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NFPA 801 Standard for Facilities Handling Radioactive Materials 1995 Edition

NFPA

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101

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Policy Adopted by NFPA Board of Directors on December 3, 1982

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 documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. 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 in 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.

Statement on NFPA Procedures

This material has been developed under the published procedures of the National Fire Protection Association, which are designed to assure the appointment of technically competent Committees having balanced representation. While these procedures assure the highest degree of care, neither the National Fire Protection Association, its members, nor those participating in its activities accept any liability resulting from compliance or noncompliance with the provisions given herein, for any restrictions imposed on materials or processes, or for the completeness of the text.

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Errata

NFPA 801

Facilities Handling Radioactive Materials

1995 Edition

Reference: 3-2.1

The Committee on Atomic Energy notes the following error in the 1995 edition of NFPA 801, *Standard for Facilities Handling Radioactive Materials.* In the printing of the 1995 edition, an error inadvertently occurred.

1. *In 3-2.1 delete the word "not." Section 3-2.1 will now read as follows:*

3-2.1 Facilities having quantities of radioactive materials that might become airborne in case of fire or explosion shall be located or segregated from other important buildings or operations.

Issue Date: April 15, 1996

NFPA 801

Standard for

Facilities Handling Radioactive Materials

1995 Edition

This edition of NFPA 801, *Standard for Facilities Handling Radioactive Materials*, was prepared by the Technical Committee on Atomic Energy and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 14–16, 1994, in Toronto, Ontario, Canada. It was issued by the Standards Council on January 13, 1995, with an effective date of February 7, 1995, and supersedes all previous editions.

The 1995 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 801

The Committee on Atomic Energy was organized in 1953 for the purpose of providing the fire protection specialist with certain fundamental information about radioactive materials and their handling and to provide designers and operators of such laboratories with some guidance on practices necessary for fire safety. The first edition of NFPA 801, whose coverage was limited to laboratories handling radioactive materials, was adopted at the 1955 Annual Meeting.

In 1970 the format was revised, and it was updated to reflect current thinking and practices. It was also expanded to apply to all locations, exclusive of nuclear reactors, where radioactive materials are stored, handled, or used.

The 1975 edition was a reconfirmation of the 1970 edition with editorial changes.

The 1980 edition included a clarified statement regarding the presence of and levels of radiation; cautionary statements about the assumption of risks by the fire officer and the importance of training in the handling of radioactive materials by fire department personnel; a clarification concerning the variations of the intensity of a radiation field; and a restyling of the document to conform with the NFPA *Manual of Style*.

The 1985 edition revised and updated previous material for clarification in recognition of technology and terminology changes.

The 1991 edition was a total revision of the document and included a complete reorganization of the chapters. This was done to provide an update of the latest technology and to improve the document's user friendliness.

This latest 1995 edition includes a variety of updates necessary to convert the document from a recommended practice to a standard. One of the more noteworthy changes is a revised scope statement to recognize a threshold value with respect to the amount of radioactive materials that are stored, handled, or used.

Technical Committee on Atomic Energy

Walter W. Maybee, *Chair*
Los Alamos Nat'l Laboratories, NM

Wayne D. Holmes, *Secretary*
HSB Professional Loss Control Inc., PA

Mario A. Antonetti, Gage-Babcock & Assoc. Inc., NY
William G. Boyce, U.S. Dept. of Energy, DC
Harry M. Corson, Cerberus Pyrotronics, NJ
Rep. Nat'l Electrical Mfrs. Assn.
Donald A. Diehl, Alison Control Inc., NJ
Paul H. Dobson, Factory Mutual Research Corp., MA
Stewart M. Fastman, American Insurance Services Group Inc., NY
Paul Giaccaglia, American Nuclear Insurers, CT
Arie T. P. Go, Bechtel Corp., CA
Leonard R. Hathaway, M&M Protection Consultants, IL
LeRoy J. Hill, McDermott Inc., VA
L. S. Homa, Underwriters Laboratories Inc., IL
Jacob B. Klevan, Rolf Jensen & Assoc. Inc., VA
Thomas J. Kramer, Schirmer Engineering Corp., IL
Robert S. Levine, Nat'l Inst. of Standards & Technology, MD
Patrick M. Madden, U.S. Nuclear Regulatory Commission, DC
Anthony J. Mascena, Stone & Webster Engr Corp., NJ
Brian J. Meacham, FireTech, Switzerland
David P. Notley, Science Applications Int'l Corp. (SAIC), VA
Robert J. O'Laughlin, Knoxville, TN
Chandrakant A. Oza, General Electric Co., CA
Mark Henry Salley, Tennessee Valley Authority, TN
Jack Siegel, Ebasco, NY
Clifford R. Sinopoli, Baltimore Gas & Electric, MD
Rep. Electric Light Power Group/Edison Electric Inst.
Wayne R. Sohlman, Nuclear Mutual Ltd, DE
Rupert M. H. Terrier, Virginia Electric & Power Co., VA
Lynn K. Underwood, Wausau Insurance Cos., WI
Rep. The Alliance of American Insurers
Steven F. Vieira, Grinnel Fire Protection Systems Co., RI
Rep. Nat'l Fire Sprinkler Assn.
Michael J. Vitacco, Westinghouse Savannah River Co., SC

Alternates

Daniel L. Arnold, Rolf Jensen & Assoc., GA
(Alt. to J. B. Klevan)
Ingemar B. Asp, Gage-Babcock & Assoc. Inc., NY
(Alt. to M. A. Antonetti)
James B. Biggins, M&M Protection Consultants, IL
(Alt. to L. R. Hathaway)
Warren D. Bonisch, Schirmer Engr Corp., VA
(Alt. to T. J. Kramer)
Dennis Eaves, American Nuclear Insurers, CT
(Alt. to P. Giaccaglia)
L. Paul Herman, HSB Professional Loss Control, Inc., IL
(Alt. to W. D. Holmes)
Neal W. Krantz, Simplex, MI
(Alt. to H. M. Corson)
Jimmy J. Pierce, Tennessee Valley Authority, TN
(Alt. to M. H. Salley)
Thomas A. Storey, Science Applications Int'l Corp. (SAIC), VA
(Alt. to D. P. Notley)
Robert W. Strong, General Electric Co., CA
(Alt. to C. A. Oza)
Brian D. Tomes, Wausau Insurance Cos., TX
(Alt. to L. K. Underwood)

Nonvoting

Donald J. Keigher, Los Alamos, NM
(Member Emeritus)

Casey C. Grant, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the safeguarding of life and property from fires in which radiation or other effects of nuclear energy might be a factor.

Contents

NFPA 801

Standard for

Facilities Handling Radioactive Materials

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 6 and Appendix C.

Chapter 1 Introduction

1-1 Scope.

1-1.1* This standard addresses fire protection requirements intended to reduce the risk of fires and explosions at facilities handling radioactive materials. These requirements are applicable to all locations where radioactive materials are stored, handled, or used in quantities and conditions requiring a U.S. Nuclear Regulatory Commission license to possess or use these materials or in equal quantities or conditions at other locations.

1-1.2 This standard shall not apply to research or power reactors that are covered by NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors*, and NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*.

1-2* Purpose. This standard provides requirements for personnel responsible for the design or operation of facilities that involve the storage, handling, or use of radioactive materials.

1-3 Alternative Methods.

1-3.1 Nothing in this standard is intended to prevent or discourage the use of alternative methods, practices, or devices, provided that sufficient technical data are submitted to the authority having jurisdiction to demonstrate that the alternative method, material, practice, or device is equivalent to or superior to the requirements of this standard.

1-3.2 It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of the applicable design. In such cases, the designer shall be responsible for demonstrating the validity of the approach. This standard does not do away with the need for competent engineering judgment and is not intended as a design handbook.

1-4 Retroactivity.

1-4.1 The provisions of this standard shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire or explosion. They reflect situations and the state of the art at the time the standard was issued.

1-4.2 Unless otherwise noted, the provisions of this standard shall not be applied retroactively, except in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or adjacent property.

1-5 Definitions.

Alpha Particle. A positively charged particle emitted by certain radioactive materials, identical to the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material, as it is stopped by a sheet of paper. It is not dangerous to plants, animals, or people unless the alpha-emitting substance has entered the body.

Approved. Acceptable to the authority having jurisdiction.

NOTE: The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Beta Particle. An elementary particle emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to 1/1,837 that of a proton. A negatively charged beta particle is identical to an electron, and a positively charged beta particle is called a positron. Beta radiation can cause skin burns, and beta-emitters are harmful if they enter the body. However, beta particles are easily stopped by a thin sheet of metal.

Canyon. An enclosure beside or above a series of hot cells for the purpose of servicing the hot cells.

Cave. A small hot cell intended for a specific purpose and limited equipment.

Combustible.* Any material that, in the form in which it is used and under the conditions anticipated, will ignite and burn. A material that does not meet the definition of noncombustible or limited-combustible.

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C).

NOTE: See NFPA 30, *Flammable and Combustible Liquids Code*.

Criticality. The state of sustaining a chain reaction, as in a nuclear reactor.

Criticality Incident. An accidental, self-sustained nuclear fission chain reaction.

Decontamination. The removal of unwanted radioactive substances from personnel, rooms, building surfaces, equipment, etc., to render the affected area safe.

Fire Area. That portion of a building or facility that is separated from other areas by fire barriers.

Fire Barrier. A fire barrier is a continuous membrane, either vertical or horizontal, such as a wall or floor assembly, that is designed and constructed with a specified fire resistance rating to limit the spread of fire and that will also restrict the movement of smoke. Such barriers might have protected openings.

Fire Brigade. As used in this standard, refers to those facility personnel trained in plant fire-fighting operations.

Fire Door. A door assembly rated in accordance with NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, and installed in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*.

Fire Hazards Analysis. A comprehensive assessment of the potential for a fire at any location to ensure that the possibility of injury to people or damage to buildings, equipment, or the environment is within acceptable limits.

Fire Prevention. Measures directed toward avoiding the inception of fire.

Fire Protection. Methods of providing for fire control or fire extinguishment.

Fire Resistance Rating. The time, in minutes or hours, that materials or assemblies have withstood a fire exposure as established in accordance with the test procedures of NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*.

Fire Risk Analysis. An analysis to quantify the fire risk by determining the probability of a fire and to evaluate the probability of resultant injury to people or damage to buildings or equipment.

Fire Zone. Subdivisions of fire areas in which fire detection or suppression systems provide alarm information indicating the location of fire at a central fire control center.

