IEC 60851-3

Edition 4.0 2023-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Winding wires – Test methods – Part 3: Mechanical properties

Fils de bobinage – Méthodes d'essai – Partie 3: Propriétés mécaniques

IEC 60851-3:2023-08(en-fr)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC - webstore.iec.ch/advsearchform
La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, …). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org
Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 300 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 19 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

IEC 60851-3

Edition 4.0 2023-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Winding wires – Test methods – Part 3: Mechanical properties

Fils de bobinage – Méthodes d'essai – Partie 3: Propriétés mécaniques

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 29.060.10

ISBN 978-2-8322-7372-2

CONTENTS

FOREWORD 5
INTRODUCTION 7
1 Scope 8
2 Normative references 8
3 Terms and definitions 8
4 Test 6: Elongation 8
4.1 Elongation at fracture 8
4.2 Tensile strength 9
5 Test 7: Springiness 9
5.1 General 9
5.2 Round wire with a nominal conductor diameter from 0,080 mm up to and including 1,600 mm 9
5.2.1 Principle 9
5.2.2 Equipment 9
5.2.3 Procedure 11
5.3 Round wire with a nominal conductor diameter over 1,600 mm and rectangular wire 12
5.3.1 Principle 12
5.3.2 Equipment 12
5.3.3 Specimen 13
5.3.4 Procedure 13
6 Test 8: Flexibility and adherence 14
6.1 General 14
6.2 Mandrel winding test 14
6.2.1 Round wire 14
6.2.2 Rectangular wire 15
6.2.3 Covered bunched wire 16
6.3 Stretching test (applicable to enamelled round wire with a nominal conductor diameter over 1,600 mm) 16
6.4 Jerk test (applicable to enamelled round wire with a nominal conductor diameter up to and including 1,000 mm) 17
6.5 Peel test (applicable to enamelled round wire with a nominal conductor diameter over 1,000 mm) 17
6.6 Adherence test 19
6.6.1 General 19
6.6.2 Enamelled rectangular wire 19
6.6.3 Impregnated fibre covered round and rectangular wire 19
6.6.4 Fibre covered enamelled round and rectangular wire 19
6.6.5 Tape-wrapped round and rectangular wire (for adhesive tape only) 20
7 Test 11: Resistance to abrasion (applicable to enamelled round wire) 20
7.1 General 20
7.2 Principle 20
7.3 Equipment 20
7.4 Procedure 21
8 Test 18: Heat bonding (applicable to enamelled round wire with a nominal conductor diameter over 0,050 mm up to and including 2,000 mm and to enamelled rectangular wire) 22

8.1 General 22
8.2 Vertical bond retention of a helical coil 22
8.2.1 General 22
8.2.2 Nominal conductor diameter up to and including 0,050 mm 22
8.2.3 Nominal conductor diameter over 0,050 mm up to and including 2,000 mm 22
8.3 Bond strength of a twisted coil 25
8.3.1 General 25
8.3.2 Principle 25
8.3.3 Equipment 25
8.3.4 Specimen 25
8.3.5 Procedure 27
8.3.6 Result 27
8.4 Enamelled rectangular wire heat bonding 28
Annex A (informative) Bond strength of heat bonding wires 30
A.1 Calculation of the temperature of the twisted coil specimen 30
A.1.1 Method 30
A.1.2 Temperature coefficient 30
A.1.3 Calculation 30
A.2 Determination of the heating period 31
A.2.1 Voltage-time graphs 31
A.2.2 Voltage at maximum temperature 31
Annex B (informative) Friction test methods 36
B.1 General 36
B.2 Test A: Static coefficient of friction test method 36
B.2.1 Test method (applicable to enamelled round wires with a nominal conductor diameter from 0,050 mm up to and including 1,600 mm) 36
B.2.2 Test apparatus 36
B.3 Test B: First dynamic coefficient of friction test method 37
B.3.1 Principle 37
B.3.2 Method of test 37
B.4 Test C: Second dynamic coefficient of friction test method (applicable to enamelled round wires with a nominal conductor diameter from 0,050 mm up to and including 1,600 mm) 37
B.4.1 Test equipment 37
B.4.2 Test specimen 38
B.4.3 Specimen preparation 38
B.4.4 Procedure 39
B.5 Test D: Force of friction by the twisted pair method 40
B.5.1 Enamelled round wires with a nominal conductor diameter from 0,1 mm up to and including 1,500 mm 40
B.5.2 Test method 40
Bibliography 46

