NFPA 801

Standard for Fire Protection for Facilities Handling Radioactive Materials

2003 Edition

NFPA, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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NFPA 801

Standard for

Fire Protection for Facilities Handling Radioactive Materials

2003 Edition

This edition of NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials*, was prepared by the Technical Committee on Fire Protection for Nuclear Facilities and acted on by NFPA at its November Association Technical Meeting held November 16–20, 2002, in Atlanta, GA. It was issued by the Standards Council on January 17, 2003, with an effective date of February 6, 2003, and supersedes all previous editions.

This edition of NFPA 801 was approved as an American National Standard on January 17, 2003.

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 the document 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.

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

The 1998 edition incorporated the recommendations of NFPA 802, *Recommended Practice for Fire Protection for Nuclear Research and Production Reactors.*

The 2003 edition includes a new chapter on permanent facility shutdown and decommissioning and has been reformatted to conform to the NFPA *Manual of Style*.

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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.

This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

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.

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Fire Protection for Facilities Handling Radioactive Materials

2003 Edition

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

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, Annex D lists the complete title and edition of the source documents for both mandatory and nonmandatory extracts. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex D.

Chapter 1 Administration

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 government oversight and/or license (e.g., U.S. Nuclear Regulatory Commission or U.S. Department of Energy) to possess or use these materials and to all other locations with equal quantities or conditions.

1.1.2 This standard shall not apply to commercial power reactors that are covered by NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants*, and NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants*.

1.2 Purpose.

1.2.1* Responsibilities. This standard shall provide requirements and guidance for personnel responsible for the design, construction, operation, and regulation of facilities that involve the storage, handling, or use of radioactive materials.

1.2.2 Defense-in-Depth.

1.2.2.1 This standard shall be based on the concept of defense-in-depth.

1.2.2.2 Defense-in-depth shall be achieved when a balance of each of the following elements is provided:

(1) Preventing fires from starting
(2) Detecting fires rapidly and controlling and extinguishing promptly those fires that do occur, thereby limiting damage and consequences
(3) Providing a level of fire protection for structures, systems, and components so that a fire that is not promptly extinguished will not prevent essential facility functions from being performed

1.3* Application. These requirements shall be applicable to all locations where radioactive materials that meet the thresholds established in 10 CFR 30 are stored, handled, or used, in quantities and conditions requiring government oversight and/or license (e.g., U.S. Nuclear Regulatory Commission or U.S. Department of Energy) to possess or use these materials, and to all other locations with equal quantities or conditions.

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. 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 (AHJ) that the existing situation involves a distinct hazard to life, property, or the environment.

1.4.3 Any alteration, installation of new equipment, or change in occupancy shall meet the requirements for new construction, except where approved by the AHJ.

1.4.4 Only the altered, renovated, or modernized portion of an existing building, system, or individual component shall be required to meet the provisions of this standard that are applicable to new construction.

1.5 Equivalency.

1.5.1 Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety as alternatives to those prescribed by this standard, provided technical documentation is submitted to the AHJ to demonstrate equivalency, and the system, method, or device is approved for the intended purpose.

1.5.2 The specific requirements of this standard shall be permitted to be modified by the AHJ to allow alternative arrangements that will secure as nearly as practical the level of fire protection intended by this document.

1.5.3 In no case shall a modification afford less fire protection than that which, in the judgment of the AHJ, would be provided by compliance with the corresponding provisions contained in this standard.

1.5.4 Alternative fire protection methods accepted by the AHJ shall be considered as conforming with this standard.

1.6* Units and Formulas.

1.6.1 SI Units. Metric units of measurement in this standard shall be in accordance with the modernized metric system known as the International System of Units (SI).

1.6.2* Primary and Equivalent Values. If a value for a measurement as given in this standard is followed by an equivalent value in other units, the first stated value shall be regarded as the requirement.

1.6.3 Conversion Procedure. SI units have been converted by multiplying the quantity by the conversion factor and then rounding the result to the appropriate number of significant digits.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

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

NFPA 10, *Standard for Portable Fire Extinguishers,* 1998 edition.
NFPA 11, *Standard for Low-Expansion Foam,* 1998 edition.
NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems,* 1999 edition.
NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2000 edition.
NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 1997 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems,* 1999 edition.
NFPA 14, *Standard for the Installation of Standpipe, Private Hydrant, and Hose Systems,* 2000 edition.
NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2001 edition.
NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems,* 1999 edition.
NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 1998 edition.
NFPA 17A, *Standard for Wet Chemical Extinguishing Systems,* 1998 edition.
NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* 1999 edition.
NFPA 22, *Standard for Water Tanks for Private Fire Protection,* 1998 edition.
NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* 1995 edition.
NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2002 edition.
NFPA 30, *Flammable and Combustible Liquids Code,* 2000 edition.
NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* 2000 edition.
NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites,* 2001 edition.
NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites,* 1999 edition.
NFPA 54, *National Fuel Gas Code,* 1999 edition.
NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders,* 1998 edition.
NFPA 58, *Liquefied Petroleum Gas Code,* 2001 edition.
NFPA 70, *National Electrical Code*®, 2002 edition.
NFPA 72®, *National Fire Alarm Code*®, 1999 edition.
NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment,* 1999 edition.
NFPA 80, *Standard for Fire Doors and Fire Windows,* 1999 edition.
NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment,* 1999 edition.
NFPA 86, *Standard for Ovens and Furnaces,* 1999 edition.
NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere,* 1999 edition.
NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere,* 1999 edition.
NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* 1999 edition.
NFPA 90B, *Standard for the Installation of Warm Air Heating and Air-Conditioning Systems,* 1999 edition.
NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids,* 1999 edition.
NFPA *101*®, *Life Safety Code*®, 2000 edition.
NFPA 220, *Standard on Types of Building Construction,* 1999 edition.
NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations,* 2000 edition.
NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source,* 2000 edition.
NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials,* 2000 edition.
NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers,* 2000 edition.
NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders,* 1998 edition.
NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium,* 2000 edition.
NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium,* 1996 edition.
NFPA 600, *Standard on Industrial Fire Brigades,* 2000 edition.
NFPA 701, *Standard Methods of Fire Tests for Flame Propagation of Textiles and Films,* 1999 edition.
NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2000 edition.
NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 1997 edition.
NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants,* 2001 edition.
NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants,* 2001 edition.
NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program,* 2002 edition.
NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2000 edition.

2.3 Other Publications.

2.3.1 ASTM Publication. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 814, *Fire Tests of Through-Penetration Fire Stops,* 1994 edition.

2.3.2 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 1479, *Fire Tests of Through-Penetration Fire Stops,* 1994 edition.

2.3.3 U.S. Government Publication. U.S. Government Printing Office, Washington, DC 20402.

Title 10, Code of Federal Regulations, Part 30.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not included, common usage of the terms shall apply.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

3.2.3 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.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

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

3.2.7 Standard. A document, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

3.3 General Definitions.

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

3.3.2 Cave. See 3.3.20.1.

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

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

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

3.3.6 Fire Area. An area that is physically separated from other areas by space, barriers, walls, or other means in order to contain fire within that area.

3.3.7 Fire Barrier. A continuous vertical or horizontal construction assembly designed and constructed to limit the spread of heat and fire and to restrict the movement of smoke.

3.3.8* Fire Door. The door component of a fire door assembly.

3.3.9* Fire Emergency Organization. Personnel trained to respond to facility fire emergencies, which can include in-plant fire-fighting operations.

3.3.10 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.

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

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

3.3.13* Fire Resistance Rating. The time, in minutes or hours, that materials or assemblies have withstood a fire exposure.

3.3.14 Fire-Resistant Fluid. A listed hydraulic fluid or lubricant that is difficult to ignite due to its high fire point and autoignition temperature and that does not sustain combustion due to its low heat of combustion. [**850:**1.4]

3.3.15* Fissionable Materials. Materials that are capable of being induced to undergo nuclear fission by slow neutrons.

3.3.16* Flame Spread Rating. A relative measurement of the surface burning characteristics of building materials.

3.3.17* Gamma Rays. High-energy short-wavelength electromagnetic radiation.

3.3.18* 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.

3.3.19* Hood. An enclosure, with or without gloveports or doors, characterized by the flow of air from the room to the enclosure.

3.3.20 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.

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

3.3.21 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.