Flame Spread Rating. A relative measurement of the surface burning characteristics of building materials when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

Flammable Liquid. Any liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psi (276 kPa) absolute pressure at 100°F (37.8°C).

Gamma Rays. High-energy, short-wavelength electromagnetic radiation. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded against by dense material, such as depleted uranium, lead, water, concrete, or iron.

Glove Box. A sealed enclosure in which items inside the box are handled exclusively using long rubber or neoprene gloves sealed to ports in the walls of the enclosure. The operator places hands and forearms into the gloves from the room side of the box in order to maintain physical separation from the glove box environment while retaining the ability to manipulate items inside the box with relative freedom while viewing the operation through a window.

Hot Cell. A heavily shielded enclosure in which radioactive material can be handled safely by persons working from outside the shield using remote tools and manipulators while viewing the work through special leaded glass or liquid-filled windows or through optical devices.

Isotope. Any of two or more forms of an element having the same atomic number and similar chemical properties but differing in mass number and radioactive behavior.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Limited-Combustible.* A building construction material that, in the form in which it is used, has a potential heat value not exceeding 3,500 Btu/lb (8,141 kJ/kg) and has either a structural base of noncombustible material with a surfacing not exceeding 1/8 in. (3.2 mm) that has a flame spread rating not greater than 50, or other material having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion, even on surfaces exposed by cutting through the material on any plane.

NOTE: See NFPA 220, *Standard on Types of Building Construction*.

Listed. Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Noncombustible.* A material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors, when subjected to fire or heat. Materials that are reported as passing ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, shall be considered noncombustible materials.

Radiation. The emission and propagation of energy through matter or space by means of electromagnetic disturbances that display both wave-like and particle-like behavior. The term includes streams of fast-moving particles, such as alpha and beta particles, free neutrons, and cosmic radiation. Nuclear radiation is that emitted from atomic nuclei in various nuclear reactions including alpha, beta, and gamma radiation and neutrons.

Radiation Area. An area accessible to personnel in which there exists radiation, originating in whole or in part within radioactive material, at such levels that a major portion of the body could receive a dose in excess of 5 millirems during any single hour or a dose in excess of 100 millirems during any five consecutive days.

Radioactivity. The spontaneous decay or disintegration of an unstable atomic nucleus accompanied by the emission of radiation.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Standard. A document that contains only mandatory provisions using the word "shall" to indicate requirements. Explanatory material may be included only in the form of fine-print notes, in footnotes, or in an appendix.

1-6 Units. Metric units in this document are in accordance with the International System of Units, which is abbreviated officially as "SI" in all languages.

NOTE: For a full explanation, see ASTM E380, *Standard Practice for Use of the International System of Units.*

Chapter 2 Administrative Controls

2-1 General.

2-1.1* The intent of this chapter shall be met by incorporating the provisions of this chapter in facility operating procedures or as otherwise determined by management.

2-1.2 Administrative controls for changes in processes or equipment shall be developed to include fire protection concerns.

2-1.3 The administrative controls for facilities shall be reviewed and updated periodically.

2-2* Management Policy and Direction. Corporate management shall establish policies and institute a program to promote life safety, the conservation of property, and the continuity of operations through provisions of fire prevention and fire protection measures at each facility.

2-3* Fire Hazards Analysis.

2-3.1 A documented fire hazards analysis shall be initiated early in the design process or when configuration changes are made to ensure that the fire prevention and fire protection requirements of this standard have been evaluated. This evaluation shall consider the facility's specific design, layout, and anticipated operating needs. The evaluation shall consider acceptable means for separation or control of hazards, the control or elimination of ignition sources, and the suppression of fires. (*See Chapter 3.*)

2-3.2* For existing facilities, a documented fire hazards analysis shall be performed for all areas of the facility.

2-4 Fire Prevention Program. A written fire prevention program shall be established and shall include the following:

(a) Fire safety information for all employees and contractors, including familiarization with fire prevention procedures, emergency alarms and procedures, and procedures for reporting a fire;

(b) Documented facility inspections conducted at least monthly, including provisions for remedial action to correct conditions that increase fire hazards;

(c) A description of the general housekeeping practices and the control of transient combustibles;

(d) Control of flammable and combustible liquids and gases in accordance with the applicable documents referenced in Chapter 5;

(e) Control of ignition sources, including, but not limited to, grinding, welding, and cutting;

NOTE: See NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes.*

(f)* Fire reports, including an investigation and a statement on the corrective action to be taken; and

NOTE: See NFPA 901, *Uniform Coding for Fire Protection.*

(g) The restriction of smoking to properly designated and supervised areas of the facility.

2-5 Testing, Inspection, and Maintenance.

2-5.1 Upon installation, all fire protection systems shall be inspected and tested in accordance with the applicable documents referenced in Chapter 4.

2-5.2 All fire protection systems and equipment shall be periodically inspected, tested, and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, and the applicable documents referenced in Chapter 4.

2-5.3 Testing, inspection, and maintenance shall be documented by means of written procedures, with results and follow-up actions recorded. Specific acceptance criteria shall be provided for each operation.

2-6 Impairments.

2-6.1 A written procedure shall be established to address impairments to fire protection systems and shall include the following:

(a) Identification and tracking of impaired equipment,

(b) Identification of personnel to be notified, and

(c) Determination of needed fire protection and fire prevention measures.

2-6.2 Impairments to fire protection systems shall be as short in duration as practicable. If the impairment is planned, all necessary parts and personnel shall be assembled prior to removing the protection system(s) from service. When an unplanned impairment occurs, or when a system has discharged, the repair work or fire protection system restoration shall be expedited.

2-6.3 Once repairs are completed, tests shall be conducted to ensure proper operation and restoration of full fire protection equipment capabilities. Following restoration to service, those parties previously notified of the impairment shall be advised.

2-7* Fire Emergency Plan. A written fire emergency plan shall be developed and shall include the following:

(a) Response to fire alarms and fire systems' supervisory alarms;

(b) Notification of personnel identified in the plan;

(c) Evacuation from the fire area of personnel not directly involved in fire-fighting activities;

(d)* Coordination with security forces, radiation protection personnel, and other designated personnel for the admission of public fire department and other emergency response agencies;

(e) Fire extinguishment activities, particularly those that are unique to the facility handling radioactive materials (*see Appendix B*);

NOTE: NFPA 600, *Standard on Industrial Fire Brigades*, and OSHA 1910.156, *Fire Brigades*, should be consulted for additional information.

(f) Requirements for periodic drills and exercises to verify the adequacy of the fire emergency plan, including practice sessions coordinated around previously developed valid emergency scenarios particular to the facility; and

(g) Fire prevention surveillance.

NOTE: See NFPA 601, *Standard on Guard Service in Fire Loss Prevention.*

2-8 Fire Emergency Organization.

2-8.1 A fire emergency organization shall be provided.

2-8.2 The size of the facility and its staff, the complexity of fire-fighting problems, and the availability and response time of a public fire department shall determine the composition of the fire emergency organization.

2-8.3 Fire emergency organizations shall conduct drills at least quarterly, and they shall be critiqued by competent individuals. The drill critique shall be documented, and recommendations for improvements shall be implemented. Practice sessions shall be coordinated around previously developed valid emergency scenarios particular to the facility.

Chapter 3 General Facility Design

3-1* Special Considerations. Provisions to limit contamination shall be based on the fire hazards analysis. The design of facilities handling radioactive materials shall incorporate the following:

(a) Limits on areas and equipment subject to contamination; and

(b) Design of facilities, equipment, and utilities to facilitate decontamination.

3-2 Location with Respect to Other Buildings and within Buildings.

3-2.1 Facilities having quantities of radioactive materials that might become airborne in case of fire or explosion shall not be located or segregated from other important buildings or operations.

3-2.2 Particular attention shall be given to the location of intakes and outlets of air-cleaning systems to reduce contamination potential.

3-3* Planning for Contamination Control. The facility shall be designed to provide construction that confines a potential radiation contamination incident and shall include surface finishes that are easy to clean.

3-4* Fire Area Determination. The facility shall be subdivided into separate fire areas as determined by the fire hazards analysis for the purposes of limiting the spread of fire, protecting personnel, and limiting the consequential damage to the facility. Fire areas shall be separated from each other by barriers with fire resistance commensurate with the potential fire severity.

3-5 Construction. Buildings in which radioactive materials are to be used, handled, or stored shall be fire resistive or noncombustible (Type I or Type II in accordance with NFPA 220, *Standard on Types of Building Construction*).

3-6* Openings in Fire Barriers.

3-6.1* All openings in fire barriers shall be protected consistent with the designated fire resistance rating of the barrier.

3-6.2 Fire doors and fire windows used in fire barriers shall be installed and maintained in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows.*

3-7 Shielding. Any permanent or temporary shielding materials shall be noncombustible.

Exception: Where noncombustible materials cannot be used, limited-combustible materials shall be used and appropriate fire protection measures shall be provided as determined by the fire hazards analysis.

3-8 Interior Finish.

3-8.1 Interior finish in areas processing or storing radioactive materials shall be noncombustible and, where practicable, shall be nonporous for ease of decontamination.

3-8.2 Interior finish in areas not critical to the processing of radioactive materials shall be Class A or Class B in accordance with NFPA *101®*, *Life Safety Code®*.

3-9* Heating, Ventilating, and Air Conditioning.

3-9.1 The design of the ventilation shall be in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems;* NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems;* and NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials.*

NOTE: In addition, see NFPA 204M, *Guide for Smoke and Heat Venting.*

Exception: Where shutdown of the ventilation system is not permitted, fire dampers shall not be required for ventilation duct penetrations. Alternative means of protecting against fire propagation shall be provided.

3-9.2 The ventilation system shall be arranged such that the area containing dispersible radioactive materials remains at a lower pressure than that of adjoining areas of the facility before and during any fire incident, including during and following any actuation of fire protection systems.

3-9.3 Duct work from areas containing radioactive materials passing through nonradioactive areas shall be of noncombustible construction and shall be protected from possible exposure fires by materials having an appropriate fire resistance rating as determined by the fire hazards analysis.

3-9.4 Self-cleaning filters that pass through a viscous liquid generally yield a radioactive sludge requiring disposal and, therefore, shall be avoided, if possible, in areas where radioactive materials are handled. Because of the combustible nature of the liquid, additional fire protection features shall be provided as determined by the fire hazards analysis.

