Designation: D1351 – 20

Standard Specification for Thermoplastic Polyethylene Insulation for Electrical Wire and Cable[1]

This standard is issued under the fixed designation D1351; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers a thermoplastic insulation which consists substantially of polyethylene.

1.2 This type of insulation is considered suitable for use on wire or cable that will be used for continuous operation at conductor temperatures up to 75 °C with a maximum conductor size of 1000 kcmil (507 mm^2). The maximum voltage rating shall not exceed 35 000 V for power application or 9 000 V for series lighting.

1.3 In many instances the insulation material cannot be tested unless it has been formed around a conductor. Therefore, tests done on insulated wire or cable in this specification are solely to determine the relevant property of the insulation material and not to test the insulated conductor or completed cable.

1.4 Whenever two sets of values are stated, in different units, the values in the first set are regarded as standard, while the values in parentheses are provided for information only and are not considered standard.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable

D1711 Terminology Relating to Electrical Insulation

D2308 Specification for Thermoplastic Polyethylene Jacket for Electrical Wire and Cable

D2633 Test Methods for Thermoplastic Insulations and Jackets for Wire and Cable

D3349 Test Method for Absorption Coefficient of Ethylene Polymer Material Pigmented with Carbon Black

2.2 *ICEA Standard:*[3]

T-24-380 Guide for Partial-Discharge Procedure

3. Terminology

3.1 *Definitions:*

3.1.1 Refer to Terminology D1711 for definitions of terms used in this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aging (act of), n*—exposure of materials to air at a temperature of 100 °C for 48 h.

4. High Voltage Hazard

4.1 *High Voltage:*

4.1.1 Lethal voltages are a potential hazard during the performance of this test. It is essential that the test apparatus, and all associated equipment electrically connected to it, be properly designed and installed for safe operation.

4.1.2 Solidly ground all electrically conductive parts which it is possible for a person to contact during the test.

4.1.3 Provide means for use at the completion of any test to ground any parts which were at high voltage during the test or have the potential for acquiring an induced charge during the test or retaining a charge even after disconnection of the voltage source.

4.1.4 Thoroughly instruct all operators as to the correct procedures for performing tests safely.

4.1.5 When making high voltage tests, particularly in compressed gas or in oil, it is possible for the energy released at breakdown to be sufficient to result in fire, explosion, or rupture of the test chamber. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury. If the potential for fire exists, have fire suppression

[1] This specification is under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.07 on Electrical Insulating Materials.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from The Insulated Cable Engineers Association, Inc. (ICEA), P.O. Box 2694, Alpharetta, GA 30023, http://www.icea.net.

*A Summary of Changes section appears at the end of this standard

equipment available. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury.

5. Conductor Shields

5.1 Conductor shields shall be used on solid and stranded conductors of power cables having rated circuit voltages above 2000 V. This requirement does not apply to series lighting cables. Conductor shielding is conducting material at least 0.0025 in. (0.06 mm) thick applied over the surface of the conductor. The options include conducting nonmetallic tape, conducting compound, or conducting cement.

6. Physical Properties

6.1 The polyethylene, before application to the conductor, shall comply with the requirements of Specification D1248 for Type I; Class A, B, or C; Category 4 or 5; Grade E4 or E5. The requirements of Specification D1248 do not apply to insulation removed from the conductor.

6.2 Insulation exposed to sunlight or weather requires Specification D1248, Class C compound or suitable protective coverings. Class C compound shall meet the minimum absorption coefficient requirement in Table 1.

6.3 Specimens removed from the wire or cable and tested at 20 to 30 °C (68 to 86 °F) shall conform to the requirements for physical properties specified in Table 1. Alternatively, the insulation shall be air-oven aged without removal from the conductor.

6.4 *Thickness of Insulation*—The minimum average insulation thickness shall be as specified in Table 2 or Table 3 of this specification. The minimum thickness shall be at least 90 % of the specified minimum average thickness.

6.5 *Absorption Coefficient*—Test according to Test Method D3349. Alternatively, a certification by the manufacturer of the polyethylene compound that the requirement has been complied with shall suffice.