3.3.22 Liquid.

3.3.22.1* ***Combustible Liquid.*** A liquid that has a closed-cup flash point at or above 37.8°C (100°F).

3.3.22.2 ***Flammable Liquid.*** A liquid that has a closed-cup flash point that is below 37.8°C (100°F) and a maximum vapor pressure of 2068 mm Hg (40 psia) at 37.8°C (100°F).

3.3.23* 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.

3.3.24 Occupancy. The purpose for which a building or portion thereof is used or intended to be used. [**101:**3.3]

3.3.25 Particle.

3.3.25.1* ***Alpha Particle.*** A positively charged particle emitted by certain radioactive materials, identical to the nucleus of a helium atom.

3.3.25.2* ***Beta Particle.*** An elementary particle, emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to $\frac{1}{1837}$ that of a proton.

3.3.26* 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.

3.3.26.1 ***Nuclear Radiation.*** The emission from atomic nuclei in various nuclear reactions including alpha, beta, and gamma radiation and neutrons.

3.3.27 Radiation Area. An area, accessible to personnel, in which radiation exists, 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 (5×10^{-5} sievert) during any single hour or a dose in excess of 100 millirems (100×10^{-5} sievert) during any five consecutive days.

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

Chapter 4 Fire Protection Program

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

4.1.1 Administrative controls for changes in processes, equipment, or facilities shall be developed to include fire protection concerns.

4.1.2 For the life of the facility, the administrative controls for facilities shall be reviewed and maintained to reflect current conditions and updated periodically.

4.2 Fire Hazards Analysis. See Annex B, Fire Hazards Analysis.

4.2.1 A documented fire hazards analysis shall be initiated at the beginning of 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.

4.2.2 This evaluation shall consider the facility's specific design, layout, and anticipated operating needs.

4.2.3 The evaluation shall consider acceptable means for separation or control of hazards, the control or elimination of ignition sources, and the suppression of fires.

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

4.2.5 The evaluation shall consider the storage and use of radioactive materials, as their release under fire or explosion conditions can result in a severe hazard.

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

(1) Fire safety information for all employees and contractors, including familiarization with procedures for fire prevention, emergency alarm response, and reporting of fires
(2)*Documented facility inspections conducted at least monthly, including provisions for remedial action to correct conditions that increase fire hazards
(3)*A description of the general housekeeping practices and the control of transient combustibles
(4) Control of flammable and combustible liquids and gases and oxidizers in accordance with the applicable documents referenced in Section 7.1
(5)*Control of ignition sources including, but not limited to, grinding, welding, and cutting
(6)*Fire reports, including an investigation and a statement on the corrective action to be taken
(7)*Fire prevention surveillance
(8) The restriction of smoking to designated and supervised areas of the facility
(9)*Construction, demolition, and renovating activities that conform to the requirements of NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, such as the following:
   (a) Scaffolding, formworks, decking, and partitions used inside buildings shall be noncombustible or fire-retardant treated.
   (b) If wood is used, it shall be one of the following:
      i. Listed, pressure-impregnated, fire-retardant lumber
      ii. Treated with a listed fire-retardant coating
      iii. Timbers 15.2 cm × 15.2 cm (6 in. × 6 in.) or larger
   (c) Tarpaulins (fabrics) and plastic films shall be certified to conform to the weather-resistant and flame-resistant materials described in NFPA 701, *Standard Methods of Fire Tests for Flame Propagation of Textiles and Films.*

4.4 Testing, Inspection, and Maintenance.

4.4.1 Upon installation, fire protection systems and features shall be inspected and tested in accordance with the applicable documents referenced in Section 6.7.

4.4.2 Testing, inspection, and maintenance shall be documented by means of written procedures, with the results and follow-up actions recorded, and specific acceptance criteria shall be provided for each test.

4.5 Impairments.

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

(1) Identification, tagging, and tracking of impaired equipment
(2) Identification of personnel to be notified
(3) Determination of needed compensatory fire protection and fire prevention measures

4.5.2 Impairments to fire protection systems shall be managed to minimize the duration of the equipment outage.

4.5.2.1 If the impairment is planned, all necessary parts and personnel shall be assembled prior to removal of the protection system(s) from service.

4.5.2.2 When an unplanned impairment occurs, or when a system has discharged, the repair work or fire protection system restoration shall be expedited.

4.5.3 Once repairs are completed, tests shall be conducted to ensure that full fire protection equipment capabilities are restored and operational.

4.5.4 Following restoration to service, those parties previously notified of the impairment shall be advised.

4.6* Emergency Response. A written emergency response plan shall be developed and shall include the following:

(1) Response to fire alarms and fire systems supervisory signals
(2) Notification of personnel identified in the plan

(3) Evacuation from the fire area of personnel not directly involved in fire-fighting activities
(4)*Coordination with security forces, radiation protection personnel, and other designated personnel for the admission of public fire department and other emergency response agencies
(5)*Fire extinguishment activities, particularly those that are unique to the facility handling radioactive materials
(6) The effects of fire-fighting water on such areas, assuming disruption of the contents by accident or by fire hoses
(7) Requirements for training, drills, and exercises to verify the adequacy of the emergency response plan, including practice sessions coordinated around previously developed valid emergency scenarios particular to the facility

4.7 Facility Fire Emergency Organization.

4.7.1 A facility fire emergency organization in accordance with the requirements of NFPA 600, *Standard on Industrial Fire Brigades*, or NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, shall be provided.

4.7.2 The size of the facility and its staff, the complexity of fire-fighting problems, and the availability and response time of an off-site fire department shall determine the composition of the facility fire emergency organization.

4.7.3 Facility fire emergency organization training requirements and drill frequencies necessary to demonstrate proficiency shall be implemented in accordance with the emergency response plan in Section 4.6.

4.7.4 Drills shall be critiqued and documented.

4.7.5 Two-way communications for the facility fire emergency organization shall be provided if required by the Federal Housing Administration (FHA).

4.8 Pre-Fire Plans.

4.8.1* Detailed pre-fire plans for all site fire areas shall be developed for assisting the facility fire emergency organization.

4.8.2 Pre-fire plans shall be reviewed and updated to reflect the current facility conditions.

4.8.3* Pre-fire plans shall be made available to the facility fire emergency organization.

Chapter 5 General Facility Design

5.1* Special Considerations. The design of facilities handling radioactive materials shall incorporate the following:

(1) Limits on areas and equipment subject to contamination
(2) Design of facilities, equipment, and utilities to facilitate decontamination

5.2 Location with Respect to Other Buildings and Within Buildings.

5.2.1 Facilities having quantities of radioactive materials that can become airborne in the event of fire or explosion shall be segregated from other important buildings or operations.

5.2.2 Attention shall be given to the location of intakes and outlets of air-cleaning systems to reduce contamination potential.

5.3* Contamination Control.

5.3.1 Temporary containment structures shall be of noncombustible materials or flame-resistant materials described in NFPA 701, *Standard Methods of Fire Tests for Flame Propagation of Textiles and Films.*

5.3.2 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.

5.4* 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.

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

5.6 Openings in Fire Barriers.

5.6.1* Openings in fire barriers shall be protected consistent with the designated fire resistance rating of the barrier including, but not limited to, mechanical and electrical penetrations, building construction joints, and HVAC penetrations.

5.6.2 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.*

5.6.3 Penetration seals provided for electrical and mechanical openings shall be listed to meet the requirements of ASTM E 814, *Fire Tests of Through-Penetration Fire Stops*, or UL 1479, *Fire Tests of Through-Penetration Fire Stops.*

5.7 Shielding.

5.7.1 Any permanent or temporary shielding materials shall be noncombustible.

5.7.2 Where noncombustible materials cannot be used, fire protection measures shall be provided as determined by the fire hazards analysis.

5.8* Interior Finish.

5.8.1 Interior wall and ceiling finish in areas processing or storing radioactive materials shall be Class A, in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.*

5.8.2 Interior floor finish in areas processing or storing radioactive materials shall be Class I, in accordance with NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source.*

5.9* Heating, Ventilating, and Air Conditioning.

5.9.1* General.

5.9.1.1 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 Vapors, Gases, Mists, and Noncombustible Particulate Solids.*

5.9.1.2 Where shutdown of the ventilation system is not permitted, fire dampers shall not be required for ventilation duct penetrations, and an alternative means of protecting against fire propagation shall be provided.

5.9.2 Ductwork.

5.9.2.1 Ductwork 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 a fire resistance rating as determined by the fire hazards analysis.

