UL 2353

STANDARD FOR SAFETY

Single- and Multi-Layer Insulated
Winding Wire

UL Standard for Safety for Single- and Multi-Layer Insulated Winding Wire, UL 2353

Third Edition, Dated October 10, 2016

Summary of Topics

This revision of ANSI/UL 2353 dated January 6, 2021 includes additional clarification to dimension requirements regarding solvent based enamel coatings (Magnet wire, Litz wire); 4.1.1 and 4.1.3

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The revised requirements are substantially in accordance with Proposal (s) on this subject dated September 25, 2020.

No Text on This Page

OCTOBER 10, 2016
(Title Page Reprinted: January 6, 2021)

ANSI/UL 2353-2020

UL 2353

Standard for Safety for Single- and Multi-Layer Insulated Winding Wire

First Edition – July, 2004
Second Edition – May, 2012

Third Edition

October 10, 2016

This ANSI/UL Standard for Safety consists of the Third Edition including revisions through January 6, 2021.

The most recent designation of ANSI/UL 2353 as an American National Standard (ANSI) occurred on December 1, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

CONTENTS

INTRODUCTION

CONSTRUCTION

PERFORMANCE

MANUFACTURING AND PRODUCTION TESTS

MARKINGS

No Text on This Page

INTRODUCTION

1 Scope

1.1 This Standard contains requirements for single and multi – layer insulated winding wire used in transformers without interleaved insulation; and solid insulation and insulated winding wire without interleaved insulation intended for use in accordance with the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, the Standard for Medical Electrical Equipment, Part 1: General Requirements for Safety, UL 60601-1, the Safety of Power Transformers, Power Supplies, Reactors and Similar Products – Part 1: General Requirements and Tests, IEC 61558-1, or the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1 Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1. These requirements are not intended to prohibit use of this type of winding wire in equipment covered by the scope of other standards when these requirements are determined to be compatible with those standards.

1.2 This Standard also contains requirements for enamelled Fully-Insulated Wire (FIW) that are deemed suitable for use in end-products standards. The enamelled winding wire shall be a designated NEMA Type MW 85 as specified in the Standard for Magnet Wire, NEMA MW 1000.

1.3 These requirements cover winding wires with a diameter between 0.05 mm (0.002 in) and 5.0 mm (0.2 in) and MW 85 solvent-based enamel coated winding wires with a diameter between 0.040 mm (0.0016 in) and 1.60 mm (0.06 in).

1.4 The winding wire covered by this Standard shall also comply with the infrared analysis requirements in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

1.5 This Standard does not cover solvent-based enamel coated magnet wire unless as specified in 1.2. See the Standard for Systems of Insulating Materials – General, UL 1446. If the desired usage of the single- and multi-layer Insulated winding wire is above Class 105 (A), additional testing of the insulation system would be required in accordance with UL 1446.

2 General

2.1 Units of measurement

2.1.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

2.2 Undated references

2.2.1 Any undated reference to a code or standard appearing in the requirements of this Standard shall be interpreted as referring to the latest edition of that code or standard.

3 Glossary

3.1 In the text of this standard, the letters "ITE" refer to information technology equipment. For the purpose of this Standard, the following definitions apply. See the following standards for additional definitions:

a) The Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1;

b) The Standard for Medical Electrical Equipment, Part 1: General Requirements for Safety, UL 60601-1;

c) The Safety of Power Transformers, Power Supplies, Reactors and Similar Products – Part 1: General Requirements and Tests, IEC 61558-1; or the

d) The Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1 Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1.

3.2 BASIC INSULATION – Insulation that provides basic protection against the risk of electric shock.

3.3 CLEARANCE – The shortest distance between two conductive parts measured through air.

3.4 CREEPAGE DISTANCE – The shortest path between two conductive parts measured along the surface of the insulation.

3.5 INSULATING LAYER – A single, concentric thickness of material that is detectable with an optical or mechanical measuring device. Enamel, bond coats, etc. are not considered insulating layers. See 1.2.

