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.

Designation: D8436 – 23

Standard Specification for Fluoropolymer-based Materials for Use for Encapsulation of Downhole Cable[1]

This standard is issued under the fixed designation D8436; 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 thermoplastic fluoropolymer-based materials, intended for use as an encapsulation material for downhole cables used during well completion by the petroleum and natural gas industries.

1.1.1 The fluoropolymer-based materials to be used for this purpose shall be virgin materials and shall be permitted to contain up to 25 %, by weight, of reprocessed material (re-grind) of the same fluoropolymer generic material type. When reprocessed material is included, it shall be thoroughly mixed with virgin material.

1.2 The fluoropolymers covered by this specification include but are not limited to the following: ethylene tetrafluoroethylene (ETFE), polyethylene chlorotetrafluoroethylene (ECTFE), fluorinated ethylene propylene (FEP), polyvinylidene fluoride (PVDF), copolymers of PVDF, polychlorotrifluoroethylene (PCTFE), polytetrafluoroethylene (PTFE), and perfluoroalkoxy alkane (PFA).

1.3 This specification establishes common temperature ratings for the encapsulation materials and also describes requirements for alternative temperature ratings.

1.4 The applications for the encapsulation materials covered by this specification are all associated with downhole cables used during well completion. Such applications include, but are not limited to, the following: control lines (CL), tubing encased conductors (TEC), tubing encased fiber cables (TEF), and tubing encased power cables (TEPC). Other downhole cable products such as surface-controlled sub-surface safety valves (SCSSV or SSSV) and chemical injection lines/chemical injection tubes (CIL/CIT) are also covered by this specification.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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]

D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents

D618 Practice for Conditioning Plastics for Testing

D638 Test Method for Tensile Properties of Plastics

D883 Terminology Relating to Plastics

D975 Specification for Diesel Fuel

D1708 Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens

D1711 Terminology Relating to Electrical Insulation

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

D2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)

D3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry

D3801 Test Method for Measuring the Comparative Burning Characteristics of Solid Plastics in a Vertical Position

D4591 Test Method for Determining Temperatures and Heats of Transitions of Fluoropolymers by Differential Scanning Calorimetry

D6751 Specification for Biodiesel Fuel Blendstock (B100) for Middle Distillate Fuels

[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.

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D7869 Practice for Xenon Arc Exposure Test with Enhanced Light and Water Exposure for Transportation Coatings
E176 Terminology of Fire Standards

2.2 *UL Standards:*[3]
UL 94 Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
UL 746B Standard for Polymeric Materials—Long Term Property Evaluations
UL 1581 Reference Standard for Electrical Wires, Cables, and Flexible Cords
UL 2556 Standard Wire and Cable Test Methods

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification associated with electrical and electronic insulating materials, refer to Terminology D1711. For definitions of terms used in this specification associated with plastic materials, refer to Terminology D883. For definitions of terms used in this specification associated with fire issues, refer to Terminology E176.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *encapsulation material*—protective insulation layer used to encapsulate and protect the internal components of a downhole cable.

3.2.1.1 *Discussion*—The encapsulation material layer also provides additional functions, such as component alignment and orientation, which serves to facilitate fastening to the production casing and to improve installation and management. The encapsulation material layer also aids, when needed, for future recovery of the downhole cable.

3.2.2 *internal components*—components residing within tubes contained inside the downhole cable enclosure; they are often cables providing power or communication functions.

3.2.3 *oxygen index (OI)*—the minimum concentration of oxygen, expressed as volume percent, in a mixture of oxygen and nitrogen that will just support flaming combustion of a material initially at 23 °C ± 2 °C under the conditions of this test method. **(Test Method D2863)**

3.2.4 *reprocessed material*—scrap or waste plastic material obtained following a manufacturing process.

3.2.4.1 *Discussion*—Reprocessed material can be post-industrial recycled material (PIR) or post-consumer recycled material (PCR), obtained directly from scrap produced during the manufacturing process or sourced from a plastics recycling facility.

4. Significance and Use

4.1 The materials covered by this specification are fluoropolymer-based materials intended to be used as encapsulation materials for downhole cables.

4.1.1 The fluoropolymer encapsulation materials in this specification are intended to be used for the encapsulants but not for the wires or cables contained within the encapsulants. Fig. 1 provides an illustration of the use of the materials covered by this specification.

