



IEEE Recommended Practice for Specifying Electric Submersible Pump Cable—Ethylene— Propylene Rubber Insulation

IEEE Industry Applications Society

Developed by the
Petroleum & Chemical Industry Committee

IEEE Std 1017.2™-2021
(Revision of IEEE Std 1018-2013)



STANDARDS

IEEE Recommended Practice for Specifying Electric Submersible Pump Cable—Ethylene— Propylene Rubber Insulation

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Petroleum & Chemical Industry Committee
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Approved 23 September 2021

IEEE SA Standards Board

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Abstract: Minimum requirements for the design, construction, manufacturing, testing, purchasing, and application of electric submersible pump (ESP) cable are presented. The cable is round or flat, with ethylene–propylene rubber insulation, nitrile jacket, ethylene–propylene diene monomer (EPDM) jacket or metallic barrier, and armor or encapsulating material. These cables are for voltages not exceeding 8 kV (phase to phase) and conductor temperatures not exceeding 140 °C (284 °F) for nitrile or a maximum of 232 °C (450 °F) for EPDM jacket or metallic barrier cable. Conductors, insulation, barrier (optional), assembly with or without jacket, armor, requirements for testing by the manufacturer, and cable ampacity are all covered in the document.

Keywords: ampacity ratings, assembly, cable construction, cable testing, electric submersible pump, EPDM, EPR, ESP, ESP cable, ethylene–propylene diene monomer, ethylene–propylene rubber, IEEE 1017.2™, IEEE 1018™, submersible pump cable

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

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PDF: ISBN 978-1-5044-8000-0 STD24967
Print: ISBN 978-1-5044-8001-7 STDPD24967

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Introduction

This introduction is not part of IEEE Std 1017.2–2021, IEEE Recommended Practice for Specifying Electric Submersible Pump Cable—Ethylene–Propylene Rubber Insulation.

This document is part of the IEEE 1017 family of Electric Submersible Pump (ESP) documents. The IEEE 1017 family of documents originally included three recommended practices (RPs) including RP 1017 (now IEEE Std 1017.1™), RP 1018 (now IEEE Std 1017.2™ [B7]), and RP 1019 (now IEEE Std 1017.3™ [B8]).¹ These three RPs were the first standards sponsored by the Petroleum and Chemical Industry Committee of the IEEE Industry Applications Society.

Work began on the ESP standards in 1979. At that time, the typical life of ESP cables was significantly less than one year. Less than five vendors manufactured all ESP cable in the world. Each manufacturer used proprietary guidelines, as well as construction and performance requirements. After five years of work, the initial publication of RP 1017, RP 1018, and RP 1019 was completed in 1984. ANSI approval was obtained in 1985.

The original RPs focused on specifications for polypropylene cable (RP 1019). This was followed by the specifications for a relatively new insulation material EPDM (RP 1018). During this process, it became clear that a document outlining field testing of the cable was required. This grew into RP 1017. The voltage rating of the cables was limited to 3 kV and 5 kV. Testing was limited to dc hi-pot testing and a dc voltage withstand test.

Version 2 (1991) of RP 1018 and RP 1019 expanded with the addition of ampacity curves based on the Neher-McGrath method. The Neher-McGrath calculations were modified to make them specifically applicable to the downhole conditions experienced by the cables. No significant changes to the testing requirements contained in 1017 were made.

Version 3 of RP 1017 (2004) included the addition of general descriptions of new testing procedures including time domain reflectometers (TDRs), thumpers, bridge type fault locators, and dc burn in. Also included was a major improvement in the interpretation of dc hi-pot testing results, including methods for predicting failure of the cables without overstressing and destroying the insulation.

By the 2004 version, the cable types described in RP 1018 and RP 1019 included four types: round, round with lead sheath, flat and flat with lead sheath.

Prior to the 2004 version, all values in the ESP cable standards were based on the United States Customary System (USCS, or English Engineering Units). Due to increased globalization of IEEE standards, the IEEE Standards Association (SA) had a requirement that all published documents use SI units exclusively. The market for ESP cable standards deals almost exclusively in USCS units, so the drafts were rejected by the ballot groups. Members of the ballot group threatened to withhold approval of the IEEE RPs and move the work to other standards development organizations. This led the working group to petition the SA Standards Board (SASB) to include dual units, SI and USCS. The SASB approved the dual unit request and made a change to IEEE SA policy to allow dual units in all IEEE standards.