3.6 REINFORCED INSULATION – A single insulation that provides protection against risk of electric shock equivalent to double insulation under the conditions specified in the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, the Standard for Medical Electrical Equipment, Part 1: General Requirements for Safety, UL 60601-1, or the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1 Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1. Reinforced insulation is not required to be provided in one homogeneous piece. It may consist of several layers that cannot be tested as supplementary or basic insulation.

3.7 ROUTINE TEST – A test to which each individual sample is subjected during or after manufacture to verify that the sample complies with certain criteria.

3.8 SAMPLING TESTS – A test on a number of samples taken at random from a batch of winding wire.

3.9 SEPARABLE LAYERS – A construction that includes layers of insulation that may be separated in a non-destructive manner.

3.10 SUPPLEMENTARY INSULATION – Independent insulation applied in addition to basic insulation in order to reduce the risk of electric shock in the event of a failure of the basic insulation.

CONSTRUCTION

4 Conductor Dimensions

4.1 Single and multi – layer insulated wire

4.1.1 When determining the conductor dimensions, tin or any other metal on the conductor is allowed to remain on the conductor and included in the measurement. For film insulated Magnet Wire, the solvent based enamels are to be removed prior to any measurements. Measurements of the diameter of a solid conductor are to be made by means of a machinist's micrometer caliper having flat surfaces both on the anvil and on the end of the spindle and calibrated to read directly to at least 0.01 mm or 0.001 in, with each division of a width that facilitates estimation of each measurement to 0.001 mm or 0.0001 in. The maximum and minimum diameters at a given point on the conductor are each to be recorded to the nearest 0.001 mm or 0.0001 in, added together, and divided by 2 without any rounding of the sum or resulting average.

4.1.2 The conductor-size range shall be as specified in Conductor dimensions, Table 4.1 for wires constructed to the customary US AWG trade sizes, or Table 4.2 for wires constructed to the customary metric trade sizes and any other non-customary size. The unrounded average of the two micrometer readings is therefore to be compared directly with the minimum in the table for the purpose of determining whether the solid conductor does or does not comply with the diameter requirement.

Table 4.1
Conductor dimensions for customary US AWG trade sizes

Trade size AWG	Nominal conductor OD mm	Minimum tolerance mm	Minimum cross sectional area mm^2
44	0.051	0.003	0.00181
43	0.056	0.003	0.00221
42	0.064	0.003	0.00292
41	0.071	0.003	0.00363
40	0.079	0.003	0.00454
39	0.089	0.003	0.00581
38	0.102	0.003	0.00770
37	0.114	0.003	0.00968
36	0.127	0.003	0.0121
35	0.142	0.003	0.0152
34	0.160	0.003	0.0194
33	0.180	0.003	0.0246
32	0.203	0.003	0.0314
31	0.226	0.003	0.0391
30	0.254	0.003	0.0495
29	0.287	0.003	0.0633
28	0.320	0.003	0.0789
27	0.361	0.003	0.101
26	0.404	0.005	0.125
25	0.455	0.005	0.159
24	0.511	0.006	0.200
23	0.574	0.006	0.253
22	0.643	0.008	0.317
21	0.724	0.008	0.403
20	0.813	0.008	0.509
19	0.912	0.011	0.638
18	1.02	0.011	0.800
17	1.15	0.013	1.02
16	1.29	0.013	1.28
15	1.45	0.015	1.62
14	1.63	0.015	2.05
13	1.83	0.018	2.58
12	2.05	0.020	3.24
11	2.30	0.023	4.07
10	2.59	0.025	5.17
9	2.91	0.028	6.52
8	3.26	0.033	8.18
7	3.67	0.035	10.38
6	4.11	0.041	13.00
5	4.62	0.045	16.44
4	5.19	0.045	20.79