Figure 1 – Test equipment to determine springiness 10
Figure 2 – Construction and details of the mandrel (see Table 1) 10
Figure 3 – Test equipment to determine springiness 13
Figure 4 – Test equipment for mandrel winding test 16
Figure 5 – Test equipment for jerk test 17

Figure 6 – Test equipment for peel test 18
Figure 7 – Scraper 19
Figure 8 – Cross-section of the wire after removal of the coating 19
Figure 9 – Test equipment for unidirectional scrape test 21
Figure 10 – Test equipment for bond retention of a helical coil 24
Figure 11 – Coil winder 26
Figure 12 – Oval shape coil 27
Figure 13 – Twisting device with a load applied to the twisted coil specimen 27
Figure 14 – Arrangement of supports 28
Figure 15 – Samples for heat bonding 29
Figure A.1 – Example of voltage-time graphs of twisted coil specimens with a nominal conductor diameter of 0,300 mm with isothermic graphs 32
Figure A.2 – Example of voltage-time graphs of twisted coil specimens with a nominal conductor diameter of 0,315 mm with isothermic graphs 33
Figure A.3 – Example of voltage-time graphs of twisted coil specimens with a nominal conductor diameter of 0,355 mm with isothermic graphs 34
Figure A.4 – Example of voltage-time graphs of twisted coil specimens with a nominal conductor diameter of 0,500 mm with isothermic graphs 35
Figure B.1 – Static coefficient of friction test apparatus 41
Figure B.2 – Dynamic coefficient of friction test apparatus 42
Figure B.3 – Diagram of a typical dynamic coefficient of friction tester 43
Figure B.4 – Material – sapphire (synthetic) 44
Figure B.5 – Synthetic sapphires mounted on load block 44
Figure B.6 – Load applied perpendicular to wire path 45
Figure B.7 – Twisted specimen 45

Table 1 – Mandrels for springiness 11
Table 2 – Magnification to detect cracks 14
Table 3 – Load for peel test 18
Table 4 – Preparation of helical coils 23
Table 5 – Bond retention at elevated temperature 24
Table B.1 – Load block weights for dynamic coefficient of friction testing 39
Table B.2 – Twisted pair method 40

INTERNATIONAL ELECTROTECHNICAL COMMISSION

WINDING WIRES – TEST METHODS –

Part 3: Mechanical properties

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 60851-3 has been prepared by IEC technical committee 55: Winding wires. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2009, Amendment 1:2013 and Amendment 2:2019. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Clarification of the distance measurement for determining loss of adhesion in 6.6.3, 6.6.4 for fibre-covered wires and 6.6.5 for tape-wrapped wires.

The text of this International Standard is based on the following documents:

Draft	Report on voting
55/1938/CDV	55/1974/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60851 series, published under the general title *Winding wires – Test methods*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This part of IEC 60851 forms an element of a series of standards, which deals with insulated wires used for windings in electrical equipment. The series has three groups describing:

a) winding wires – Test methods (IEC 60851);

b) specifications for particular types of winding wires (IEC 60317);

c) packaging of winding wires (IEC 60264).

WINDING WIRES – TEST METHODS –

Part 3: Mechanical properties

1 Scope

This part of IEC 60851 specifies the following test methods for winding wires:

– Test 6: Elongation;
– Test 7: Springiness;
– Test 8: Flexibility and adherence;
– Test 11: Resistance to abrasion;
– Test 18: Heat bonding.