TABLE 1 Physical Properties of Compound

Unaged Requirements:	
Tensile strength, minimum, psi (MPa)	1500 (10.4)
Elongation at rupture, minimum, %	350
Aged Requirements:	
After air oven aging at 100 ± 1 °C for 48 h:	
Tensile strength, % retention, minimum	75
Elongation at rupture, % retention, minimum	75
Absorption Coefficient, minimum, absorbance/nm	320

7. Electrical Requirements

7.1 **Warning—**These electrical tests involve the use of high voltages. See 4.1.

7.2 *Order of Testing*—Perform the partial discharge, ac voltage, insulation resistance, and dc voltage tests in that order when any of these tests are specified. The sequence of other testing is not specified.

7.3 *Partial Discharge*—When tested in accordance with ICEA T-24-380, as modified in Test Methods D2633, each length of completed shielded power cable rated for service at 2001 V and above shall comply with the minimum partial discharge extinction level. See Test Methods D2633.

7.4 *AC Voltage Test*—The insulated conductor shall withstand the ac voltage specified in Table 2 or Table 3 for 5 min as modified in Test Methods D2633. Unless otherwise specified, this test shall be omitted for nonshielded conductors rated up to 5000 V if the dc voltage test described in 7.7 is performed.

7.5 *Insulation Resistance*—The insulated conductor shall have an insulation-resistance value equal to or greater than that corresponding to a constant of 50 000 MΩ-1000 ft at 60 °F (15.6 °C). When the temperature of the water in which the insulation is tested differs from 60 °F, a correction factor must be applied. Table 1 of Test Methods D2633 contains the correction factors. Each insulation or cable manufacturer can furnish the 1 °F coefficient for their insulation material by using the procedure given in Test Methods D2633. Multiply the measured value by the correction factor to obtain the insulation resistance value corrected to 60 °F.

7.6 *DC Voltage Test (Cables Rated at 5001 V and Above)*—Upon completion of the insulation resistance test, each length of insulated power cable rated for service at 5001 V and over shall withstand for 15 min the dc test voltage given in Table 2 or Table 3 as modified in Test Methods D2633.

7.7 *DC Voltage Test (Cables Rated at 5000 V or Less)*—Upon completion of the insulation resistance test, each nonshielded conductor rated up to 5000 V shall withstand for 5 min the dc test voltage given in Table 2 or Table 3 as modified in Test Methods D2633. Unless otherwise specified, it is acceptable to omit this test for nonshielded conductors rated up to 5000 V if the ac voltage test described in 7.4 has been performed.

8. Keywords

8.1 cable; conductor; electrical; insulation; polyethylene; thermoplastic; wire

TABLE 2 Conductor Sizes, Insulation Thicknesses, and Test Voltages for Polyethylene-insulated Power Cables[A]

NOTE 1—Column A thicknesses (0 to 2000 V) are applicable to single-conductor power cables for general application when a black pigmented insulation is used without a further covering.

NOTE 2—Column B thicknesses (0 to 2000 V) are applicable to multiple-conductor cables with an outer covering and to single-conductor cables with an outer covering.

NOTE 3—To limit the maximum voltage stress on the insulation at the conductor to a safe value, the minimum size of the conductor shall be in accordance with Table 2.

For cables or conditions of service where mechanical stresses govern, such as in submarine cables or long vertical risers, it is possible that these minimum conductor sizes will not be strong enough.

NOTE 4—Polyethylene insulation used on nonshielded cable without an outer covering shall be black pigmented insulation meeting the requirements for both polyethylene insulation and polyethylene jacket.

NOTE 5—Polyethylene insulation used on nonshielded cable without an outer covering for rated circuit voltages of 2001 to 5000 V shall be ozone and discharge resistant when tested in accordance with Specification D2308.

NOTE 6—Carbon-black-pigmented polyethylene insulation shall not be used on power cable rated over 5000 V.