Table 4.2
Solid conductor diameters for non-AWG sizes

Nominal conductor OD mm	Minimum tolerance mm
0.050 ≥ 0.403	0.003
0.404 ≥ 0.510	0.005
0.511 ≥ 0.642	0.006
0.623 ≥ 0.911	0.008
0.912 ≥ 1.150	0.011
1.151 ≥ 1.449	0.013
1.450 ≥ 1.828	0.015
1.829 ≥ 2.051	0.018
2.052 ≥ 2.303	0.020
2.304 ≥ 2.587	0.023
2.588 ≥ 2.905	0.025
2.906 ≥ 3.263	0.028
3.264 ≥ 3.664	0.033
3.665 ≥ 4.114	0.035
4.115 ≥ 4.619	0.041
4.620 ≥ 5.000	0.045

4.1.3 The total cross sectional area of the conductors in a stranded wire shall be at least equivalent to the minimum cross sectional area of the equivalent solid wire as noted in Table 4.1 for customary US AWG trade sizes, or calculated using the tolerances specified in Table 4.2 for wires constructed to the customary metric trade sizes and any other non-customary size. The unrounded average of two micrometer readings taken on at least five strands shall be used to calculate the total cross sectional area and compared directly with the minimum in the table for the purpose of determining whether the stranded wire does or does not comply with the requirement. For a stranded conductor made up of film insulated Magnet Wire using solvent based enamel coatings, the enamel coating shall be removed prior to measuring conductor diameters to determine cross sectional area.

4.2 Fully insulated wire (FIW)

4.2.1 When determining the conductor dimensions solvent based enamels are to be removed prior to any measurements. Measurements of the diameter of a solid conductor are to be made by means of a machinist's micrometer caliper having flat surfaces both on the anvil and on the end of the spindle and calibrated to read directly to at least 0.01 mm or 0.001 in, with each division of a width that facilitates estimation of each measurement to 0.001 mm or 0.0001 in. The maximum and minimum diameters at a given point on the conductor are each to be recorded to the nearest 0.001 mm or 0.0001 in, added together, and divided by 2 without any rounding of the sum or resulting average.

5 Number of Layers

5.1 Single and multi – layer insulated wire

5.1.1 Transformer winding wire with extruded or spirally wrapped insulation where the layers can be individually tested for electric strength shall comply with one of the following constructional requirements:

a) Basic insulation consisting of at least one layer of material, which complies with the Electric Strength Test – Straight Sample, Section 8, for basic insulation;

b) Supplementary insulation consisting of at least two layers of material, each of which complies with the Electric Strength Test – Straight Sample, Section 8, for supplementary insulation;

c) Supplementary insulation consisting of three layers of material for which all combinations of the two layers together complies with the Electric Strength Test – Straight Sample, Section 8, for supplementary insulation;

d) Reinforced insulation, intended for use in Information Technology equipment, consisting of at least two layers of material, each of which complies with the Electric Strength Test – Straight Sample, Section 8, for reinforced insulation; or

e) Reinforced insulation consisting of three layers of materials for which all combinations of two layers together complies with the Electric Strength Test – Straight Sample, Section 8, for reinforced insulation.

5.1.2 Transformer winding wire with extruded or spirally wrapped insulation where the layers cannot be individually tested and only the finished wire can be tested, shall comply with one of the following constructional requirements:

a) Basic insulation: one layer extruded, or wrapped;

b) Supplementary insulation: two layers extruded or wrapped (one layer wrapped with 50% or greater overlap is considered equivalent to two layers of insulation);

c) Reinforced insulation: three layers wrapped or extruded.

5.1.3 All layers of insulation are not required to be made from the same material.

5.1.4 For spirally wrapped insulation that is constructed such that the creepage and clearance distances between layers, as wrapped, are less than those provided in the minimum creepage and clearance distances for Pollution Degree 1, of the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, the Standard for Medical Electrical Equipment, Part 1: General Requirements for Safety, UL 60601-1, or the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1 Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1. The path between layers shall be sealed as for a cemented joint, and tested in accordance with the requirements for spacings filled by the insulation compounds as specified in UL 60950-1, UL 60601-1, and UL 61800-5-1. The test voltages for the electric strength tests are to be increased to 1.6 times their normal values.

