

# CONSOLIDATED VERSION

# VERSION CONSOLIDÉE



**Winding wires – Test methods –  
Part 3: Mechanical properties**

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

IEC 60851-3:2009

<https://standards.iteh.ai/standards/iec/60851-3-2009>



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2013 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
Fax: +41 22 919 03 00  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://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 corrigenda or an amendment might have been published.

#### Useful links:

IEC publications search - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

The advanced search enables you 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It also gives information on projects, replaced and withdrawn publications.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](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available on-line and also once a month by email.

Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary (IEV) on-line.

Customer Service Centre - [webstore.iec.ch/csc](http://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: [csc@iec.ch](mailto:csc@iec.ch).

### A propos de la CEI

La Commission Electrotechnique Internationale (CEI) 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 CEI

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

#### Liens utiles:

Recherche de publications CEI - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

La recherche avancée vous permet de trouver des publications CEI 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.

Just Published CEI - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Restez informé sur les nouvelles publications de la CEI. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (VEI) en ligne.

Service Clients - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: [csc@iec.ch](mailto:csc@iec.ch).

# CONSOLIDATED VERSION

# VERSION CONSOLIDÉE



**Winding wires – Test methods –  
Part 3: Mechanical properties**

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

<https://standards.iteh.ai/standards/iec/60851-3-2009>

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

ICS 29.060.10

ISBN 978-2-8322-0939-4

**Warning! Make sure that you obtained this publication from an authorized distributor.  
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

Withdrawn

iTech Standards  
(<https://standards.iteh.ai>)  
Document Preview

[IEC 60851-3:2009](#)

<https://standards.iteh.ai/catalog/standards/sic/62919d43-979c-4738-941a-8a2be477b575/iec-60851-3-2009>

## REDLINE VERSION

## VERSION REDLINE



**Winding wires – Test methods –  
Part 3: Mechanical properties**

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

IEC 60851-3:2009

<https://standards.iteh.ai/standards/iec/62919d43-979c-4738-941a-8a2be477b575/iec-60851-3-2009>

## CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Normative references .....	7
3 Test 6: Elongation .....	7
3.1 Elongation at fracture .....	7
3.2 Tensile strength .....	7
4 Test 7: Springiness.....	8
4.1 Round wire with a nominal conductor diameter from 0,080 mm up to and including 1,600 mm .....	8
4.1.1 Principle .....	8
4.1.2 Equipment.....	8
4.1.3 Procedure.....	9
4.2 Round wire with a nominal conductor diameter over 1,600 mm and rectangular wire .....	10
4.2.1 Principle .....	10
4.2.2 Equipment.....	10
4.2.3 Specimen .....	11
4.2.4 Procedure.....	11
5 Test 8: Flexibility and adherence .....	12
5.1 Mandrel winding test .....	12
5.1.1 Round wire.....	12
5.1.2 Rectangular wire .....	13
5.1.3 Covered bunched wire.....	14
5.2 Stretching test (applicable to enamelled round wire with a nominal conductor diameter over 1,600 mm).....	14
5.3 Jerk test (applicable to enamelled round wire with a nominal conductor diameter up to and including 1,000 mm).....	15
5.4 Peel test (applicable to enamelled round wire with a nominal conductor diameter over 1,000 mm).....	15
5.5 Adherence test .....	17
5.5.1 Enamelled rectangular wire .....	17
5.5.2 Impregnated fibre covered round and rectangular wire .....	17
5.5.3 Fibre covered enamelled round and rectangular wire.....	17
5.5.4 Tape wrapped round and rectangular wire (for adhesive tape only) .....	18
6 Test 11: Resistance to abrasion (applicable to enamelled round wire).....	18
6.1 Principle.....	18
6.2 Equipment.....	18
6.3 Procedure .....	19
7 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).....	20
7.1 Vertical bond retention of a helical coil .....	20
7.1.1 Nominal conductor diameter up to and including 0,050 mm .....	20
7.1.2 Nominal conductor diameter over 0,050 mm up to and including 2,000 mm .....	20
7.2 Bond strength of a twisted coil.....	23
7.2.1 Principle .....	23
7.2.2 Equipment.....	23