For definitions, general notes on test methods and the complete series of test methods for winding wires, IEC 60851-1 applies. This document also provides recommended friction test methods in Annex B.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60851-2:2009, *Winding wires – Test methods – Part 2: Determination of dimensions*
IEC 60851-2:2009/AMD1:2015
IEC 60851-2:2009/AMD2:2019

ISO 178:2019, *Plastics – Determination of flexural properties*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

4 Test 6: Elongation

4.1 Elongation at fracture

Elongation is the increase in length expressed as a percentage of the original length.

A straight piece of wire shall be elongated to the point of fracture of the conductor at a rate of (5 ± 1) mm/s with an elongation tester or with tensile testing equipment with a free measuring length of between 200 mm and 250 mm. The linear increase at fracture shall be calculated as a percentage of the free measuring length.

Three specimens shall be tested. The three single values shall be reported. The mean value represents elongation at fracture.

4.2 Tensile strength

Tensile strength is the ratio of the force at fracture to initial cross-section.

A straight piece of wire shall be elongated to the point of fracture of the conductor at a rate of (5 ± 1) mm/s with tensile testing equipment with a free measuring length of between 200 mm and 250 mm and which records the force at fracture.

Three specimens shall be tested. The initial cross-section and the three single values of the force at fracture shall be reported. The mean value of the ratio of the force at fracture and the initial cross-section represents the tensile strength.

5 Test 7: Springiness

5.1 General

Springiness is the recoil measured in degrees after the wire is wound in the form of a helical coil or bent through an angle.

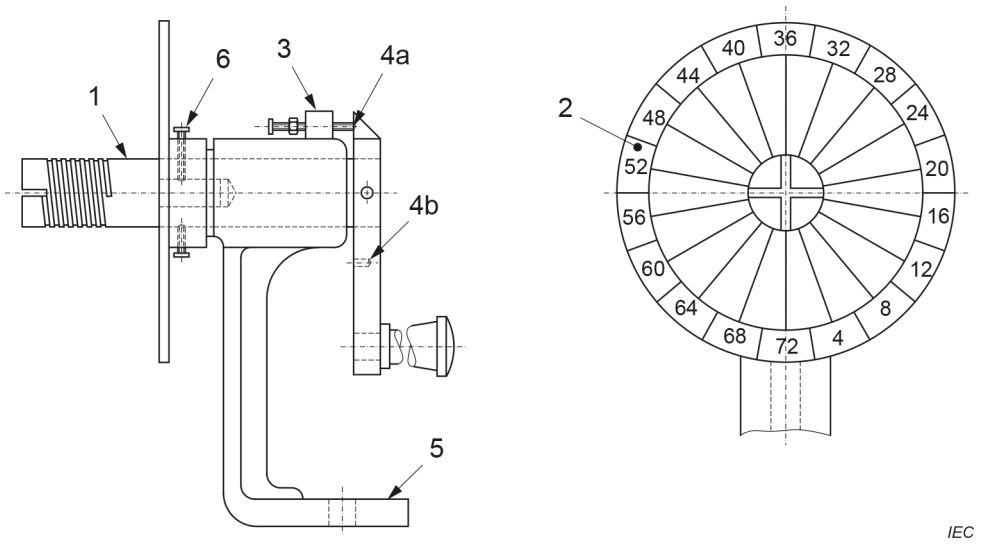
5.2 Round wire with a nominal conductor diameter from 0,080 mm up to and including 1,600 mm

5.2.1 Principle

A straight piece of wire is wound five times around a mandrel with a diameter and under a tension applied to the wire as specified in the relevant standard. The reading of the angle by which the end of the five turns recoils is the measure of springiness.