5.9.2.2 Where the corrosive nature of the effluents conveyed precludes the use of metallic ducts, other materials listed for this application shall be permitted.

5.9.3 Filters.

5.9.3.1* Air entry filters shall have approved filter media that produce a minimum amount of smoke (UL Class I) when subjected to heat.

5.9.3.2 Roughing or prefilters, where necessary, shall be constructed of noncombustible materials.

5.9.3.3* 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.

5.9.4 High-Efficiency Particulate Air (HEPA) Filtration Systems.

5.9.4.1 All HEPA filtration systems shall be analyzed in the fire hazards analysis.

5.9.4.2 HEPA filtration systems shall be provided with fire detection when required by the fire hazards analysis.

5.9.4.3* Fixed fire suppression shall be provided when required by the fire hazards analysis.

5.9.5 Smoke Control.

5.9.5.1* Fresh-air inlets shall be located to reduce the possibility of smoke, toxic materials, or radioactive contaminants being introduced.

5.9.5.2 Fresh-air inlets shall be located where it is most unlikely for radioactive contaminants to be present.

5.9.5.3 Smoke, corrosive gases, and the nonradioactive substances that are released by a fire shall be vented from their place of origin directly to a safe location.

5.9.5.4 Radioactive materials that are released by fire shall be confined, removed from the exhaust ventilation airstream, or released under controlled conditions.

5.9.5.5* Smoke control systems shall be provided for fire areas based on the fire hazards analysis.

5.9.5.6 Smoke exhaust from areas that at any time contain radioactive substances shall not be ventilated outside the building.

5.9.5.7 Smoke control systems for such areas shall be connected to treatment systems to preclude release of radioactive substances.

5.9.5.8* Enclosed stairwells shall be designed to minimize smoke infiltration during a fire.

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

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

5.9.5.11 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.

5.9.5.12 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.

5.10 Drainage.

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

5.10.1* Drainage or containment shall be provided and accomplished by one or more of the following methods:

(1) Floor drains
(2) Floor trenches
(3) Open doorways or other wall openings
(4) Curbs for containing or directing drainage
(5) Equipment pedestals
(6) Pits, sumps, and sump pumps

5.10.2 The provisions for drainage design in areas handling radioactive materials and in any associated drainage facilities (e.g., pits, sumps, and sump pumps) shall be sized to accommodate all of the following:

(1) The spill of the largest single container of any flammable or combustible liquid used or stored in the area
(2) The credible volume of discharge (as determined by the fire hazards analysis) for the suppression system operating for a period of 30 minutes where automatic suppression is provided throughout
(3) The volume based on a manual fire-fighting flow rate of 1893 L/min (500 gpm) for a duration of 30 minutes where automatic suppression is not provided throughout, unless the fire hazards analysis demonstrates a different flow rate and duration
(4) The contents of piping systems and containers that are subject to failure in a fire where automatic suppression is not provided throughout
(5) Credible environmental factors, such as rain and snow, where the installation is outside

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

5.10.4 Where gaseous fire suppression systems are installed, floor drains shall be provided with seals, or the fire suppression system shall be sized to compensate for the loss of fire suppression agents through the drains.

5.11 Emergency Lighting.

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

5.11.2 Emergency lighting shall be provided for critical operations areas, such as areas where personnel are required to operate valves, dampers, and other controls in an emergency.

5.12 Lightning Protection. Lightning protection, where required, shall be provided in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems.*

5.13 Electrical Systems.

5.13.1* 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.

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

5.14 Storage.

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

5.14.2 Continuous Use Materials. Those quantities of chemicals, materials, and supplies needed for immediate or continuous use shall be permitted to be available for use.

5.14.3 Storage of Radioactive Materials.

5.14.3.1 Care shall be exercised in selecting the locations for the storage of radioactive material.

5.14.3.2* Consideration shall be given to the storage of radioactive compressed gases, if any, as their release under fire or explosion conditions can result in a severe life safety threat and loss by contamination.

5.14.3.3 Storage facilities for such gases shall be designed with consideration given to the specific characteristics of the gases.

5.15 Plant Control, Computer, and Telecommunications Rooms. Plant control, computer, and telecommunications rooms shall meet the applicable requirements of NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment.*

5.16 Life Safety. NFPA *101®*, *Life Safety Code®*, shall be the standard for life safety from fire in the design and operation of facilities handling radioactive materials, except where modified by this standard.

Chapter 6 General Fire Protection Systems and Equipment

6.1* General Considerations.

6.1.1* A fire hazards analysis shall be performed to determine the fire protection requirements for the facility.

6.1.2 Automatic sprinkler protection shall be provided unless the fire hazards analysis in Section 4.2 dictates otherwise.

6.1.3 As determined by the fire hazards analysis, special hazards shall be provided with additional fixed fire protection systems.

6.1.4* For locations where fissile materials might be present and could create a potential criticality hazard, combustible materials shall be excluded.

6.1.5 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.

6.1.6 Fissile materials shall be arranged such that neutron moderation and reflection by water shall not present a criticality hazard.

6.2 Water Supply.

6.2.1* General.

6.2.1.1 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.*

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

6.2.1.3 The fire protection water supply system shall be arranged in conformance with NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*; 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.

6.2.2 Water Tanks and Pumps. Where an auxiliary supply is required by the fire hazards analysis, each supply shall be capable of meeting the requirements of 6.2.1.

6.2.2.1 Where multiple fire pumps are required, the pumps shall not be subject to a common failure, electrical or mechanical, and shall have capacity to meet the fire flow requirements determined by 6.2.1 with the largest pump out of service.

6.2.2.2* Fire pumps shall be automatic-starting with manual shutdown.

6.2.2.3 The manual shutdown shall be only at the pump controllers.

6.2.2.4* If tanks are for dual-purpose use, they shall be arranged to provide the water supply requirements as determined by 6.2.1 for fire protection use only.

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

6.2.3 Multiple Water Supplies. If multiple water supplies are used, each water supply shall be connected to the fire main by a separate connection that is arranged and valve-controlled to minimize the possibility of multiple supplies being impaired simultaneously.

6.3* Valve Supervision. All fire protection water system control valves shall be monitored under a periodic inspection program *(see Chapter 4)* and shall be supervised in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*; NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*; NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*; NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*; or *NFPA 72®*, *National Fire Alarm Code®*; as applicable.

6.4 Supply Mains and Hydrants.

6.4.1 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.*

6.4.2 Where required by the fire hazards analysis, the supply mains shall be looped and sized to supply the flow requirements as determined by 6.2.1.

6.5 Standpipe and Hose Systems.

6.5.1 Standpipe and hose systems as required by the fire hazards analysis shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe, Private Hydrant, and Hose Systems*.

6.5.2 Spray nozzles having shutoff capability and listed for use on electrical equipment shall be provided on hose located in areas near energized electrical equipment.

6.6 Portable Fire Extinguishers. Fire extinguishers shall be installed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

6.7 Fire Suppression Systems and Equipment.

6.7.1* Fire suppression systems and equipment shall be provided in all areas of a facility as determined by the fire hazards analysis.

6.7.2 Where fire suppression systems are required, the design, installation, maintenance, and testing of such systems shall be in accordance with the following NFPA standards, as applicable: 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 13, *Standard for the Installation of Sprinkler Systems*; NFPA 14, *Standard for the Installation of Standpipe, Private Hydrant, and Hose Systems*; NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*; NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*; NFPA 17, *Standard for Dry Chemical Extinguishing Systems*; NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*; NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*; NFPA 750, *Standard on Water Mist Fire Protection Systems*; and NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*.

6.7.3 The selection of the extinguishing agent system shall be based upon the following:

(1) Type of hazard
(2) Effect of agent discharge on equipment
(3) Health hazards
(4) Cleanup after agent discharge
(5) Effectiveness of agent in suppressing fire
(6) Cost of agent, including life cycle costs
(7) Availability of agent
(8) Criticality safety
(9) Environmental impact

6.8 Fire Alarm Systems.

6.8.1 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®*.

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

6.8.3 The fire alarm system for the facility shall provide the following:

(1) Manual fire alarm system by which employees can report fires or other emergencies
(2) Facility-wide alarm system by which personnel can be alerted of an emergency
(3) Means to notify the off-site fire department

6.9* Unattended Facilities.

6.9.1 The fire hazards analysis shall determine the amount of fire protection necessary if it 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.

