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

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

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Fire Hazard Assessment Technical Committee
of the
IEEE Dielectrics and Electrical Insulation Society

Approved September 15, 1993

IEEE Standards Board

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.

The work was sponsored by the IEEE Dielectrics and Electrical Insulation Society S-32, with ongoing coordination with IEEE SCC-18 (NFPA Standards).

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

At the time this guide was completed, the Dielectrics and Electrical Insulation Society (DEIS) Fire Hazard Assessment Technical Committee Working Group had the following membership:

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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]

[1]ANSI/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.

[2]ASTM 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 E176-91d[6] 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.

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[3]IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembé, 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.

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

[5]ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembé, 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.

[6]Information 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 ($kJ/m^2/s$)].

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 ($kJ/m^2/s$).

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.

The large-scale fire hazard evaluations can be conducted by professional fire test engineers and nationally recognized test laboratories.

4.2 Hazards from insulating materials in electrical systems

Fire hazards in electrical systems are minimized by the use of fuses, circuit breakers, and other devices. Guidelines for specific equipment such as transformers and motors are defined in standards and codes such as ANSI/NFPA 70-1993, National Electrical Code (NEC). However, experience has shown that fires cannot totally be eliminated by such "active protection" because unforeseen events occur (e.g., those that are caused by human error, malfunction of circuit protection, or other failures).

It is therefore desirable to use "passive fire protection," i.e., selection of materials that resist ignition and fire propagation and evolve low levels of fire products.

The fire hazard assessment of individual materials and combinations of materials requires testing over a range of fire or heat flux conditions that can be related to the fire scenarios discussed above.

4.2.1 Fire conditions

In large-scale fires, flames are turbulent, and heat flux from the flame, received by the material, is predominately radiative. In small-scale fires, flames are laminar, and heat flux from the flame, received by the material, is predominately convective. The major differences between small- and large-scale fires are due to the following:

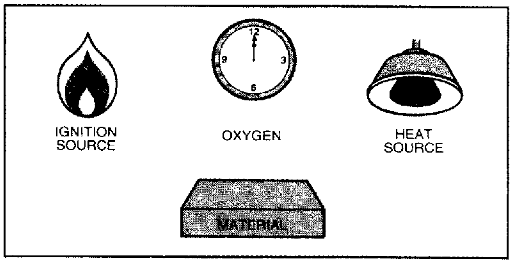
a) Heat flux differences, radiative vs. convective.
b) Presence of external heat sources, such as hot walls, ceilings, and other burning objects. In large-scale fires, the external heat flux can be very significant because the heat source surfaces are extended. In small-scale fires, the external heat flux is either absent or small because the heat source surfaces are small.
c) Mixing of the material vapors and fire products with air. In large-scale fires, which are turbulent, the material vapors, fire products, and air are reasonably well mixed compared to the small-scale fires, which are laminar.
d) Fire ventilation. Small- and large-scale fires can be well- or under-ventilated. Most fires start out well ventilated because ample oxygen is usually available. A fire may become underventilated later in its growth period. The behavior of well-ventilated fires is very different from that of under-ventilated fires.

In the end-use applications, the size of dielectrics and insulation materials and products can be very small, such as small electronic components, or be very large, such as grouped electrical cables. Thus, depending on applications, the dielectrics and insulation materials may be involved in small- and large-scale fires. Therefore, many methods have been developed for the fire behavior assessment of such materials.

Before one selects test methods for specific systems and applications, it is important to gain a fundamental understanding of what happens when materials burn.

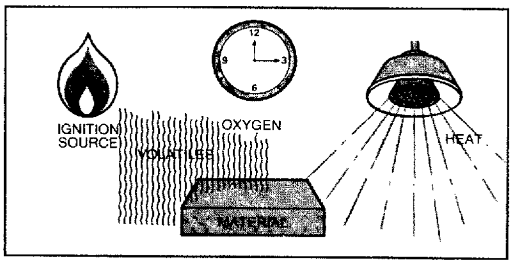
4.2.2 General description of the fire behavior of materials

Three things are necessary for combustion: a combustible material, oxygen, and a heat/ignition source.

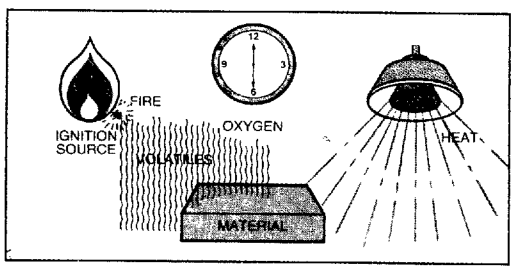


It is realized that the first of these, a combustible material, includes almost all materials. Nearly all materials burn, given oxygen, an ignition source, and sufficient heat to raise the temperature of the material to its fire point.

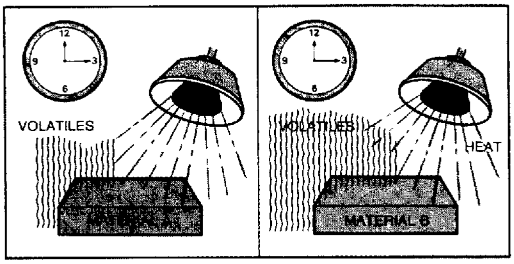
As the first step in the combustion process, the heat breaks down some of the combustible material into lower-molecular-weight solids, liquids, and gases, which may volatilize. The volatiles mix with the oxygen in the air and may form a mixture that can burn.



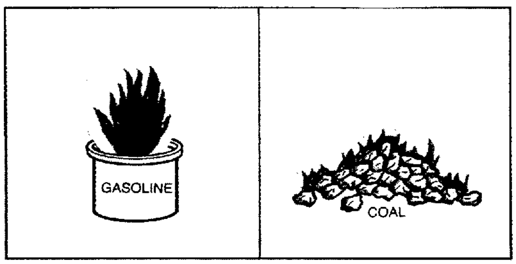
When the mixture comes in contact with an ignition source such as a flame or an arc, fire results.



Different materials give off different quantities of volatiles when subjected to the same amount of heat.