Version 4 (2013) of the RPs primarily involved editorial cleanup and verification of table values. Discussion began on advanced test methods, but these test methods were not included in this version. Discussions also began on inclusion of 8 kV rated cables.

The current version of the IEEE 1017 family of RPs (version 5) contains the most significant modifications to the RPs in their 40-year history. Version 5 includes greatly expanded content and a complete revamp of the group of RPs. The first major modification was renumbering of the RPs to emphasize the continuity of the standards as a group. RP 1017 became RP 1017.1, RP 1018 became RP 1017.2, and RP 1019 became RP

¹The numbers in brackets correspond to those of the bibliography in Annex C.

1017.3. All three RPs were expanded to include 8 kV rated cable in addition to the 3 kV and 5 kV historic rated voltages. Additionally, cable sizes were expanded to include #3/0 AWG and #4/0 AWG.

RP 1017.1 was expanded to include all testing: factory, acceptance, and field testing. Additionally, advanced test methods including very low frequency tan-delta (VLF tan-delta) and partial discharge (PD) were included, along with interpretation guidance. Testing for surface feedthroughs and downhole connectors was added. New tests for qualification of encapsulating materials for non-lead metallic barrier cables with encapsulating jacket were also added.

RP 1017.2 and RP 1017.3 were modified to remove testing (pulled into RP 1017.1) and were expanded to include non-lead metallic barrier cables (sometimes called “tubing encapsulated power cable” or “TEPC”). The insulating and jacket material specifications were expanded to include reinforced high modulus materials. Finally, the Neher-McGrath curves were updated to correct an error and to make them more readable and usable.

This recommended practice, under the jurisdiction of the Petroleum and Chemical Industry Committee of the IEEE Industry Applications Society, may be used by anyone desiring to do so and is presented as minimum criteria for installation and field testing of this class of submersible cable. It is not intended to restrict innovation or to limit development of improvements in cable design. Every effort has been made to assure the accuracy and reliability of the data contained herein. However, the committee makes no representation, warranty, or guarantee in connection with the publication of this recommended practice and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use, for any conflict, or for the infringement of any patent resulting from the use of this recommended practice.

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1. Overview

1.1 Scope

This recommended practice establishes recommendations for three-conductor round and flat oil-well cables consisting of ethylene–propylene rubber (EPR) insulated copper conductors used in supplying three-phase ac electric power to submersible pump motors. These ~~The three major~~ cables may also include additional coverings consisting of wraps, metallic armor or barriers, and/or nonmetallic jackets or sheaths selected on the basis of mechanical and environmental conditions. ~~by~~ ~~components are as follows:~~

- a) ~~Cables with copper conductors, ethylene propylene diene monomer (EPDM) insulation, nitrile jacket, and metallic armor~~
- b) ~~Cables with copper conductors, EPDM insulation, EPDM jacket, and metallic armor~~
- e) ~~Cables with copper conductors, EPDM insulation, lead sheath, and metallic armor~~

1.2 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (shall equals is required to).^{2,3}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (should equals is recommended that).

The word *may* is used to indicate a course of action permissible within the limits of the standard (may equals is permitted to).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (can equals is able to).

1.3 Specifications and standards

Cables meeting the requirements of the recommended practice should be rated for voltages not exceeding 8 ~~3 kV~~ or 5 kV (phase to phase).

²The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

³The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

Conductor operating temperatures for cables should not exceed 232 °C (450 °F). Use of cable above rated temperature can cause premature deterioration of the insulation. Low-temperature handling below -10 °C (14 °F) may cause cracking of the insulation or jacket.

Cable purchased under the recommendation of this recommended practice, unless otherwise specified herein, should meet the requirements of ASTM A90, ASTM B3, ASTM B8, ASTM B33, ASTM B189, ASTM B496, ASTM D412, ANSI/ICEA S-96-659 and ANSI /NEMA WC71, ICEA S-19 96-81/NEMA WC3, and ICEA S-61-402/ NEMA WC5, where applicable.⁴¹

1.4 Application considerations

While operating temperature is the main factor in selecting the type of insulation to be used, ~~there are~~ many other factors ~~that~~ should be considered when choosing an appropriate electric submersible pump (ESP) cable design. Conductor size, insulation thickness, types of barriers or braids, jacket material, cable geometry, armor material, and thickness should all be chosen with respect to specific well and operational factors, including but not limited to the following:

- The economic impact of conductor size selection.
- Anticipated life expectancy of various cable options in specific well conditions.
- Start-up current and maximum voltage drop to ensure assure motor starting capability.
- Voltage rating to optimize cable and system run life.
- The projected heat rise due to voltage imbalance.
- Available space between the tubing and the casing.
- The amount and type of gas in the well.
- Corrosiveness of the well environment.