3-9.5 Roughing filters, where necessary, shall be constructed of noncombustible materials.

Exception: Where combustible filters or particulates are present in the ventilation system, additional fire protection features shall be provided as determined by the fire hazards analysis.*

3-9.6 HEPA Filtration Systems.

3-9.6.1 All HEPA filtration systems shall be analyzed in the fire hazards analysis.

3-9.6.2* HEPA filtration systems with a leading surface area greater than 16 ft^2 (1.49 m^2) shall be provided with fire detection and suppression systems.

3-9.7 Smoke Control.

3-9.7.1* Fresh-air inlets shall be located to reduce the possibility of radioactive contaminants being introduced. Such inlets shall be located where it is most unlikely for radioactive contaminants to be present.

3-9.7.2 Smoke, corrosive gases, and the nonradioactive substances that might be freed by a fire shall be vented from their place of origin directly to a safe location. Radioactive materials that are released by fire shall be confined, removed from the exhaust ventilation airstream, or released under controlled conditions.

3-9.7.3 Ventilation systems designed to exhaust smoke or corrosive gases shall be evaluated to ensure that inadvertent operation or failures shall not violate the controlled areas of the facility design.

3-9.7.4 Smoke control systems shall be provided for fire areas based upon the fire hazards analysis.

NOTE: Separate smoke control systems are preferred; however, smoke ventilation can be integrated into normal ventilation systems using automatic or manually positioned dampers and motor speed control.

3-9.7.5 Smoke exhaust from areas that at any time contain radioactive substances shall not be ventilated outside the building. Smoke control systems for such areas shall be connected to treatment systems to preclude release of radioactive substances.

3-9.7.6 Enclosed stairwells shall be designed to minimize smoke infiltration during a fire.

NOTE: Stairwells serve as escape routes and fire-fighting access routes. Suitable methods of ensuring a smoke-free stairwell include pressurization of stairwells (*see NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems*) and the construction of smokeproof towers. (*See NFPA 101, Life Safety Code.*)

3-9.7.7 Where natural-convection ventilation is used, the smoke and heat ventilation shall be provided in accordance with the fire hazards analysis.

NOTE: Where mechanical ventilation is used, 300 cfm (8.5 m^3/min) is equal to 1 ft^2 (0.09 m^2) of natural-convection vent area.

3-9.7.8* The ventilation system shall be designed, located, and protected such that airborne corrosive products or contamination shall not be circulated.

3-9.7.9 The power supply and controls for mechanical ventilation systems shall be located outside the fire area served by the system or protected from fire damage.

3-9.7.10 Fire suppression systems shall be installed to protect filters that collect combustible material, unless the elimination of such protection is justified by the fire hazards analysis.

3-10 Drainage.

CAUTION: For facilities handling fissionable materials, areas where water can accumulate shall be analyzed for criticality potential.

3-10.1* Provisions shall be made in all fire areas of the facility for removal of all liquids directly to safe areas or for containment within the fire area in order to reduce the potential for flooding of equipment and adverse impact on other areas. Drainage and the prevention of equipment flooding shall be accomplished by one or more of the following:

(a) Floor drains;
(b) Floor trenches;
(c) Open doorways or other wall openings;
(d) Curbs for containing or directing drainage;
(e) Equipment pedestals; or
(f) Pits, sumps, and sump pumps.

3-10.2 Drainage Design.

3-10.2.1 The provisions for drainage in areas handling radioactive materials and in any associated drainage facilities (pits, sumps, and sump pumps) shall be sized to accommodate all of the following:

(a) The spill of the largest single container of any flammable or combustible liquids in the area;

(b) The credible volume of discharge (as determined by the fire hazards analysis) for the suppression system operating for a period 30 min where automatic suppression is provided throughout;

(c) The volume based on a manual fire-fighting flow rate of 500 gpm (1892.5 L/min) for a duration of 30 min where automatic suppression is not provided throughout, unless the fire hazards analysis demonstrates a different flow rate and duration;

(d) The contents of piping systems and containers that are subject to failure in a fire where automatic suppression is not provided throughout; and

(e) Credible environmental factors such as rain and snow where the installation is outside.

3-10.2.2 Radioactive or potentially radioactive drainage piping shall not be routed through clean areas.

3-10.3 Floor drainage from areas containing flammable or combustible liquids shall be trapped to prevent the spread of burning liquids beyond the fire area.

3-10.4 Where gaseous fire suppression systems are installed, floor drains shall be provided with adequate seals, or the fire suppression system shall be sized to compensate for the loss of fire suppression agent through the drains.

3-11 Emergency Lighting.

3-11.1 Emergency lighting shall be provided for means of egress in accordance with NFPA *101, Life Safety Code.*

3-11.2 Emergency lighting shall be provided for critical operations areas, i.e., areas where personnel might be required to operate valves, dampers, and other controls in an emergency.

3-12 Lightning Protection. Lightning protection, where required, shall be provided in accordance with NFPA 780, *Lightning Protection Code.*

3-13 Light and Power.

3-13.1* An auxiliary power system shall be available to supply power for temporary lighting, ventilation, and radiation monitoring equipment in those facilities where the radioactive materials being handled are potentially dangerous to personnel.

3-13.2* Electrical conduits leading to or from radioactively "hot" areas shall be sealed internally to prevent the spread of radioactive materials. Only utilities required for operation within radioactively "hot" areas shall enter the hot area.

3-13.3 Less hazardous dielectric fluids shall be used in place of hydrocarbon-based insulating oils for transformers and capacitors located inside buildings or where they are an exposure hazard to important facilities.

3-13.4 All electrical systems shall be installed in accordance with NFPA 70, *National Electrical Code®.*

3-14 Storage.

3-14.1 General. Chemicals, materials, and supplies shall be in separate storerooms located in areas where no work with radioactive materials is conducted.

Exception: Those quantities of chemicals, materials, and supplies needed for immediate or continuous use.

3-14.2 Storage of Radioactive Materials.

3-14.2.1 Radioactive materials shall not be stored in the same area as combustible materials. Separate or remotely located noncombustible storage facilities shall be used to store radioactive materials safely.

3-14.2.2* Special consideration shall be given to the storage of radioactive compressed gases, as their release under fire or explosion conditions can result in a severe life safety threat and loss by contamination. Storage facilities for such gases shall be designed with special consideration given to the specific characteristics of the gases.

3-14.2.3* Care shall be exercised in selecting the locations for the storage of radioactive waste material. Such material shall not be located near the fresh-air intakes to the heating, ventilation, and air conditioning systems nor the air intakes for air compressors.

Chapter 4 General Fire Protection Systems and Equipment

4-1* General Considerations.

4-1.1 A fire hazards analysis shall be conducted to determine the fire protection requirements for the facility.

4-1.2 Automatic sprinkler protection provides the best means for controlling fires and shall be provided unless the hazards analysis in Section 2-3 dictates otherwise. As determined by the fire hazards analysis, special hazards shall be provided with additional fixed protection systems.

4-1.3* For locations where fissile materials might be present that could create a potential criticality hazard, combustible materials shall be excluded. If combustible materials are unavoidably present in a quantity sufficient to constitute a fire hazard, water or another suitable extinguishing agent shall be provided for fire-fighting purposes. Fissile materials shall be arranged such that neutron moderation and reflection by water shall not present a criticality hazard.

4-2 Water Supply.

4-2.1* General.

4-2.1.1 The water supply for the permanent fire protection installation shall be based on the largest fixed fire suppression system(s) demand, including the hose stream allowance, in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

4-2.1.2 For common service water/fire protection systems, the maximum anticipated service water demand shall be added to the fire protection demand.

4-2.1.3 The fire protection water supply system shall be arranged in conformance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps;* NFPA 22, *Standard for Water Tanks for Private Fire Protection;* and NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* as applicable.

4-2.2 Where an auxiliary supply is required by the fire hazards analysis, each supply shall be capable of meeting the requirements of 4-2.1.

4-2.2.1 Where multiple fire pumps are required, the pumps shall not be subject to a common failure, electrical or mechanical, and shall be of sufficient capacity to meet the fire flow requirements determined by 4-2.1 with the largest pump out of service.

4-2.2.2* Fire pumps shall be automatic-starting with manual shutdown. The manual shutdown shall be at the pump controllers only.

NOTE: For unattended facilities, see Section 4-9.

4-2.2.3* If tanks are for dual-purpose use, they shall be arranged to provide the water supply requirements as determined by 4-2.1 for fire protection use only.

4-2.2.4* Where water tanks are used, they shall be filled from a source capable of replenishing the supply for the fire protection needs of an 8-hour period.

4-2.3 If multiple water supplies are used, each water supply shall be connected to the fire main by separate connections that are arranged and valve controlled to minimize the possibility of multiple supplies being impaired simultaneously.

4-3* Valve Supervision. All fire protection water system control valves shall be monitored under a periodic inspection program (*see Chapter 2*) and shall be supervised by one of the following methods:

(a) Electrical supervision with audible and visual signals on the main fire control panel or at another constantly attended location in accordance with NFPA 72, *National Fire Alarm Code;* or

(b) Valves locked open with keys available only to authorized personnel.

4-4 Supply Mains and Hydrants.

4-4.1 Supply mains and fire hydrants as required by the fire hazards analysis shall be installed on the facility site in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*

4-4.1.1 Where required by the fire hazards analysis, the supply mains shall be looped and of sufficient size to supply the flow requirements as determined by 4-2.1.

4-4.1.2 Indicator control valves shall be installed to provide adequate sectional control of the fire main loop to minimize protection impairments.

4-4.2 Each hydrant shall be equipped with a separate shutoff valve located on the branch connection to the supply main.

4-5 Standpipe and Hose Systems.

4-5.1 Standpipe and hose systems shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

4-5.2 Hose station location shall take into account safe egress for personnel operating hose lines.

4-5.3 Spray nozzles having shutoff capability and listed for use on electrical equipment shall be provided on hoses located in areas near energized electrical equipment.

4-6 Portable Fire Extinguishers. Suitable fire extinguishers shall be installed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.*

4-7 Fire Suppression Systems and Equipment.