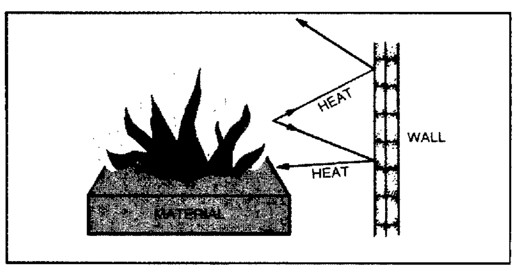


Also, some materials give off volatiles that ignite at lower temperatures or produce more heat per pound than volatiles from other materials. Therefore, the nature of a fire varies depending on the nature of the material burned.



With all other conditions equal, gasoline produces a fast, violent flame ... *whereas coal produces a slow, gradual flame.*

When a material burns, it releases heat. Some of the heat ends up being fed back into the material being burned. The flow of heat per unit area is often called heat flux.



Typically, in large fires, a significant amount of heat given off is radiated back into the material being burned. This flux further heats the material, increasing the rate of volatilization. The fire in turn burns more rapidly.

It is apparent that fire intensity and its associated hazards are governed by the following factors:

a) The rate at which a material vaporizes
b) The flammability of the vapors
c) The amount and rate of heat, smoke, and toxic and corrosive materials released by the burning material

It is likewise apparent that different materials have significantly different fire intensities and associated fire hazards.

4.2.2.1 Heat release

The two measures of heat release that are of particular interest are as follows:

a) *Heat of combustion*. The thermal energy (chemical, convective, and radiative) per unit mass, i.e., MJ/kg (BTU/lb), released during burning.
b) *Rate of heat release*. The rate at which a material releases heat during burning, i.e., kW/m^2 ($kJ/m^2/s$).

In fires, combustion is never complete; thus the actual thermal energy released per unit mass is defined as heat of combustion.

Because heat is necessary to start and to sustain a fire, the material's endothermic (heat-absorbing) characteristics as well as its exothermic (heat-releasing) characteristics should be considered. Endothermic features include heat capacity, i.e., the heat required to raise the temperature of a unit mass of material by one degree, and heat of gasification, i.e., the heat required to convert a unit mass of material to a vapor.

The ratio of endothermic to exothermic characteristics (heat absorbed to heat released) is an indication of the amount of thermal energy (flux) available to feed back to the fire. Many materials burn with excess feedback. This excess feedback continues the escalation of the fire intensity until most of the material vaporizes and burns. The heat at the surface of a burning material is the sum of heat flux from external sources and the heat evolved from the burning insulation material.

4.2.2.2 Heat release rate

When determining the hazards associated with fire, two elements of heat release are commonly considered. Convective heat release is a measure of the heat contained in the hot gases produced, which generally rise and damage ceilings and roofs. Radiative heat release is a measure of the heat radiating from flames. This heat may ignite adjacent materials and frequently hampers the activities of fire fighters. A third element, conductive heat release, is a measure of the energy released directly from a burning material to whatever is in direct contact with it.

4.2.2.3 Smoke, and toxic and corrosive products

Fire-related injuries or deaths occur for a variety of reasons. Some are the result of the destruction of tissues by heat. Smoke and other combustion gases can reduce visibility and act as irritants, which makes it difficult for people to move out of hazardous areas.

It is generally recognized that smoke, and other nonthermal fire products, not burns, are the cause of death of the majority of people who die in fires. They are also responsible for millions of dollars of contamination damage, including corrosion, to buildings and equipment. Public concern about these fire products has increased in recent years. Test methods to assess hazards associated with these products are under development.

4.2.3 Principles for the evaluation of the fire behavior of insulation materials

Several principles are used for the characterization of the fire behavior of materials.

4.2.3.1 Fire initiation

The resistance to fire initiation is examined in terms of ignition. The material or the product is exposed to a heat source, such as a flame, a radiant panel, etc. The time it takes for the sample to ignite (piloted or self-ignition) is measured. The temperature to which the material has to be heated for ignition to occur is defined as either the fire point minimum surface temperature for piloted ignition or the fire point minimum surface temperature for self-ignition. The relationship between the time-to-ignition and the external heat flux is often used to determine the heat flux below which ignition is not possible; this is defined as the critical heat flux for ignition.

The values of fire point and critical heat flux can be used to assess the resistance of materials and products to fire initiation and propagation.

4.2.3.2 Fire propagation

Fire propagation is the movement of a flame front on the surface of materials and products beyond the ignition zone. The fire propagation characteristics of materials and products are assessed in terms of the following:

a) Extent of flame propagation beyond the ignition zone
b) Minimum oxygen concentration and temperature of the environment
c) Heat release rate

4.2.3.3 Thermal and nonthermal fire hazards

The hazard expected due to the generation of heat in a fire is defined as the thermal fire hazard. Hazards from combustion products (smoke, and toxic and corrosive fire products) far enough away from the fire where the heat of combustion gases are unlikely to cause damage are defined as nonthermal fire hazards.

The heat release rate and generation rate of fire products are measured by exposing samples to various external heat flux values. The heat release rate is the rate of energy release associated with the combustion of a material. As a result of this combustion, oxygen is depleted, and carbon dioxide and carbon monoxide are produced along with other products such as soot and smoke. The convective heat release rate is defined as the rate associated with the flow of hot fire product-air mixture away from the combustion zone. The radiative heat release rate is defined as the rate associated with the heat that is radiated away from the combustion zone.

The generation of smoke is assessed in terms of light obscuration, which is a measurement of the fraction of light transmitted across a known path length. The smoke obscuration is defined in terms of specific optical density and mass optical density. The magnitude of the optical density is used to assess the smoke forming characteristics of the materials and products.

The toxicity of the fire products can be assessed by exposing animals to the products or by analyzing the constituents of the gases evolved. The test results are expressed in terms of a minimum mass or the concentration of the material or the product to cause death in 50% of the animals and may be expressed as LC_{50} or LD_{50}.

The corrosiveness of the fire products is assessed by exposing metal coupons or corrosion probes (targets) to the fire products directly in the gas phase or in solutions.

Table 1 lists the test standards by the type of property they measure.