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

Chapter 7 Special Hazards in Nuclear Facilities

7.1* General.

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

7.1.2 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, *Liquefied Petroleum Gas Code*.

7.1.3 Solid and liquid oxidizing agents shall be stored and handled in accordance with NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*.

7.1.4 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*.

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

7.1.6 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*.

7.1.7 Combustion and safety controls and interlocks shall be tested after maintenance activities, and at other intervals in accordance with the equipment manufacturer's recommendations.

7.1.8* Accident Involving Fissionable Materials. Fissile materials shall be used, handled, and stored with provisions to prevent the accidental assembly of fissile material into critical masses.

7.2* Hospitals.

7.2.1 The appropriate form of fire protection for areas where radioactive materials exist in hospitals shall be based on the fire hazards analysis.

7.2.2 Precautions shall be taken, as required, if the radioactive materials are stored or used in ways that cause them to be more susceptible to release from their containers.

7.3 Uranium Enrichment, Fuel Fabrication, and Fuel Reprocessing Facilities.

7.3.1 General. Special hazards related to fire problems shall be controlled by at least one of the following:

(1) Location
(2) Safe operating procedures
(3) Fixed protection systems
(4) Inerting
(5) Any other methods acceptable to the AHJ

7.3.2* Flammable and Combustible Liquids and Gases.

7.3.2.1 In enclosed spaces in which combustible gas could accumulate outside of the storage vessels, piping, and utilization equipment, combustible-gas analyzers that are designed for the specific gas shall be installed.

7.3.2.1.1 The analyzer shall be set to alarm at a concentration no higher than 25 percent of the lower explosive limit.

7.3.2.2 Flammable and combustible liquids in enclosed spaces in which vapors have the potential to accumulate outside of the storage vessels, piping, and utilization equipment shall be installed with combustible-vapor analyzers appropriate for the vapors generated.

7.3.2.2.1 The analyzer shall be set to alarm at a concentration no higher than 25 percent of the lower explosive limit.

7.3.2.3 Safety controls and interlocks for combustible, flammable liquids and flammable gases and their associated delivery systems shall be tested on a predetermined schedule and after maintenance operations.

7.3.2.4 Hydraulic fluids used in presses or other hydraulic equipment shall be the fire-resistant fluid type.

7.3.2.5 Solvents.

7.3.2.5.1* Where a flammable or combustible solvent is used, it shall be handled in a system that does not allow uncontrolled release of vapors.

7.3.2.5.2 Approved operating controls and limits shall be established.

7.3.2.5.3 An approved fixed fire-extinguishing system shall be installed or its absence justified to the satisfaction of the AHJ.

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

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

7.3.3 Pyrophoric Materials.

7.3.3.1* Operating controls and limits for the handling of pyrophoric materials shall be established to the satisfaction of the AHJ.

7.3.3.2 A supply of an extinguishing medium shall be available in all areas where fines and cuttings of pyrophoric materials are present. *(See Section 7.1.)*

7.4 Hot Cells, Caves, Glove Boxes, and Hoods.

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

7.4.2* Fire suppression shall be provided in all cells, caves, glove boxes, and hoods that contain combustible metals or organic liquids in quantities that have the potential to cause a breach of the hot cells, glove boxes, hoods, or caves.

7.4.3 Hot Cells and Caves.

7.4.3.1 Hot cells and caves shall be of noncombustible construction.

7.4.3.2 Where hydraulic fluids are used in master slave manipulators, fire-resistant fluids shall be used.

7.4.3.3 Combustible concentrations inside the cells and caves shall be kept to a minimum.

7.4.3.4 Where combustibles are present, a fixed extinguishing system shall be installed in the cell or cave.

7.4.3.5 If explosive concentrations of gases or vapors are present, an inert atmosphere shall be provided, or the cell or cave and its ventilation system shall be designed to withstand pressure excursions.

7.4.4* Glove Boxes and Hoods.

7.4.4.1 The glove box, windows, and hoods shall be of noncombustible construction.

7.4.4.2 The number of gloves shall be limited to the minimum necessary to perform the operations.

7.4.4.3 When the gloves are not being used, they shall be tied outside the box.

7.4.4.4 When the gloves are no longer needed for operations, they shall be removed and glove port covers installed.

7.4.4.5 Doors shall remain closed when not in use.

7.4.4.6 The concentration of combustibles shall be limited to the quantity necessary to perform the immediate task.

7.4.4.7 Where combustibles are present, a fire suppression system or fixed inerting system shall be provided.

7.4.4.8 If fixed extinguishing systems are utilized, the internal pressurization shall be calculated in order to prevent gloves from failing or being blown off.

7.4.4.9* A means shall be provided to restrict the passage of flame between glove boxes and hoods that are connected.

7.4.5 Research and Production Reactors.

7.4.5.1 Reactivity control shall be capable of inserting negative reactivity to achieve and maintain subcritical conditions in the event of a fire.

7.4.5.2 Inventory and pressure control shall be capable of controlling coolant level such that fuel damage as a result of a fire is prevented.

7.4.5.3 Decay heat removal shall be capable of removing heat from the reactor core such that fuel damage as a result of fire is prevented.

7.4.5.4 Vital auxiliaries shall be capable of performing the necessary functions in the event of a fire.

7.4.5.5 Process monitoring shall be capable of providing the necessary indication in the event of a fire.

Chapter 8 Fire Protection During Permanent Facility Shutdown and Decommissioning

8.1 Application. This chapter shall apply to facilities or those portions therein that have permanently ceased operations.

8.1.1 As decommissioning progresses, the fire protection systems and features necessary to protect personnel, emergency responders, nuclear materials, and the environment shall be maintained.

8.1.2 The requirements of this chapter shall be applied in addition to the applicable requirements of NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*.

8.2 Fire Protection Program. The facility shall continue to maintain a fire protection plan as specified by Chapter 4.

8.2.1 This plan shall continue a fire protection program that supports the shutdown and decommissioning plan.

8.2.2 The fire protection plan, commensurate with the changes in fire hazards and the potential release of hazardous and radiological materials to the environment, shall establish the following:

(1) Controls governing the identification of fire hazards and the changes in fire mitigation strategies resulting from permanent shutdown and decommissioning
(2) Controls governing fire area boundaries or barriers used to isolate areas with significant hazards
(3) Controls governing the testing, maintenance, and operability of required fire protection systems and features
(4) Administrative controls governing general fire prevention activities, such as control of combustibles and ignition sources
(5) Controls governing facility features necessary for occupant life safety and personnel evacuation in the event of a fire
(6) Controls governing fire detection and notification, firefighting capabilities, and emergency response

8.3* Fire Hazards Analysis. The evaluation of fire hazards, fire risks, and the requirement of fire protection and life safety systems and features shall be documented in a fire hazards analysis. *(See Section 4.2.)*

8.4 Maintaining Fire Protection Capability. The fire protection plan and program elements shall be maintained during permanent shutdown and facility decommissioning, commensurate with the changes in fire hazards and the potential release of hazardous and radiological materials to the environment.

8.4.1* Means of Egress Features. Facility means of egress features shall be maintained consistent with the requirements for facilities under construction as required by the fire hazards analysis.

8.4.2 Water Supply.

8.4.2.1 An adequate and reliable fire protection water supply, distribution system, and fire hydrants shall be provided/maintained.

8.4.2.2 Heat shall be provided to protect the fire-fighting water supply, distribution, and delivery systems (e.g., water tanks, fire pumps, and standpipe systems).

8.4.3* Automatic Suppression Systems.

8.4.3.1 Automatic fire suppression systems (typically automatic sprinklers) required to protect personnel, emergency responders, and the environment shall be maintained as primary protection.

8.4.3.2 Heat shall be provided to prevent wet pipe systems from freezing as required by NFPA 13, *Standard for the Installation of Sprinkler Systems*.

8.4.3.3 The suppression systems for a given facility area shall not be rendered inoperable until the system is no longer relied upon to mitigate the fire hazards present as documented in the fire hazards analysis.

8.4.4 Standpipes and Hose Systems. Existing standpipe and hose systems shall remain functional to support facility shutdown and decommissioning activities as required by the fire hazards analysis.

8.4.5 Fire Detection, Alarm, and Notification.

8.4.5.1 A means for detecting a fire at or within the facility, alerting personnel to evacuate the facility, providing notification to a constantly attended location, and initiating emergency response shall be maintained during permanent shutdown and decommissioning.