5.2.2 Equipment

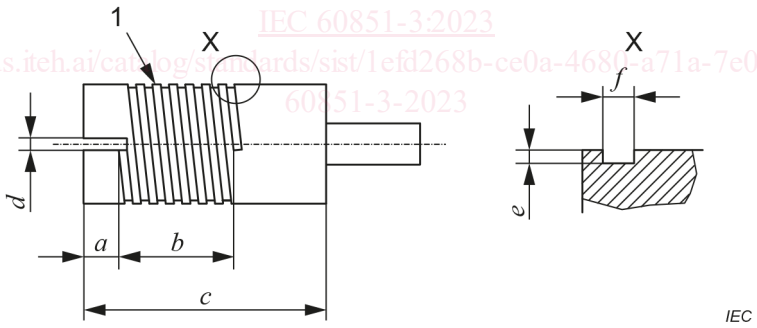
Figure 1 shows an example of the test equipment with details of the mandrel given in Figure 2 and Table 1. Figure 2 indicates a helical groove, which may be used to facilitate winding. The provision of this groove, however, is not mandatory. The dial is marked with 72 equally spaced divisions so that with five turns of the wire the reading corresponds to the number of degrees that each turn springs back.



Key

1 mandrel
2 dial
3 locking device
4 locking device
5 base-plate
6 mandrel-fixing screw

Figure 1 – Test equipment to determine springiness



Key

1 7 threads
2 part X enlarged

Figure 2 – Construction and details of the mandrel (see Table 1)

Table 1 – Mandrels for springiness

Mandrel diameter [a] mm	Dimensions [b] mm					
	a	b	c	d	e	f
5	6,0	7,5	32	0,30	0,05	0,13
7	6,0	9,0	34	0,40	0,07	0,18
10	6,0	9,0	34	0,60	0,10	0,25
12,5	6,0	9,0	40	0,80	0,14	0,35
19	10,0	11,0	45	1,20	0,20	0,50
25	12,5	12,5	45	2,00	0,28	0,70
37,5	12,5	14,5	47	2,40	0,40	1,00
50	12,5	17,5	50	3,00	0,80	2,00

[a] At the bottom of the groove, if provided.

[b] See Figure 2.

5.2.3 Procedure

The specified mandrel shall be mounted and locked in position with its axis horizontal and with the slot or hole for fastening the wire corresponding with the zero of the dial. The mandrel shall be dusted with powdered talc (French chalk) to prevent the wire clinging to the mandrel.

A tension shall be applied to a straight piece of wire of about 1 m in length by attaching the specified load to one end of the wire. The handle to rotate the mandrel shall be unlatched. The other end of the wire shall be inserted into the slot or hole so that sufficient wire projects on the other side of the mandrel and the wire is in firm contact with the mandrel. The weight shall be slowly lowered with the wire suspended vertically below the mandrel and with the dial zero and the slot or hole pointing downwards.

With the free end of the wire being held securely, the mandrel shall be rotated for five complete turns counterclockwise (looking at the face of the dial) and further until the zero on the dial is vertically upwards. The handle shall then be latched in this position. The load shall be removed while the wire is held in position, and the wire shall then be cut about 25 mm beyond the end of the fifth turn. This end of the wire shall be bent into a vertical position in line with the dial zero to act as a pointer.

A pencil or similar tool shall be placed to the left of this end of the wire to prevent any sudden springback. The coil shall then be allowed to unwind slowly and without jerking.

NOTE If the wire springs back suddenly, it is possible to obtain erroneous results.

The mandrel and the dial shall then be unlatched and rotated clockwise to bring the pointer back into a vertical position. The springback angle is equal to the reading on the dial in line with the pointer. With very springy wires, the pointer may recoil more than one complete revolution. If this is the case, 72 shall be added to the dial reading for each complete revolution of recoil.

Three specimens shall be tested. The three single values shall be reported. The mean value represents springiness.