Table 1—Selection of test methods

Fire initiation	Fire propagation	Thermal fire hazard	Nonthermal fire hazard
ASTM D56-87	ASTM D635-91	ASTM E906-83	ASTM E662-92
ASTM D92-90	ASTM D3801-80	ASTM E1354-92	ASTM E906-83
ASTM D93-90	ASTM E84-91a	FAA 14 CFR Appendix F Part 3 (1985)	ASTM E1354-92
ASTM D2863-87	ASTM E162-90	ISO 5660-1992	IEC 754-1 (1982)
ASTM D3713-78	ASTM E163-84		UL 1685-1992
ASTM D3874-90	ASTM E286-85		
ASTM E659-78	ASTM E814-83		
ASTM E681-85	Factory Mutual Specification Test Standard 3972 (1989)		
IEC 707 (1981)	IEC 332-1 (1979)		
ISO 181-1981	IEEE Std 1202-1991		
ISO 871-1980	ISO 4589-1984		
UL 94-1991	UL 94-1991		
	UL 1666-1991		
	UL 1685-1992		

4.3 Large-scale testing

During the past 10-15 years, confidence of fire researchers in the results of traditional small-scale testing has decreased and it is now realized that the development of any reliable small-scale test should be based on sound principles of fire dynamics, and that the measured aspect of fire performance should agree well with performance in a "real" or large-scale fire situation. Therefore, conducting large-scale tests that reasonably simulate an actual fire situation is a necessity. From these tests, the following types of information are being determined:

a) Comparative fire performance
b) Fundamental information concerning fire growth to flashover conditions
c) Information and concepts for modeling and for the development of reliable small-scale tests

A greater use of full-scale testing to assess fire performance during the past decade has come about mainly through the need to demonstrate relative fire safety to regulatory and insurance interests. At present, these large-scale tests are the fastest approach to "realistic" determination of fire performance. Full-scale tests should be designed so that

- The test conditions represent important potential fire situations or scenarios
- All important variables are controlled
- The test can be conducted in a repeatable way

Consideration of all of the parameters is a complex task. The basic objective of the test must be established, i.e., whether it is a determination of life hazard or property hazard, or both. For example, for life hazard, the time to reach a certain gas temperature or a certain level of such gases as carbon monoxide would be critical. For hazard to the structure, fire resistance time of the protective materials around structural elements is critical.

Based on the knowledge of fire behavior gained from large-scale testing, reliable small-scale tests can and are being developed.

5. Bibliography

5.1 IEEE documents

The Color Book series of the IEEE is the most widely accepted series of practical design documents for electrical facilities. Guidelines for specific equipment applications and procedures for evaluating benefits and suitability of alternative concepts are contained in the following:

[B1] IEEE Std 141-1986 (Reaff 1992), IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book) (ANSI).

[B2] IEEE Std 142-1991, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book) (ANSI).

[B3] IEEE Std 241-1990, IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gray Book) (ANSI).

[B4] IEEE Std 242-1986 (Reaff 1991), IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book) (ANSI).

[B5] IEEE Std 399-1990, IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis (IEEE Brown Book) (ANSI).

[B6] IEEE Std 446-1987, IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE Orange Book) (ANSI).

[B7] IEEE Std 493-1990, IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book) (ANSI).

[B8] IEEE Std 602-1986, IEEE Recommended Practice for Electric Systems in Health Care Facilities (IEEE White Book) (ANSI).

[B9] IEEE Std 1202-1991, IEEE Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies (ANSI).

5.2 National Electrical Safety Code (NESC)

[B10] ANSI C2-1993, National Electrical Safety Code.
The NESC, under the IEEE secretariat positions, is the second most broadly distributed and utilized consensus standard for the electrical utility industry.

5.3 ANSI/NFPA documents

[B11] ANSI/NFPA 75-1992, Electronic Computer/Data Processing Equipment.

[B12] ANSI/NFPA 220-1992, Types of Building Construction.

[B13] ANSI/NFPA 259-1987, Potential Heat of Building Materials.
This document presents the standard means of measuring the total heat release possible from building materials under specified conditions.

[B14] ANSI/NFPA 262-1990, Test for Fire and Smoke Characteristics of Wires and Cables.

[B15] ANSI/NFPA 907M-1988, Investigation of Fires of Electrical Origin.

5.4 ASTM documents

[B16] ASTM D56-87, Test Method for Flash Point by Tag Closed Tester.

[B17] ASTM D92-90, Test for Flash and Fire Points by Cleveland Open Cup.

[B18] ASTM D93-90, Test Methods for Flash Point by Pensky-Martens Closed Tester.

[B19] ASTM D350-91, Test Methods for Flexible Treated Sleeving Used for Electrical Insulation.

[B20] ASTM D635-91, Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position.

[B21] ASTM D876-90, Test Methods for Non-Rigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation.

[B22] ASTM D1000-88, Method for Testing Pressure-Sensitive Adhesive Coated Tapes Used for Electrical Insulation.

[B23] ASTM D2633-82 (Reaff 1989), Method of Testing Thermoplastic Insulations and Jackets for Wire and Cable.

[B24] ASTM D2671-91, Test Methods for Heat-Shrinkable Tubing for Electrical Use.

[B25] ASTM D2863-87, Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index).

[B26] ASTM D3713-78 (Reaff 1988), Test Method for Measuring Response of Solid Plastics to Ignition by a Small Flame.

[B27] ASTM D3801-80 (Reaff 1987), Method for Measuring the Comparative Extinguishing Characteristics of Solid Plastics in a Vertical Position.

[B28] ASTM D3874-90, Test Method for Ignition of Materials by Hot Wire Sources.

[B29] ASTM E84-91a, Test Method for Surface Burning Characteristics of Building Materials.

[B30] ASTM E162-90, Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source.

[B31] ASTM E163-84, Methods of Fire Tests of Window Assemblies.

[B32] ASTM E286-85, Test Method for Surface Flammability of Building Materials Using an 8-ft (2.44-m) Tunnel Furnace.

[B33] ASTM E659-78 (Reaff 1989), Test Method for Autoignition Temperature of Liquid Chemicals.