8.4.5.2* Where no automatic fire detection or suppression system exists, a means for manually notifying building occupants and summoning emergency responders of a fire event shall be provided.

8.4.6 Fire Confinement.

8.4.6.1 Fire barriers shall be maintained as necessary to isolate fire hazards; aid in the ability to contain, fight, and control a fire effectively; protect personnel evacuation routes; and minimize the release of hazardous and radiological materials during the course of permanent shutdown and decommissioning.

8.4.6.2 Evaluation of fire barriers shall be documented in the fire hazards analysis.

8.4.7 Portable Fire Extinguishers. Portable fire extinguishers shall be provided in accordance with the fire hazards analysis (FHA).

8.4.8 Emergency Response. Emergency response capability as specified in Chapter 4, commensurate with the changes in fire hazards and the potential release of hazardous and radiological materials to the environment, shall be maintained during permanent shutdown and decommissioning as required by the fire hazards analysis.

8.4.9* Pre-Fire Plans.

8.4.9.1 The pre-fire plan requirements of Section 4.8 shall be maintained during permanent shutdown and decommissioning.

8.4.9.2 Revisions to the pre-fire plans shall be made when changes in occupancy, hazard, or activity occur that affect emergency response strategies.

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.1.1 These requirements are applicable to all locations where radioactive materials are stored, handled, or used in quantities and conditions requiring government oversight and/or license (e.g., U.S. Nuclear Regulatory Commission or U.S. Department of Energy) to possess or use these materials and to all other locations with equal quantities or conditions. 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.1.2.1 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. Handling of radioactive materials includes those instances where the material is contained within other containment systems for the purposes of transportation, radiation, or contamination control.

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 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants*, and NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants*.

This standard covers those requirements intended to ensure that the consequences of fire will have minimal and acceptable impact on the safety of the public, on-site personnel, and the environment; the physical integrity of facility components and property; and the continuity of operations.

A.1.3 The threshold requirements apply regardless of whether a license is issued or not.

A.1.6 For a full explanation, see ASTM E 380, *Standard Practice for Use of the International System of Units*.

A.1.6.2 A given equivalent value might be approximate.

A.3.2.1 Approved. 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 that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, 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.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations 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.

A.3.3.8 Fire Door. A fire door complies with NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, and is installed in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*.

A.3.3.9 Fire Emergency Organization. For more information, refer to NFPA 600, *Standard on Industrial Fire Brigades*, and NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*.

A.3.3.13 Fire Resistance Rating. Fire resistance ratings comply with the test procedures of NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*.

A.3.3.15 Fissionable Materials. Examples include uranium 233 and 235 and plutonium.

A.3.3.16 Flame Spread Rating. Flame spread ratings are determined by NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

A.3.3.17 Gamma Rays. 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.

A.3.3.18 Glove Box. The operator places his or her hands and forearms into the gloves from the room outside of the box in order to maintain physical separation from the glove box environment. This allows the operator to retain the ability to manipulate items inside the box with relative freedom while viewing the operation through a window.

A.3.3.19 Hood. The airflow is typically from the least contaminated area to the more contaminated area. Hoods are sometimes referred to as *sashhoods* when used as a means of introducing materials or items to a hood or glove box.

A.3.3.22.1 Combustible Liquid. See NFPA 30, *Flammable and Combustible Liquids Code*.

A.3.3.23 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. *(See* NFPA 220, *Standard on Types of Building Construction.)*

Materials that are reported as passing ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C,* are considered noncombustible materials.

A.3.3.25.1 Alpha Particle. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material, as it can be stopped by a sheet of paper. This particle is not dangerous to plants, animals, or people, unless the alpha-emitting substance has entered the body.

A.3.3.25.2 Beta Particle. 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.

A.3.3.26 Radiation. The term includes streams of fast-moving particles, such as alpha and beta particles, free neutrons, and cosmic radiation.

A.4.1 Proper preventive maintenance of operating equipment as well as adequate training of facility personnel are important aspects of a viable fire prevention program.

A.4.2.4 A fire risk evaluation should be considered to supplement the fire hazards analysis. For guidance on conducting a fire risk evaluation, refer to NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants.*

A.4.3(2) Facility inspections are intended to locate unnecessary transient combustibles, identify uncontrolled ignition sources, and detect obstructions to the means of egress.

A.4.3(3) This would include any material that, in the form in which it is used and under the conditions anticipated, will ignite and burn.

A.4.3(5) A fatality occurred when a welder's anticontamination clothing ignited. Contributing factors included untreated cotton clothing, the lack of a fire watch, and the limiting of the welder's senses by the use of a respirator and welding mask. Appropriate precautions should be taken for workers performing hot work under these conditions. *(See* NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work.)*

A.4.3(6) For further information, refer to NFPA 901, *Standard Classifications for Incident Reporting and Fire Protection Data.*

A.4.3(7) For further information, refer to NFPA 601, *Standard for Security Services in Fire Loss Prevention.*

A.4.3(9) The use of noncombustible or fire-retardant concrete formwork is especially important for large structures (e.g., reactor buildings and turbine generator pedestals) where large quantities of forms are used.

Pressure-impregnated fire-retardant lumber should be used in accordance with its listing and the manufacturer's instructions. Where exposed to the weather or moisture (e.g., concrete forms), the fire retardant used should be suitable for this exposure. Fire-retardant coatings are not acceptable on walking surfaces or surfaces subject to mechanical damage.

Use of fire-retardant paint requires special care. Inconsistent application and exposure to weather can reduce the effectiveness of fire-retardant coatings. Large timbers are occasionally used to support large pieces of equipment during storage or maintenance. The size of these timbers makes them difficult to ignite, and they do not represent an immediate fire threat.

A.4.6 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. OSHA 29 CFR 1910.38, *Employee Emergency Plans and Fire Prevention*, should be consulted for additional information.

A.4.6(4) 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 and should be based on the knowledge and importance of the operation to be accomplished.

A.4.6(5) NFPA 600, *Standard on Industrial Fire Brigades*, NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, and OSHA 29 CFR 1910.156, *Fire Brigades*, should be consulted for additional information.

A.4.8.1 Pre-fire plans should be developed with the assistance of the facility fire emergency organization. The pre-fire plans should include, but not be limited to, the following pertinent issues:

(1) Fire hazards in area
(2) Chemical hazards in area
(3) Radiation hazards
(4) Egress access
(5) Emergency lighting
(6) Fire protection systems/equipment in area
(7) Special fire-fighting instructions
(8) Ventilation systems/airflow path
(9) Utilities
(10) Special considerations on adjoining areas

A.4.8.3 Pre-fire plans should be made available to offsite fire departments as appropriate.

A.5.1 The design and installation of service facilities — such as light and power, heating, cooling, ventilation, storage, and waste disposal materials — might not present any unusual problems at facilities not handling radioactive materials; however, 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 such service facilities has contributed to the need for extensive decontamination following fires and explosions. Good practice demands detailed analysis of the design of each service for the purpose of determining its effect on 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.5.3 The extent to which decontamination might be necessary depends on 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 effective emergency planning procedures.

A.5.4 Determination of fire area boundaries should be based on consideration of the following:

(1) Types, quantities, density, and locations of combustible materials and radioactive materials
(2) Location and configuration of equipment
(3) Consequences of inoperable equipment
(4) Location of fire detection and suppression systems
(5) Personnel safety/exit requirements

It is recommended that most fire barriers separating fire areas be of three-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:

(1) To separate manufacturing areas and radioactive materials storage areas from each other and from adjacent areas
(2) 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.
(3) To separate rooms with major concentrations of electrical equipment, such as switchgear rooms and relay rooms, from adjacent areas
(4) To separate battery rooms from adjacent areas
(5) To separate a maintenance shop(s) from adjacent areas
(6) 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
(7) To separate fire pumps from adjacent areas
(8) To separate warehouses and combustible storage areas from adjacent areas
(9) To separate emergency generators from each other and from adjacent areas
(10) To separate fan rooms and plenum chambers from adjacent areas
(11) To separate office areas from adjacent areas

A.5.6.1 Fire barriers also serve as radiation shields, ventilation barriers, and flood or watertight enclosures; these concerns also should be taken into consideration.