4-7.1* Fire suppression systems and equipment shall be provided in all areas of a facility as determined by the fire hazards analysis. Where required, the design of the fire suppression systems shall be in accordance with the following NFPA standards:

NFPA 11, *Standard for Low-Expansion Foam*

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*

NFPA 13, *Standard for the Installation of Sprinkler Systems*

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*

NFPA 17A, *Standard for Wet Chemical Extinguishing Systems.*

4-7.2 The selection of the extinguishing agent system shall be based upon:

(a) Type of hazard;

(b) Effect of agent discharge on equipment;

(c) Health hazards;

(d) Cleanup after agent discharge;

(e) Effectiveness of agent in suppressing fire;

(f) Cost of agent, including life cycle costs;

(g) Availability of agent;

(h) Criticality safety; and

(i) Environmental impact.

4-8 Fire Signaling Systems.

4-8.1 Fire detection and automatic fixed fire suppression systems shall be equipped with local audible and visual notification appliances with annunciation on the main fire control panel or at another constantly attended location in accordance with NFPA 72, *National Fire Alarm Code.*

4-8.2 Automatic fire detectors shall be installed in accordance with NFPA 72, *National Fire Alarm Code,* and as required by the fire hazards analysis.

4-8.3 The fire signaling system for the facility communications system shall provide the following:

(a) Manual fire alarm system by which employees can report fires or other emergencies,

(b) Facility-wide alarm system by which personnel can be alerted of an emergency,

(c) Two-way communications for the facility emergency organization if determined to be required by the fire hazards analysis (*see Sections 2-3 and 2-7*), and

(d) Means to notify the public fire department.

4-9* Unattended Facilities.

4-9.1 Additional fire protection measures shall be provided if the fire hazards analysis identifies that a delayed response or lack of communications in an unattended facility can result in a major fire spread prior to the arrival of fire-fighting personnel.

4-9.2 Remote annunciation of the fire-signaling panels shall be transmitted to one or more constantly attended locations.

Chapter 5 Special Hazards in Nuclear Facilities

5-1* General.

5-1.1 Combustion and safety controls and interlocks shall be tested periodically and after major maintenance activities in accordance with the equipment manufacturer's recommendations.

5-1.2 Flammable and combustible liquids shall be stored and handled in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

5-1.3 Flammable and combustible gases shall be stored and handled in accordance with NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites;* NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites;* NFPA 54, *National Fuel Gas Code;* NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders;* and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

5-1.4 Solid and liquid oxidizing agents shall be stored and handled in accordance with NFPA 43A, *Code for the Storage of Liquid and Solid Oxidizers*.

5-1.5 Combustible metals shall be stored and handled in accordance with NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders;* NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium;* and NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*.

5-1.6 Fire protection for laboratories involved with radioactive materials shall be in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*.

5-1.7 Ovens, furnaces, and incinerators involved with radioactive materials shall be in accordance with the requirements of NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment;* NFPA 86, *Standard for Ovens and Furnaces;* NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere;* and NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*.

5-2* Hospitals. The appropriate form of fire protection for areas where radioactive materials exist in hospitals shall be based on the fire hazards analysis. Additional precautions shall be taken as required if the radioactive materials are stored or used in ways that might cause them to be more susceptible to release from their containers.

5-3 Fuel Fabrication and Fuel Reprocessing Facilities.

5-3.1 Special hazards related to the fire problems associated with fuel fabrication facilities shall be controlled by at least one of the following:

(a) Location,

(b) Safe operating procedures,

(c) Fixed protection systems,

(d) Inerting, or

(e) Any other methods acceptable to the authority having jurisdiction.

5-3.2* Flammable and Combustible Liquids and Gases.

5-3.2.1 In enclosed spaces in which combustible gas could accumulate outside of the storage vessels, piping, and utilization equipment, combustible-gas analyzers that are appropriate to the specific gas shall be installed. The analyzer shall be set to alarm at a concentration no higher than 25 percent of the lower explosive limit.

5-3.2.2 Flammable and combustible liquids in enclosed spaces in which vapors could accumulate outside of the storage vessels, piping, and utilization equipment, shall be installed with combustible-vapor analyzers appropriate for the vapors generated. The analyzer shall be set to alarm at a concentration no higher than 25 percent of the lower explosive limit.

5-3.2.3 In addition to the requirements of NFPA 30, *Flammable and Combustible Liquids Code*, for bulk storage of major combustible or flammable liquid gas piping systems, the fire hazards analysis shall consider the need for automatic shutoffs, excess flow valves, or emergency vents as required.

5-3.2.4 Safety controls and interlocks for bulk-storage, major combustible or flammable liquid gas piping systems shall be tested periodically and tested after maintenance operations.

5-3.2.5 Piping for all hazardous gas systems shall be periodically leak-tested at least annually or as required by the equipment manufacturer.

5-3.2.6 Hydraulic fluids used in presses or other hydraulic equipment shall be the synthetic, fire-resistant (low-hazard) type.

5-3.3 Solvents.

5-3.3.1* Where a flammable or combustible solvent is used, it shall be handled in a system that does not allow uncontrolled release of vapors. Approved operating controls and limits shall be established. An approved fixed system for fire extinguishing shall be installed or its absence justified to the satisfaction of the authority having jurisdiction.

5-3.3.2* Solvent distillation and recovery equipment for flammable or combustible liquids shall be isolated from areas of use by 3-hour fire barriers.

5-3.4* In order to ensure the safe operation of process evaporators, such as Plutonium Uranium Reduction and Extraction (PUREX), means shall be provided to prevent entry of excess quantities of water-soluble solvents into the evaporators.

5-3.5* Operating controls and limits for the handling of pyrophoric materials shall be established to the satisfaction of the authority having jurisdiction. A supply of an appropriate extinguishing medium shall be available in all areas where fines and cuttings of such materials are present. (*See Section 5-1.*)

5-4 Hot Cells, Glove Boxes, Hoods, and Caves.

5-4.1 All glove boxes, hoods, cells, and caves shall be provided with a means of fire detection if used in the handling of pyrophoric materials, oxidizers, or organic liquids.

5-4.2* Fire suppression shall be provided in all glove boxes, cells, hoods, and caves that might contain combustible metals or organic liquids in quantities that could cause a breach of integrity.

5-4.3 Hot Cells.

5-4.3.1 Hot cells shall be of noncombustible construction. Liquid-filled windows shall contain a noncombustible medium, such as zinc bromide solution.

5-4.3.2 Where hydraulic fluids are used in master slave manipulators, synthetic fire-resistant (low-hazard) hydraulic fluids shall be used.

5-4.3.3 Combustible concentrations inside the cells shall be kept to a minimum. Where combustibles are present, a fixed extinguishing system shall be installed in the cell. If explosive concentrations of gases or vapors are present, an inert atmosphere shall be provided, or the cell and ventilation system shall be designed to withstand pressure excursions.

5-4.3.4 Noncombustible filters shall be used, or a fire suppression system shall be provided. (*See also Section 4-7.*)

5-4.3.5 A documented daily housekeeping inspection shall be made for each hot cell.

5-4.4* Glove Boxes.

5-4.4.1 The glove box and window shall be of noncombustible construction.

5-4.4.2 The number of gloves shall be limited to the minimum necessary to perform the operations. When the gloves are not being used, they shall be tied outside the box. When the gloves are no longer needed for operations, the gloves shall be removed and glove port covers installed.

5-4.4.3 The concentration of combustibles shall be kept to a minimum. Where combustibles are present, a fire suppression system or fixed inerting system shall be provided. If fixed extinguishing systems are utilized, the internal pressurization shall be calculated in order to prevent gloves from failing or being blown off.

5-4.4.4 Fire dampers shall be provided between glove boxes that are operated in series.

5-4.4.5 Noncombustible filters shall be used, or a fire suppression system shall be provided.

5-4.4.6 A documented daily housekeeping inspection shall be made for each glove box.

Chapter 6 Referenced Publications

6-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

6-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, 1990 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1991 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*, 1994 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1993 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1992 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1992 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 43A, *Code for the Storage of Liquid and Solid Oxidizers*, 1990 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1991 edition.

NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, 1990 edition.

NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, 1994 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders*, 1993 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, 1994 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1990 edition.

NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, 1991 edition.

NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*, 1990 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, 1993 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1992 edition.

NFPA *101, Life Safety Code,* 1994 edition.

NFPA 220, *Standard on Types of Building Construction,* 1992 edition.

NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials,* 1990 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies,* 1990 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials,* 1990 edition.

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders,* 1993 edition.

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium,* 1987 edition.

NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium,* 1987 edition.

NFPA 780, *Lightning Protection Code,* 1992 edition.

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants,* 1993 edition.

6-1.2 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E136-1982, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C.*

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1.1 The objectives of this standard are to reduce personal hazards, provide protection from property damage, and minimize process interruption resulting from fire and explosion. Radioactive contamination might or might not be a factor in these risks.

A-1-2 The nature of radioactive materials is such that their involvement in fires or explosions can impede the efficiency of fire-fighting personnel, thus causing increased potential for damage by radioactive contamination.

Various types of emitted radiation are capable of causing damage to living tissue. In particular, fire conditions can cause the formation of vapors and smoke that contaminate the building of origin or neighboring buildings and outdoor areas. The fire protection engineer's main concern is to prevent the release or loss of control of these materials by fire or during fire extinguishment. This is especially important because radioactivity is not detectable by any of the human senses.

For additional requirements for light water nuclear power reactors, see NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants,* and the recommendations for research reactors described in NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors.*

A-1-5 Definitions.

Combustible. The three terms used to describe the combustibility of materials — noncombustible, limited-combustible, and combustible — have specific definitions. When attempting to classify the combustibility of a material, ensure that the definitions of all three terms are thoroughly understood.

Limited-Combustible. The three terms used to describe the combustibility of materials — noncombustible, limited-combustible, and combustible — have specific definitions. When attempting to classify the combustibility of a material, ensure that the definitions of all three terms are thoroughly understood.

Noncombustible. The three terms used to describe the combustibility of materials — noncombustible, limited combustible, and combustible — have specific definitions. When attempting to classify the combustibility of a material, ensure that the definitions of all three terms are thoroughly understood.

A-2-1.1 Chapter 2 provides criteria for the development of administrative procedures and controls necessary for the execution of fire prevention and fire protection activities and practices for facilities handling radioactive materials.

A-2-2 Proper preventive maintenance of operating equipment as well as adequate facility personnel training are important aspects of a viable fire prevention program.

A-2-3 Fire Hazards Analysis. A thorough analysis of the fire potential is necessary to incorporate adequate fire protection into the facility design. Integrated design of systems is necessary to ensure the safety of the facility and the operators from the hazards of fire and to protect property and continuity of production.