[B34] ASTM E681-85 (Reaff 1991), Test Method for Limits of Flammability of Chemicals.

[B35] ASTM E814-83, Methods for Fire Tests of Through-Penetration Fire Stops.

[B36] ASTM E931-85, Practice for Assessment of Fire Risk by Occupancy Classification (Commentary).

[B37] ASTM E1354-92, Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter.

5.5 CSA documents

[B38] C22.2 No. 0.3-M-1985, Test Methods for Electrical Wires and Cables.

5.6 Factory Mutual documents

[B39] FM Approval Standard Class Number 6933-1979, Less Flammable Transformer Fluids.

[B40] Loss Prevention Data Sheet 1–1 Oct. 1978 Building Construction and Materials. Factory Mutual Engineering.

[B41] Loss Prevention Data Sheets 5–4, 14–8; Sep. 1986, Less Flammable Liquid Transformers. Factory Mutual Engineering.

[B42] Loss Prevention Data Technical Advisory Bulletin, Cable Flammability, 5-31, U-5. Factory Mutual Research Corporation, Norwood, MA. Nov. 1989.

[B43] Specification Test Standard, Cable Fire Propagation Class Number 3972. Factory Mutual Research Corporation, Norwood, MA. July 1989.

5.7 IEC documents

[B44] IEC 332-1 (1979), Tests on electric cables under fire conditions—Part 1: Test on a single vertical insulated wire or cable, 2d ed.

[B45] IEC 707 (1981), Methods of test for the determination of the flammability of solid electrical insulating materials when exposed to an igniting source.

[B46] IEC 745-1 (1982), Safety of hand-held motor-operated electric tools—Part 1: General requirements.

[B47] IEC 754-1 (1982), Test on gases evolved during combustion of electric cables—Part 1: Determination of the amount of halogen acid gas evolved during the combustion of polymeric materials taken from cables.

[B48] IEC 950 (1991), Safety of information technology equipment, including electrical business equipment, 2d ed.

5.8 ISO documents

[B49] ISO 181-1981, Plastics—Determination of flammability characteristics of rigid plastics in the form of small specimens in contact with an incandescent rod.

[B50] ISO 871-1980, Plastics—Determination of temperature of evolution of flammable gases (decomposition temperature) from a small sample of pulverized material.

[B51] ISO 4589-1984, Plastics—Determination of flammability by oxygen index.

[B52] ISO 5660-1992, Fire tests—Reaction to fire—Rate of heat release from building products.

[B53] ISO Technical Report 5924-1989, Fire tests—Reaction to fire—Smoke generated by building products (dual-chamber test).

[B54] ISO Technical Report 9122, Toxicity testing of fire effluents—Parts 1 through 5.

5.9 UL documents

[B55] "Fact Finding Investigation: Flammability of Transformer Fluids in a Pool Fire Scenario," Nov. 1987. UL Reference: R12117, 86NK13392.

[B56] UL 94-1991, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.

[B57] UL 1072-1986, Medium-Voltage Power Cables.

[B58] UL 1277-1989, Electrical Power and Control Tray Cables With Optional Optical-Fiber Members.

[B59] UL 1581-1991, Reference Standard for Electrical Wires, Cables, and Flexible Cords.

[B60] UL 1666-1991, Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts.

[B61] UL 1685-1992, Vertical-Tray Fire-Propagation and Smoke-Release for Electrical and Optical-Fiber Cables.

5.10 Other documents

[B62] 40 CFR Part 761, "PCB's in Electrical Transformers; Final Rule," Federal Register, July 17, 1985, Part 4, Environmental Protection Agency.

[B63] FAA 14 CFR, "Improved Flammability Standard for Materials used in the Interiors of Transport Category Airplane Cabins, Appendix F, Part 3: Test Method to Determine the Heat Release Rate from Cabin Materials Exposed to Radiant Heat," Federal Register, Apr. 16, 1985, vol. 50, no. 73, p. 15042.

[B64] Peck, C. G., "Fire and Explosion Hazards of Liquid-Filled Electrical Equipment, Part I: An Overview," *Insurance Technical Bureau*, London, pp. 64–68, July 1984.

[B65] *The BOCA® National Building Code*, 1990, Building Officials and Code Administrators (BOCA) International, Inc.

[B66] *The Standard Building Code*, 1991 ed., Southern Building Code Congress, International (SBCCI), Inc.

[B67] *Uniform Building Code™*, 1991 ed., and 1993 Accumulative Supplement, International Conference of Building Officials (ICBO).

Annex A

NEC and product listings

(informative)

(This informative annex is not a part of IEEE Std 1221-1993, IEEE Guide for Fire Hazard Assessment of Electrical Insulating Materials in Electrical Power Systems, but is included for information only.)

ANSI/NFPA 70-1993, National Electrical Code (NEC), the most broadly distributed and utilized consensus standard, provides practical guidelines for the use of electricity. It is offered for use in law and for regulatory purposes in the interest of life and property protection. Users of the NEC should consult applicable federal, state, and local laws and regulations. Annex B of this guide lists the regulations and codes concerned with safety and provides the addresses for many of the agencies and organizations working in this field. A state or locality may adopt the NEC by reference in laws, ordinances, regulations, administrative orders, and similar instruments. Any amendments (deletions, additions, and changes) made by the state or locality should be noted in the adoption document.

The original code document leading to the NEC was developed in 1897 as a result of the united efforts of various insurance, architectural, and allied interests. The National Fire Protection Association (NFPA) has acted as sponsor of the NEC since 1911. The NFPA has an Electrical Section that provides opportunity for NFPA members interested in electrical safety to become better informed and to contribute to the continuing development of the NEC and other NFPA standards. Since 1959, the NEC has been amended every three years. A code cycle for the NEC consists of the following:

a) Anyone may submit proposals, by certain cutoff dates, to amend it.
b) Code-making panel meetings are held to act on the proposals.
c) Correlating committee meetings are held to verify consistency and compliance with NFPA regulations that govern committee projects.
d) A Technical Committee Report (TCR) is generated.
e) Anyone may submit comments on the TCR.
f) Code-making panel meetings are held to act on the comments.
g) Correlating committee meetings are again held to verify consistency and compliance with NFPA regulations that govern committee projects.
h) A Technical Committee Documentation (TCD) is generated.
i) Final action/adoption of the TCD is accomplished at an NFPA Annual Meeting.
j) A new NEC is issued.

