

IEEE Guide for Fire Hazard Assessment of Electrical Insulating Materials in Electrical Power Systems

Sponsor

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IEEE Dielectrics and Electrical Insulation Society**

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Abstract: Fire hazards from electrical distribution and utilization systems installed in industrial, residential, and public buildings/areas are covered. A method for practical fire hazard assessment for electrical equipment containing insulating materials, based on relevant fire or failure scenarios drawn from service experience and engineering analysis, is established. The relationship between small-scale material tests and large-scale fire hazard tests is discussed. Written for the electrical engineer responsible for the safety of electrical systems and equipment, this guide provides guidelines for design of insulation systems and selection of insulating materials and aids in the use of codes, regulations, standards, product listings, and testing to improve safety.

Keywords: combustion, corrosive combustion products, critical heat flux, electrical systems, fire hazard, fire point, fire propagation, flammable, flash point, heat release rate, insulating materials, National Electric Code (NEC), pyrolysis, risk assessment, smoke, toxic combustion products

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Introduction

(This introduction is not a part of IEEE Std 1221-1993, IEEE Guide for Fire Hazard Assessment of Electrical Insulating Materials in Electrical Power Systems.)

This guide was prepared by the Dielectrics and Electrical Insulation Society (DEIS) Technical Committee S-32-12: Fire Hazard Assessment Technical Committee.

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A first draft of this document was discussed during the inaugural meeting of this technical committee held in Los Angeles on May 18, 1988.

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IEEE Guide for Fire Hazard Assessment of Electrical Insulating Materials in Electrical Power Systems

1. Overview

This guide covers fire hazards from electrical distribution and utilization systems installed in industrial, residential, and public buildings/areas. This guide also describes how a practical fire hazard assessment can be established for electrical equipment containing insulating materials. The hazard assessment should be based on relevant fire or failure scenarios based on service experience and engineering analysis. The relationship between small-scale material tests and large-scale fire hazard tests is discussed.

This guide is written for the electrical engineer responsible for the safety of electrical systems and equipment. It provides guidelines for the design of insulation systems and the selection of insulating materials. This guide aids the engineer in the use of codes, regulations, standards, product listings, and testing to improve safety.

The key fire hazard parameters are as follows:

- a) Ease of ignition
- b) Flame propagation (spread)
- c) Heat release rate
- d) Light obscuration (smoke production rate)
- e) Corrosive combustion products
- f) Toxic combustion products

2. References

This guide shall be used in conjunction with the following standards. When the following standards are superseded by an approved revision, the revision shall apply.

ANSI/NFPA 70-1993, National Electrical Code.¹

ANSI/NFPA 263-1986, Heat and Visible Smoke Release Rates for Materials and Products.

This document specifies a testing method for the determination of release rates of heat and visible smoke from materials and products when exposed to different levels of radiant heat.

ASTM E176-91d, Terminology Relating to Fire Standards.²

¹ANSI/NFPA publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA, and also from Publications Sales, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA.

²ASTM publications are available from the Customer Service Department, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA.

ASTM E535-92, Practice for Preparation of Fire Test Standards.

ASTM E662-92, Test Method for Specific Optical Density of Smoke Generated by Solid Materials.

ASTM E906-83, Test Method for Heat and Visible Smoke Release Rates for Materials and Products.

IEC Guide 104 (1984), Guide to the drafting of safety standards, and the role of Committees with safety pilot functions and safety group functions, 2d ed., and Amendment No. 1 (1989).³

IEC 695-1-1 (1982), Fire hazard testing—Part 1: Guidance for the preparation of requirements and test specifications for assessing fire hazard of electrotechnical products—General guidance, 1st ed.

IEEE Std 383-1974 (Reaff 1992), IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations (ANSI).⁴

ISO 3261-1975, Fire tests—Vocabulary.⁵

NOTE: Additional relevant national and international standards are listed in the bibliography in clause 5.

3. Definitions

3.1 Risk assessment

3.1.1 hazard: An intrinsic property or condition that has the potential to cause harm or damage.

3.1.2 risk: The combination of the probability of an abnormal event or failure and the consequence(s) of that event or failure to a system's components, operators, users, or environment.

3.1.3 risk analysis: A procedure to develop probability estimates of occurrence of each specific **hazard**.

