

IEEE Recommended Practice for Specifying Electric Submersible Pump Cable—Polypropylene Insulation

IEEE Industry Applications Society

Sponsored by the
Petroleum and Chemical Industry Committee



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IEEE Recommended Practice for Specifying Electric Submersible Pump Cable—Polypropylene Insulation

Sponsor

**Petroleum and Chemical Industry Committee
of the
IEEE Industry Applications Society**

Approved 6 March 2013

IEEE-SA Standards Board

Abstract: Minimum requirements for the design, construction, manufacturing, testing, purchasing, and application of electric submersible pump cable are presented. The cable is round or flat, with polypropylene rubber insulation, nitrile or polyethylene jacket, and armor. These cables are for voltages not exceeding 3 kV or 5 kV (phase to phase) and conductor temperatures not exceeding 96 °C (205 °F) maximum for nitrile or a maximum minimum of –10 °C (14 °F) minimum. Conductors, insulation, assembly and 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, ESP cable, field cable testing, IEEE 1019™, submersible pump cable, testing polypropylene

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Subrota Bairagi
Larry V. Dairymple
Michael Dowling

Marcus O. Durham
Nicole Fenyo
William McBride
David Modos

David H. Neuroth
Tim Waters
Alan Watt

The following members of the individual balloting committee voted on this recommended practice. Balloters may have voted for approval, disapproval, or abstention.

John Barker
David Burns
Paul Cardinal
Keith Chow
Cameron Chung
Glenn Davis
Wolfgang Dlugas
Gary Donner
Marcus O. Durham
Robert A. Durham

Randall Groves
Werner Hoelzl
Richard Hulett
Robert Konnik
Jim Kulchisky
Michael Lauxman
Greg Luri
Arturo Maldonado
John Mcalhaney, Jr.
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Michael S. Newman

Lorraine Padden
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K. James Phillips
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Robert Schuermann
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Patrick Gibbons
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Lisa Perry
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Introduction

This introduction is not part of IEEE Std 1019-2013, IEEE Recommended Practice for Specifying Electric Submersible Pump Cable—Polypropylene Insulation.

This recommended practice, under the jurisdiction of the Petroleum and Chemical Industry Committee of the IEEE Industry Applications Society, presents the minimum requirements for the construction, manufacturing, purchasing, and application of electric submersible pump cable. The configuration of the cable is either round or flat, with polypropylene insulation, with a nitrile jacket, and armor.

Anyone desiring to use this recommended practice may do so. It is presented as minimum criteria for construction 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 specification and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use; for any violation of any federal, state, or municipal regulation with which it may conflict; or for the infringement of any patent resulting from the use of this document.

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1. Overview

1.1 Scope

This recommended practice establishes requirements for three-conductor round-and-flat-type oil-well cable used in supplying three-phase ac electric power to submersible pump motors. The major cable components are copper conductors, polypropylene insulation, polymeric jacket, and galvanized [metallic](#) armor.

1.2 Specification and standards

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

Conductor operating temperatures for cables should not exceed 96 °C (205 °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 19](#)/NEMA [WC71, ICEA S-19-81/NEMA WC3](#), and ICEA S-61-402/NEMA WC5, where applicable.¹

1.3 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 economic impact of conductor size selection
- Start-up current and maximum voltage drop to assure motor starting
- Voltage rating to optimize cable and system run life

¹Information on references can be found in Clause 2.

- 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
- 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 off shore 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

Because there are so many considerations 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 particular cable offerings and its input can be invaluable in choosing the proper cable to maximize the value of cable investments. API 11 S3 and API RP 11S5 contain information regarding the installation and application of submersible pump cable.

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 ~~The purpose of this recommended practice is not to condone or disapprove~~ of such practice. However, but 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 field, such operation produces stresses through the insulation/jacket dielectric which shortens cable life. For safety considerations, cable used on the surface between the wellhead and the ventilated junction box should be buried or enclosed in appropriate raceway and is properly ~~that shortens cable life. ICEA S-61-402/NEMA WC-5 recommends a 173% insulation level for grounded phase operation, but this is often impractical for downhole oil well cable; therefore, this specifying standard recommends insulation thickness based on a normal three phase energized delta or wye system, with no phase grounded.~~

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). ~~recommended practice.~~ For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

[ANSMCEA S-96-659/NEMA WC71, Nonshielded Cables Rated 2001 - 5000 Volts.²](#)

API RP 11 S3, Recommended Practice for Electric Submersible Pump Installations³ ~~2nd ed~~².