The efforts to amend and maintain the NEC are supported by various insurance, inspection, labor, manufacturer, contractor, testing/certifying, power and communication utilities, building and housing, professional and technical groups, governmental, and trade association interests. The representation of these interests is given in table A1.

The NEC is not intended as a design specification nor as an instruction manual for untrained persons. The NEC covers installations of electrical conductors and equipment within or on public and private buildings or other structures, including mobile homes, recreational vehicles, and floating buildings; and other premises such as yards, carnivals, parking and other lots, and industrial substations. The NEC does not cover installations in: ships or watercraft, other than floating buildings, railway rolling stock, aircraft, or automotive vehicles other than mobile homes and recreational vehicles; installations underground in mines; installation of railways; installations for generation, transformation, transmission, or distribution of power used exclusively for operation of rolling stock; installations used exclusively for signalling and communication purposes; installation of communication equipment under the exclusive control of communication utilities; and installations under the exclusive control of electric utilities. It is the intent of the NEC that the code cover installations in buildings used by the utilities that are not an integral part of a generating plant, substation, or control center.

Table A1—Representation of interests

Representation	Name of interest
All 20 panels plus the correlating committees	International Association of Electrical Inspectors (IAEI) International Brotherhood of Electrical Workers (IBEW) National Electric Manufacturers Association (NEMA) National Electrical Contractors Association (NECA) Underwriters Laboratories (UL) Electric Light and Power Group (EL&P)
At least 15 panels	The Institute of Electrical and Electronics Engineers (IEEE) Chemical Manufacturers Association (CMA)
7 panels	Aluminum Association (AA)
6 panels	Veterans Administration (VA)
1 panel	National Elevator Industry (NEI) Vinyl Institute (VI) American Petroleum Institute (API)

The authority having jurisdiction for enforcing the NEC will normally be the governmental bodies exercising legal jurisdiction over electrical installations. In some cases, inspectors may mandate applications and grant exceptions or waive specific requirements.

The NEC may require new products, constructions, or materials that may not yet be available at the time the code is adopted. In such events, the authority having jurisdiction may permit the use of the products, constructions, or materials that comply with the most recent previous edition of the code in force.

For specific items of equipment and materials referred to in the NEC, examinations for safety made under standard conditions will provide a basis for approval where the record is made generally available by

- Organizations properly equipped and qualified for experimental testing
- Inspections of the run of goods at factories
- Service-value determination through field inspections

Electrical conductors, equipment, and materials suitable for a specific service, purpose, environment, or application may be "approved," "identified," "labeled," or "listed." Conductors and equipment required or permitted by the NEC shall be acceptable only if approved. Approved means acceptable to the authority having jurisdiction. Identified means recognized as suitable for the specific service, purpose, function, use, environment, application, etc., and may be determined by a qualified testing laboratory, inspection agency, or other organization concerned with product evaluation. Such identification includes labeling or listing. Labeled or listed means that the conductors, equipment, or material meet appropriate standards or have been tested and found suitable for use in a specified manner.

Chapter 1 through 4 of the NEC generally apply except as amended by Chapters 5 through 7 for particular conditions. Chapter 5 through 7 apply to special occupancies, special equipment, or other special conditions, and they supplement or modify the general rules. Chapter 8 covers communication systems and is independent of the other chapters except where they are specifically referenced therein. Chapter 8 consists of tables and examples. Annex C of this guide lists the sections of the NEC that address fire safety.

The NEC addresses fire safety but does not address all of the fire hazards associated with electricity. No mention is made in the text of the NEC about the ease of ignition, rate of flame spread or heat release, total heat flux, corrosiveness, or toxicity. Inside the front cover of the NEC, under "Policy Adopted by NFPA Board of Directors on December 3, 1982," the following statement is given: "The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire." NFPA has dealt with that subject in its technical committee documentation for many years. The Board has, therefore, asked all NFPA Technical Committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees on meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

Annex B

Regulations and safety codes—How to obtain information on hazard assessment and electrical engineering

(informative)

(This informative annex is not a part of IEEE Std 1221-1993, IEEE Guide for Fire Hazard Assessment of Electrical Insulating Materials in Electrical Power Systems, but is included for information only.)

The purpose of this annex is to familiarize the user of this guide with some of the sources of information concerning the fire hazards of materials used as electrical insulation.

B.1 Building codes

The ultimate regulatory process is the responsibility of the individual states, which in turn have delegated this in whole or in part to local governments.

Help is available to these local governments in the form of model building codes. The three most widely used are as follows:

a) The BOCA® National Building Code - Building Officials and Code Administrators (BOCA) International, Inc.
b) The Standard Building Code - Southern Building Code Congress, International (SBCCI), Inc.
c) Uniform Building Code™ - International Conference of Building Officials (ICBO)

B.2 Key federal organizations

Useful information can be obtained from the following:

a) Consumer Product Safety Commission (CPSC)
b) Department of Defense (DOD)
c) Department of Energy (DOE)
d) Department of Transportation (DOT)
e) Environmental Protection Agency (EPA)
f) Federal Aviation Administration (FAA)
g) Federal Fire Prevention and Control Administration (FFPCA)
h) National Aeronautics and Space Administration (NASA)
i) National Center for Toxicological Research (NCTR)
j) National Institute for Occupational Safety and Health (NIOSH)
k) National Institute of Environmental Health Services (NIEHS)
l) National Institute of Standards and Technology (NIST) (Formerly NBS)

B.3 Key standard code organizations

a) American Society for Testing and Materials
b) Building Officials and Code Administrators International, Inc. (BOCA®)
c) Canadian Standards Association (CSA)
d) Industry Associations, e.g., NEMA
e) International Conference of Building Officials (ICBO)
f) International Electrotechnical Commission (IEC)

g) International Organization for Standardization - TC-92
h) Military Standards
i) National Fire Protection Association (NFPA)
j) Southern Building Code Congress, International (SBCCI), Inc.