3.1.4 risk assessment: The process and procedures of identifying, characterizing, quantifying, and evaluating **risks** and their significance.

3.2 Fire hazards

Listings of standard terms can be found in ASTM E176-91d⁶ and ISO 3261-1975.

3.2.1 active fire protection: The minimizing of **fire hazards** in electrical systems by the use of fuses, circuit breakers, and other devices.

3.2.2 approved (NEC): Acceptable to the authority having jurisdiction.

3.2.3 auto ignition: Ignition without a pilot source.

3.2.4 combustible: Capable of undergoing **combustion** in air, at pressures and temperatures that might occur during a fire in a building, or in a more severe environment when specified.

³IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁴IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁵ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse. ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁶Information on references can be found in clause 2.

3.2.5 combustion: A chemical process of oxidation that occurs at a rate fast enough to produce heat and usually light, either as a glow or flame.

3.2.6 conductive heat release: The energy released from a burning material to whatever is in direct contact with it.

3.2.7 convective heat release: The heat contained in the hot gases produced in a fire.

3.2.8 corrosion: A process of gradual weakening or destruction, usually by a chemical action.

3.2.9 critical heat flux: The **heat flux** below which ignition is not possible.

3.2.10 endothermic: Characterized by or formed with the absorption of heat.

3.2.11 exothermic: Characterized by or formed with the release of heat.

3.2.12 fire endurance: A measure of the elapsed time during which a material or assembly continues to exhibit **fire resistance** under specified conditions of test and performance.

3.2.13 fire exposure: The **heat flux** of a fire, with or without direct flame impingement, to which a material, product, building element, or assembly is exposed.

3.2.14 fire gases: The airborne products emitted by a material undergoing **pyrolysis** or **combustion** that at the relevant temperature exist in the gas phase.

3.2.15 fire hazard: A fire **risk** greater than an acceptable level.

3.2.16 fire performance characteristic: A response of a material, product, or assembly to a prescribed source of heat or flame under controlled fire conditions. Such characteristics include ease of ignition, flame spread, **smoke** generation, **fire endurance** of the material, corrosiveness, and toxicity of the smoke generated.

3.2.17 fire performance test: A procedure that measures a response of a material, product, or assembly to heat or flame under controlled fire conditions.

3.2.18 fire point: The lowest temperature at which a specimen will sustain burning for five seconds (see 4.2.3.1).

3.2.19 fire products: Heat, **smoke**, and toxic and corrosive products.

3.2.20 fire propagation: The movement of a flame front on the surface of materials and products beyond the ignition zone.

3.2.21 fire resistance: The property of a material or assembly to withstand fire or give protection from it. As applied to elements of buildings, it is characterized by the ability to confine a fire or to continue to perform a given structural function, or both.

3.2.22 flame spread index: A number or classification indicating a comparative measure derived from observations made during the progress of the boundary of a zone of flame under defined test conditions.

3.2.23 flammable: Subject to easy ignition and rapid flaming **combustion**.

3.2.24 flashover: The transition from a localized fire to the general conflagration within the compartment when all fuel surfaces are burning.

3.2.25 flash point: The lowest temperature of a sample at which application of an ignition source causes the vapor of the sample to ignite momentarily under specified conditions of test.

