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Designation: D 1351 – 9702

An American National Standard

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

This standard is issued under the fixed designation D 1351; 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 continuous operation for 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 or cable. Therefore, tests done on insulated wire or cable in this document are solely to determine the relevant property of the insulation material and not to test the insulated conductor or completed cable.

1.4 ~~T~~Whenever two sets of values ~~stated in inch-pound units~~ are presented, in different units, the ~~standard, except~~ values in ~~cases where SI units~~ the first set are ~~more appropriate. The values~~ the standard, while those in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

[1] This specification is under the jurisdiction of ASTM Committee ~~D-9~~ D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.18 on Solid Insulations, Non-Metallic Shieldings and Coverings for Electrical and Telecommunication Wires and Cables.

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D 618 Practice 1248 Specification for Conditioning Polyethylene Plastics Extrusion Materials for Testing Wire and Cable[2]
D 1248 Specification for Polyethylene Plastics Molding and Extrusion Materials[2]
D 1711 Terminology Relating to Electrical Insulation[3]
D 2308 Specification for Thermoplastic Polyethylene Jacket for Electrical Insulated Wire and Cable[3]
D 2633 Methods of Testing Thermoplastic Insulations and Jackets for Wire and Cable[4]
D 3349 Test Method for Absorption Coefficient of Ethylene Polymer Material Pigmented with Carbon Black[4]
2.2 *ICEA Standard:*
T-24-380 Guide for Partial-Discharge Procedure[5]

3. Terminology

3.1 *Definitions:*
3.1.1 Refer to Terminology D 1711 for definitions pertinent to this specification.
3.2 *Definition of Term Specific to This Standard:*
3.2.1 *aging, n*—exposure of materials to air at 100°C for 48 h.

4. Conductor Shields

4.1 Use conductor shields 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. It may be conducting nonmetallic tape, conducting compound, or conducting cement.

5. Physical Properties

5.1 The polyethylene, before application to the conductor, shall comply with the requirements of Specification D 1248 for Type I; Class A, B or C; Category 4 or 5; Grade E4 or E5. The requirements of Specification D 1248 do not apply to the insulation removed from the conductor.
5.2 Insulation exposed to sunlight or weather requires Specification D 1248, Class C compound or suitable protective coverings. Class C compound shall meet the minimum absorption coefficient requirement in Table 1.
5.3 Specimens removed from the wire or cable and tested at 20 to 30°C (68 to 80°F) shall conform to the requirements for physical properties specified in Table 1. The insulation may be air-oven aged without removal from the conductor.
5.4 *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.
5.5 *Absorption Coefficient*—See Test according to Test Method D 3349. Instead of testing insulation removed from the conductor, a A certification by the manufacturer of the polyethylene compound that the requirement has been complied with shall may suffice.

6. Electrical Requirements

6.1 *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.
6.2 *Partial Discharge*—When tested in accordance with ICEA T-24-380, as modified in Test Methods D 2633, 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 D 2633.
6.3 *AC Voltage Test*—The insulated conductor shall withstand the ac voltage specified in Table 2 or Table 3 for 5 min. Unless otherwise specified, this test may be omitted for nonshielded conductors rated up to 5000 V if the dc voltage test described in 6.6

[2] *Annual Book of ASTM Standards*, Vol 08.01.
[3] *Annual Book of ASTM Standards*, Vol 10.01.
[4] *Annual Book of ASTM Standards*, Vol 10.02.
[5] Available from the Insulated Cable Engineers Association, P.O. Box 440, South Yarmouth, MA 02664.

TABLE 1 Physical Properties of Compound

Unaged Requirements:	
Tensile strength, min, psi (MPa)	1400 (9.7)
Elongation at rupture, min, %	350
Aged Requirements:	
After air oven aging at 100 ± 1°C for 48 h:	
Tensile strength, min, psi (MPa)	1050 (7.3)
Tensile strength, min, psi (MPa)	75
Elongation at rupture, min, %	265
Absorption Coefficient, min, absorbance/mm	320

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, these minimum conductor sizes may 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 D 2308.

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 (mm²)	Insulation Thickness for 100 and 133 Percent Insulation Levels,[C] Grounded and Ungrounded Neutral				a-c Test Voltage, kV, for 100 and 133 Percent Insulation Levels,[C] Grounded and Ungrounded Neutral		d-c Test Voltage, kV, for 100 and 133 Percent Insulation Levels,[C] Grounded and Ungrounded Neutral	
		Column A		Column B		A	B	A	B
		mils	mm	mils	mm				
~~0 to 600~~	~~14 to 9D (2.08 to 6.63)~~	~~45~~	~~1.14~~	~~30~~	~~0.76~~	~~4.0~~	~~3.5~~	~~12.0~~	~~10.5~~
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 9D (2.08 to 6.63)~~	~~60~~	~~1.52~~	~~45~~	~~1.14~~	~~5.5~~	~~5.5~~	~~16.5~~	~~16.5~~
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
		100 Percent Insulation Level,~~[E]~~[D] Grounded Neutral		133 Percent Insulation Level, Ungrounded Neutral		100 Percent Insulation Level,~~[E]~~[D] Grounded Neutral	133 Percent Insulation Level, Ungrounded Neutral	100 Percent Insulation Level, Grounded Neutral	133 Percent Insulation Level, Ungrounded Neutral
		NONSHIELDED~~[F]~~[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
Rated Circuit Voltage, Phase to Phase, V[B]	Conductor Size, Awg or kcmil (mm²)	100 Percent Insulation Level,~~[E]~~[D] Grounded Neutral		133 Percent Insulation Level, Ungrounded Neutral		100 Percent Insulation Level,~~[E]~~[D] Grounded Neutral	133 Percent Insulation Level, Ungrounded Neutral	100 Percent Insulation Level, Grounded Neutral	133 Percent Insulation Level, Ungrounded Neutral
		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 15000~~	~~2 to 1000 (33.62 to 507)[G]~~	~~175~~	~~4.45~~	~~215~~	~~5.46~~	~~27~~	~~33~~	~~70~~	~~80~~
8001 to 15000	2 to 1000 (33.62 to 507)[F]	175	4.45	215	5.46	27	33	70	80
15001 to 25000	1 to 1000 (42.41 to 507)	260	6.60	345	8.76	38	49	100	125
25001 to 28000	1 to 1000 (42.41 to 507)	280	7.11			42		105	
28001 to 35000	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 percent during continuous operation or (*2*) 10 percent 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 Percent Level—Cables in this category may 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 may be used also 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 may be encountered in the case of ground faults.