5.1.5 One layer of material wound for spirally wrapped insulation with more than 50% overlap is considered to constitute two layers.

5.1.6 Solvent based enamel insulation used to coat the conductor is not to be counted as a layer when determining basic, supplementary and reinforced insulation.

5.2 Fully insulated wire (FIW)

5.2.1 For FIW the following layer thickness requirements apply:

a) A minimum increase of diameter due to insulation of 0.001 mm (0.00004 in) and a diameter range of 0.040 – 0.16 mm (0.0016 – 0.0063 in); or

b) A minimum increase of diameter due to insulation of 0.002 mm (0.00008 in) and a diameter range greater than 0.16 – 1.60 mm (0.0063 – 0.063 in).

5.2.2 The manufacturer must declare the type of insulation they are producing and also indicate the number of layers that will make up their insulation, i.e. basic, supplementary or reinforced. For example, a manufacturer may declare that their 0.60 mm conductor coated with 50 layers (each layer a minimum of 0.001 mm) of insulation will be considered their supplementary insulation.

6 Thickness of Insulation

6.1 The average thickness of insulation is to be determined by means of one of the following methods: See 6.3.

a) Use of a machinist's micrometer caliper. The caliper is to have flat surfaces on the anvil and on the end of the spindle and is to be calibrated to read directly to at least 0.001 mm or 0.0001 in.

b) Use of a dead-weight dial micrometer. The micrometer is to be capable of exerting the forces indicated in 6.5 (a) and (b) onto a sample through a flat, rectangular presser foot 1.98 by 9.52 mm or 0.078 by 0.375 in. The anvil of the instrument is to be of the same dimensions as the presser foot.

c) A microscope or other optical instrument calibrated to read directly to at least 0.001 mm or 0.0001 in is to be used to measure the maximum thickness of each insulation layer, conductor diameter and overall wire diameter.

6.2 When using a machinist's micrometer caliper or dead weight micrometer the procedures described in 6.3 – 6.9 shall be followed. When using a microscope or other optical instrument the procedures described in 6.3, 6.11 – 6.13 shall be followed.

6.3 Samples of the smallest and largest wire size are to be selected to represent the entire size range. The layers are to be concentric and must be well defined. The use of different color pigments for each layer has been found to aide in providing the necessary distinction between layers. Solvent-based enamel is considered to be single-layer insulation even if it uses different color pigments for the necessary distinction between layers. It is not considered to be multi-layer insulation.

6.4 During the measurements, the sample, the measuring instrument, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F).

6.5 The diameter of the insulated wire, per 6.6, shall be measured in each of the four quadrants of the circular sample. The minimum and maximum measurements of the wire shall be recorded, and the average of those two readings shall be identified as the overall diameter. The insulation, one layer at a time, shall then be removed from the wire, without damaging the wire or other layers of insulation, at approximately the same points where the measurements for the insulated wire were made. The minimum and maximum measurements of the bare wire and each layer of insulation shall be recorded. If a dead-weight dial micrometer is used the spindle force applied shall be as follows:

a) For wire 25 AWG and smaller, 0.8 – 1.4 N (3 – 5 ozf);

b) For wire larger than 25 AWG, 2.2 – 2.8 N (8 – 10 ozf).

6.6 The diameter of the insulated wire shall be calculated in the following manner:

$$(D_I) = (D_O) - (D_B)$$

In which:

D_I is the diameter of the insulated wire.

D_O is the overall diameter.

D_B *is the diameter of the bare wire.*

6.7 The average of the two recorded measurements over the conductor is to be subtracted from the average measurement over the insulation. The result is to be divided by two and then rounded as indicated in 6.8 or 6.9 to the nearest 0.001 in or 0.01 mm. The rounded result is to be taken as the average thickness of insulation.