The following steps are recommended as part of the analysis procedure:

(1) Prepare a general description of the physical characteristics of the facilities that outlines the fire prevention and fire protection systems to be provided. Define the fire hazards that can exist, and state the loss-limiting criteria to be used in the design of the facility.

(2) List the codes and standards to be used for the design of the fire protection systems. Include the published standards of the National Fire Protection Association. Indicate specific sections and paragraphs.

(3) Define and describe the characteristics associated with potential fire for all areas that contain combustible materials, such as maximum fire loading, hazards of flame spread, smoke generation, toxic contaminants, and contributing fuels. Consider the use and effect of noncombustible and heat-resistant materials.

(4) List the fire protection system criteria and the criteria to be used in the basic design for such items as water supply, water distribution systems, and fire pump safety.

(5) Describe the performance criteria for the detection systems, alarm systems, automatic suppression systems, manual systems, chemical systems, and gas systems for fire detection, confinement, control, and extinguishment.

(6) Develop the design considerations for suppression systems and for smoke, heat, and flame control, combustible and explosive gas control, and toxic and contaminant control. Select the operating functions of the ventilating and exhaust systems to be used during the period of fire extinguishment and control. List the performance criteria for the fire and trouble annunciator warning systems and the auditing and reporting systems.

(7) Consider the qualifications necessary for personnel performing inspection checks and the frequency of testing needed to maintain reliable alarm, detection, and suppression systems.

(8) Use the features of building and facility arrangements and the structural design features to generally define the methods for fire prevention, fire extinguishing, fire control, and control of hazards created by fire. Fire barriers, egress, fire walls, and the isolation and containment features that should be provided for flame, heat, hot gases, smoke, and other contaminants should be carefully planned. Outline the drawings and list of equipment and devices that are needed to define the principal and auxiliary fire protection systems.

(9) Identify the dangerous and hazardous combustibles and the maximum quantities estimated to be present in the facility. Consider where these materials can be appropriately located in the facility.

(10) Review the types of potential fires, based on the expected quantities of combustible materials, their estimated severity, intensity, duration, and the hazards created. For each of the types reviewed, indicate the total time involved and the time for each step from the first alert of the fire hazard until safe control and extinguishment is accomplished. Describe in detail the facility systems, functions, and controls that will be provided and maintained during the fire emergency.

(11) Define the essential electric circuit integrity needed during fire. Evaluate the electrical and cable fire protection, the fire confinement control, and the extinguishing systems that will be needed to maintain their integrity.

(12) Carefully review and describe the control and operating room areas and the protection and extinguishing systems provided for these areas. Do not overlook the additional facilities provided for maintenance and operating personnel, such as kitchens, maintenance storage, and supply cabinets.

(13) Analyze the available forms of back-up or public fire protection that can be considered for the installation. Review the back-up fire department, equipment, number of personnel, special skills, and training needed.

(14) List and describe the installation, testing, and inspection necessary during construction of the fire protection systems that demonstrate the integrity of the systems as installed. Evaluate the operational checks, inspection, and servicing needed to maintain such integrity.

(15) Evaluate the program for training, updating, and maintaining competence of the facility fire-fighting and operating crew. Provisions should be required to maintain and upgrade the fire-fighting equipment and apparatus during facility operation.

(16) Review the qualifications for the fire protection engineer or consultant who will assist in the design and selection of equipment. This individual will also inspect and test the physical features of the completed system and develop the total fire protection program for the operating facility.

(17) Evaluate life safety, protection of critical process/safety equipment, provisions to limit contamination, potential for radioactive release, and restoration of the facility after a fire.

A-2-3.2 A fire risk analysis might also be required to be performed.

A-2-4(f) Refer to Figure A-2-4(f).

A-2-7 It is important that the responding fire brigade or public fire fighting forces be familiar with access, facility fire protection systems, emergency lighting, specific hazards, and methods of fire control.

A-2-7(d) Using information provided by a health physicist, the level of radiation risk to be assumed should be decided by the officer in charge of the fire-fighting operation, based on the knowledge and importance of the operation to be accomplished.

A-3-1 Special Considerations. The design and installation of service facilities such as light and power, heating and ventilation, storage, and waste disposal at facilities not handling radioactive materials might not present any unusual problems. The introduction of radioactive materials into a facility poses additional hazards to both personnel and property that warrant special consideration of these services. Inadequate attention to the design features of service facilities unfortunately has contributed to the extent of decontamination found to be necessary following fires and explosions. It is considered good practice to analyze the design of each service for the purpose of determining the effect the service would have upon the spread of contamination following a fire or criticality accident. An appraisal of the severity of contamination spread then can be used to determine the necessity for modifying the design of the service facility under consideration.

A-3-3 Planning for Decontamination. The extent to which decontamination might be necessary depends upon the amount of radioactive material being released, its half-life, its chemical and physical form, and the type of radiation emitted. Taking all of these factors into account, a realistic assumption should be made as to the extent of a possible contamination incident. When decontamination is necessary, it can be costly and time consuming. These factors tend to raise costs and therefore justify capital expenditures to reduce them to a minimum through good emergency planning procedures.

A-3-4 Determination of fire area boundaries should be based on consideration of the following:

(a) Types, quantities, density, and locations of combustible material and radioactive materials;

(b) Location and configuration of equipment;

(c) Consequences of losing equipment;

(d) Location of fire detection and suppression systems; and

(e) Personnel safety/exit requirements.

It is recommended that most fire barriers separating fire areas be of 3-hour fire resistance rating unless a fire hazards analysis indicates otherwise. If a fire area is defined as a detached structure, it should be separated from other structures by an appropriate distance (*see NFPA 80A, Recommended Practice for Protection of Buildings from Exterior Fire Exposures*). Fire area boundaries typically are provided as follows:

(a) To separate manufacturing areas and radioactive materials storage areas from each other and from adjacent areas;

(b) To separate control rooms, computer rooms, or combined control/computer rooms from adjacent areas. Where a control room and computer room are separated by a common wall, the wall might not be required to have a fire resistance rating;

Name of company: ____________________

Date of fire: __________ Time of fire: __________ Operating facility: __________

Under construction: ____________________

Location where fire occurred: ____________________

Description of facility, fire area, or equipment (include nameplate rating) involved: __________

____

Cause of fire, such as probable ignition source, initial contributing fuel, equipment failure causing ignition, etc:

____

____

____

Story of fire, events, and conditions preceding, during, and after the fire: __________

____

____

____

Types and approximate quantities of portable extinguishing equipment used: __________

____

____

Was fire extinguished with portable equipment only? __________ Was public fire department called? ____

Employee fire brigade at this location? __________ Qualified for incipient fires? __________

For interior structural fires? __________

Was fixed fire extinguishing equipment installed? ____________________

Specify type of fixed extinguishing system: ____________________

Automatic operation __________, manually actuated __________, or both __________

Specify type of detection devices: ____________________

Did fixed extinguishing system control __________ and/or extinguish fire? ______ or both? ______

Did detection devices and extinguishing system function properly? __________

If no, why? ____________________

____

Estimated direct damage due to fire: $__________, or, between $ __________ and $ __________

Estimated additional (consequential) loss: $ __________ Nature of additional loss: __________

____

____

Estimated time to complete repairs/replacement of damaged equipment/structure: __________

Number of persons injured: __________ Number of fatalities: __________

What corrective or preventive suggestions would you offer to others who may have similar equipment, structures, or extinguishing systems? __________

____

____

Submitted by: ____________________ Title: __________

Figure A-2-4(f) Sample fire report.

(c) To separate rooms with major concentrations of electrical equipment, such as switchgear rooms and relay rooms, from adjacent areas;

(d) To separate battery rooms from adjacent areas;

(e) To separate a maintenance shop(s) from adjacent areas;

(f) To separate the main fire pump(s) from the reserve fire pump(s), where these pumps provide the only source of water for fire protection;

(g) To separate fire pumps from adjacent areas;

(h) To separate warehouses and combustible storage areas from adjacent areas;

(i) To separate emergency generators from each other and from adjacent areas;

(j) To separate fan rooms and plenum chambers from adjacent areas; and

(k) To separate office areas from adjacent areas.

A-3-6 Penetration seals provided for electrical and mechanical openings should be listed or should meet the requirements of ASTM E814, *Fire Tests of Through-Penetration Fire Stops*, or UL 1479, *Fire Tests of Through-Penetration Fire Stops*.

A-3-6.1 Fire barriers also might be permitted to serve as radiation shields, HVAC air envelopes, or flood or watertight enclosures, and these concerns also should be taken into consideration.

A-3-9 Ventilation of a nuclear facility involves balanced air differentials between building areas, comfort ventilation, and heat removal from areas where heat is generated by equipment. This need also includes fire area isolation and smoke removal equipment, as well as equipment for filtering radioactive gases.

A-3-9.1 If plastic ducts are used, they should be listed fire retardant types and should be evaluated in the fire hazards analysis.

A-3-9.5 Exception. The use of filters of low combustibility, such as those that comply with UL 586, *Standard for Test Performance of High Efficiency Particulate, Air Filter Units*, and UL 900, *Standard for Test Performance of Air Filter Units*, is recommended. Their use reduces the likelihood of the spread of contamination by fire. In the absence of protection systems within the ducts and for the filter banks, fires in combustible filters become extremely difficult to extinguish.

A-3-9.6.2 HEPA filtration systems with a leading surface area of 16 ft^2 (1.49 m^2) or less can be provided with fire detection and suppression systems to preclude the filter media being damaged by hot gases and flames.

A-3-9.7.1 For example, fresh-air inlets should not be located near storage areas of combustible radioactive waste material that, upon ignition, could discharge radioactive combustion products that might be picked up by the ventilating system.

A-3-9.7.8 A breakdown in an air-cleaning system can be more serious if the discharged air can be drawn immediately into another system. General isolation of radiation facilities from all other facilities causes an increase in both construction and operating costs but should be undertaken if justified by a study of the possible results of a contamination incident. In order to avoid unnecessary accidents, such facilities should be located separately from those handling explosives or flammable materials.

A-3-10.1 For further information, see NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, Appendix A.

A-3-13.1 The lights, ventilation, and operation of much remote-controlled equipment are dependent upon a reliable source of electrical power. The location of transformers, switches, and control panels should be well-removed from high-activity areas to ensure that maintenance work can be done without direct exposure to radiation from such areas. The need for effective ventilation during and immediately after an emergency such as a fire is of considerable importance.