- 3.2.26 heat capacity:** The heat required to raise the temperature of a unit mass of material by one degree.
- 3.2.27 heat flux:** The flow of heat per unit area; i.e., thermal energy incident upon a surface area per unit time [kW/m^2 ($\text{kJ/m}^2/\text{s}$)].
- 3.2.28 heat of combustion:** The thermal energy (chemical, convective, and radiative) per unit mass, i.e., MJ/kg (BTU/lb), released during burning.
- 3.2.29 heat of gasification:** The heat required to convert a unit mass of material to a vapor.
- 3.2.30 heat release rate:** The rate of energy release associated with the **combustion** of a material, i.e., kW/m^2 ($\text{kJ/m}^2/\text{s}$).
- 3.2.31 identified (NEC):** Recognized as suitable for a specific service, purpose, function, use, environment, application, etc.
- 3.2.32 ignition temperature:** The lowest temperature at which sustained **combustion** of a material can be initiated under specified conditions.
- 3.2.33 labeled (NEC):** Conductors, equipment, or materials that meet appropriate standards or that have been tested and found suitable for use in a specified manner.
- 3.2.34 listed (NEC):** See **labeled (NEC)**.
- 3.2.35 mass burning rate:** Mass loss per unit time by materials burning under specified conditions.
- 3.2.36 nonthermal fire hazard:** A **hazard** resulting from **combustion** products (such as **smoke** and toxic and corrosive **fire products**).
- 3.2.37 optical density of smoke:** A measure of the attenuation of a light beam passing through **smoke**, expressed as the common logarithm of the ratio of the incident flux, I_0 , to the transmitted flux, I [$D = \log_{10} (I_0/I)$].
- 3.2.38 passive fire protection:** The selection of materials that resist ignition and **fire propagation**, and produce low levels of **fire products**.
- 3.2.39 piloted ignition:** Initiation of **combustion** as a result of contact of a material or its vapors with an energy source such as a flame, spark, electrical arc, or glowing wire.
- 3.2.40 pyrolysis:** Irreversible chemical decomposition caused by heat, usually without oxidation.
- 3.2.41 radiative heat release:** The heat radiating from flames.
- 3.2.42 self-heating:** The result of **exothermic** reactions, occurring in some materials under certain conditions, whereby heat is liberated at a rate sufficient to raise the temperature of the material.
- 3.2.43 self-ignition:** Ignition resulting from **self-heating**.
- 3.2.44 smoke:** The airborne solid and liquid particulates and gases evolved when a material undergoes **pyrolysis** or **combustion**.
- 3.2.45 surface flame spread:** The propagation of a flame away from the source of ignition across the surface of a liquid or a solid.
- 3.2.46 thermal fire hazard:** A **hazard** resulting from the generation of heat in a fire.

4. Assessment of hazards associated with fires involving electrical systems

4.1 General

Recently, considerable efforts have been directed toward making laboratory-scale tests more predictive of large-scale phenomena.

Traditionally, the fire hazard assessment of insulating materials was based on standard and nonstandard tests evaluating the ignitability of a sample under specified conditions. The fire-behavior of materials in a full-scale fire, however, is not usually predicted by traditional small-scale tests.

Most valid fire hazard tests are those that evaluate the fire hazard of a system or a product under conditions closely simulating the potential fire-failure mode and fire condition in the equipment installation. The relationship between material test data and the fire risk of an installation should be established through initial large-scale testing.

Performance of products in a real fire is affected by a combination of factors. Some of these are controlled by the environment (e.g., the size of the room, the ventilation conditions, and the type of construction). Other controlling factors are the circumstances under which the products are used (e.g., their orientation and the amount present) and the product's flammability behavior (e.g., ease of ignition; heat release rate; flame-spread rate; and rate of generation of smoke, and toxic and corrosive products under different fire conditions).

In order to design electrotechnical products with acceptable characteristics for minimizing fire hazard, careful attention should be paid to the permissible mechanical, electrical, and thermal stresses. This minimizes the possibility of fire hazard under conditions of normal use, foreseeable abnormal use, and faulty operational conditions. The desired fire safety normally can be achieved by employing one or more of the following safeguards:

- Parts and/or circuit-design and protection that, under overload or failure, are not likely to ignite or to cause ignition
- Materials, including enclosures, that are sufficiently resistant to probable ignition sources and heat within an electrotechnical product
- Designs that adequately restrict the propagation of fire and spread of flame (e.g., fire walls and fire stops)
- Early warning and egress planning in conjunction with automatic extinguishing systems so that personnel are able to exit in a swift, orderly manner
- Appropriate enclosures to protect sensitive equipment
- Automatic extinguishing systems in conjunction with air handling systems to capture and move the products of combustion away from personnel and sensitive equipment

Hazard assessment proceeds as follows:

- a) Establish major hazard scenarios for specific equipment and systems from failure reports, statistics, and experience.
- b) Define major fire hazard scenarios of electrical systems and establish a model of fire development for full-scale tests.
- c) Subject individual components of a system to a set of small-scale test methods conducted at heat flux and temperature conditions expected in a real fire situation.
- d) Identify the criteria of procedures, such as models, to evaluate the fire hazard.