5.3 Round wire with a nominal conductor diameter over 1,600 mm and rectangular wire

5.3.1 Principle

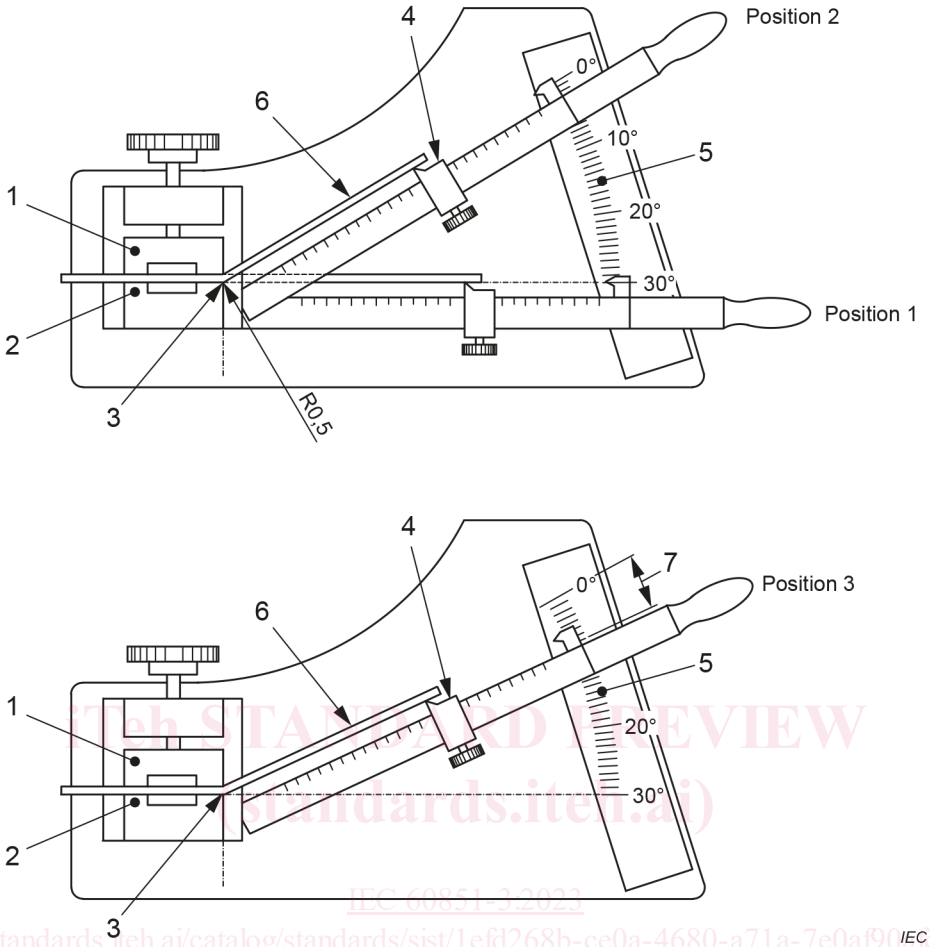
A straight piece of wire shall be bent through an angle of 30°. After removing the force, the reading of the angle by which the wire springs back is the measure of springiness.

5.3.2 Equipment

Figure 3 shows an example of the test equipment basically consisting of two jaws, one of which is fixed (2) and one is movable (1), and a sector graduated in degrees (5) with the 0° to 10° sector of the scale graduated in 0,5° increments. 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 (3). The lever arm with its fulcrum placed at the centre of the arc can move over the graduated sector in the vertical plane.

The lever arm shall have a pointer or marker to provide a proper reading of the springback angle. On the lever arm with approximately 305 mm length scaled off in millimetres with the origin at the centre of the arc, is a slider (4) with a knife edge.

Dimensions in millimetres



Key

1 moveable jaw
2 fixed jaw
3 centre of graduated sector
4 slider
5 graduated sector
6 wire specimen
7 springback

Figure 3 – Test equipment to determine springiness

5.3.3 Specimen

A wire sample of at least 1 200 mm in length shall be removed from the spool with as little bending of the wire as possible. It shall be straightened by hand and cut into three pieces each of 400 mm length. Elongation by tools shall not be used. Unnecessary bending shall be avoided to minimize work hardening.

5.3.4 Procedure

The conductor diameter or thickness, multiplied by 40, determines the position of the slider on the lever arm. The specimen shall be tightened between the jaws with a force just sufficient to prevent slipping. The specimen shall be tightened in such a position as to allow bending the wire in the same direction as it was wound on the spool. The free end of the specimen shall exceed the slider knife edge by (12 ± 2) mm.