B.4 Associations

a) American Society of Testing and Materials (ASTM)
b) Institute of Electrical and Electronics Engineers (IEEE)
c) National Fire Prevention Association (NFPA)
d) Society for Fire Prevention
e) Society of the Plastics Industry, Inc.

B.5 Other sources of information

B.5.1 Government agencies

a) National Materials Advisory Board (NMAB)
National Academy of Sciences (NAS)
Commission on Sociotechnic Systems
2101 Constitution Avenue
Washington, DC 20418

b) National Research Council (NRC)
National Academy of Sciences
Assembly of Life Sciences
Committee on Fire Toxicology
Board on Toxicology—Environmental Health Hazards
2010 Constitution Avenue
Washington, DC 20418

c) Federal Aviation Administration (FAA) Technical Center
Atlantic City Airport, NJ 08405

d) Federal Aviation Administration (FAA)
Civil Aeromedical Institute (CAMI)
Aviation Toxicology Laboratory
Mike Monroney Aeronautical Center
P.O. Box 25082
Oklahoma City, OK 73125

e) U.S. Department of the Interior
Bureau of Mines
Pittsburgh Research Center
P.O. Box 18070
Pittsburgh, PA 15236

f) U.S. Department of Transportation
DOT/Transportation Systems Center
Kendall Square
Cambridge, MA 01242

g) National Aeronautic and Space Administration (NASA)

1) NASA/Ames Research Center
Moffett Field, CA 94035

2) NASA/Johnson Space Center
Houston, TX 77058

3) NASA/Langley Research Center
Langley Station
Hampton, VA 23655

4) NASA/Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135

5) Jet Propulsion Laboratory (JPL)
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91103

h) U.S. Department of Commerce
National Institute of Standards and Technology (NIST)
Building and Fire Research Laboratory
Gaithersburg, MD 20899

B.5.2 Non-Government sources

Factory Mutual Research Corporation
1151 Boston-Providence Turnpike
Norwood, MA 02062

Annex C

NEC sections addressing fire hazards of electrical systems

(informative)

(This informative annex is not a part of IEEE Std 1221-1993, IEEE Guide for Fire Hazard Assessment of Electrical Insulating Materials in Electrical Power Systems, but is included for information only.)

Section 300-21 addresses "Spread of Fire or Products of Combustion." The mandatory requirements for fire protective issues are characterized by the use of the word "shall." They include: Fire rated constructions as found in Sections 300-21,331-3(s), 450-21, 450-22, 450-23, 450-24, 450-26, 450-27, 450-42, 725-2(a), 760-2(a), 770-2(a), 800-52(b), and 820-52(b); Fire safeguards as found in Sections 450-21, 450-22, 450-23, 450-24, 450-26, 450-27, and 450-42; Flame-retardant, fire-retardant, and fire-resistant materials as found in Table 310-13 and Sections 318-5(f), 328-30, 331-1, 340-3, 347-1, 351-22, 352-21, 645-5(d)(5), 725-51(a), 725-51(b), 725-51(c), 725-51(d), 729-51(e), 760-17(c)(4), 760-17(c)(5), 760-17(c)(6), 760-51(d), 760-51(e), 760-51(f), 770-51(a), 770-51(b), 770-51(c), 800-51(a), 800-51(b), 800-51(c), 800-51(d), 820-51(a), 820-51(b), 820-51(c) and 820-51(d); noncombustible materials or separation from combustible materials as found in Sections 380-9, 410-56(d), 450-21, 450-22, 450-23 and 450-27; less-flammable materials as found in Section 450-23; nonflammable materials as found in Section 450-24; and low-smoke materials as covered in Sections 725-51(a), 760-17(c)(4), 760-51(d), 770-51(a), 800-51(a) and 820-51(a). 820-52(b) states: "Electrical installations in hollow spaces, vertical shafts, and ventilation or air-handling ducts shall be so made that the possible spread of fire or products of combustion will not be substantially increased. Openings around electrical penetrations through fire resistance rated walls, partitions, floors, or ceilings shall be fire stopped using approved methods to maintain the fire-resistance rating."

Table 310-13 contains certain conductor types (MTW, THHN, THHW, THW, THWN, TW, and XHHW) whose insulation must be flame retardant.

Table 310-13 contains certain conductor types (RH, RHH, RHW, RHW-2, TA, and TBS) whose outer jacket must be flame retardant.

Table 310-13 contains certain conductor types (MTW, RHH, RHW, SIS, THHN, THW, THWN, TW, and XHHW) whose insulations and outer coverings that meet the requirements for flame-retardant, limited smoke and are so listed shall be permitted to be designated limited smoke with the suffix /LS after the code type designation.

Table 310-61 contains conductor types (MV-75, MV-85, and MV-90) whose insulations and outer coverings that meet the requirements for flame-retardant, limited smoke and are so listed shall be permitted to be designated limited smoke with the suffix /LS after the code type designation.

Sections 318-3(a)(1) and 340-1 stipulate that cables that are specifically approved for installation in cable trays are required, but these sections do not contain any statement that such tray cable be flame retardant or flame resistant or resistant to spread of fire. [B57][7] and [B58] for tray cable for 600 V (or cable for use in cable tray for medium-voltage) cover the flame test requirements for cables to be installed in cable tray.

Section 318-5(f) stipulates that nonmetallic cable trays shall be made of flame-retardant material.

Section 328-30 stipulates that flat conductor cable insulation material shall be flame retardant.

[7]The numbers in brackets correspond to those in the bibliography in clause 5.

Section 331-1 stipulates that electrical nonmetallic tubing shall be composed of material that is flame retardant. A fine print note (FPN) states it is intended that the material used has ignitability, flammability, smoke generation, and toxicity characteristics that do not exceed those of rigid (nonplasticized) polyvinyl chloride.

Section 331-3(2) states: "Electrical nonmetallic tubing and fittings shall be permitted concealed within walls, floors, and ceilings where the walls, floors, and ceilings provide a thermal barrier of material which has at least a 15 minute flame rating as identified in listings of fire rated assemblies."