A-3-13.2 It is important that electrical equipment be selected for its ease of decontamination and early restoration to service in those areas where a contamination is considered likely.

A-3-14.2.2 Special noncombustible storage facilities located remotely from the main facility might be necessary in some cases.

A-3-14.2.3 If the products of combustion of waste materials containing long-lived and highly active radioactive materials are dispersed through heating, ventilation, and air conditioning or compressed air systems, a decontamination problem of serious magnitude could result.

A-4-1 The facilities covered in this document vary widely in terms of function and the type of operations, as well as the type and quantity of radioactive material that might be present. The intent of this section is to specify the fire protection requirements for only those fire areas (or the whole) of the facility where radioactive materials are present.

A-4-1.3 In handling fissile materials, precautions should be taken not only to protect against the normal radiation hazard but also against the criticality hazard caused by the assembly of a minimum critical mass. To avoid criticality during fire emergencies, fissile materials that have been arranged to minimize the possibility of a criticality hazard should be moved only if absolutely necessary. If it becomes necessary to move such fissile materials, it should be done under the direction of a responsible person on the staff of the facility and in batches that are below the critical mass, or the materials shall be moved in layers that minimize the possibility of a criticality occurring. Since water is a reflector and a moderator of neutrons, concern for a criticality hazard sometimes leads to the unjustified and unevaluated exclusion of fire protection water from the area where fissile materials are stored or handled. The possibility of water moderation and reflection causing a criticality accident can be calculated in advance. If, in fact, such a hazard exists, combustible material that would necessitate the use of water for fire fighting should be eliminated. In many facilities, fissile materials are stored and handled in sprinklered areas.

A-4-2.1 Water quality can present long-term problems related to fire protection water supply. Factors to be considered should include water hardness, corrosiveness, presence of micro-organisms, and other problems that are unique to the type of facility.

A-4-2.2.2 For further information, see NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

A-4-2.2.3 For further information, see NFPA 22, *Standard for Water Tanks for Private Fire Protection.*

A-4-2.2.4 The 8-hour requirement for refilling can be extended if the initial supply exceeds the recommendations of 4-2.1. It normally is preferred for the refilling operation to be accomplished on an automatic basis.

A-4-3 All fire protection water system control valves should be supervised as recommended in NFPA 26, *Recommended Practice for the Supervision of Valves Controlling Water Supplies for Fire Protection.*

A-4-7.1 For the design of closed-head foam-water sprinkler systems, see NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems.*

A-4-9 Facilities that are operated unattended or with minimal staffing present special fire protection concerns. Consideration should be given both to the delayed response time for the fire brigade or public fire-fighting personnel and to the lack of personnel available to alert others on-site to a fire condition.

A-5-1 The principal fire hazards encountered in special radiation facilities will vary with the particular occupancy. In general, the requirements of this standard apply to all facilities handling radioactive materials within the scope of the document. Special occupancy fire hazards associated with particular operations are described in this chapter along with the special fire protection methods that apply to those hazards, with the exception of hazards associated with nuclear power plants and nuclear research reactors.

A-5-2 Radioactive materials are used in hospitals for a variety of purposes, including biomedical tracers, disease therapy, and laboratory analysis. General fire protection requirements for hospitals should be in accordance with NFPA 99, *Standard for Health Care Facilities.*

Radioactive materials used in hospitals rarely constitute a fire hazard themselves. Most often, the fire hazard associated with these materials is contamination of personnel, equipment, buildings, or the environment as a result of fire damage to containers and the subsequent release of radioactive materials.

Biomedical Tracers. Radioactive solutions can be administered to a patient intravenously or orally. The movement of the solution, as traced by monitoring the radioactivity level in different parts of the body, indicates the rate of various metabolic processes or the flow rate of blood. By comparing research data on healthy individuals with that of those known to have specific diseases, a patient's condition can be diagnosed without surgery.

Disease Therapy. Radioactive solutions can be administered to a patient intravenously or orally. The solution is designed to concentrate in specific organs or diseased tissue. The irradiation of the organ or tissue by the concentrated solution can alter the functioning of the organ (such as the thyroid gland) or kill diseased tissue (such as certain cancer cells).

Laboratory Analysis. Radioactive materials in solutions of known concentration are frequently used for laboratory analysis.

A-5-3.2 Combustible gases, such as hydrogen, ethylene, propane, acetylene, and natural gas, present both fire and explosion hazards. They should be used only in accordance with operating controls and limits required by the applicable NFPA standards.

A-5-3.3.1 Where solvents are used in fuel processing, consideration should be given to using solvents with the lowest fire and explosion hazard consistent with the requirements of the process.

A-5-3.3.2 Explosion-relief panels should be provided for solvent recovery areas.

A-5-3.4 Where using nitric acid during scrap recovery, experience and experiments have confirmed that exothermic reactions of distinctive violence can occur between tributylphosphate and uranyl nitrate or between tributylphosphate and nitric acid, or both.

A-5-3.5 Fines and cuttings from materials such as zirconium constitute a pyrophoric hazard.

A-5-4.2 The preferred method of suppression is an automatic sprinkler system, although other methods of suppression also may be permitted where installed in accordance with the applicable NFPA standard.

A-5-4.4 The external radiation hazard present during fabrication of Uranium-235 fuel elements is of a low order. Uranium-233 and Plutonium-239 present severe inhalation hazards to personnel; therefore, an enclosed protection system should be required to be used. These systems are called glove boxes. They can be extensive, with an appreciable amount of glass, and can present unique fire protection problems. Under normal conditions, substantial protection can be provided against the existing radiation hazard. On the other hand, if a criticality incident should occur, the type and quantity of radiation emitted can create grave hazards to personnel. Even a small fire within a glove box can produce serious consequences if not controlled properly. Fire control systems and procedures for glove boxes should be carefully developed and implemented before the boxes are used. Generally, such protective systems are custom-designed for the specific application.

Appendix B Sources of Radiation — The Nature of the Fire Problem

B-1 General.

B-1.1 Radioactive materials are substances that spontaneously decay, emitting energetic rays or particles in the process. Certain radioactive elements occur in more than one form. The various forms are chemically identical but differ in their atomic weights and are called isotopes. Those that are radioactive are called radioactive isotopes (radioisotopes). It is possible for an element to have one or more nonradioactive (stable) isotopes and one or more radioactive isotopes (radionuclides). Each of the radioisotopes emits a definitive type or types of radiation. In discussing radioactive material, therefore, it is always necessary to use the terminology that identifies the particular isotope, such as Uranium-238 or, alternatively, 238 Uranium.

B-1.1.1 Some radioisotopes occur in nature and can be separated by various physical or chemical processes; others are produced in particle accelerators or nuclear reactors.

B-1.1.2 Emissions from radioactive materials cannot be detected directly by any of the human senses. Radioactive materials themselves present no unusual fire hazards, as their fire characteristics are no different from the fire characteristics of the nonradioactive form of the same element.

B-1.1.3 The presence of radioactive materials can complicate a fire-fighting situation by presenting hazards unknown to the fire fighter and causing real or wrongly anticipated hazards to fire fighters, which can inhibit normal fire-fighting operations. The dispersal of radioactive materials by fumes, smoke, water, or by the movement of personnel can cause a radiation contamination incident that can contribute significantly to the extent of damage, complicate cleanup and salvage operations, delay the restoration of normal operations, and affect personnel safety.

B-2 Fire Problems.

B-2.1 Facilities handling radioactive materials should be designed and operated with special recognition given to the properties of radioactive materials. The effects of the presence of radioactive substances on the extent of loss caused by fire or explosion include:

(a) Possible interference with manual fire fighting due to the fear of exposure of fire fighters to radiation.

(b) Possible increased delay in salvage work and in resumption of normal operations following fire, explosion, or other damage due to radioactive contamination and the subsequent need for decontamination of buildings, equipment, and materials.

(c) Possible increase in the total damage due to buildings and equipment contaminated beyond the point where they are usable.

B-2.2 Radioactive materials can be expected to melt, vaporize, become airborne, or oxidize under fire conditions. None of these alterations will slow or halt radioactivity. It is conceivable that certain radioactive materials under fire conditions might be converted to radioactive vapor or oxidized to a radioactive dust or smoke. This dust or smoke could be carried by air currents and subsequently deposited on other parts of the burning buildings or even on neighboring buildings or land. These aggravated loss and personal injury characteristics of radioactive materials justify a high degree of protection against fire and explosion at those facilities where these potential hazards exist. The use of least combustible building components and equipment is highly desirable in those areas where radioactive materials are to be stored or used. Some form of automatic protection, such as automatic sprinklers, is highly advantageous wherever combustibles are encountered. The installation of automatic extinguishing systems reduces the need for personnel exposure to possible danger, starts the fire control process automatically, sounds an alarm, and makes efficient use of the available water supply. However, caution should be exercised to ensure that the hazards of criticality and reactivity are considered.

B-2.3 Some commonly encountered radionuclides are pyrophoric (e.g., uranium, plutonium) and, as such, should be given special consideration. Radionuclides generate heat and might need to be cooled in storage; these also require special consideration.

B-2.4 In view of the possibility of the spread of radioactive materials during a fire, certain precautions and procedures should be incorporated into emergency planning for fire-fighting operations.

B-2.5 The property manager should keep the local fire department advised of the locations and general nature of radioactive materials available. Emergency planning is essential so that fire fighters can function at maximum efficiency without exposure to harmful radiation and without unwarranted fears of the radiation hazard that can inhibit the fire-fighting effort. Where criticality incidents or exposure to radioactive materials is possible, mutual aid arrangements should maximize the use of on-site expertise. Specific provision should be made where necessary by the property manager and the fire department for monitoring service, protective clothing, and respiratory protective equipment, the need for which should be determined by the nature of the specific hazard. The radiation hazard usually can be anticipated in emergency planning studies.

B-3 Radiation Hazards and Protection Methods.

B-3.1 Significant levels of radiation exposure can occur under emergency conditions and can cause acute injury or death. However, fire fighters should be aware that radiation exposures that are tolerable in the event of a fire or other accident, especially where rescue operations are warranted, are unacceptable on a regular basis.

