NFPA 801

Standard for Fire Protection for Facilities Handling Radioactive Materials

1998 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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Fire Protection For Facilities Handling Radioactive Materials

1998 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 the National Fire Protection Association, Inc., at its Fall Meeting held November 17–19, 1997, in Kansas City, MO. It was issued by the Standards Council on January 16, 1998, with an effective date of February 6, 1998, and supersedes all previous editions.

This edition of NFPA 801 was approved as an American National Standard on March 31, 1998.

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 incorporates the recommendations of NFPA 802, *Recommended Practice for Fire Protection for Nuclear Research and Production Reactors.*

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

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

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Standard for

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

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

Chapter 1 Introduction

1-1 Scope.

1-1.1* This standard addresses fire protection requirements intended to reduce the risk of fires and explosions at facilities handling radioactive materials. These requirements are applicable to all locations where radioactive materials are stored, handled, or used in quantities and conditions requiring government oversight (e.g., U.S. Nuclear Regulatory Commission or U.S. Department of Energy, etc.) license 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 power reactors that are covered by NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, and NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants*.

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

1-3 Alternative Methods.

1-3.1 Nothing in this standard is intended to prevent 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 authority having jurisdiction to demonstrate equivalency, and the system, method, or device is approved for the intended purpose.

1-3.2 The specific requirements of this standard shall be permitted to be modified by the authority having jurisdiction to allow alternative arrangements that will secure as nearly as practical the level of fire protection intended by this document. In no case shall the modification afford less fire protection than that which, in the judgment of the authority having jurisdiction, would be provided by compliance with the corresponding provisions contained in this standard.

1-3.3 Alternative fire protection methods accepted by the authority having jurisdiction shall be considered as conforming with this standard.

1-4 Retroactivity.

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

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

1-5 Definitions.

Alpha Particle. A positively charged particle emitted by certain radioactive materials, identical to the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material, as it 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.

Approved.* Acceptable to the authority having jurisdiction.

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

Beta Particle. An elementary particle, emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to $^1/_{1837}$ that of a proton. A negatively charged beta particle is identical to an electron, and a positively charged beta particle is called a positron. Beta radiation can cause skin burns, and beta-emitters are harmful if they enter the body. However, beta particles are easily stopped by a thin sheet of metal.

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

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

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

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

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

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

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

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

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

Fire Damper.* A device, installed in an air-distribution system, designed to close automatically upon detection of heat, to interrupt migratory airflow, and to restrict the passage of flame. A combination fire and smoke damper meets the requirements of both.

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

Fire Emergency Organization. As used in this standard, refers to those facility personnel trained to respond to facility fire emergencies that can include in-plant fire-fighting operations. For more information refer to NFPA 600, *Standard on*

Industrial Fire Brigades, and NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program.*

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

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

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

Fire-Rated Penetration Seal. An assembly provided in an opening in a fire barrier for the passageway of pipes, cables, trays, and so forth, to maintain the fire resistance rating of the fire barrier.

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

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

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

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

Fissionable Materials. Materials which are capable of being induced to undergo nuclear fission by slow neutrons (e.g., uranium 233 and 235 and plutonium).

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

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

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

Glove Box. A sealed enclosure in which items inside the box are handled exclusively using long rubber or neoprene gloves sealed to ports in the walls of the enclosure. The operator places 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.

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

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

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

Limited-Combustible.* A building construction material that, in the form in which it is used, has a potential heat value not exceeding 3500 Btu/lb (8141 kJ/kg) and has either a structural base of noncombustible material with a surfacing not exceeding $^1/_8$ in. (3.2 mm) that has a flame spread rating not greater than 50, or other material having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion, even on surfaces exposed by cutting through the material on any plane.

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 identified standards or has been tested and found suitable for a specified purpose

Noncombustible.* A material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials that are reported as passing ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 °C,* shall be considered noncombustible materials.

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

Radiation Area. An area accessible to personnel in which there exists radiation, originating in whole or in part within radioactive material, at such levels that a major portion of the body could receive a dose in excess of 5 millirems (5×10^{-5} sievert) during any single hour or a dose in excess of 100 millirems (100×10^{-5} sievert) during any 5 consecutive days.

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

Shall. Indicates a mandatory requirement.

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

Standard. A document, 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, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

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

Chapter 2 Administrative Controls

2-1 General.

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

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

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

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

2-3* Fire Hazards Analysis.