6.8 Rounding to the nearest 0.001 in – A number in the third decimal place is to remain unchanged when the number in the fourth decimal place is 0 – 4 and the number in the third decimal place is odd or even, or when the number in the fourth decimal place is 5 and the number in the third decimal place is even (0, 2, 4, and so forth). A number in the third decimal place is to be increased by 1 when the number in the fourth decimal place is 6 – 9 and the number in the third decimal place is odd or even, or when the number in the fourth decimal place is 5 and the number in the third decimal place is odd (1, 3, 5, and so forth).

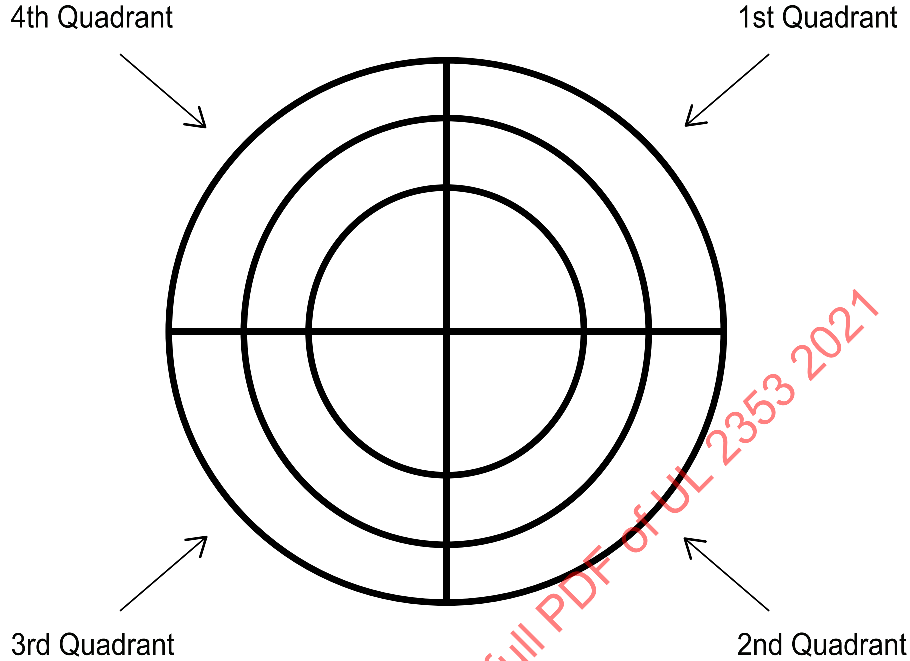
6.9 Rounding to the nearest 0.01 mm – A number in the second decimal place is to remain unchanged when the number in the third decimal place is 0 – 4 and the number in the second decimal place is odd or even, or when the number in the third decimal place is 5 and the number in the second decimal place is even (0, 2, 4, and so forth). A number in the second decimal place is to be increased by 1 when the number in the third decimal place is 6 – 9 and the number in the second decimal place is odd or even, or when the number in the third decimal place is 5 and the number in the second decimal place is odd (1, 3, 5, and so forth).

6.10 A sample of each wire size is to be cut and a casting is to be made using an epoxy resin or other similar resin. Each cut is to be clean and perpendicular to the longitudinal axis of the wire. After the resin has cured a minimum of 24 h at 24 ±8°C (75.2 ±14.4°F) – 50 ±15% RH, the layers of insulation are to be measured. An equivalent method that allows for the individual layers to be measured is also acceptable.

6.11 For single and mulit-layer wires, one thickness measurement is to be made in each of the 4 quadrants of the circular sample, for total insulation thickness as shown in Figure 6.1. The measurements shall be made at thinnest point in a given quadrant. The thickness of an enameled, bond coat or other non-insulating layer is not required to be measured.