4.1.2 The fluoropolymer-based materials to be used for this purpose shall be virgin materials and shall be permitted to contain up to 25 % by weight of reprocessed material (regrind) of the same fluoropolymer type. When reprocessed material is included, it shall be thoroughly mixed with virgin material.

4.1.3 The source of the reprocessed fluoropolymer-based material shall be either postindustrial recycled material or post-consumer recycled material.

4.2 Downhole cables are cables used during the process of injecting chemicals into a well stream in order to assist in the production of oil or gas. This is accomplished using a system of pumps, flat-packs, and valves.

4.3 Cables installed in oil or gas wells are exposed to severe mechanical and chemical conditions. Cable damage during run-in and subsequent completion processes such as hydraulic fracturing can lead to premature cable failures.

4.4 Encapsulation is the provision of a protective insulative layer that surrounds and protects the internal components of a downhole cable. In addition, encapsulation provides additional functions, which can include, but are not limited to, alignment and orientation of components, so as to facilitate fastening to the production casing. Encapsulation can also potentially improve management of the production casing as well as installation, and, when needed, future recovery.

4.5 Production casing is a large diameter pipe assembled and inserted into a recently drilled section of a borehole.

4.6 Flatpacks are assemblies of small diameter metal tubes and other components held together by an encapsulation material layer. Components of the assemblies include, but are not limited to, various types of cables, as described in Annex A1. The various components of a flatpack are normally oriented in a parallel fashion, and the encapsulation material is applied to the outer layer, typically a rectangular cable.

4.7 The specific applications of the encapsulation materials covered by this specification are described in Annex A1.

4.8 This is a specification for electrical insulating materials intended for specific applications as encapsulation materials. Processing of any material into a product, including those covered by this specification, is likely to have a significant effect on performance. Thus, additional requirements above those outlined in this specification will be potentially needed for individual applications.

5. Properties of Encapsulation Materials

5.1 The encapsulation material shall consist of a fluoropolymer-based material.

5.2 The fluoropolymer-based material shall comply with encapsulation material property requirements in Section 7. Tests shall be performed with the encapsulation material as shown below:

5.2.1 Test the unaged encapsulation material for melting point, tensile strength at break, tensile elongation at break, and flammability (7.1).

[3] Available from Underwriters Laboratories (UL), UL Headquarters, 333 Pfingsten Road, Northbrook, IL, 60062, http://www.ul.com.

iTeh Standards (https://standards.iteh.ai) Document Preview
ASTM D8436-23

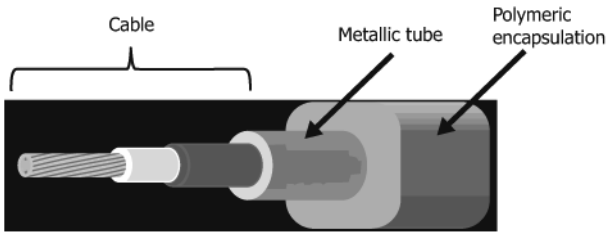

FIG. 1 Example of Application of Encapsulation Materials Covered by this Specification

5.2.2 Test the encapsulation material for retention of tensile properties and weight gain after aging in a diesel fuel, namely B20 diesel fuel (7.2).

5.2.3 Test the encapsulation material for retention of tensile properties and weight gain after aging in an aromatic fuel blend comprised of Fuel C (7.3).

5.2.4 Test the encapsulation material for retention of tensile properties after aging in an acid, namely 90 % sulfuric acid (7.4).

5.2.5 Test the encapsulation material for retention of tensile properties and for no visible changes after weathering with a xenon arc (7.5).

5.2.6 Test the encapsulation material after heat exposure for establishing a temperature rating (7.6).

5.3 Prior to conducting any of the tests required in this specification, the test specimens shall be annealed. The standard annealing conditions to be used is a temperature of 90 °C ± 2 °C (194 °F ± 3.6 °F) for a period of 2 h unless noted otherwise.

5.4 All aging tests involving fuels or combustible chemicals shall be conducted in an explosion-proof oven capable of temperature control with a range of ±2 °C of the specified test temperature.