⁴¹Information on references can be found in Clause 2. Some standards have been superseded and are no longer active.

- The effect of any corrosion inhibitors or other chemical additives on insulation properties.
- The type of annulus fluid surrounding the cable when it is set above a packer.
- The rate and frequency of decompression cycles.
- The magnitude and frequency of temperature cycles.
- Crane pick weight capacity in offshore applications.

~~— Future uses for the cable beyond the well under consideration~~

- Inclusion of chemical injection or communication lines in the cable.
- Wellbore trajectory.
- Clamping and banding methods.

— Adjustable speed drive (ASD) harmonics that can add electrical and thermal stress to the cable.

— Considerations for thermal expansion of tubing encapsulated power cable (TEPC):

- Size and stiffness of the ESP cable may create safety concerns for standard well cable cutting tools that might not be adequate for the task under emergency (e.g., rig blow out) conditions.
- There is potential for trapped pressure inside the metal barrier when coming out of well.
- The potential for damaging floating shield currents with encapsulation, no armor and the three conductor barriers isolated.

Because ~~there are so~~ many considerations are involved in making the proper cable selection, it is very important for the operator to engage the assistance of its supplier's cable application engineers during the cable selection process. Each manufacturer has extensive experience with all the features and benefits of ~~their~~its particular cable offerings, and its input can be invaluable in choosing the proper cable to help maximize the value of cable investments. API 11S3 [\[B1\]](#) and API RP 11S5 [\[B3\]](#) contain information regarding the installation and application of submersible pump cable.

CAUTION

For nonlead metallic barrier cables encapsulated in polymer, ensure that the metallic barriers are bonded together and effectively grounded at both ends. This reduces the risk of voltage buildup on the isolated conductive surfaces.

NOTE—While this recommended practice recognizes the common practice of continuing to operate the pump's electrical system after a phase has faulted to ground and that some power distribution systems are even designed with one corner of the delta system grounded, it neither condones nor disapproves of such practice. However, the user should be aware that such operation produces a higher than normal phase-to-ground voltage across the insulation jacket dielectric of the two ungrounded conductors. Due to the disruption of the normally balanced three-phase fields, such operation produces stresses through the insulation/jacket dielectric which shortens cable life.⁵

CAUTION

Cable used on the surface between the wellhead and the ventilated junction box should be buried or enclosed in appropriate raceway and shall be properly grounded.

⁵[Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.](#)

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI/NEMA WC 71/ICEA S-96-659, Standard for Nonshielded Cables Rated 2001—5000 Volts for Use in the Distribution of Electric Energy.⁶⁻²

ASTM A90, Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.⁷⁻⁴

ASTM B3, Standard Specification for Soft or Annealed Copper Wire.

ASTM B8, Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.

ASTM B33, Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes.

ASTM B189, Standard Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes.

ASTM B496, Standard Specification for Compact Round Concentric-Lay-Stranded Copper Conductors.

⁶ANSI publications are available from the American National Standards Institute (<https://www.ansi.org/>). NEMA publications are available from the National Electrical Manufacturers Association (<https://www.nema.org/>).

²ICEA publications are available from ICEA, P.O. Box 20048, Minneapolis, MN 55420, USA (<http://www.icea.org/>).

⁷⁴ASTM publications are available from the American Society for Testing and Materials, ~~100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA~~ (<https://www.astm.org/>).

[ASTM D412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension.](#)

[ICEA S-19-81/NEMA WC3, Rubber Insulated Wire and Cable.](#)⁸

[ICEA S-61-402/NEMA WC5, Thermoplastic-Insulated Wire and Cable.](#)

~~IEEE Std 1017TM, IEEE Recommended Practice for Field Testing Electric Submersible Pump Cable.~~^{5,6}

3. Definitions

[For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.](#)⁹

cable tensile strength: The strength of the cable is determined by the strength of the conductors. The other components of the cable can be eliminated as strength members. The cables are not designed to be used as a pulling device for components such as packers, seals, pumps, and motors.