7.2.3 Specimen .....	23
7.2.4 Procedure.....	25
7.2.5 Result.....	25
Annex A (informative) Bond strength of heat bonding wires .....	27
Annex B (informative) Friction test methods.....	33
Bibliography.....	48
Figure 1 – Test equipment to determine springiness .....	8
Figure 2 – Construction and details of the mandrel (see Table 1).....	9
Figure 3 – Test equipment to determine springiness .....	11
Figure 4 – Test equipment for mandrel winding test.....	14
Figure 5 – Test equipment for jerk test.....	15
Figure 6 – Test equipment for peel test.....	16
Figure 7 – Scraper.....	17
Figure 8 – Cross-section of the wire after removal of the coating.....	17
Figure 9 – Test equipment for unidirectional scrape test.....	19
Figure 10 – Test equipment for bond retention of a helical coil.....	22
Figure 11 – Coil winder.....	24
Figure 12 – Oval shape coil.....	25
Figure 13 – Twisting device with a load applied to the twisted coil specimen .....	25
Figure 14 – Arrangement of supports .....	26
Figure A.1 – Example of voltage-time graphs of twisted coil specimens with a nominal conductor diameter of 0,300 mm with isothermic graphs .....	29
Figure A.2 – Example of voltage-time graphs of twisted coil specimens with a nominal conductor diameter of 0,315 mm with isothermic graphs .....	30
Figure A.3 – Example of voltage-time graphs of twisted coil specimens with a nominal conductor diameter of 0,355 mm with isothermic graphs .....	31
Figure A.4 – Example of voltage-time graphs of twisted coil specimens with a nominal conductor diameter of 0,500 mm with isothermic graphs .....	32
Figure B.1 – Static coefficient of friction test apparatus.....	40
Figure B.2 – Dynamic coefficient of friction test apparatus .....	41
Figure B.3 – <del>Diagram of a typical</del> dynamic coefficient of friction test apparatus.....	43
Figure B.4 – <del>Detail drawing of friction head assembly with mechanical dynamometer</del> Material – sapphire (synthetic).....	45
Figure B.5 – <del>Load block with</del> Synthetic sapphires mounted on load block .....	46
Figure B.6 – Load applied perpendicular to wire path.....	47
Figure B.7 – Twisted specimen .....	47
Table 1 – Mandrels for springiness .....	9
Table 2 – Magnification to detect cracks .....	12
Table 3 – Load for peel test .....	16
Table 4 – Preparation of helical coils .....	21
Table 5 – Bond retention at elevated temperature.....	22
Table B.1 – Load block weights for dynamic coefficient of friction testing.....	38
Table B.2 – Twisted pair method.....	39

## 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 provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 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) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

**This Consolidated version of IEC 60851-3 bears the edition number 3.1. It consists of the third edition (2009) [documents 55/1043/CDV and 55/1059/RVC] and its amendment 1 (2013) [documents 55/1392/FDIS and 55/1407/RVD]. The technical content is identical to the base edition and its amendment.**

**In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions and deletions are displayed in red, with deletions being struck through. A separate Final version with all changes accepted is available in this publication.**

**This publication has been prepared for user convenience.**



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

With respect to the previous edition, significant technical changes appear in Subclause 5.3, Jerk test.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

**IMPORTANT – The “colour inside” logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication 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).

Withdrawing

iTech Standards  
(<https://standards.itih.ai>)  
Document Preview

<https://standards.itih.ai/standards/iec/60851-3:2009>

<https://standards.itih.ai/standards/iec/60851-3:2009>

# WINDING WIRES – TEST METHODS –

## Part 3: Mechanical properties

### 1 Scope

This part of IEC 60851 specifies the following methods of test 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 methods of test and the complete series of methods of test for winding wires, see IEC 60851-1.