5.5 The test specimens shall be conditioned under a standard laboratory atmosphere, at a temperature of 23 °C ± 2 °C (73.4 °F ± 3.6 °F) and a relative humidity of 50 % ± 10 % for not less than 40 h prior to any property test required in Section 7, in accordance with Procedure A of Practice D618.

6. Determination of Tensile Properties

6.1 Tensile properties shall be determined as described in 6.2 through 6.4.

6.2 Tensile properties of PVDF, copolymers of PVDF and PCTFE materials shall be determined by using Type I or Type II tensile bars as described in Practice D638.

6.3 Tensile properties of ETFE, ECTFE, FEP, PTFE, and PFA materials shall be determined by using microtensile bars from Test Method D1708. The reason for using Test Method D1708 is that it has been shown that the use of Type I and Type II tensile bars as described in Practice D638 is inappropriate for those materials as Practice D638 test bars give inaccurate results due to slippage and deformation.

6.4 If no specific information is available for a particular fluoropolymer material, Practice D638 shall be used.

7. Specification Property Requirements

7.1 *Unaged Encapsulation Material*—Property requirements of the unaged encapsulation material are shown in Table 1. The tests shall be performed on test specimens annealed in accordance with 5.3, followed by conditioning in accordance with 5.5. Tensile properties shall be determined in accordance with Section 6. The encapsulation material shall meet all the requirements described in Table 1.

7.1.1 Test Method D4591 is a test method for assessing melting points of fluoropolymers by differential scanning calorimetry. However, Test Method D4591 states that, in general, Test Method D3418 shall be used for assessing such melting points, whenever possible. There are instances, however, when following Test Method D3418 will not give the desired results, will not provide information needed for proper interpretation of the resultant thermal curve, or will require more time for the analysis than be spent for results having suitable precision, in which case the use of Test Method D4591 is necessary.

7.2 *Diesel Fuel Aged Encapsulation Material*—Property requirements after aging in diesel fuel are shown in Table 2. The diesel fuel to be used shall be B20 diesel fuel, composed of 20 % biodiesel, in accordance with Specification D6751, and diesel Grade No. 1, in accordance with Specification D975. The tests shall be performed on test specimens annealed in accordance with 5.3, followed by conditioning in accordance with 5.5. Tensile properties shall be determined in accordance with Section 6. The encapsulation materials shall be exposed to the diesel fuel unstressed (see Practice D543) for a period of 14 days at a temperature of 70 °C ± 2 °C (158 °F ± 3.6 °F). The encapsulation material shall meet all the requirements described in Table 2.

TABLE 1 Material Property Requirements for Downhole Encapsulation Materials

Unaged Requirements		Standard
Melting point, second heat, min, ºC (ºF)	125 (257)	Test Method D4591
Tensile strength at break, min, MPa (psi)	13.8 (2000)	Test Methods D638, or Test Method D1708
Elongation at rupture, min, %	30	Test Methods D638, or Test Method D1708
Flammability @ thickness of 3 mm (⅛ in.)	V-0	Test Method D3801, or UL 94
Oxygen Index (OI), min @ thickness of 3 mm (⅛ in.)	30	Test Method D2863

TABLE 2 Retention of Properties for Downhole Encapsulation Materials Aged in Diesel Fuel

Diesel-fuel Aged Requirements		Standard
Tensile strength at break, retention	At least 85 % of unaged value	Test Methods D638, or Test Method D1708, and Practice D543 (Practice A, Procedure II)
Elongation at rupture, retention	At least 85 % of unaged value	Test Methods D638, or Test Method D1708, and Practice D543 (Practice A, Procedure II)
Weight gain (maximum)	5 % of unaged value	Practice D543 (Practice A, Procedure I)

7.3 *Aromatic Fuel Aged Encapsulation Material*—Property requirements after aging in an aromatic fuel blend are shown in Table 3. The fuel to be used shall be Fuel C, comprised of 50 % isooctane and 50 % toluene, in accordance with Practice D543. The tests shall be performed on test specimens annealed in accordance with 5.3, followed by conditioning in accordance with 5.5. Tensile properties shall be determined in accordance with Section 6. The materials shall be exposed to the aromatic fuel blend unstressed (see Practice D543) for a period of 14 days at a temperature of 70 °C ± 2 °C (158 °F ± 3.6 °F). The encapsulation material shall meet all the requirements described in Table 3.

