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(Revision of  
IEEE Std 1018-1991)

IEEE Standards

# 1018™

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

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**IEEE Industry Applications Society**

Sponsored by the  
Petroleum and Chemical Industry Committee



3 Park Avenue, New York, NY 10016-5997, USA

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

Approved 1 February 2005

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Approved 23 September 2004

**IEEE-SA Standards Board**

**Abstract:** Minimum requirements for the construction, manufacturing, purchasing, and application of electric submersible pump cable are presented. The cable is round or flat, with ethylene–propylene rubber insulation, nitrile jacket, ethylene–propylene diene monomer (EPDM) jacket or lead sheath, and armor. These cables are for voltages not exceeding 3 kV or 5 kV (phase to phase) and conductor temperatures not exceeding 140 °C (284 °F) for nitrile or a maximum of 204 °C (400 °F) for EPDM jacket or lead sheath cable. Conductors, insulation, barrier (optional), assembly and jacket, armor, requirements for testing by the manufacturer, and cable ampacity are covered.

**Keywords:** ampacity ratings, assembly, cable construction, cable testing, field testing, submersible pump cable

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# Introduction

This introduction is not part of IEEE Std 1018-2004, IEEE Recommended Practice for Specifying Electric Submersible Pump Cable—Ethylene-Propylene Rubber 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 ethylene-propylene rubber insulation, with a nitrile jacket, EPDM jacket, or lead sheath 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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# IEEE Recommended Practice for Specifying Electric Submersible Pump Cable—Ethylene-Propylene Rubber Insulation

## 1. Scope

This recommended practice establishes requirements for three-conductor new round-and-flat-type oil-well cables used in supplying three-phase ac electric power to submersible pump motors. The three major cables by components are (1) cables with copper conductors, ethylene-propylene diene monomer (EPDM) insulation, nitrile jacket, and galvanized armor; (2) cables with copper conductors, EPDM insulation, EPDM jacket, and galvanized armor; and (3) cables with copper conductors, EPDM insulation, lead sheath, and galvanized armor. Cables meeting the requirements of the recommended practice should be rated for voltages not exceeding 3 kV or 5 kV (phase to phase).

Conductor temperatures for cables with nitrile jacket should not exceed 140 °C (284 °F). Use of nitrile jacketed cable above the rated temperature can cause premature hardening of the jacket, which therefore reduces the jacket life. Conductor temperatures for cables with EPDM jacket or lead sheath may be rated up to 204 °C (400 °F); for temperatures rated over 204 °C (400 °F), please consult cable suppliers. Voltage ratings are nominal phase-to-phase ratings.

Cable purchased under the recommendation of this recommended practice, unless otherwise specified herein, should meet the requirements of ASTM B3, ASTM B8, ASTM B33, ASTM B189, ASTM B496, and ICEA S-68-516/NEMA WC 8, where applicable.<sup>1</sup>

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. The purpose of this recommended practice is not to condone or disapprove of such practice, 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. ICEA S-68-516/NEMA WC 8 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.

<sup>1</sup>Information on references can be found in Clause 2.

## 2. Normative references

The following referenced documents are indispensable for the application of this recommended practice. For dated references, only the edition cited applies. For undated references, the latest edition of the reference document (including any amendments or corrigenda) applies.

API RP 11S3, Recommended Practice for Electric Submersible Pump Installations, 2nd ed.<sup>2</sup>

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, 1st ed.

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.<sup>3</sup>

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.

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.

ICEA S-68-516/NEMA WC 8, Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.<sup>4</sup>

IEEE Std 1017™, IEEE Recommended Practice for Field Testing Electric Submersible Pump Cable.<sup>5</sup>

## 3. Conductors

### 3.1 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.

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

<sup>3</sup>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/>).

<sup>4</sup>ICEA publications are available from ICEA, P.O. Box 20048, Minneapolis, MN 55420, USA (<http://www.icea.org/>).

<sup>5</sup>IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

### 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 noncompact 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 ( $\Omega/\text{km}$ @ 25 °C) |               |
|--------------------|----------------|----------------|------------------------------------|-----------------|----------------|----------------------------------------------------|---------------|
|                    |                |                | Solid                              | Stranded 7 wire | Compact 7 wire | Plain copper                                       | Tinned copper |
| 10 mm <sup>2</sup> | 10.0           | 88.5           | 3.57                               | —               | —              | 1.87                                               | 1.88          |
| 6 Awg              | 13.3           | 118.0          | 4.11                               | —               | —              | 1.32                                               | 1.36          |
| 16 mm <sup>2</sup> | 16.0           | 140.0          | 4.48                               | —               | —              | 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 <sup>2</sup> | 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          | —                                  | 10.80           | —              | 0.266                                              | 0.276         |

### 3.3 Conductivity

Conductors should have a direct current resistance at 25 °C (77 °F), not to exceed the values listed in Table 1 or Table 2.

## 4. Insulation

### 4.1 Material

Insulation should be constructed of ethylene-propylene rubber that meets the properties shown in Table 3 when tested in accordance with ICEA S-68-516/NEMA WC 8.

**Table 2—Conductor characteristics (inch-pound units)**

| Conductor          | Conductor area | Nominal weight | Nominal diameter of conductor (inches) |                 |                | Conductor resistance ( $\Omega/\text{kft}$ @ 77 °F) |               |
|--------------------|----------------|----------------|----------------------------------------|-----------------|----------------|-----------------------------------------------------|---------------|
| Trade size         | (cmil)         | (lb/kft)       | Solid                                  | Stranded 7 wire | Compact 7 wire | Plain copper                                        | Tinned copper |
| 10 mm <sup>2</sup> | 19 644         | 59.7           | 0.140                                  | —               | —              | 0.569                                               | 0.572         |
| 6 Awg              | 26 240         | 79.4           | 0.162                                  | —               | —              | 0.403                                               | 0.414         |
| 16 mm <sup>2</sup> | 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 <sup>2</sup> | 49 305         | 149.2          | 0.222                                  | —               | —              | 0.226                                               | 0.228         |
| 2 Awg              | 66 360         | 206.0          | 0.258                                  | —               | —              | 0.159                                               | 0.169         |
| 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         |

**Table 3—Ethylene-propylene properties**

|                                                    |               |
|----------------------------------------------------|---------------|
| <b>Physical requirements—unaged</b>                |               |
| Tensile strength, minimum, MPa                     | 6.2 (900 psi) |
| Elongation at rupture, minimum, percent            | 100           |
| <b>Physical requirements—aged in air</b>           |               |
| <b>Oven at 121 °C (250 °F) for 1 week</b>          |               |
| Tensile strength, minimum, percent of unaged value | 70            |
| Elongation at rupture, minimum, percent retention  | 70            |

## 4.2 Gas blockage

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 hour 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.