Figure 6.1

Optical measurement quadrants

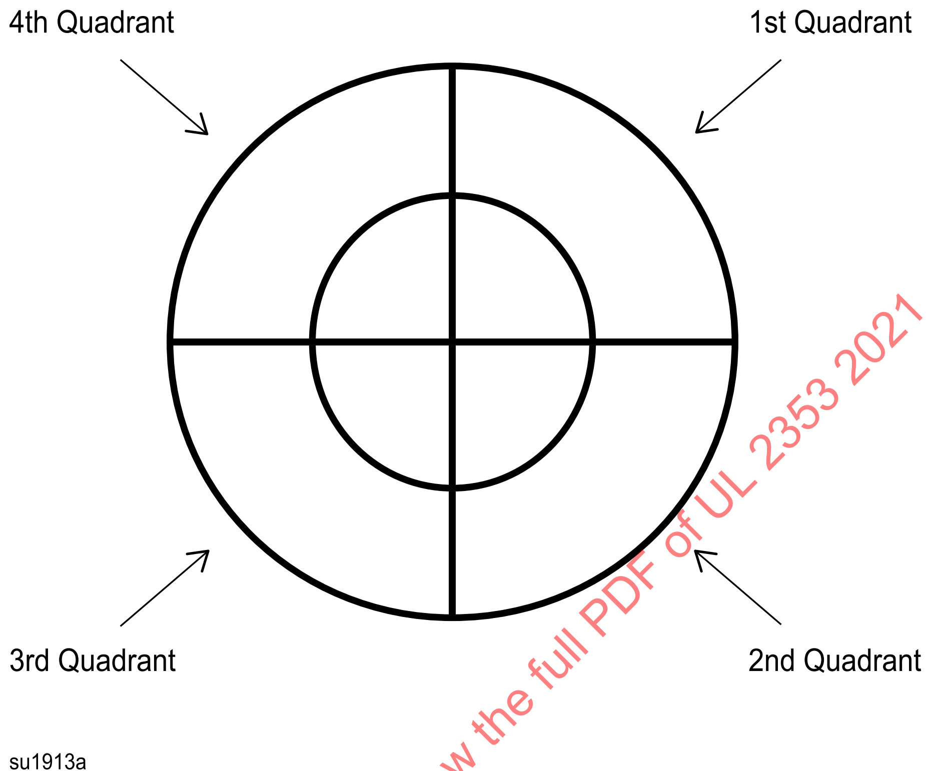


su1913

6.12 For fully insulated wires (FIW), one thickness measurement is to be made in each of the 4 quadrants of the circular sample, reference Figure 6.2. The measurements shall be made at thickest point in a given quadrant.

Figure 6.2

Optical measurement



6.13 The thickness measurements shall be rounded as follows:

a) Rounding to the nearest 0.0001 in – A number in the third decimal place is to remain unchanged when the number in the fourth decimal place is 0 – 4. A number in the third decimal place is to be increased by 1 when the number in the fourth decimal place is 6 – 9.

b) Rounding to the nearest 0.001 mm – A number in the second decimal place is to remain unchanged when the number in the third decimal place is 0 – 4. A number in the second decimal place is to be increased by 1 when the number in the third decimal place is 6 – 9.

6.14 *Deleted*

PERFORMANCE

7 General

7.1 Unless otherwise specified, all tests are to be conducted at temperatures from 15 – 35°C (59 – 95°F), and at a relative humidity of 45 – 75%. Before measurements are made, the specimens are to be preconditioned under these atmospheric conditions for a period of time that is sufficient to allow the wire to reach stability.

7.2 Testing is to be conducted on samples of the smallest and largest conductor sizes to represent the range of sizes using the same insulation thickness. Additional samples may be necessary to cover a range of insulation thicknesses.

7.3 Performance tests conducted on wire whose insulation was wrapped or extruded over a bare conductor are representative of wire of the same construction except with the insulation wrapped or extruded insulation over enameled magnet wire.

7.4 Performance tests conducted on wire whose insulation was wrapped or extruded over an enameled magnet wire are only representative of similarly constructed wire produced using chemically and thermally similar enameled magnet wire.