B-3.2 Nature of the Hazard of Radioactivity. In order that fire-fighting personnel understand how to protect themselves against dangerous amounts of radiation effectively, it is necessary that they be familiar with the basic nature of radiation and the safeguards that generally are provided under normal operating conditions at those facilities where this hazard exists. While quite brief and simplified, the following paragraphs should assist the fire fighter in identifying those areas of concern:

(a) Radioactivity can be defined as the spontaneous emission of rays or particles during a change in an atom's nucleus. Radioactive decay is the spontaneous disintegration of a nucleus. Each radioactive isotope has a half-life — a period of time that is a characteristic of the particular isotope in which the intensity of nuclear radiation ascribable to that isotope progressively decreases by half. However, products formed by the radioactive decay of the original isotope can, in turn, be radioactive.

(b) The units for measuring the quantity of radioactivity in the source material are the curie, the millicurie (one one-thousandth curie), and the microcurie (one one-millionth curie). The term curie was originally designated as the standard for measuring the disintegration rate of radioactive substances in the radium family (expressed as 3.7×10^{10} atomic disintegrations per sec per gram of radium). It has now been adapted to all radioisotopes and refers to the amount of the isotope that has the same disintegration rate as 1 gram of radium.

Historically, the curie has been, and remains, the most commonly used unit for source strength. However, the SI unit for source strength is the becquerel. One becquerel is equal to one disintegration per sec. Hence, one curie is equal to 3.7×10^{10} becquerels.

(c) The sources of radiation likely to be encountered induce alpha particles, beta particles, gamma rays, and neutrons. The first three emit from many radioactive materials, and neutrons are likely to be present in the vicinity of nuclear reactors or accelerators only while reactors or accelerators are in operation, or they can emit from certain special neutron source materials. Neutrons, alpha particles, and beta particles are small bits of matter — smaller than an individual atom. Gamma rays (and x-rays) are electromagnetic radiations (similar to radio waves but with much shorter wavelengths).

(d) All radioactive emissions are capable of injuring living tissue. The fact that these radiations are not detectable by the senses makes them insidious, and serious injury can occur without an individual's awareness. Because of their relatively high penetrating power, gamma rays and neutrons can be a serious external hazard (i.e., potential severe danger even when from a source outside the body). Beta particles, which are less penetrating, can be somewhat of an external hazard if encountered within inches but are mainly an internal hazard; alpha particles, because of their extremely low penetrating power, are entirely an internal hazard (i.e., injure the body only if emanating from a source within the body after having entered the body by inhalation or ingestion or through a wound).

(e) These radiations are measured in roentgens, a unit representing the amount of radiation absorbed or the amount that will produce a specific effect. Radiation doses are measured in rems, a dose unit that will produce a specified effect in humans. The ultimate effect upon the human body depends on how and where the energy is expended. In industry, safeguards are provided for the purpose of keeping radiation exposure to personnel to a practical minimum and under certain amounts.

Historically, the roentgen and rem have been, and remain, the most commonly used units for radiation dosage. The current SI unit for dosage is the sievert. One sievert is equal to 100 rem. A sievert is equivalent to one joule per kilogram.

(f) In an emergency case, such as a necessary rescue operation, it is considered acceptable for the exposure to be raised within limits for single doses. The EPA 520/1-75-001, *Manual of Protective Action Guide and Protective Actions for Nuclear Incidents*, has recommended that, in a life-saving action, such as search for and removal of injured persons or entry to prevent conditions that would injure or kill numerous persons, the planned dose to the whole body should not exceed 75 rems. During circumstances that are less threatening to life, where it is still desirable to enter a hazardous area to protect facilities, to eliminate further escape of effluents, or to control fires, it is recommended that the planned dose to the whole body should not exceed 25 rems. These rules can be applied to a fire fighter for a single emergency; further exposure is not recommended. Internal radiation exposure by inhalation or ingestion can be guarded against by adequate respiratory equipment.

B-3.3 Personnel Protection Methods. Monitoring is the process of measuring the intensity of radiation associated with a person, object, or area. It is done by means of instruments that can be photographic or electronic. Instruments used by personnel for radiation detection or measurement include:

(a) Film badge — a piece of photographic film that records gamma and beta radiation

(b) Pocket dosimeter — measures gamma radiation

(c) Geiger-Muller counter — measures beta and gamma radiation

(d) Scintillation counter — measures alpha, beta, and gamma radiation

(e) Ionization chamber — measures alpha, beta, and gamma radiation

(f) Proportional counter — measures alpha radiation

(g) Gamma survey meter — measures intensity of gamma radiation

(h) TLD (Thermoluminescent Dosimeter) — a crystal chip that records beta, gamma, and neutron radiation.

B-3.3.1 Common effects of excessive (200 roentgens or more) nuclear radiation on the body include vomiting, fever, loss of hair, loss of weight, decrease in the white blood cell count, and increased susceptibility to disease. Radioactive materials absorbed into the body often tend to accumulate at a particular location (e.g., plutonium and strontium tend to collect in the bone). The radioactivity concentrated in a particular organ gradually destroys the cell tissue so that the organ is no longer capable of performing its normal function, and the entire body suffers.

B-3.3.2 Radiation injury requires prompt, highly specialized treatment. Instruments should be provided to detect radiation contamination in clothing or on the skin. There should be a routine monitoring of the degree of exposure to the various particles and rays. Personnel working in the facility will generally be required to wear pocket radiation meters or indicators that are examined periodically, and records of the exposure should be kept for future reference.

B-3.3.3 The practice of placarding dangerous areas is for the protection of both regular operating personnel and those, such as fire fighters, who might have to deal with an emergency situation. If fire fighters are to have the best protection, they should inspect the premises where there might be radiation hazards to consider during fire operations well before a fire occurs. Also, by frequent follow-up inspections, they should reach an agreement with the emergency director or other personnel directing the facilities regarding steps to be taken in case of fire.

B-3.3.4 Fire fighters who might attend fires in properties where there are hazards of radioactivity should be given special training in proper protective clothing and cleanup or decontamination of their persons, clothing, or equipment. In all cases, they should have available and be trained in the use of suitable radiation monitoring equipment or have monitoring specialists with them.

B-3.4 Protection from External Radiation. In the case of external nuclear radiation, the dosage and resulting injury to humans can be kept to a minimum in several ways:

(a) The smallest possible portion of the body only should be exposed (e.g., the hands, rather than the entire body).

(b) The time spent in the hazardous area and, therefore, the time of exposure, can be kept to a minimum by efficient organization of the work procedure.

(c) The intensity of radiation during exposure can be minimized by maintaining the greatest possible distance from the radiation source (e.g., by using long-handled tools for manipulating radioactive materials); or by the use of suitable materials interposed between the radiation source and the person to serve as a shield. Radiation intensity decreases inversely by an amount equal to the square of the distance from the source only where the source is a point source. This relationship is more complex with multiple point sources and does not apply to large sources until the distance is equal to one-half the maximum dimension of the source. Practically speaking, this could be 30 ft to 50 ft (9.1 m to 15.2 m). The cases in which a fire fighter will encounter a single point source are probably in the minority, and, therefore, the more conservative formula should be used.

B-3.5 Protection from Internal Radiation. The possibility of radioactive materials entering the body can be reduced by wearing protective face masks and clothing while in a hazardous area. These masks should fit properly and be of a type that prevents the entry into the lungs or digestive system of the particular radioactive materials encountered. Clothing should be of such type to prevent the entry of radioactive materials into the body through wounds, scratches, or skin abrasions. Eating, drinking, smoking, and chewing should be prohibited while exposed to, or while awaiting decontamination after being in, radioactive areas.

B-3.5.1 Personnel working with radioisotopes are commonly subjected to routine biomedical checks for possible ingested radioactivity. Where applicable, routine checks also are made to verify that a permissible concentration of radioactive material in the body, the air, or elsewhere has not been exceeded.

B-3.5.2 Biomedical checks are promptly conducted whenever human ingestion of dangerous quantities of radioactive materials is suspected for any reason. When fire fighters are exposed to radiation and there is any doubt as to the severity of the exposure, they should be given a biomedical examination.

B-4 Sealed and Unsealed Radioactive Materials.

B-4.1 For purposes of this standard, a "sealed" radiation source is one that is tightly encapsulated (or the practical equivalent by bonding or other means) and is not intended to be opened at the facility. An "unsealed" source is one that is not so sealed or is intended to be opened at the facility, or both.

B-4.2 The protection of properties against the spread of radioactive contamination as the result of fire or explosion is simplified considerably by the fact that many radioactive materials are shipped, stored, and, in some cases, used, without ever exposing the radioactive material itself to air. In many cases the shipping containers, or even the use containers, might have sufficient integrity to withstand a fire or an external explosion. Examples include metallic cobalt-60 sources tightly encapsulated in steel and sealed sources used in "beta gauge" thickness and measuring devices. There have been several instances of stainless steel encapsulated beta gauge sources surviving appreciable fire exposures without release of the radioactive isotope contained therein.

B-4.3 The principal reason radioactive materials are sealed is to prevent spread of contamination. In some cases, the manufacturer of the container might not thoroughly consider fire resistance, and it is important to remember that a sealed source can burst if its contents are subject to thermal expansion as a result of exposure to fire.

B-4.4 Unsealed sources, such as can be found in laboratories during their transfer and use, can be spread about readily during a fire or an explosion.

B-5 Applications.

B-5.1 The specific application for ionizing radiation is governed somewhat by the physical makeup of its source, its sealed or unsealed form, and sometimes by its radiation intensity.

B-5.2 Most of the thousands of scientific and industrial uses of radioactive materials take advantage of one or more of the types of radiations emitted, i.e., alpha, beta, gamma rays, and neutrons. Certain radioisotope applications take advantage of the ultrasensitive detection capability of certain instruments for extremely small amounts of radioisotopes. Other uses take advantage of the ability of radiation to penetrate matter, while the extremely energetic sources have the ability to bring about biological, chemical, and physical changes.

B-5.3 The most common nuclear radiation applications can be grouped into the following categories:

(a) Radioisotope "tracer" applications utilize small amounts of short-lived, unsealed sources, involving easily detectable radiation emissions of the particular radioisotope employed. Such applications have found wide use in medical diagnosis, biological and agricultural explorations, water surveys, irrigation control, underground leak and seepage detection, atmospheric pollution, flow and transport rates in processing operations, lubrication and wear measurements, rapid chemical analysis for continuous process control, and activation analysis.

(b) Radioactive gauges and process control instruments utilize the more penetrating types of radiation from sources that are sealed to prevent the radioactive material from leaking. The radioactive material in no way enters into the system or process. This includes a wide range of operations, from measuring thickness or density to monitoring height and levels in storage and process equipment.