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

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

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

(a) Fire safety information for all employees and contractors, including familiarization with procedures for fire prevention, emergency alarm response, and reporting of fires

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

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

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

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

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

(g) *Fire prevention surveillance

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

(i) *Temporary construction, demolition, and renovating activities shall conform to the requirements of NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*

1. Noncombustible or fire-retardant scaffolds, formwork, decking, and partitions shall be used both inside and outside of permanent buildings where a fire could cause substantial damage or delay construction schedules.
2. Listed pressure-impregnated fire-retardant lumber or listed fire-retardant coatings shall be used.
3. Tarpaulins (fabrics) and plastic films shall be certified to conform to the weather-resistant and fire-retardant materials described in NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films.*

2-5 Testing, Inspection, and Maintenance.

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

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

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

2-6 Impairments.

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

(a) Identification and tracking of impaired equipment

(b) Identification of personnel to be notified

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

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

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

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

(a) Response to fire alarms and fire systems supervisory signals

(b) Notification of personnel identified in the plan

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

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

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

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

2-8 Facility Fire Emergency Organization.

2-8.1 A facility fire emergency organization shall be provided.

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

2-8.3 Facility fire emergency organization training requirements and drill frequencies necessary to demonstrate proficiency shall be implemented in accordance with the fire emergency action plan in Section 2-7. Drills shall be critiqued and documented.

2-9 Prefire Plans.

2-9.1* Detailed prefire plans for all site fire areas shall be developed for assisting the facility fire emergency organization.

2-9.2 Prefire plans shall be reviewed and, if necessary, updated periodically.

2-9.3* Prefire plans shall be made available to the facility fire emergency organization.

Chapter 3 General Facility Design

3-1* Special Considerations. The design of facilities handling radioactive materials shall incorporate the following:

(a) Limits on areas and equipment subject to contamination

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

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

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

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

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

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

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

3-6 Openings in Fire Barriers.

3-6.1* Openings in fire barriers shall be protected consistent with the designated fire resistance rating of the barrier. This shall include, but not be limited to, mechanical and electrical penetrations, building construction joints, and HVAC penetrations.

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

3-6.3 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.*

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

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

3-8 Interior Finish. Interior finish in areas processing or storing radioactive materials shall be limited-combustible and, where practicable, shall be nonporous for ease of decontamination.

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

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

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

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

3-9.3 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 an appropriate fire resistance rating as determined by the fire hazards analysis.

Exception: Where the corrosive nature of the effluents conveyed precludes the use of metallic ducts, plastic ducts shall be permitted. If plastic ducts are used, they shall be listed fire-retardant types and be evaluated in the fire hazards analysis.

3-9.4* Air entry filters shall have approved filter media that produces a minimum amount of smoke (UL Class I) when subjected to heat.

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

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

3-9.6 HEPA Filtration Systems.

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

3-9.6.2 HEPA filtration systems shall be provided with fire detection when required by the fire hazards analysis.

3-9.6.3* Fixed fire suppression shall be provided when required by the fire hazards analysis.

3-9.7 Smoke Control.

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

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

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

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

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

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

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

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

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

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

3-10 Drainage.

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

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

(a) Floor drains

(b) Floor trenches

(c) Open doorways or other wall openings

(d) Curbs for containing or directing drainage

(e) Equipment pedestals

(f) Pits, sumps, and sump pumps

3-10.2 Drainage Design.

3-10.2.1 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:

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

(b) 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

(c) The volume based on a manual fire-fighting flow rate of 500 gpm (1892.5 L/min) 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

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

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

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

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

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

3-11 Emergency Lighting.

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

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

3-12 Lightning Protection. Lightning protection, where required, shall be provided in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems*.

3-13 Light and Power.

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

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

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

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

3-14 Storage.

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

Exception: Those quantities of chemicals, materials, and supplies needed for immediate or continuous use shall be permitted to be available for use.

3-14.2 Storage of Radioactive Materials.

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

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

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

3-15 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.*

3-16 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 4 General Fire Protection Systems and Equipment

4-1* General Considerations.

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

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

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

4-2 Water Supply.

4-2.1* General.

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

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

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

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

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

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

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

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

4-2.3 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.

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

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

(b) Valves locked in the open position with keys available only to authorized personnel

4-4 Supply Mains and Hydrants.

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

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

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

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

4-5 Standpipe and Hose Systems.

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

4-5.2 The safe egress for personnel operating hose lines shall be taken into account when locating hose stations.

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

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

4-7 Fire Suppression Systems and Equipment.

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

NFPA 11, *Standard for Low-Expansion Foam*

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

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

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

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

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

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

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

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

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*

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

NFPA 750, *Standard on Water Mist Fire Protection Systems*

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*

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

(a) Type of hazard

(b) Effect of agent discharge on equipment

(c) Health hazards

(d) Clean-up after agent discharge

(e) Effectiveness of agent in suppressing fire

(f) Cost of agent, including life cycle costs

(g) Availability of agent

(h) Criticality safety

(i) Environmental impact

4-8 Fire Alarm Systems.

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

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

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

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

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

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

(c) Means to notify the public fire department

4-9* Unattended Facilities.