A.5.8 *Limited-combustible* is defined as follows: A material not complying with the definition of noncombustible material that, in the form in which it is used, has a potential heat value not exceeding 8141 kJ/kg (3500 Btu/lb) where tested in accordance with NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, and complies with (1) or (2): (1) Materials having a structural base of noncombustible material, with a surfacing not exceeding a thickness of 3.2 mm (⅛ in.) that have a flame spread index not greater than 50; (2) materials, in the form and thickness used, other than described in (1), having neither a flame spread index greater than 25 nor evidence of continued progressive combustion and of such composition that surfaces that would be exposed by cutting through the material on any plane would have neither a flame spread index greater than 25 nor evidence of continued progressive combustion. (Materials subject to increase in combustibility or flame spread index beyond the limits herein established through the effects of age, moisture, or other atmospheric condition are considered combustible.)

A.5.9 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 for ventilation also includes fire area isolation and smoke removal equipment, as well as equipment for filtering radioactive gases.

A.5.9.1 In addition, see NFPA 204, *Standard for Smoke and Heat Venting*.

A.5.9.3.1 Self-cleaning filters that pass through a viscous liquid generally yield a radioactive sludge requiring disposal and, therefore, should be avoided in areas where radioactive materials are handled. Because of the combustible nature of the liquid, additional fire protection features should be provided as determined by the fire hazards analysis.

A.5.9.3.3 This would include any material that in the form in which it is used and under the conditions anticipated, will ignite and burn.

A.5.9.4.3 Where the detection system activates a suppression system, the selection of the detectors should minimize false actuations.

A.5.9.5.1 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 transported by the ventilating system.

A.5.9.5.5 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.

A.5.9.5.8 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®)*.

A.5.9.5.9 Where mechanical ventilation is used, 8.5 m^3/min (300 ft^3/min) is equal to 0.09 m^2 (1 ft^2) of natural-convection vent area.

A.5.9.5.10 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 facilities handling explosives or flammable materials.

A.5.10.1 For further information, see NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, Annex A.

A.5.13.1 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 both during and immediately following an emergency such as a fire is of considerable importance.

A.5.13.2 Electrical circuits and components in reactor facilities present the same type of fire protection problems as in other industrial facilities. The prime concern in the reactor facility is directed toward those circuits and components essential to continued operation of the reactor and particularly to those essential to a safe shutdown under emergency conditions. For these reasons, special care is devoted to redundancy of systems, emergency power supplies, separation, physical protection, and reliability.

A.5.14.3.2 Special noncombustible storage facilities remotely located from the main facility might be necessary.

A.6.1 The facilities covered in this document vary widely in terms of function and 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.6.1.1 Automatic sprinkler protection provides the best means for controlling fires and should be provided unless the fire hazards analysis in Section 4.2 dictates otherwise. As determined by the fire hazards analysis, special hazards should be provided with additional fixed fire protection systems.

A.6.1.4 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 should be moved in layers that minimize the possibility of a criticality occurring.

A.6.2.1 Water quality can present a long-term problem to fire protection water supplies. Factors to be considered should include water hardness, corrosiveness, presence of microorganisms, and other problems that are unique to the type of facility.

A.6.2.2.2 For further information, see NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*. For unattended facilities, see Section 6.9 of this document.

A.6.2.2.4 For further information, see NFPA 22, *Standard for Water Tanks for Private Fire Protection*.

A.6.2.2.5 The eight-hour requirement for refilling can be extended if the initial supply exceeds the recommendations of 6.2.1. The preferred method for the refilling operation is automatic.

A.6.3 All fire protection water system control valves should be supervised.

A.6.7.1 For the design of closed-head foam-water sprinkler systems, see NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*.

A.6.9 Facilities that operate 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.7.1 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 Chapter 8, along with the special fire protection methods that apply to those hazards, with the exception of hazards associated with nuclear power plants.

A.7.1.8 Since water is a reflector and moderator of neutrons, it is theoretically possible that an arrangement of subcritical fissionable material could be made critical by the introduction of water. Storage containers, shelving, and storerooms are required to be designed to prevent the accidental assembly of a critical mass. In many cases, the areas are designed to be critically safe even when completely submerged in water. Emergency planning should include the effects of fire-fighting water on critically safe areas, assuming disruption of the contents by the accident or by fire hoses. If manual fire fighting poses a potential hazard under the worst conditions, then it is essential that any required fire-extinguishing capability be self-contained and automatic in operation.

Experience to date has shown that such reactions have been self-limiting but do result in minor distribution of radioactive products over the immediate area accompanied by a brief, very intense burst of nuclear radiation that could be lethal.

A.7.2 *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 are radioactive solutions that 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 uses radioactive solutions that 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).

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

A.7.3.2 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.7.3.2.5.1 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.7.3.2.5.4 Explosion-relief panels should be provided for solvent recovery areas.

A.7.3.2.5.5 Experience and experiments have confirmed that using nitric acid during scrap recovery can result in exothermic reactions of distinctive violence between tributylphosphate and uranyl nitrate, between tributylphosphate and nitric acid, or both.

A.7.3.3.1 Fines and cuttings from materials, such as zirconium, constitute a pyrophoric hazard.

A.7.4.2 The preferred method of suppression is an automatic sprinkler system, although other methods of suppression can also be permitted when installed in accordance with the applicable NFPA standard.

A.7.4.4 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. 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.

A.7.4.4.9 To restrict the passage of flame fire dampers, inerting or fixed fire suppression should be provided.

A.8.3 Fire protection and life safety systems deemed no longer necessary during permanent shutdown and/or decommissioning of the facility should be justified and documented in the fire hazards analysis. Fire hazards within these facilities during this portion of their life cycle may change over time. Fire protection and life safety systems and features must be adequate to deal with these changes. The fire hazards analysis should be reviewed and revised when appropriate if significant changes in occupancy, hazard, or activity occur that affect fire safety.

A.8.4.1 Locked and abandoned facilities where there is no human occupancy need not maintain emergency means of egress features. Changing facility configurations during the course of permanent shutdown and decommissioning should consider the impact on emergency lighting, exit marking, and evacuation alarm requirements.

A.8.4.3 The decision to deactivate automatic fire suppression systems in large facilities must reflect the possibility that the responding fire brigade or department might not be able to enter the facility safely to initiate or maintain manual fire suppression efforts. Disabled or deactivated fire suppression systems or features might be abandoned in place until they can be dismantled as part of the facility demolition activities.

All retained interior fire protection systems and features should be maintained operational to the maximum extent possible during the course of interior decommissioning activities. Temporary deactivation of fire protection systems and features to facilitate decommissioning activities should be treated as an impairment, with appropriate interim compensatory measures implemented until the fire protection feature is returned to service.

A.8.4.5.2 This capability might consist of an exterior fire alarm pull station or call box reporting to a constantly attended location, telephone, radio, or some combination of these based on the accessibility of the devices to personnel and their reliability. This capability should be justified and documented in the fire hazards analysis.

A.8.4.9 Nuclear facilities that are permanently shut down, abandoned, and/or undergoing decommissioning should be routinely inspected and reviewed by representatives of the emergency response organization(s) and fire protection engineering staff, consistent with established operating procedures. Reviews by emergency response organizations should be conducted for the purposes of facility familiarization and revalidation of the pre-fire plans. Drills and training exercises should also be conducted at these facilities at a frequency commensurate with the fire risks and complexity of the facility.

Annex B Fire Hazards Analysis

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

B.1 General. A thorough analysis of the fire potential is necessary in order 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 NFPA. 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) 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 planned care-

fully. Outline the drawings and list of equipment and devices that are needed to define the principal and auxiliary fire protection systems.

(8) Identify the dangerous and hazardous combustibles and the maximum quantities estimated to be present in the facility. Consider where these materials can be located appropriately in the facility.
(9) Based on the expected quantities of combustible materials, review the types of potential fires, their estimated severity, intensity, duration, and the potential hazards created. For each fire scenario reviewed, indicate the total time from the first alert of the fire hazard until safe control and extinguishment are accomplished. Describe in detail the facility systems, functions, and controls that will be provided and maintained during the fire emergency.

    Use of fire-retardant paint requires special care. Inconsistent application and exposure to weather can reduce the effectiveness of fire-retardant coatings. Large timbers are occasionally used to support large pieces of equipment during storage or maintenance. The size of these timbers makes them difficult to ignite, and they do not represent an immediate fire threat.
(10) Define the essential electric circuit integrity needed during fire. Evaluate the electrical and cable fire protection, the fire confinement control, and the fire extinguishing systems that will be needed to maintain their integrity.
(11) 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.
(12) Analyze the available forms of backup or public fire protection that can be considered for the installation. Review the backup fire department, equipment, number of personnel, special skills, and training needed.
(13) Evaluate the inspection, testing, and maintenance needed to maintain the fire protection system's integrity, considering the effects of radiation.
(14) 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.