NOTE—For additional discussion and calculations, refer to 11.1.

copper coating: Metal coatings such as lead or tin alloys are used on copper wires for many reasons. These reasons include annealing the copper during manufacture, preventing sulfur-cured compounds from bonding to the copper, mitigating copper corrosion from sulfur-bearing compounds, and inhibiting propylene from decomposition.

elongation: The ~~percent~~ change in length for a given length.

ethylene–propylene diene monomer (EPDM): Terpolymer of ethylene, propylene, and a diene with the residual unsaturated portion of the diene in the side chain.

⁸[ICEA publications are available from the Insulated Cable Engineers Association \(https://www.icea.org/\).](https://www.icea.org/)

⁹[IEEE Standards Dictionary Online](http://dictionary.ieee.org) is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

ethylene-propylene monomer (EPM): Comprises copolymers of ethylene and propylene.

ethylene-propylene rubber (EPR): Used as a generic term to define [ethylene-propylene monomer \(EPM\)](#) or [ethylene-propylene diene monomer \(EPDM\)](#) insulation.

hoop strength: ~~It is~~ A measure of the tangential resistance to radial expansion. As internal gas pressure pushes in a radial direction, it creates a tendency for the surface of the insulation and jacket to elongate and rupture in a tangential direction. The hoop strength resists this tendency and can be aided by additional wraps applied over the round components.

imbalance: [Voltage and current in three-phase system normally are equal but with slight changes in impedance in each phase; these can vary slightly from nominal values. Imbalance is the difference in voltage and current between the three phases of a cable system due to the impedance differences.](#)

~~compounds~~ **modulus (of a compound):** A relative measure of the force achieved at a given elongation of the material. It is normally recorded as a stress (megapascal or pound-force per square inch) at the given percent elongation. A lower modulus material has more of a tendency to give before breaking, that is, less resistance to expansion.

shunt admittance: The reciprocal of impedance, with the units “Siemens” (S).

NOTE—As used in this recommended practice, shunt admittance is a measure of leakage conductance to ground through the cable insulation.

tensile strength: The tensile stress required to break the item.

tensile stress: The elongating force exerted per unit area.

toughness factor: It is a measure of material performance under duress. It measures the ability of a material to withstand energy input over a unit of time. The toughness of a material equals one half the product of the material’s tensile strength and elongation ratings. For the same toughness factor, a more brittle material will have greater tensile strength and less elongation, whereas a more gummy material will have less tensile strength and more elongation.

transpositional splice: Splice where two of the thru conductors in a flat cable are swapped while the third conductor is left as-is. This can help alleviate imbalance in the cable impedance.

ultimate elongation: The ~~percent~~ change in length at rupture.

voltage stress: It may be thought of as the electrical pressure being applied to the insulation in an effort to burst through the material and short to ground. It could be thought of as analogous to water pressure in a pipe, where the higher the pressure, the harder it tries to burst through. For an electrical insulation material, the resistance to bursting through is known as the dielectric breakdown strength. It is usually expressed in terms of volts/millimeter (or volts/mil) required to puncture a sample of known thickness.

NOTE—For additional discussion and calculations, refer to 11.1.

4. Conductors

4.1 Material

Conductors should be annealed, coated or uncoated, copper in accordance with ASTM B3 for uncoated conductors, in accordance with ASTM B33 for tin-coated conductors, or in accordance with ASTM B189 for lead or lead-alloy coated conductors.

4.2 Construction

Conductors should be solid or concentric-stranded as shown in Table 1 and Table 2. Concentric-stranded conductors should conform to ASTM B8, or when compact round conductors are used, they should conform to ASTM B496, with diameters nominally 92% of corresponding noncompact conductors. When stranded products are used, the interstices should be filled for gas blockage.

Table 1—Conductor characteristics (metric units)

		Nominal weight	Nominal diameter of conductor (mm)			Conductor resistance (Ω/km @ 25 °C)	
Trade size	(mm ²)	(kg/km)	Solid	Stranded 7 wire	Compact wire	Plain copper	Coated copper ^a
10 mm ²	10	88.5	3.57	—	—	1.87	1.88
6 Awg	13.3	118	4.11	—	—	1.32	1.36
16 mm ²	16	140	4.51	—	—	1.17	1.18
4 Awg	21.1	188	5.19	—	—	0.83	0.856

(New)