API RP 11S4, Recommended Practice for Sizing and Selection of Electric Submersible Pump Installation, ~~3rd ed.~~

[API RP 11S5, Recommended Practice for Application of Electric Submersible Pump Cable Systems.](#)

API RP 11S6, Recommended Practice for Testing of Electric Submersible Pump Cable Systems, ~~1st ed.~~

ASTM A90, Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.⁴³

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 Purpose.

^{2 4} ICEA publications are available from ICEA, P.O. Box 20048, Minneapolis, MN 55420, USA (<http://www.icea.net/>).

^{3 2} API publications are available from the Publications Section, American Petroleum Institute, 1200 L Street NW, Washington, DC ~~20005~~, USA (<http://www.api.org/>).

⁴³ ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

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.

ASTMD412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension.

ICEA S-19-81/NEMA WC3, Rubber Insulated Wire and Cable ~~for the Transmission and Distribution of Electrical Energy~~⁴.

ICEAS-61-402/NEMAWC5, Thermoplastic-Insulated Wire and Cable ~~the Transmission and Distribution of Electrical Energy~~.

[IEEE Std 1017™, IEEE Recommended Practice for Field Testing Electric Submersible Pump Cable](#).^{5/6}

3. Conductors

3.1 Material

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

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3.2 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 non-compact conductors. When stranded products are used, the interstices should be filled for gas blockage.

Table 1—Conductor characteristics (metric units)

Conductor	Conductor area	Nominal weight	Nominal diameter of conductor (mm)			Conductor resistance (fi/km @ 25 °C)	
Trade size	(mm ²)	(kg/km)	Solid	Stranded 7 wire	Compact 7 wire	Plain copper	Coated ~~Tinned~~ 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 ~~48~~	—	—	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 ~~80~~	—	0.266	0.276

^a[Coated refers to tin, lead, or lead alloy](#)

Table 2— Conductor characteristics (inch-pound units)

Conductor	Conductor area	Nominal weight	Nominal diameter of conductor (in)			Conductor resistance (fi/kFt @ 77 °F)	
Trade size	(cmil)	(lb /kft)	Solid	Stranded 7 wire	Compact 7 wire	Plain copper	Coated ~~Tinned~~ 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~~ 169
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

^a[Coated 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](#) ~~not to exceed the values listed in.~~

4. Insulation

4.1 Material

Insulation should be a thermoplastic polypropylene meeting the properties shown in Table 3 when tested in accordance with ICEA S-61-402/NEMA WC5, Section 6, except that pull rate should be 5.08 cm/mm (2.0 in/min). The polypropylene should be copper stabilized.

Table 3—Polypropylene properties⁷

Physical requirements— unaged	
Tensile strength, minimum MPa	20.7 (3000 psi)
Elongation at rupture, minimum, percent	250
Physical requirements— aged in air oven at 121 °C (250 °F) for 1 week	
Tensile strength, minimum, percent of imaged value	75
Elongation at rupture, minimum, percent retention	75

4.2 Construction

The insulation should be extruded on the conductor. For 3-kV rated cable, average wall thickness should be 1.9 mm (0.075 in) or more, with a minimum wall thickness of 1.7 mm (0.068 in) at any point. For 5-kV rated cable, average wall thickness should be 2.3 mm (0.090 in) or more, with a minimum wall thickness of 2.1 mm (0.081 in) at any point.

⁷ 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.

4.3 Gas blockage [for stranded conductors](#)

A 30-cm (12-in) specimen of insulated conductor removed from finished cable should be subjected to a 0.035-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 = 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. Assembly and Jacket

5.1 Material

The typical jacket is an oil-resistant thermosetting nitrile rubber meeting the properties shown in Table 4 when tested in accordance with ASTM D412.

An alternative jacket material used in high water cut, low-temperature applications is polyethylene. Cables using thermoplastic polyethylene have an upper conductor temperature limit of 80 °C (176 °F).