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

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

Chapter 5 Special Hazards in Nuclear Facilities

5-1* General.

5-1.1 Flammable and combustible liquids shall be stored and handled in accordance with NFPA 30, *Flammable and Combustible Liquids Code.*

5-1.2 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.*

5-1.3 Solid and liquid oxidizing agents shall be stored and handled in accordance with NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers.*

5-1.4 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.*

5-1.5 Fire protection for laboratories involved with radioactive materials shall be in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals.*

5-1.6 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.*

5-1.7 Combustion and safety controls and interlocks shall be tested periodically and after major maintenance activities, in accordance with the equipment manufacturer's recommendations.

5-1.8 Accident Involving Fissionable Materials.

5-1.8.1 The fissionable materials, uranium 233 and 235 and plutonium, shall be used with provisions to prevent the accidental assembly of fissionable material into critical masses.

5-1.8.2 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 shall include the effects of fire-fighting water on such 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.

5-1.8.3 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.

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

5-3 Uranium Enrichment, Fuel Fabrication, and Fuel Reprocessing Facilities.

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

(a) Location
(b) Safe operating procedures
(c) Fixed protection systems
(d) Inerting
(e) Any other methods acceptable to the authority having jurisdiction

5-3.2* Flammable and Combustible Liquids and Gases.

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

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

5-3.2.3 Safety controls and interlocks for combustible, flammable liquids and flammable gases and their associated delivery systems shall be tested periodically and after maintenance operations.

5-3.2.4 Hydraulic fluids used in presses or other hydraulic equipment shall be the fire-resistant fluid type.

5-3.2.5 Solvents.

5-3.2.5.1* Where a flammable or combustible solvent is used, it shall be handled in a system that does not allow uncontrolled release of vapors. Approved operating controls and limits shall be established. An approved fixed system for fire extinguishing shall be installed or its absence justified to the satisfaction of the authority having jurisdiction.

5-3.2.5.2* Solvent distillation and recovery equipment for flammable or combustible liquids shall be isolated from areas of use by 3-hour fire barriers.

5-3.2.5.3* In order to ensure the safe operation of process evaporators, such as Plutonium Uranium Reduction and Extraction (PUREX), means shall be provided to prevent entry of excess quantities of water-soluble solvents into the evaporators.

5-3.2.5.4* Operating controls and limits for the handling of pyrophoric materials shall be established to the satisfaction of the authority having jurisdiction. A supply of an appropriate extinguishing medium shall be available in all areas where fines and cuttings of such materials are present. (*See Section 5-1.*)

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

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

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

5-4.3 Hot Cells.

5-4.3.1 Hot cells shall be of noncombustible construction.

5-4.3.2 Where hydraulic fluids are used in master slave manipulators, fire-resistant fluids shall be used.

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

5-4.4* Glove Boxes.

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

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

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

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

5-4.5 Research and Production Reactors. This section establishes the additional fire protection criteria applicable to nuclear research and production reactors.

5-4.6 Control Systems and Equipment.

5-4.6.1 Reactor control systems shall be designed to be fail-safe such that loss of the control systems will not result in a hazardous condition.

Exception: Where fail-safe design is not possible or control is necessary under adverse conditions, duplicate control circuitry shall be provided.

5-4.6.2* Reactor control circuits and equipment required for primary reactor safety shall be electrically supervised. The circuits shall be arranged to produce audible or visual alarm signals if the circuit conductors are grounded or accidentally broken.

Exception: Reactor control circuits and equipment intended to monitor special services, such as air supply, tank liquid levels, and so forth, shall be permitted to be arranged to produce audible or visual trouble signals rather than alarm signals if a conductor on the circuit is grounded or broken.

5-4.6.3* Features of good design shall include compartmentalization, minimization of combustible materials, and installation of automatic fixed extinguishing systems. Alternative systems for control and safe shutdown of the reactor shall be in separate fire areas.

5-4.6.4* Electrical control equipment, wiring, and other electrical facilities that are important to the operation and safe shutdown of a reactor plant shall be protected by fire-rated separation and automatic fire extinguishing systems as determined by the fire hazards analysis. *(See Section 2-3.)*

5-4.7* Incompatible Materials. The fire hazards analysis shall consider the inherent hazards associated with the use of incompatible reactor materials in fire situations.

5-4.8 *Life Safety Code*®. Research and production reactors shall be considered special purpose industrial occupancies in accordance with NFPA *101*, *Life Safety Code.*

Chapter 6 Referenced Publications

6-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix C.

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

NFPA 10, *Standard for Portable Fire Extinguishers,* 1998 edition.

NFPA 11, *Standard for Low-Expansion Foam,* 1998 edition.

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

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 1998 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 1997 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 1996 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 1996 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 1996 edition.