Conductor	Conductor area	Nominal weight	Nominal diameter of conductor (mm)			Conductor resistance (Ω/km @ 25 °C)	
Trade size	(mm ²)	(kg/km)	Solid	Stranded 7 wire	Compact wire	Plain copper	Coated copper ^a
10 mm ²	10.0	88.5	3.57	—	—	1.87	1.88
6 Awg	13.3	118.0	4.11	—	—	1.32	1.36
16 mm ²	16.0	140.0	4.51	—	—	1.17	1.18
4 Awg	21.1	188.0	5.19	—	—	0.830	0.856
4 Awg	21.1	188.0	—	5.89	5.41	0.846	0.882
25 mm ²	25.0	222.0	5.64	—	—	0.742	0.749
2 Awg	33.6	306.0	6.54	—	—	0.522	0.538
2 Awg	33.6	306.0	—	7.42	6.81	0.531	0.554
1 Awg	42.4	386.0	7.35	—	—	0.413	0.426
1 Awg	42.4	386.0	—	8.33	7.57	0.423	0.440
1/0 Awg	53.5	475.0	—	9.35	8.56	0.335	0.348
2/0 Awg	67.4	599.0	—	10.52	—	0.266	0.276

(Deleted)

Table 1—Conductor characteristics (metric units) (continued)

		Nominal weight	Nominal diameter of conductor (mm)			Conductor resistance (Ω/km @ 25 °C)	
4 Awg	21.1	188	—	5.89	5.41	0.846	0.882
25 mm ²	25	222	5.64	—	—	0.742	0.749
2 Awg	33.6	306	6.54	—	—	0.522	0.538
2 Awg	33.6	306	—	7.42	6.81	0.531	0.554
1 Awg	42.4	386	7.35	—	—	0.413	0.426
1 Awg	42.4	386	—	8.33	7.57	0.423	0.44
1/0 Awg	53.5	475	—	9.35	8.56	0.335	0.348
2/0 Awg	67.4	599	—	10.52	—	0.266	0.276
3/0 Awg	85.0	771	—	11.79	—	0.207	0.215
4/0 Awg	107	972	—	13.26	—	0.164	0.170

(New)

^aCoated refers to tin, lead, or lead alloy.

Table 2—Conductor characteristics (inch-pound units)

		Nominal weight	Nominal diameter of conductor (in)			Conductor resistance (Ω/kft @ 77 °F)	
Trade size	(cmil)	(lb/kft)	Solid	Stranded 7 wire	Compact wire	Plain copper	Coated copper ^a
10 mm ²	19 644	59.7	0.14	—	—	0.569	0.572
6 Awg	26 240	79.4	0.162	—	—	0.403	0.414
16 mm ²	31 109	95.6	0.178	—	—	0.357	0.36
4 Awg	41 740	126	0.204	—	—	0.253	0.261
4 Awg	41 740	126	—	0.232	0.213	0.258	0.263
25 mm ²	49 305	149.2	0.222	—	—	0.226	0.228
2 Awg	66 360	206	0.258	—	—	0.159	0.164
2 Awg	66 360	206	—	0.292	0.268	0.162	0.174
1 Awg	83 690	260	0.289	—	—	0.126	0.13
1 Awg	83 690	260	—	0.328	0.298	0.129	0.134
1/0 Awg	105 600	319.2	—	0.368	0.337	0.102	0.106
2/0 Awg	133 100	402.7	—	0.414	—	0.081	0.084
3/0 Awg	167 800	518.1	—	0.464	—	0.063	0.065
4/0 Awg	211 600	653.1	—	0.522	—	0.050	0.052

(New)

Conductor	Conductor area	Nominal weight	Nominal diameter of conductor (in)			Conductor resistance (Ω/kft @ 77 °F)	
Trade size	(cmil)	(lb/kft)	Solid	Stranded 7 wire	Compact wire	Plain copper	Coated copper ^a
10 mm ²	19 644	59.7	0.140	—	—	0.569	0.572
6 Awg	26 240	79.4	0.162	—	—	0.403	0.414
16 mm ²	31 109	95.6	0.178	—	—	0.357	0.360
4 Awg	41 740	126.0	0.204	—	—	0.253	0.261
4 Awg	41 740	126.0	—	0.232	0.213	0.258	0.263
25 mm ²	49 305	149.2	0.222	—	—	0.226	0.228
2 Awg	66 360	206.0	0.258	—	—	0.159	0.164
2 Awg	66 360	206.0	—	0.292	0.268	0.162	0.174
1 Awg	83 690	260.0	0.289	—	—	0.126	0.130
1 Awg	83 690	260.0	—	0.328	0.298	0.129	0.134
1/0 Awg	105 600	319.2	—	0.368	0.337	0.102	0.106
2/0 Awg	133 100	402.7	—	0.414	—	0.081	0.084

(Deleted)

^aCoated refers to tin, lead, or lead alloy.