Sections 333-3 for armored cable, 334-24 for metal-clad cable, 336-27 for nonmetallic-sheathed cable, 337-9 for shielded nonmetallic-sheathed cable, and 340-6 for tray cable state that such cables that are flame retardant and have limited smoke characteristics shall be permitted to be identified with the suffix /LS.

Section 340-3 stipulates that insulated conductors of sizes no. 18 and no. 16 shall be in accordance with 725-16, and that the outer sheath shall be flame retardant.

Section 347-1 stipulates that rigid nonmetallic conduit for use aboveground shall be flame retardant.

Section 351-22 stipulates that liquid tight flexible nonmetallic conduit shall be flame resistant.

Section 352-21 stipulates that surface nonmetallic raceways shall be flame retardant.

Article 370 presently contains no statement that nonmetallic boxes be flame retardant or flame resistant.

Article 373 presently contains no statement that nonmetallic cabinets be flame retardant or flame resistant.

Articles 210, 250, 305, 410, 501, 502, 517, 520, 550, 551, 553, 680, and 720 presently contain no statements that receptacles be flame retardant or flame resistant.

Article 380 presently contains no statement that switches be flame retardant or flame resistant.

Section 380-9 stipulates that flush snap switches that are mounted in ungrounded metal boxes and located within reach of conducting floors or other conducting surfaces shall be provided with faceplates of nonconducting, noncombustible material.

Table 400-4 contains certain flexible cords and cables (DP and E) whose insulations and outer coverings that meet the requirements for flame-retardant, limited smoke and are so listed shall be permitted to be designated limited smoke with the suffix /LS after the code type designation.

Table 402-3 contains certain fixture wires (RFHH-2, RFHH-3, TF, TFF, TFN, TFFN, XF, and XFF) whose insulations and outer coverings that meet the requirements for flame-retardant, limited smoke and are so listed shall be permitted to be designated limited smoke with the suffix /LS after the code type designation.

Section 410-56(d) stipulates that receptacle faceplates of insulating material shall be noncombustible.

Section 450-21 stipulates (by exception No. 2) that dry type transformers of more than 112.5 kVA size, with 80 °C rise or higher ratings and completely enclosed except for ventilating openings do not require installation in transformer rooms of fire resistant construction.

Section 450-22 stipulates that open dry type transformers installed outdoors exceeding 112.5 kVA shall not be located within 12 in of combustible materials of buildings.

Section 450-23 stipulates that less-flammable liquid insulated transformers shall be permitted to be installed without a vault in Type I and Type II buildings in areas in which no combustible materials are stored, provided there is a liquid confinement area, the liquid has a fire point of not less than 300 °C, and the installation complies with all restrictions provided for in the listing of the liquid. Liquid-insulated transformers located indoors and rated over 35 000 V shall be installed in transformer vaults constructed as described in Section 450-42. Less-flammable liquid-insulated transformers shall be permitted to be installed outdoors attached to, adjacent to, or on the roof of Type I or Type II buildings. Such installations attached to, adjacent to, or on the roof of other than Type I or Type II buildings, adjacent to combustible material, fire escapes, or door and window openings, shall be provided with one or more safeguards according to the degree of hazard. Recognized safeguards are fire barriers, space separation, and compliance with all of the requirements provided for in the listing. An FPN stipulates that "noncombustible" refers to Type I and Type II building construction and noncombustible materials as defined in [B12].

Section 450-24 indicates that nonflammable fluid-insulated transformers shall be permitted to be installed indoors or outdoors. Such transformers located indoors and rated over 35 000 V shall be installed in transformer vaults constructed as described in Section 450-42. An FPN indicates that safety will be increased if fire hazard analyses are performed for such transformer installations. A nonflammable dielectric fluid is one that does not have a flash point or fire point, and is not flammable in air.

Section 450-26 stipulates that oil-insulated transformers installed indoors shall be installed in transformer vaults constructed as described in Section 450-42. Certain exceptions apply for: 112.5 kVA or less size, below 600 V windings, electric furnace transformers not exceeding 75 kVA, transformers in detached buildings, and transformers used in surface mining provided that

- Provision is made for draining leaking fluid to ground
- Safe egress is provided for personnel
- A minimum 0.25 in thick steel barrier is provided for personnel protection

Section 450-27 stipulates that for oil-insulated transformers installed outdoors, combustible material, combustible buildings, and parts of buildings, fire escapes, and door and window openings shall be safeguarded from fires originating in oil-insulated transformers installed on roofs, attached to, or adjacent to a combustible building or combustible material. Recognized safeguards are space separations, fire-resistant barriers, automatic water spray systems, and enclosures that confine the oil of a ruptured transformer tank.

Section 610-2(b) stipulates that where a crane, hoist, or monorail hoist operates over readily combustible material, the resistors shall be placed in a well-ventilated cabinet composed of noncombustible material so constructed that it will not emit flames or molten metal.

Section 645-2 stipulates that for electronic computer/data processing equipment a separate heating/ventilating/air conditioning system shall be provided that is dedicated for that use, is separated from other areas of occupancies, and may also serve the electronic computer/data processing equipment room if fire/smoke dampers are provided at the point of penetration of the room boundary. Such dampers shall operate on activation of smoke detectors and also by operation of the disconnecting means for power to all electronic equipment in the electronic computer/data processing equipment room. An FPN refers to [B11].

Section 645(d)(5) requires type DP cables having adequate fire resistance characteristics for use under raised floors of computer rooms.

Section 725-2(a) refers to "Spread of Fire or Products of Combustion" as found in Section 300-21.

Section 725-51(a) stipulates that Type CL2P and CL3P plenum cables shall be listed as having adequate fire resistance and low-smoke-producing characteristics. An FPN indicates that one method of defining low-smoke-producing cable is by establishing an acceptable value of the smoke produced when tested in accordance with [B14] to a maximum peak optical density of 0.5 and a maximum average optical density of 0.15; and similarly one method of defining fire resistant cables is by establishing maximum allowable flame travel distance of 5 ft when tested in accordance with the same test.

