened between the jaws, sufficiently to prevent slipping with the direction of the former curvature *upwards*, or away from the operator to leave a free length of specimen extending approximately 12 mm beyond the slider knife edge.

By means of the lever arm, starting at the initial position (the 30° scale mark, position 1), the wire is gently bent 30° (to the 0° scale mark, position 2). The time of this bending shall be not less than 2 s, not more than 5 s.

The specimen is held at the 0° point (bent at 30°) for a maximum of 2 s.

The lever arm is gently returned in the reverse direction at the same angular rate at which it was initially moved until the slider knife edge moves away from the wire specimen. The lever arm is again raised until the slider knife edge again just contacts the wire specimen without moving it. The lever arm pointer will now indicate the springback in degrees.

2.5.2.5 Value of springback The value of the springback (∞) is read on the scale shown by the position of the lever arm on the graduated sector in position 3.

Three specimens shall be tested. The results of the three specimens shall not differ by more than 1° over a consecutive length of sample. The declared result shall be the average of the three specimens.

2.6 BREAKDOWN VOLTAGE

2.6.1 Test voltage The voltage to be applied shall be an a.c. voltage having a nominal frequency of 50 Hz and be of sinusoidal waveform, the peak value being within the limits of $\sqrt{2} \pm 5$ percent (1.34 to 1.48) $\times$ the r.m.s. value. The test transformer shall have a rated power of at least 500 V.A and shall provide a current of sinusoidal waveform, the peak value being within $\sqrt{2} \pm 5$ percent of the r.m.s. value.

To detect breakdown, the overcurrent device shall operate when a current of 5 mA or more flows in the high voltage circuit. The test voltage source shall have a capacity to supply a current of 5 mA with a maximum voltage drop of 2 percent.

The voltage, expressed as its r.m.s. value, shall be applied at zero and increased at a uniform rate of approximately 100 ± 5 V/s until breakdown occurs. In the event of breakdown occurring in less than 5 s, the rate of increase shall be halved. Where the breakdown voltage is equal to or greater than 2500 V, the rate-of-rise shall be approximately 500 ± 25 V/s.

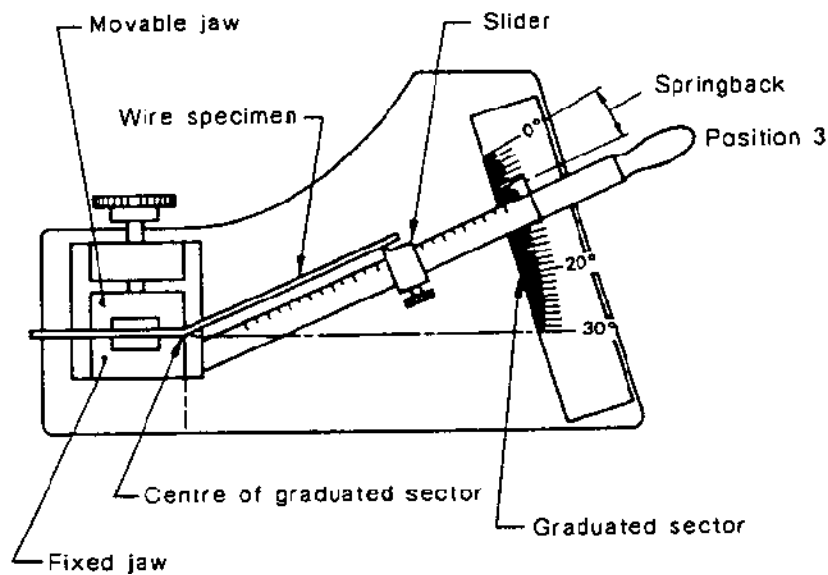
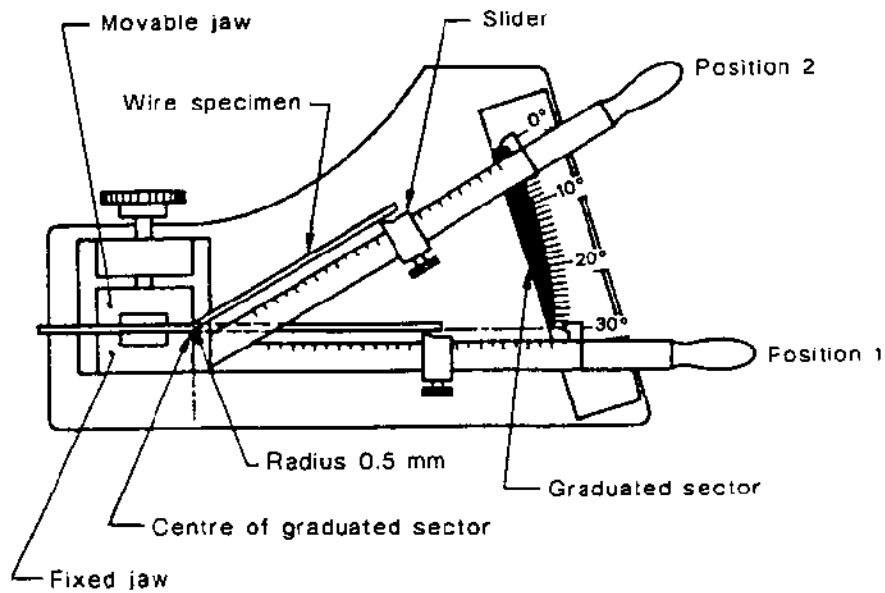