3.3 Conductivity

~~Table 1 and Table 2 represent the nominal conductor direct current resistance at 25 °C (77 °F). For single conductor and flat parallel lay cable, the resistance should not exceed 102% of the appropriate value in Table 1 or Table 2. For twisted assemblies of three cables, the resistance should not exceed 104% of the appropriate value in Table 1 or Table 2.~~

5. Insulation

5.1 Material

Insulation should be constructed of ethylene-propylene rubber that meets the properties shown in Table 3 when tested in accordance with applicable portions of ANSI/NEMA WC 71/ICEA S-96-659.

Table 3—Ethylene-propylene properties^{a7}

Physical requirements—unaged	
Tensile strength, minimum, MPa	6.2 (900 psi)
Elongation at rupture, minimum, percent	100

Table 3—Ethylene-propylene properties^a (continued)

Physical requirements—unaged	
Physical requirements—aged in air oven at 121 °C (250 °F) for 1 week	
Tensile strength, minimum, percent of unaged value	70
Elongation at rupture, minimum percent retention	70

~~⁷For special purpose compound designs (e.g. High Modulus compounds), deviations from the tabulated tensile and elongation minimum can be made, and should be as agreed upon between customer and supplier.~~

^{a8}For special-purpose compound designs (e.g., high modulus compounds), deviations from the tabulated tensile and elongation minimum can be made and should be as agreed upon between customer and supplier.

5.2 Gas blockage for stranded conductors

A 30_-cm (12_-in) specimen of insulated conductor removed from finished cable should be subjected to a 0.03- MPa (5_-psi) differential air pressure for a period of 1 h at 25 °C (77 °F). The sample ends should be cut off flush with a fine-toothed saw blade, and one end of the sample should have a short section of clear flexible plastic tubing slid over the insulation to enable the specimen to be pressurized. The tubing should be attached in place with a small hose clamp [minimum width of binding collar [equals](#) = 6.4 mm (0.250 in)]. The clamp should be tightened with minimum torque to prevent leakage. The opposite end of the sample should be left submerged in water. No air bubbles should be detected at the submerged end of the cable during the test period.

5.3 Construction

The insulation should be extruded on the conductor [with thicknesses as specified in 5.3.1 and 5.3.2.](#)

[5.3.1 Cable without metallic barrier](#)

~~4.3.1 Non lead sheath product~~

For 3_-kV rated cable, average insulation wall thickness should be 1.9 mm (0.075 in) or more. The insulation minimum wall thickness should not be less than 1.7 mm (0.068 in) at any point. For 5_-kV rated cable, the insulation average wall thickness should be 2.3 mm (0.090 in) or more. The insulation minimum wall thickness should not be less than 2.1 mm (0.081 in) at any point. [For 8 kV rated cable, the insulation average wall thickness should be 2.92 mm \(115 mil\). The insulation wall thickness should not be less than 2.63 mm \(0.104 in\) at any point.](#)

5.3.2 Cable with metallic barrier

~~4.3.2 Lead sheath product~~

For 5-kV rated cable, the insulation average wall thickness should be 1.9 mm (0.075 in) or more. The insulation minimum wall thickness should not be less than 1.7 mm (0.068 in) at any point. [For 8 kV rated systems, average wall thickness should be 2.29 mm \(90 mil\) or more. The insulation minimum wall thickness should not be less than 2.06 mm \(0.081 in\).](#) Considerations other than voltage stress impact the thickness of insulation.

6. Barrier (optional)

6.1 Material

At the option of the purchaser, each insulated conductor could have additional constraining coverings used for fluid protection and hoop strength. These additional coverings may be extruded fluoropolymers, wrapped tapes, or tape and woven braid.

6.2 Flat cable with lead sheath

[For flat cable with lead sheath](#), each insulated conductor should have a lead sheath extruded over the insulation. The average wall thickness should be 1.0 mm (0.040 in), with a minimum thickness of 0.8 mm (0.032 in).

6.3 Flat cable with metallic (nonlead) barrier

[For flat cable with metallic \(nonlead\) barrier](#), each insulated conductor should have a seam-welded metallic tubing applied over the insulation. The thickness of the metallic sheath may vary from 0.5 mm (0.029 in) to 2.5 mm (0.099 in), dependent on the metal used and the specific application requirements.