(c) Certain of the intensive sources of radiation have the ability to ionize gases. One of the important applications is the prevention of the accumulation of static electricity on moving machinery. The ionized air affects an "atmospheric grounding" and prevents buildup of static charges (radium and polonium as low-penetrating alpha emitters have been used, along with the more penetrating beta emitter, krypton-85). These sources also are being used as activating agents with self-luminous (phosphorescent) paints and coatings for various markings, emergency lighting, and instrument panels.

(d) Radioactive materials are being employed in the development of atomic batteries (as "isotopic power fuels"). The small currents generated are utilized in low-current demand micro-circuits; also, the liberation of thermal energy during radioisotope decay is converted into useful electricity through thermoelectric couples or thermionic systems. The sources include some fission products and some of the radioactive materials obtained by neutron irradiation of special target materials.

(e) Powerful sources are used in industrial radiography and nondestructive testing of critical process equipment. The leading industrially used isotope of high-energy emission is cobalt-60, which is obtained by the activation of cobalt in a reactor.

The industrial radiographer has a choice of x-ray machines or radioisotopes. In many cases, the latter offers the most advantages. The increased availability of cobalt-60 and iridium sources has resulted in radiographic inspections becoming commonplace. Steel thicknesses from 1/2 in. to 6 in. (12.7 mm to 152 mm) can be evaluated radiographically, and many companies are now licensed to provide such examination services.

Other radioisotopes that have less energetic gamma ray emissions than cobalt-60 are coming into wider use for lighter materials such as aluminum, copper, zinc, and thin sections of steel.

(f) Powerful sources of high intensity radiation, such as cobalt-60, are used in food preservation and in radiological sterilization of pharmaceutical and medical supplies. Research and development indicate considerable promise in polymerization of plastics, vulcanization of rubber, improvement of wood properties, graft polymerization of plastics, and catalyzation of chemical reactions.

B-6 Nuclear Reactor Fuel Element Manufacture.

B-6.1 Certain radioactive nuclides are fissile. Neutrons absorbed by such nuclides emit additional neutrons plus energy, largely in the form of heat. Because more neutrons are emitted than are absorbed, a self-sustained nuclear chain reaction is possible when certain conditions are met. These conditions include a minimum quantity of fissile material (critical mass) and other factors such as shape, geometry, reflection, and moderation (or slowing of neutrons). Fissile materials used in a nuclear reactor are arranged in specific arrays using fuel elements in order to optimize conditions for fission to take place. When a nuclear chain reaction takes place where it was not intended, a criticality accident is said to have occurred.

B-6.2 In addition to the hazards of radiation and the potential for accidental criticality, fuel element manufacture often involves the use of combustible metals such as uranium and plutonium and combustible cladding material such as zirconium. The prevention of fires involving combustible metals requires special techniques. (*See NFPA 480, Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders; NFPA 481, Standard for the Production, Processing, Handling, and Storage of Titanium; and NFPA 482, Standard for the Production, Processing, Handling, and Storage of Zirconium.*)

B-6.3 It is important to remember that nuclear fuel elements are extremely valuable, and extraordinary precautions can be necessary to protect them from the effects of an otherwise inconsequential fire.

B-7 Nuclear Fuel Reprocessing.

B-7.1 Reactors generally are capable of utilizing only a very small portion of the fuel contained in their elements, and, as a result, it is economical to recover the remaining fuel by processing the so-called "spent" elements in specially designed facilities. These facilities contain large quantities of radioactive materials (fission products) extracted from spent nuclear fuel elements that were produced as by-products during nuclear fission. Processing operations usually involve large quantities of flammable or corrosive liquids, or both. Fire and explosion hazards are present, and the possibility of an accidental criticality incident, although guarded against and remote, also is present.

B-7.2 The large quantities of highly radioactive materials present necessitate massive shielding for personnel safety, and most chemical processing and maintenance operations are conducted entirely by remote controls. Fire hazards are present during the sawing and chopping of fuel elements containing combustible metals, either in the form of fuel or cladding, and in the chemical processing operation. Specially designed fire detection and control systems are used to protect these operations. Ventilating systems should be arranged to maintain their integrity under fire conditions. Such facilities handling large quantities of highly radioactive materials demand the application of a high degree of fire protection planning in all areas.

B-8 Particle Accelerators.

B-8.1 Particle accelerators include Van de Graaff generators, linear accelerators, cyclotrons, synchrotrons, betatrons, and bevatrons. These machines are used, as their name implies, to accelerate the various charged particles that compose atoms to tremendous speeds and, consequently, to high energy levels. Radiation machines furnish scientists with atomic particles in the form of a beam that can be utilized for fundamental studies of atomic structure. In addition, they furnish high-energy radiation that can be utilized for radiography, therapy, or chemical processing.

B-8.1.1 These machines emit radiation only while in operation, and attempts to extinguish a fire in the immediate vicinity of the machine should be delayed until the machine power supply can be disconnected.

B-8.1.2 Certain "target" materials become radioactive when bombarded by atomic particles, and, for this reason, monitoring equipment should be used during fire-fighting operations to estimate the radiation hazard. The usual hazard presented by particle accelerators is largely that posed by electrical equipment. There are, however, some other significant hazards. Some installations have used such hazardous materials as liquid hydrogen, or other flammable materials, in considerable quantities. Large amounts of paraffin have been used for neutron shielding purposes, and the possible presence of combustible oils used for insulating and cooling is an additional hazard.

B-8.2 Industrial applications include chemical activation, acceleration of polymerization in plastics production, and the sterilization and preservation of packaged drugs and sutures. The general fire protection and prevention measures for these machines should include the use of noncombustible or limited-combustible (Type I or Type II) construction housing, noncombustible or slow-burning (*see IEEE-383, Standard for Type of Class IE Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations*) wiring and interior finishing, and the elimination of as much other combustible material as possible (*see NFPA 220, Standard on Types of Building Construction*). Automatic sprinkler protection should be provided for areas having hazardous amounts of combustible material or equipment. Special fire protection should be provided for any high-voltage electrical equipment.

B-9 Isotope Production Facilities.

B-9.1 General. Practical methods for production of radioactive isotopes include neutron activation of naturally occurring elements in reactors, fission of fissile material in reactors and extraction of radioactive fission products, and absorption of subatomic particles by atoms exposed in reactors or particle accelerators.

B-9.2 Isotope Production in Reactors. Radioisotopes are produced in nuclear reactors by either bombardment of stable atoms with neutrons or other subatomic particles that cause transformation of the stable nucleus of the atom into an unstable or radioactive nucleus, or by separation of radioactive fission products from uranium used in the reactor.

B-9.2.1 Activation of isotopes in reactors generally is the result of the exposure of an element to a neutron flux resulting in a transmutation of the element due to neutron capture and alpha, beta, or proton decay. Fire hazards associated with reactor operations for this type of isotope production are described in NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors.*

B-9.2.2 Various radioisotopes are produced as the result of fission of uranium in reactors. These isotopes can be removed from the fuel by chemical extraction following removal of the fuel from the reactor. Fire protection for reactor operations is described in NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors.*

B-9.3 Radiation Machines. Some radioisotopes are produced by exposing stable isotopes to high-energy subatomic particles. High-velocity subatomic particles are accelerated in particle accelerators such as Van de Graaff generators, linear accelerators, cyclotrons, or synchrotrons. These machines involve high-voltage electric and magnetic fields and produce radiation only while operating. Fire hazards associated with such machines are similar to any large electrical installation.

Appendix C Referenced Publications

C-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*, 1994 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1993 edition.

NFPA 26, *Recommended Practice for the Supervision of Valves Controlling Water Supplies for Fire Protection*, 1988 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 99, *Standard for Health Care Facilities*, 1993 edition.

NFPA *101, Life Safety Code*, 1994 edition.

NFPA 204M, *Guide for Smoke and Heat Venting*, 1991 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*, 1993 edition.

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium*, 1987 edition.

NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*, 1987 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1992 edition.

NFPA 601, *Standard on Guard Service in Fire Loss Prevention*, 1992 edition.

NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors*, 1993 edition.

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, 1993 edition.

NFPA 901, *Uniform Coding for Fire Protection*, 1990 edition.

C-1.2 Other Publications.

C-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19105.

ASTM E380, *Standard Practice for Use of the International System of Units*, Rev A-89.

ASTM E814, *Fire Tests of Through-Penetration Fire Stops*, 1988 edition.

C-1.2.2 EPA Publication. Environmental Protection Agency, 401 M Street SW, Washington, DC 20460.

EPA 520/1-75-001, *Manual of Protective Action Guide and Protective Actions for Nuclear Incidents.*

C-1.2.3 IEEE Publication. Institute of Electrical and Electronics Engineers, 345 East 47 Street, New York, NY 10070.

IEEE 383, *Standard for Type of Class IE Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations*, 1974 edition.

C-1.2.4 OSHA Publication. Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Washington, DC 20210.

OSHA 1910.156, *Fire Brigades*, 1981.

C-1.2.5 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 586, *Standard for Test Performance of High Efficiency Particulate, Air Filter Units*, sixth edition.

UL 900, *Standard for Test Performance of Air Filter Units*, fifth edition.

UL 1479, *Fire Tests of Through-Penetration Fire Stops*, 1983 edition.

Appendix D Additional Publications

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

The following is a selection of additional reference materials.

The National Council on Radiation Protection and Measurement has issued a number of reports on specific radiation protection subjects. These reports are available from NCRP Publications, P.O. Box 4867, Washington, DC 20008, or from the U.S. Government Printing Office. Some applicable publications include:

NCRP 30, *Safe Handling of Radioactive Materials-NBS Handbook 92*, 1964.

NCRP 38, *Protection Against Neutron Radiation*, 1971.

NCRP 39, *Basic Radiation Protection Criteria*, 1971.

Standards of the U.S. Nuclear Regulatory Commission for protection against radiation are published in the *Code of Federal Regulations*, Part 20, Chapter 1, Title 10, available at most libraries. Revisions are printed in the Federal Register, available at subscribing libraries or by subscription from the U.S. Government Printing Office.

Nuclear Safety, a bimonthly magazine is available from the U.S. Government Printing Office. It covers many areas of interest, including general safety, accident analysis, operating experiences, and current events.

Specific requirements for facilities handling radioactive materials have been issued by the American Nuclear Insurers, Town Center, Suite 300S, 29 South Main Street, West Hartford, CT 06107-2445, and the MAERP Reinsurance Association, 1151 Boston-Providence Turnpike, Norwood, MA 02062.

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