8 Electric Strength Test – Straight Sample

8.1 For all constructions, five straight lengths of any wire 305-mm (12-in) long are to be subjected to an electric strength test in accordance with the requirements for electric strength as specified in the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, the Standard for Medical Electrical Equipment, Part 1: General Requirements for Safety, UL 60601-1, or the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1 Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1. The test voltage is to be in accordance with the applicable test voltages for electric strength tests in the Test Voltages for Electric Strength Tests Based on Peak Working Voltages (Part 1 and Part 2) Tables of UL 60950-1, the Test Voltages Table of UL 60601-1, or the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1 Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1, Table 5.2.3.2.2DV.1 for basic and supplementary insulation and Table 21, Column 3 for reinforced insulation unless otherwise indicated below. The voltage is to be applied between the conductor and foil wrapped in direct contact with the center 150 mm (6 in) of the sample.

8.2 Additionally, for any wire evaluated for compliance with 5.1.1, five samples of each layer are to be subjected to an electric strength test in accordance with the requirements for electric strength, as specified in the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, or the Standard for Medical Electrical Equipment, Part 1: General Requirements for Safety, UL 60601-1. This additional test is also required for insulation used in products evaluated in accordance with the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1 Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1. The test voltage is to be as specified in Table 5.2.3.2.2DV.1 for basic and supplementary insulation and as specified in Table 21, Column 3 for reinforced insulation. The test voltage is to be in accordance with test voltages for electric strength tests, in UL 60950-1 or from UL 60601-1. The voltage is to be applied between the conductor and foil wrapped in direct contact with the center 150 mm (6 in) of the sample. For separable constructions, the voltage is to be applied through each layer of tape for one- and two-layer constructions, and through all combinations of any two layers for three-layer constructions, by the means of flat-surfaced electrodes. The test voltage shall be applied at a rate of 500 V/s. to the specified test voltage and held for 60 s.

8.3 There shall be no insulation breakdown during this test. Insulation breakdown is determined to have occurred when the current which flows as a result of the application of the test voltage rapidly increases in an uncontrolled manner (i.e. the insulation does not restrict the flow of the current). Corona discharge or a single momentary flashover is not regarded as insulation breakdown.

9 Electrical Strength Test – Twisted Sample

9.1 For all constructions, five samples of the wire prepared in the manner described in 9.2 and tested at room temperature, are to be subjected to an electric strength test in accordance with the requirements for electric strength, in the following standards:

a) Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1; or the

b) Standard for Medical Electrical Equipment, Part 1: General Requirements for Safety, UL 60601-1; or the

c) Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1 Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1.

9.2 A straight piece of the finished wire construction, approximately 400 mm (16 inches) in length, with the insulation removed at both ends, is to be twisted 360° back on itself for a distance of 125 ±5 mm (5 ±0.2 in). The load applied to the wire pair and the number of twists, shall be as provided in Loads applied to the wire pairs and number of twists, Table 9.1. The loop at the end of the twisted section is to be cut at two places to provide a maximum spacing between the cut ends. Any bending to ensure an adequate separation between the two wire ends is to be arranged to avoid sharp bends or damage to the insulation.

Table 9.1
Loads applied to the wire and number of twists

Nominal conductor diameter				Load		Number of twists
Over		Up to and including				
mm	(in)	mm	(in)	N	(lbf)	
0.05	(0.0025)	0.06	(0.0020)	0.05	–	46
0.07	(0.0028)	0.09	(0.0035)	0.10	–	41
0.100	(0.004)	0.250	(0.009)	0.85	(0.19)	33
0.250	(0.009)	0.355	(0.014)	1.70	(0.38)	23
0.355	(0.014)	0.500	(0.019)	3.40	(0.76)	16
0.500	(0.019)	0.710	(0.027)	7.00	(1.57)	12
0.710	(0.027)	1.060	(0.041)	13.50	(3.03)	8
1.060	(0.041)	1.40	(0.055)	27.00	(6.06)	6
1.400	(0.055)	2.000	(0.078)	54.00	(12.14)	4
2.000	(0.078)	5.000	(0.200)	108.00	(24.27)	3
Note – For fully insulated wire (FIW), the wire size range is only applicable from 0.040 mm – 1.60 mm.						