Annex C Sources of Radiation — The Nature of the Fire Problem

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

C.1 General.

C.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) isotope(s) and one or more radioactive isotope(s) (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.

C.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.

C.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.

C.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 that 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.

C.2 Fire Problems.

C.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 the following:

(1) Possible interference with manual fire fighting due to the fear of exposure of fire fighters to radiation
(2) 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
(3) Possible increase in the total damage due to buildings and equipment contaminated beyond the point where they are usable

C.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 the 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.

C.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.

C.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.

C.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.

C.3 Radiation Hazards and Protection Methods.

C.3.1 General. 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.

C.3.2 Nature of the Hazard of Radioactivity. In order that fire-fighting personnel understand how to protect themselves effectively against dangerous amounts of radiation, 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.

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.

The units for measuring the quantity of radioactivity in the source material are the curie, the millicurie (one one-thousandth of a curie), and the microcurie (one one-millionth of a 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 second 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 one 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 second. Hence, 1 curie is equal to 3.7×10^{10} becquerels.

The sources of radiation likely to be encountered include alpha particles, beta particles, gamma rays, and neutrons. The first three emit from many radioactive materials. 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).

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., they pose a 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, ingestion, or through a wound).

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 on 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. One sievert is equivalent to one joule per kilogram.

In an emergency situation, such as a 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.

C.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 the following:

(1) *Film badge.* A piece of photographic film that records gamma and beta radiation
(2) *Pocket dosimeter.* Measures gamma radiation
(3) *Geiger–Müller counter.* Measures beta and gamma radiation
(4) *Scintillation counter.* Measures alpha, beta, and gamma radiation
(5) *Ionization chamber.* Measures alpha, beta, and gamma radiation

(6) *Proportional counter.* Measures alpha radiation
(7) *Gamma survey meter.* Measures intensity of gamma radiation
(8) *Thermoluminescent dosimeter (TLD).* A crystal chip that records beta, gamma, and neutron radiation

C.3.3.1 Common effects of excessive (200 roentgens or more) nuclear radiation on the body include vomiting, fever, loss of hair, weight, loss, decrease in the white blood cell count, and increased susceptibility to disease. Radioactive materials absorbed into the body often 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.

C.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 their exposure should be kept for future reference.

C.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.

C.3.3.4 Fire fighters who might be called to 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.

C.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.

(1) The smallest possible portion of the body should be exposed (e.g., the hands, rather than the entire body).
(2) 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.
(3) 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 interposing suitable materials 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 9.1 m to 15.2 m (30 ft to 50 ft). The instances 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.

C.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 particular radioactive materials encountered from entering the lungs or digestive system. Clothing should be of such type as to prevent the entry of radioactive materials into the body through wounds, scratches, or skin abrasions. While exposed to radiation or while awaiting decontamination after being in radioactive areas, personnel should be prohibited from eating, drinking, smoking, and chewing.

C.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 has not been exceeded in the body, the air, or elsewhere.

C.3.5.2 Biomedical checks are conducted promptly 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.

C.4 Sealed and Unsealed Radioactive Materials.

C.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.

C.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 to air. In many cases, the shipping containers, or even the used 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 radioisotope contained therein.

C.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.

C.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.

C.5 Applications.

C.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.

C.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: namely, alpha, beta, gamma rays, and neutrons. Particular 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.

C.5.3 The most common nuclear radiation applications can be grouped into the following categories:

(1) 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.
(2) 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 situation includes a wide range of operations, from measuring thickness or density to monitoring height and levels in storage and process equipment.
(3) Certain 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 effects 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.
(4) 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 microcircuits; 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.
(5) 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 12.7 mm to 152 mm (½ in. to 6 in.) 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.
(6) 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.

C.6 Nuclear Reactor Fuel Element Manufacture.

C.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.

C.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.*)

C.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.

C.7 Nuclear Fuel Reprocessing.

C.7.1 Reactors generally are capable of utilizing only a very small portion of the fuel contained in their elements. 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.

C.7.2 The large quantities of highly radioactive materials present necessitate massive shielding for personnel safety. 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.

C.8 Particle Accelerators.

C.8.1 Particle accelerators include Van de Graaff generators, linear accelerators, cyclotrons, synchrotrons, betatrons, and bevatrons. These machines are used, as their names imply, 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.

C.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.

C.8.1.2 Certain target materials become radioactive when bombarded by atomic particles. 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. The possible presence of combustible oils used for insulating and cooling is an additional hazard.

C.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.

C.9 Isotope Production Facilities.

C.9.1 General. Practical methods for production of radioisotopes 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.

C.9.2 Isotope Production in Reactors. Radioisotopes are produced in nuclear reactors either by 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.

C.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.

C.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.

C.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.

C.10 Research and Production Reactors.

C.10.1 Power Level. High power levels are generally associated with power and production reactors. Small units, such as some package research reactors, can pose problems due to the possibility of their being located in existing facilities or multiple occupancy buildings. While the maximum credible loss in nuclear terms can be much reduced, the fire exposure can actually be greater.

C.10.2 Coolants and Moderators. These can run the gamut from simple water systems in pool reactors to pumped water systems in boiling water reactors (BWR) or pressurized water reactors (PWR), or to circulating gas systems in high-temperature gas reactors (HTGR). Particular fire protection problems are presented by liquid metal-cooled reactors that generally use sodium systems. Particular fire protection problems can also be presented by liquid metal, fast breeder reactors, and graphite-moderated reactors.

C.10.3 Fuel. The susceptibility and quantity of the fuel material itself can be a factor. While uranium and plutonium are combustible metals, fuel elements composed of these metals generally use oxide fuels (in effect, the fuel is already burnt and, therefore, incapable of combustion), but some reactors might use other forms, such as carbide, which can be pyrophoric. Even when such forms are not subject to fire exposure, such as in a water pool reactor, the manufacture, storage, and handling of the fuel can pose fire protection problems.

C.10.4 Shielding. The nature of the shield material used for biological radiation protection varies from massive concrete to paraffin or wood/plastic compositions. Beyond the fuel contribution of some types of material, a fire burning or melting the shielding can pose a radiation exposure problem to responding emergency forces.

C.10.5 Control Systems. Reactor control systems and safety systems are of utmost importance. The control system design is fitted to the technical characteristics of the reactor and capable of producing power changes at acceptable rates. The control system design also makes it possible to produce and maintain the desired power level within the reactor in such a manner that excessive temperatures are avoided. The safety system also is adapted to the characteristics of the reactor and the instrument and control systems. It responds to signals from the instruments in such ways as to prevent, by automatic action, operational variables from exceeding safe limits. It also, on appropriate signals, warns of incipient changes in performance and, if necessary, shuts down the reactor.

C.10.5.1 Since the control system is vital to the adequate functioning and safe operation of the reactor, the protection of the control room, cableways, emergency power supply, and electrically or hydraulically operated equipment in general is of prime importance. Protection for the control room should be fully consistent with that for important computer rooms.

C.10.5.2 While comprehensive, automatic control systems are essential elements in reactor safety, the effectiveness of the total safeguards also depends on the proper execution of operating procedures that are technically sound and comprehensive.

C.10.6 Classification. There is no single system of reactor classification. A reactor is generally classified by a combination name indicating one or more of its properties such as end-use, type of coolant or moderator, fuel form, neutron speed, and so on. These are generally shortened to an acronym in common usage. Thus, we have high-temperature gas reactor (HTGR) and liquid metal, fast breeder reactor (LMFBR).

C.10.7 Hydrogen Explosions.

C.10.7.1 The intense gamma radiation to which light or heavy water is subjected causes some decomposition into hydrogen and oxygen. Sealed reactors using water for moderator or coolant, or both, are equipped with collecting chambers to prevent the accumulation of hydrogen/oxygen mixtures from occurring in the reactor or accompanying piping.

C.10.7.2 Usually the hydrogen and oxygen are recombined catalytically. In reactors, such as the swimming pool type, the rate of evolution of hydrogen is such that dissipation of the gas through openings present in a normal building — doors, crevices, and the like — will be adequate to prevent concentrations of hydrogen within the explosive range.