FIGURE 2.4 APPARATUS FOR MEASUREMENT OF SPRINGINESS

2.6.2 Test for round copper nominal conductor diameters not exceeding 0.100 mm

2.6.2.1 Test at room temperature A highly polished metal cylinder having a diameter as specified in Table 2.3 for a particular conductor diameter shall be mounted with its axis horizontal and shall be electrically connected to the earth terminal of the high voltage test machine. The high voltage terminal of the machine shall be positioned vertically above the cylinder as shown in Figure 2.5.

One end of a specimen shall have the conductor exposed by removing the enamel and shall be connected to the high voltage terminal. The specimen shall be wound once around the cylinder and put into tension by the attachment of a weight to the lower end to keep the specimen in close contact with the cylinder. The tension shall be as specified in Table 2.3 for a particular conductor diameter.

A test voltage as specified in Clause 2.6.1 shall be applied between the specimen and the cylinder.

TABLE 2.3
CYLINDER DIAMETERS AND TENSIONS FOR
BREAKDOWN VOLTAGE TEST
(ROUND COPPER CONDUCTORS)

Nominal conductor diameter mm	Cylinder diameter mm	Tension N
>0.020 ≤0.025	25 ±0.5	0.02 ±0.001
>0.025 ≤0.100	30 ±0.5	0.05 ±0.002

2.6.2.2 Test at elevated temperature The specimen shall be prepared as for the test at room temperature, and placed in a suitable equipment already stabilized at the required temperature $\pm 5^{\circ}\text{C}$. The specimen shall be allowed to attain that temperature and the voltage shall be applied while it is in the oven.

The test shall be made not less than 15 min after the specimen is placed in the oven. The total time in the oven shall not exceed 30 min.

2.6.2.3 Number of tests Five specimens shall be tested but if one only of the specimens fails a further batch of five shall be tested, of which none shall fail.

2.6.3 Round copper nominal conductor diameters exceeding 0.100 mm but not exceeding 2.50 mm and round aluminium nominal conductor diameters exceeding 0.200 mm but not exceeding 2.50 mm

2.6.3.1 Test at room temperature A specimen with a length of approximately 400 mm shall be formed into a U-shape and twisted together for a distance of 125 mm with a device as shown in Figure 2.6. The tension on the specimen pairs while being twisted, and the number of twists over the 125 mm twisted length, shall be within $\pm 5\%$ of the value specified in Table 2.4 or 2.5, as appropriate.

The loop at the end of the twisted section shall be cut at two places so as to provide the maximum spacing between the cut ends. If the specimen at either end requires to be bent to ensure adequate separation, care shall be taken to avoid sharp bends or damage to the enamel.

A test voltage as specified in Clause 2.6.1 shall be applied between the conductors.