9.3 The test voltage:

a) For reinforced insulation used in ITE equipment is not to be less than 6,000 Vrms;

b) For reinforced insulation used in medical equipment is to use the appropriate test voltages as specified in the dielectric strength tests, Standard for Medical Electrical Equipment, Part 1: General Requirements for Safety, UL 60601-1, or 6,000 Vrms, whichever is greater;

c) For basic or supplementary insulation is not to be less than twice the appropriate test voltages as specified in the electric strength tests in the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, or 3,000 Vrms, whichever is greater; or

d) For basic and supplement insulation is not to be less than twice the appropriate test voltages as specified in Table 5.2.3.2.2DV.1 and for reinforced insulation is not to be less than twice the appropriate test voltages as specified in Table 21, Column 3 the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1 Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1.

9.4 The wire is to be subjected to a test voltage, substantially sine-wave in form, having a frequency of either 50 Hz or 60 Hz. The voltage applied between the conductors of the wires is to be raised from zero to the prescribed voltage at a rate of 500 V/s and held at that value for 60 s. There shall be no insulation breakdown during the test. Insulation breakdown is determined to have occurred when the current which flows as a result of the application of the test voltage rapidly increases in an uncontrolled manner (i.e. the insulation does not restrict the flow of the current). Corona discharge or a single momentary flashover is not regarded as insulation breakdown.

10 Flexibility and Adherence Test

10.1 For all constructions, three samples each consisting of a straight piece of wire at least 305-mm (12-in) long is to be wound for 10 continuous and adjacent turns around a polished mandrel of the diameter specified in mandrel diameter, Table 10.1. The mandrel is to be rotated with a rate of 1 – 3 revolutions per second (r/s) with tension applied to the wire that is sufficient to keep it in contact with the mandrel. Elongating or twisting of the wire is to be avoided. Any suitable equipment is not prohibited from being used.

Table 10.1
Mandrel diameter

Nominal conductor diameter,		Mandrel diameter,	
mm	(in)	mm ±0.2 mm	(in ±0.01 in)
0.05 – 0.34	(0.002 – 0.014)	4.0	(0.16)
0.35 – 0.49	(0.014 – 0.019)	6.0	(0.24)
0.50 – 0.74	(0.019 – 0.029)	8.0	(0.31)
0.75 – 2.49	(0.029 – 0.099)	10.0	(0.39)
2.5 – 5.00	(0.100 – 0.200)	Four times the conductor diameter	Four times the conductor diameter
Note – For fully insulated wire (FIW), the wire size range is only applicable from 0.040 – 1.60 mm.			

10.2 After winding, the specimen is to be examined for exposure of the base conductor or delamination by visual examination. There shall be no exposure of bare conductor, or delamination of the insulation.

10.3 After visual examination of the specimen, the sample is to be subjected to electric strength tests for insulation as specified in the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, the Standard for Medical Electrical Equipment, Part 1: General Requirements for Safety, UL 60601-1, or the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1 Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1. The voltage is to be applied between the conductor and the mandrel.

10.4 The test voltage:

a) For reinforced insulation used in ITE equipment is to use the appropriate test voltages as specified in the electric strength tests, in the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, or 3,000 Vrms, whichever is greater;

b) For reinforced insulation used in medical equipment is to use the appropriate test voltages as specified in the dielectric strength tests in the Standard for Medical Electrical Equipment, Part 1: General Requirements for Safety, UL 60601-1, or 3,000 Vrms, whichever is greater;

c) For basic or supplementary insulation is to use the appropriate test voltages as specified in the dielectric strength tests in UL 60950-1, or 1,500 Vrms, whichever is greater; or

d) For basic and supplement insulation as specified in Table 5.2.3.2.2DV.1 and as specified in Table 21, Column 3 for reinforced insulation the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1 Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1.