133 Percent Level —This insulation level corresponds to that formerly designated for ungrounded systems. Cables in this category may be applied in situations where the clearing time requirements of the 100 percent 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 may also be used when additional insulation strength over the 100 percent level category is desirable.

~~*173 Percent Level*—Cables in this category should be applied on systems where the time required to de-energized a grounded section is indefinite. Their use is recommended also for resonant grounded systems. Consult the manufacturer for insulation thicknesses.~~

[D] ~~S~~ Where additiongale-co indsuelatiorn thicablknes ins izes 9 Awg (6.63 mm²) an d smallesired, it shall not be u the samed as for direc thea 133 percenth bur insulation level.

~~[E] Where additional insulation thickness is desired, it shall be the same as for the 133 percent 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]~~[F] For 133 percent insulation level (ungrounded neutral), the minimum conductor size is 1 Awg (42.41 mm²).

TABLE 3 Conductor Sizes, Insulation Thicknesses and Test Voltages for Polyethylene-Insulated Series Lighting Cables

Circuit Voltage, V[A,B]	Conductor Size, Awg (mm²)	Insulation Thickness[B]		test Voltage, kV	
		mils	mm	a-c	d-c
~~0 to 1000~~	~~10 to 8C (5.26 to 8.37)~~	~~45~~	~~1.14~~	~~5.5~~	~~16.5~~
	~~6 to 4 (13.30 to 21.15)~~	~~55~~	~~1.40~~	~~7.0~~	~~21.0~~
0 to 1000	10 to 8 (5.26 to 8.37)	45	1.14	5.5	16.5
	6 to 4 (13.30 to 21.15)	55	1.40	7.0	21.0
~~1001 to 2000~~	~~10 to 8C (5.26 to 8.37)~~	~~55~~	~~1.40~~	~~7.0~~	~~21.0~~
	~~6 to 4 (13.30 to 21.15)~~	~~65~~	~~1.65~~	~~8.0~~	~~24.0~~
1001 to 2000	10 to 8 (5.26 to 8.37)	55	1.40	7.0	21.0
	6 to 4 (13.30 to 21.15)	65	1.65	8.0	24.0
~~2001 to 3000~~	~~10 to 8C (5.26 to 8.37)~~	~~75~~	~~1.90~~	~~10~~	~~30~~
	~~6 to 4 (13.30 to 21.15)~~	~~90~~	~~2.29~~	~~10~~	~~30~~
2001 to 3000	10 to 8 (5.26 to 8.37)	75	1.90	10	30
	6 to 4 (13.30 to 21.15)	90	2.29	10	30
3001 to 6000	8 to 4 (8.37 to 21.15)	110	2.79	13	35
6001 to 9000	8 to 4 (8.37 to 21.15)	150	3.81	19	55

The following tabulation of series lighting transformer ratings is representative of those in common use:

Rating, kW	6,6-A Secondary		20-A Secondary	
	Full-load Voltage, V, with Protectors	Open-circuit Voltage, V, Without Protectors	Full-load Voltage, V, with Protectors	Open-circuit Voltage, V, Without Protectors
10	1515	2090	500	690
15	2272	3090	750	1020
20	3030	4115	1000	1360
25	3787	5110	1250	1685
30	4545	6130	1500	2020
40	6060	8180	2000	2700

[A] A separate jacket is not required. If protectors are employed, the thickness shall be determined by the full-load voltage. If the circuit is to be operated without protectors, the thickness shall be determined by the open-circuit voltage.

[B] The highest circuit voltage at each step represents the maximum operating voltage recommended for that thickness of insulation.

[C] ~~Single-conductor cables sizes 9 Awg (6.63 mm²) and smaller shall not be used for direct earth burial.~~

is to be performed.

6.4 *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 D 2633 contains the correction factors. Each insulation manufacturer can furnish the 1°F coefficient for their insulation material by using the procedure given in Test Methods D 2633. Multiply the measured value by the correction factor to obtain the insulation resistance value corrected to 60°F.

6.5 *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.

6.6 *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. Unless otherwise specified, this test may be omitted for nonshielded conductors rated up to 5000 V if the ac voltage test described in 6.3 has been performed.

7. Keywords

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

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