Section 725-51(b) stipulates that Type CL2R and CL3R riser cables shall be listed as having fire-resistant characteristics capable of preventing the carrying of fire from floor to floor. An FPN indicates that one method of defining fire-resistant characteristics capable of preventing the carrying of fire from floor to floor is that the cables pass the requirements of [B60].

Section 725-51(c) stipulates that Type CL2 and CL3 cables shall be listed as being resistant to the spread of fire. An FPN indicates that one method of defining resistance to spread of fire is that the cables do not spread fire to the top of the tray in the "Vertical Tray Flame Test" in [B59]; and another method of defining resistance to the spread of fire is for the damage not to exceed 4 ft 11 in, when performing CSA Vertical Flame Test Cables in Cable Trays in [B38].

Section 725-51(d) stipulates that Type CL2X and CL3X cables shall be listed as being flame retardant. An FPN indicates that one method of determining that cable is flame retardant is by testing the cable to the "VW-1 (Vertical Wire) Flame Test" in [B59].

Section 725-51(e) stipulates that Type PLTC nonmetallic sheathed power-limited try cable be resistant to the spread of fire. An FPN indicates the same method(s) for defining resistance to spread of fire as covered in Section 725-51(c).

Section 760-2(a) refers to "Spread of Fire or Products of Combustion" as found in Section 300-21.

Section 760-17(c)(4) stipulates that Type NPLFP nonpower-limited fire protective signalling plenum cable shall be listed as having adequate fire resistance and low-smoke-producing characteristics. An FPN indicates the same method for defining low-smoke-producing cable and fire-resistant cable as covered in Section 725-51(a).

Section 760-17(c)(5) stipulates that Type NPLFR nonpower-limited fire protective signalling riser cable shall be listed as having fire resistant characteristics capable of preventing the carrying of fire from floor to floor. An FPN indicates the same method of defining fire-resistant characteristics capable of preventing the carrying of fire from floor to floor as covered in Section 725-51(b).

Section 760-17(c)(6) stipulates that Type NPLF nonpower-limited fire protective signalling cable shall be listed as being resistant to the spread of fire. An FPN indicates the same method(s) of defining resistance to the spread of fire as covered in Section 725-51(c).

Section 760-51(d) stipulates that Type FPLP power-limited fire alarm plenum cable shall be listed as having adequate fire resistance and low-smoke-producing characteristics. An FPN indicates the same method for defining low-smoke-producing cable and fire-resistant cable as covered in Section 725-51(a).

Section 760-51(e) stipulates that Type FPLR power-limited fire alarm riser cable shall be listed as having fire-resistant characteristics capable of preventing the carrying of fire from floor to floor. An FPN indicates the same method of defining fire-resistant characteristics capable of preventing the carrying of fire from floor to floor as covered in Section 725-51(b).

Section 760-51(f) stipulates that Type FPL power-limited fire alarm cable shall be listed as being resistant to the spread of fire. An FPN indicates the same method(s) of defining resistance to the spread of fire as covered in Section 725-51(c).

Section 770-2(a) refers to "Spread of Fire or Products of Combustion" as found in Section 300-21.

Section 770-51(a) stipulates that Type OFNP and OFCP nonconductive and conductive optical fiber plenum cables shall be listed as having adequate fire resistance and low-smoke-producing characteristics. An FPN indicates the same method for defining low-smoke-producing cable and fire-resistant cable as covered in Section 725-51(a).

Section 770-51(b) stipulates that Type OFNR and OFCR nonconductive and conductive optical fiber riser cables shall be listed as having fire-resistant characteristics capable of preventing the carrying of fire from floor to floor. An FPN indicates the same method of defining fire-resistant characteristics capable of preventing the carrying of fire from floor to floor as covered in Section 725-51(b).

Section 770-51(c) stipulates that Type OFN and OFC nonconductive and conductive optical fiber cables shall be listed as being resistant to the spread of fire. An FPN indicates the same method(s) of defining resistance to the spread of fire as covered in Section 725-51(c).

Section 800-51(a) stipulates that Type CMP communications plenum cable shall be listed as having adequate fire resistance and low-smoke-producing characteristics. An FPN indicates the same method for defining low-smoke-producing cable and fire-resistant cable as covered in Section 725-51(a).

Section 800-51(b) stipulates that Type CMR communications riser cable shall be listed as having fire-resistant characteristics capable of preventing the carrying of fire from floor to floor. An FPN indicates the same method of defining fire-resistant characteristics capable of preventing the carrying of fire from floor to floor as covered in Section 725-51(b).

Section 800-51(c) stipulates that Type CM communications cable shall be listed as being resistant to the spread of fire. An FPN indicates the same method(s) of defining resistance to the spread of fire as covered in Section 725-51(c).

Section 800-51(d) stipulates that Type CMX communications cable shall be listed as being flame retardant. An FPN indicates the same method(s) of defining flame retardant as covered in Section 725-51(d).

Section 800-52(b) contains the same statements about "Spread of Fire or Products of Combustion" as found in Section 300-21.

Section 820-51(a) stipulates that Type CATVP community antenna television plenum cable shall be listed as having adequate fire resistance and low-smoke-producing characteristics. An FPN indicates the same method for defining low-smoke-producing cable and fire-resistant cable as covered in Section 725-51(b).

Section 820-51(b) stipulates that Type CATVR community antenna television riser cable shall be listed as having fire-resistant characteristics capable of preventing the carrying of fire from floor to floor. An FPN indicates the same method of defining fire-resistant characteristics capable of preventing the carrying of fire from floor to floor as covered in Section 725-51(b).

Section 820-51(c) stipulates that Type CATV community antenna television cable shall be listed as being resistant to the spread of fire. An FPN indicates the same method(s) of defining resistance to the spread of fire as covered in Section 725-51(c).

Section 820-51(d) stipulates that Type CATVX community antenna television cable shall be listed as being flame retardant. An FPN indicates the same method(s) of defining flame retardant as covered in Section 725-51(d).

Section 820-52(b) contains the same statements about "Spread of Fire or Products of Combustion" as found in Section 300-21.

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