C.11 Open Pool Reactor (Swimming Pool Reactor).

C.11.1 Field of Use. The open pool (swimming pool) reactor is useful for research purposes and is considered versatile, economical, and relatively safe. The shielding that can be provided by the water moderator and the visibility afforded by its transparency are operating advantages.

C.11.2 Description. The reactor itself is basically an open-top tank filled with purified water. The water in the tank serves as coolant, moderator, reflector, and shield. One pool of this type is concrete, 12.2 m long × 6.1 m wide × 6.1 m deep (40 ft long × 20 ft wide × 20 ft deep). Some reactors have a considerable number of ports (beam holes) in the wall so that various experimental apparatus can be set up for the use of the radiation produced (*see Figure C.11.2*). The building housing the reactor and the working space around it would ordinarily have a tight wall and roof of metal or concrete.

C.11.3 Fuel. The fuel is usually enriched uranium in rods or plates. A typical element consists of aluminum-clad plates grouped into fuel assemblies usually about 610 mm × 76 mm × 76 mm (24 in. × 3 in. × 3 in.). (Enriched uranium simply means that the percentage of U-235 is higher than in natural uranium. The higher the enrichment, the smaller the fuel core can be.) A cluster of rods or plates is arranged in a core suspended by a cage in the water from a movable bridge across the top of the pool.

C.11.4 Controls. Control of the rate at which neutrons are produced is provided by inserting boron or cadmium rods in the proper geometrical pattern between the fuel elements to absorb neutrons. Usually two or three rods are used as control rods and one or two are safety shutdown rods in combination with 15 to 30 fuel elements. The movement of control rods and fuel elements is accomplished by control mechanisms electrically or hydraulically operated. These are so arranged that, in case of electric or hydraulic failure, the control rods will return by gravity to a position that will shut down the reactor.

C.11.5 Criticality. In this type of reactor, a critical mass can be reached with about 2.7 kg (6 lb) of 90 percent enriched uranium fuel in a pool of the dimensions described. With lesser degrees of enrichment, more fuel would be required.

C.11.6 Hazards. This being a water-moderated reactor, hydrogen and oxygen are produced in small amounts by the action of radiation. Provisions need to be made for safe disposal of this by ventilation.

C.11.6.1 Certain reactor or reactor-fuel materials can be subject to chemical action between themselves or such materials as the water moderator, especially at the high temperatures that can be produced accidentally. Obvious hazards are those in the electrical control equipment. Accidents to the electrical equipment should not result in a hazard in the reactor. Because these reactors are used for research, many varieties of chemicals can be brought into the working area around the reactor by various experimental setups (*see Figure C.11.2*). Hazards associated with the combustibility, flammability, and explosiveness of these chemicals and their reactivity with air, water, and other chemicals should be kept in mind in evaluating the hazard in the reactor building at any given time.

C.11.6.2 Defects in fuel element cladding might permit leakage of some radioactive products into the water of the pool.

C.11.6.3 Combustible acoustic or other wall finishes introduce unnecessary fire hazards. Furniture should be noncombustible.

C.11.6.4 General protective measures should include portable extinguishers and automatic extinguishing systems.

C.11.6.5 Normal use of this type of reactor is at power levels where ordinary convection will dissipate heat produced at the core. Heat might be produced rapidly enough to release steam at the pool surface in the event of failure or slow operation of controls. Violent boiling can spread contamination outside of the reactor pool. This might prevent the use of the reactor for an extended period of time and present a decontamination problem. The worst conceivable (but highly improbable) disturbance might produce steam violent enough to cause local structural damage, blow off any apparatus at the top of the pool, and probably damage the building.

C.11.7 Site Factors. While this type of reactor could, under conditions of poor building design, introduce some exposure hazard, its fire exposure hazard, on the whole, is low, and the radioactive contamination hazard does not appear to be excessive. Because of the reactor's requirement for water, it would likely be located in a place where a satisfactory water supply for fire fighting could be provided.

C.11.8 Organization for Fire Protection. There should be a fire protection organization. The use of a research reactor means that teams of scientists from a number of separate agencies (several departments of a university, for example) are likely to be occupying the premises at any given time. Each might be performing experiments that introduce some fire hazard condition.

The agency responsible for the operation of the reactor or plant should consider having on duty during all working times persons who are technically competent to handle the overall use and operation of the reactor and the building. Whether the reactor and the building can safely be left in the hands of a custodian at times when it is not used, such as nights, weekends, or holidays, should be considered. In addition, the custodial force should be fully instructed in fire-fighting and ventilation procedures, and arrangements should be made in advance so that if members of a public fire department are likely to respond to a fire call, there will be some responsible administrative officer or custodian who will know under what arrangements the public fire force can go to work. Such arrangements should be worked out between the administration of the reactor property and the officials of the city or fire district.

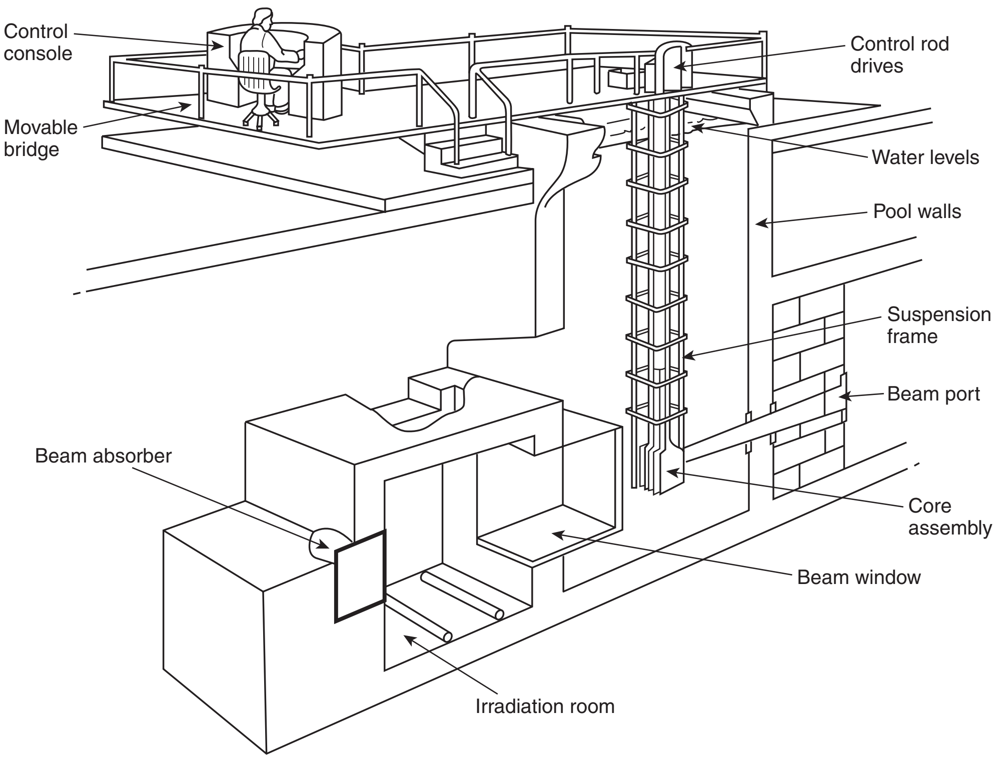

FIGURE C.11.2 Open Pool (Swimming Pool) Reactor Assembly.

Annex D Informational References

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

D.1 Referenced Publications. The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not part of the requirements of this document unless also listed in Chapter 2.

D.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*, 2001 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 1999 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 1999 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1998 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2000 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 1999 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1999 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 2001 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, 1999 edition.

NFPA 99, *Standard for Health Care Facilities*, 2002 edition.

NFPA *101*®, *Life Safety Code*®, 2000 edition.

NFPA 204, *Standard for Smoke and Heat Venting*, 1998 edition.

NFPA 220, *Standard on Types of Building Construction*, 1999 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1999 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, 1999 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 2000 edition.

NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 1998 edition.

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders,*, 1998 edition.

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium,* 2000 edition.

NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium,* 1996 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 2000 edition.

NFPA 601, *Standard for Security Services in Fire Loss Prevention*, 2000 edition.

NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants*, 2001 edition.

NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants*, 2001 edition.

NFPA 901, *Standard Classifications for Incident Reporting and Fire Protection Data*, 2001 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 2002 edition.