Rated Circuit Voltage, Phase to Phase, V[B]	Conductor Size, Awg or kcmil (mm^2)	Insulation Thickness for 100 and 133 % Insulation Levels,[C] Grounded and Ungrounded Neutral				a-c Test Voltage, kV, for 100 and 133 % Insulation Levels,[C] Grounded and Ungrounded Neutral		d-c Test Voltage, kV, for 100 and 133 % Insulation Levels,[C] Grounded and Ungrounded Neutral	
		Column A		Column B		A	B	A	B
		mils	mm	mils	mm				
0 to 600	14 to 9 (2.08 to 6.63)	45	1.14	30	0.76	4.0	3.5	12.0	10.5
	8 to 2 (8.37 to 33.62)	60	1.52	45	1.14	5.5	5.5	16.5	16.5
	1 to 4/0 (42.41 to 107.2)	80	2.03	55	1.40	7.0	7.0	21.0	21.0
	225 to 500 (114 to 253)	95	2.41	65	1.65	8.0	8.0	24.0	24.0
	525 to 1000 (266 to 507)	110	2.79	80	2.03	10.0	10.0	30.0	30.0
601 to 2000	14 to 9 (2.08 to 6.63)	60	1.52	45	1.14	5.5	5.5	16.5	16.5
	8 to 2 (8.37 to 33.62)	70	1.78	55	1.40	7.0	7.0	21.0	21.0
	1 to 4/0 (42.41 to 107.2)	90	2.29	65	1.65	8.0	8.0	24.0	24.0
	225 to 500 (140 to 253)	105	2.67	75	1.90	9.5	9.5	28.5	28.5
	525 to 1000 (266 to 507)	120	3.05	90	2.29	11.5	11.5	34.5	34.5
Rated Circuit Voltage, Phase to Phase, V[B]	Conductor Size, Awg or kcmil (mm^2)	100 % Insulation Level,[D] Grounded Neutral		133 % Insulation Level, Ungrounded Neutral		100 % Insulation Level,[D] Grounded Neutral	133 % Insulation Level, Ungrounded Neutral	100 % Insulation Level, Grounded Neutral	133 % Insulation Level, Ungrounded Neutral
		mils	mm	mils	mm	mils	mm	mils	mm
NONSHIELDED[E]									
2001 to 5000	8 to 4/0 (8.37 to 107.2)	110	2.79	110	2.79	13	13	35	35
	225 to 500 (114 to 253)	120	3.05	120	3.05	13	13	35	35
	525 to 1000 (266 to 507)	130	3.30	130	3.30	13	13	35	35
SHIELDED									
2001 to 5000	8 to 1000 (8.37 to 507)	90	2.29	90	2.29	13	13	35	35
5001 to 8000	6 to 1000 (13.30 to 507)	115	2.92	140	3.56	18	22	45	45
8001 to 15 000	2 to 1000 (33.62 to 507)[F]	175	4.45	215	5.46	27	33	70	80
15 001 to 25 000	1 to 1000 (42.41 to 507)	260	6.60	345	8.76	38	49	100	125
25 001 to 28 000	1 to 1000 (42.41 to 507)	280	7.11			42		105	
28 001 to 35 000	1/0 to 1000 (53.49 to 507)	345	8.76			49		125	

[A] For series lighting cables, see Table 3.

[B] The actual operating voltage shall not exceed the rated circuit voltage by more than (1) 5 % during continuous operation, or (2) 10 % during emergencies lasting not more than 15 min.

[C] The selection of the cable insulation level to be used in a particular installation shall be made on the basis of the applicable phase to phase voltage and the general system category as outlined below:

100 % Level—It is appropriate for cables in this category to be applied where the system is provided with relay protection such that ground faults will be cleared as rapidly as possible, but in any case within 1 min. While these cables are applicable to the great majority of cable installations which are on grounded systems, they are also potentially suitable on other systems for which the application of cables is acceptable provided the above clearing requirements are met in completely de-energizing the faulted section. In common with other electrical equipment, the use of cables is not recommended on systems where the ratio of the zero to positive phase reactance of the system at the point of cable application lies between –1 and –40 since excessively high voltages will be encountered in the case of ground faults.

133 % Level—This insulation level corresponds to that formerly designated for ungrounded systems. It is appropriate for cables in this category to be applied in situations where the clearing time requirements of the 100 % level category cannot be met, and yet there is adequate assurance that the faulted section will be de-energized in a time not exceeding 1 h. They are also suitable for use when additional insulation strength over the 100 % level category is desirable.

[D] Where additional insulation thickness is desired, it shall be the same as for the 133 % insulation level.

[E] Where cable is provided with a protective covering, these insulation thicknesses shall be 90 mils (2.29 mm) for all conductor sizes listed.

[F] For 133 % insulation level (ungrounded neutral), the minimum conductor size is 1 Awg (42.41 mm^2).