### 2 Normative references

The following referenced documents are indispensable for the application 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 60851-1, *Winding wires – Test methods – Part 1: General*

IEC 60851-2:1996, *Winding wires – Test methods – Part 2: Determination of dimensions*

ISO 178:2001, *Plastics – Determination of flexural properties*  
Amendment 1:2004

### 3 Test 6: Elongation

#### 3.1 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  $(5 \pm 1)$  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.

#### 3.2 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  $(5 \pm 1)$  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.

#### 4 Test 7: Springiness

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

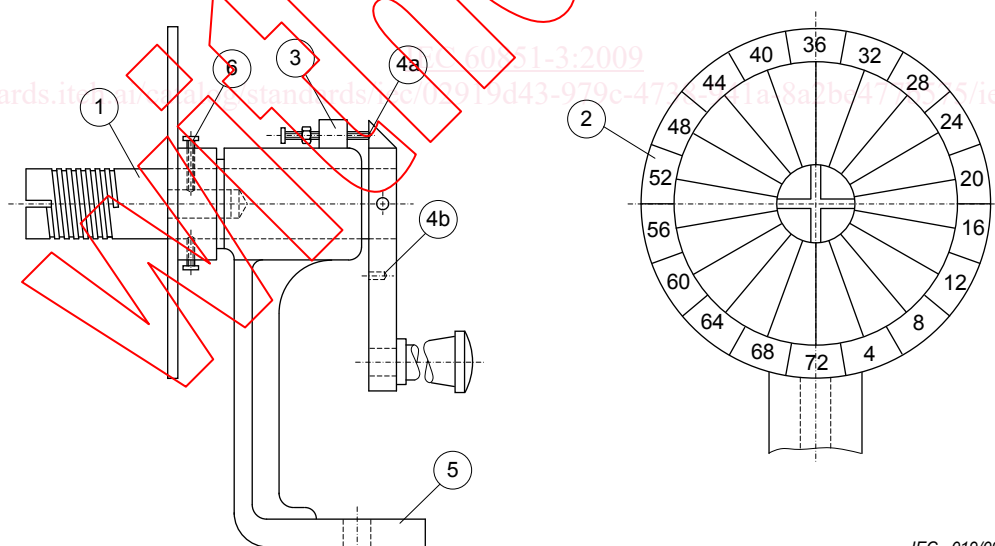
##### 4.1 Round wire with a nominal conductor diameter from 0,080 mm up to and including 1,600 mm

###### 4.1.1 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.

###### 4.1.2 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.

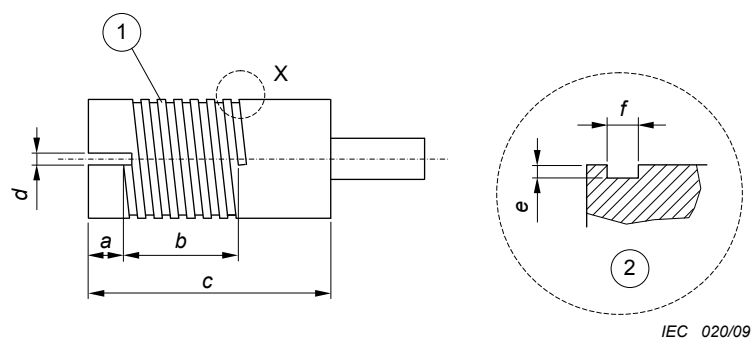


IEC 019/09

#### 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



IEC 020/09

**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 <sup>a</sup> mm	Dimensions <sup>b</sup> 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

<sup>a</sup> At the bottom of the groove, if provided.  
<sup>b</sup> See Figure 2.

**4.1.3 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 counter clockwise (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, erroneous results may be obtained.

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 has to 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.

#### **4.2 Round wire with a nominal conductor diameter over 1,600 mm and rectangular wire**

##### **4.2.1 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.

##### **4.2.2 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.