7.4 *Sulfuric Acid Aged Encapsulation Material*—Property requirements after aging in sulfuric acid are shown in Table 4. The sulfuric acid shall be 90 % sulfuric acid. The tests shall be performed on test specimens annealed in accordance with 5.3, followed by conditioning in accordance with 5.5. Tensile properties shall be determined in accordance with Section 6. The encapsulation materials shall be exposed to the acid unstressed (see Practice D543) for a period of 14 days at a temperature of 70 °C ± 2 °C (158 °F ± 3.6 °F). The encapsulation material shall meet all the requirements described in Table 4.

7.5 *Weathering*—Property requirements after weathering are shown in Table 5. The tests shall involve exposure to a xenon arc in accordance with Practice D7869, for 80 cycles, at 24 h per cycle. The tests shall be performed on test specimens annealed in accordance with 5.3, followed by conditioning in accordance with 5.5. Tensile properties shall be determined in accordance with Section 6. The encapsulation material shall meet all the requirements described in Table 5.

7.6 *Thermal Aging to Establish Temperature Ratings:*

7.6.1 *Aging to Establish Temperature Ratings*—The test specimens shall be annealed for 2 h at the required aging temperature, which shall be 15 °C (27 °F) above the desired temperature rating (T_r, in °C). The test specimens shall be conditioned in accordance with 5.5. The test specimens shall be aged by being held at the same aging temperature for 60 days. After thermal aging, the material shall be tested for tensile strength and elongation at break, in accordance with Section 6, and it shall retain at least 70 % of the unaged values for both properties. Encapsulation materials meeting these requirements shall be considered to have achieved a T_r temperature rating.

7.6.2 *Alternative Requirement for Temperature Ratings*—Eq 1, contained in UL 1581 and in UL 2556, establishes a recommended temperature for aging (rounded to the nearest whole number). In Eq 1, T_c is the conditioning temperature (in °C) and T_r is the desired temperature rating for the encapsulation material (also in °C).

$$T_c = 1.02(T_r + 273) - 273 \quad (1)$$

Thus, as an alternative to the procedure in 7.6.1, the test specimens shall be annealed for 2 h at the required aging temperature T_c in accordance with Eq 1 and conditioned in accordance with 5.5. The test specimens shall be aged by being held at the same temperature T_c for 150 days. After thermal aging, the encapsulation material shall be tested for tensile strength and elongation at break, in accordance with Section 6, and it shall retain at least 70 % of the unaged values for both properties. Encapsulating materials meeting these requirements shall be considered to have achieved a T_r rating.

7.6.3 *Requirements for a 105 °C (221 °F) Temperature Rating*—The annealing and aging temperature shall be 120 °C ± 2 °C (248 °F ± 3.6 °F), when aged for 60 days. Alternatively, the annealing and aging temperature shall be 113 °C ± 2 °C (235.4 °F ± 3.6 °F), when aged for 150 days.

7.6.4 *Requirements for a 125 °C (257 °F) Temperature Rating*—The annealing and aging temperature shall be 140 °C ± 2 °C (284 °F ± 3.6 °F), when aged for 60 days. Alternatively, the annealing and aging temperature shall be 133 °C ± 2 °C (271.4 °F ± 3.6 °F), when aged for 150 days.

7.6.5 *Requirements for a 150 °C (302 °F) Temperature Rating*—The annealing and aging temperature shall be 165 °C ± 2 °C (329 °F ± 3.6 °F), when aged for 60 days. Alternatively, the annealing and aging temperature shall be 158.5 °C ± 2 °C (317.3 °F ± 3.6 °F), when aged for 150 days.

7.6.6 *Relative Thermal Index*—Encapsulation materials having a relative thermal index (RTI) of T_r or more, when tested in accordance with UL 746B, shall meet the intent of this

TABLE 3 Retention of Properties for Downhole Encapsulation Materials Aged in Fuel C

Aromatic Fuel Blend Aged Requirements		Standard
Tensile strength at break, retention	At least 85 % of unaged value	Test Methods D638, or Test Method D1708, and Practice D543 (Practice A, Procedure II)
Elongation at rupture, retention	At least 85 % of unaged value	Test Methods D638, or Test Method D1708, and Practice D543 (Practice A, Procedure II)
Weight gain (maximum)	5 % of unaged value	Practice D543 (Practice A, Procedure I)