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems,* 1995 edition.

NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems,* 1994 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 Centrifugal Fire Pumps,* 1996 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection,* 1996 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,* 1998 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 1996 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* 1996 edition.

NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites,* 1996 edition.

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

NFPA 54, *National Fuel Gas Code,* 1996 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,* 1998 edition.

NFPA 70, *National Electrical Code*®, 1996 edition.

NFPA 72, *National Fire Alarm Code*®, 1996 edition.

NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment,* 1995 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows,* 1995 edition.

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

NFPA 86, *Standard for Ovens and Furnaces,* 1995 edition.

NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere,* 1995 edition.

NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere,* 1995 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems,* 1996 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems,* 1996 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials,* 1995 edition.

NFPA *101*®, *Life Safety Code*®, 1997 edition.

NFPA 220, *Standard on Types of Building Construction,* 1995 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations,* 1996 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials,* 1995 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies,* 1995 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials,* 1996 edition.

NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers,* 1995 edition.

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

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium,* 1995 edition.

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

NFPA 600, *Standard on Industrial Fire Brigades,* 1996 edition.

NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films,* 1996 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems,* 1996 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 1997 edition.

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants,* 1998 edition.

NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants,* 1995 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program,*1997 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 1996 edition.

6-1.2 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 °C,* 1996.

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

6-1.3 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

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

Appendix A Explanatory Material

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

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

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

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

For additional requirements for light water nuclear power reactors, see NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants,* and for the requirements for advanced light water nuclear reactors, see NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants.*

A-1-5 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-1-5 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-5 Combustible. The three terms used to describe the combustibility of materials — noncombustible, limited-combustible, and combustible — have specific definitions. When attempting to classify the combustibility of a material, ensure that the definitions of all three terms are thoroughly understood. *(See NFPA 220, Standard on Types of Building Construction.)*

A-1-5 Combustible Liquid. See NFPA 30, *Flammable and Combustible Liquids Code.*

A-1-5 Fire Damper. Some such devices are listed in the Underwriters Laboratories Inc. *Building Materials Directory* under the category "Fire Dampers (ALBR)."

A-1-5 Limited-Combustible. The three terms used to describe the combustibility of materials — noncombustible, limited-combustible, and combustible — have specific definitions. When attempting to classify the combustibility of a material, ensure that the definitions of all three terms are thoroughly understood. *(See NFPA 220, Standard on Types of Building Construction.)*

A-1-5 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-1-5 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.)*

A-1-6 For a full explanation, see ASTM E 380, *Standard Practice for Use of the International System of Units.*

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

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

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

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

(a) 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.

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

(c) 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.

(d) 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.

(e) 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.

(f) 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.

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

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

(i) Review the types of potential fires, based on the expected quantities of combustible materials, 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 is accomplished. Describe in detail the facility systems, functions, and controls that will be provided and maintained during the fire emergency.

(j) 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.

(k) 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.

(l) 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.

(m) Evaluate the inspection, testing, and maintenance needed to maintain the fire protection system's integrity considering the effects of radiation.

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

A-2-3.2 The fire risk analysis should be considered to supplement the fire hazards analysis.

A-2-4(b) Facility inspections are intended to locate unnecessary transient combustibles, identify uncontrolled ignition sources, and detect obstructions to the means of egress.

A-2-4(e) A fatality occurred to a welder whose anticontamination clothing ignited. Contributing factors included untreated cotton clothing, the lack of a fire watch, and the welder's senses limited by the use of a respirator and welding mask. Appropriate precautions should be taken for workers performing hotwork under these conditions. *(See NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes.)*

A-2-4(f) For further information, refer to NFPA 901, *Standard Classifications for Incident Reporting and Fire Protection Data,* and NFPA 902, *Fire Reporting Field Incident Guide.*

A-2-4(g) For further information, refer to NFPA 601, *Standard for Security Services in Fire Loss Prevention.*

A-2-4(i) 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.

A-2-7 It is important that the responding fire brigade or public fire-fighting forces be familiar with access, facility fire protection systems, emergency lighting, specific hazards, and methods of fire control. OSHA 29 CFR 1910.38, *Employee Emergency Plans and Fire Prevention,* should be consulted for additional information.

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

A-2-7(e) 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-2-9.1 Prefire plans should be developed with the assistance of the facility fire emergency organization. The prefire plans should include, but not be limited to, the following pertinent issues:

(a) Fire hazards in area
(b) Chemical hazards in area
(c) Radiation hazards
(d) Egress access
(e) Emergency lighting
(f) Fire protection systems/equipment in area
(g) Special fire-fighting instructions
(h) Ventilation systems/airflow path
(i) Utilities
(j) Special considerations on adjoining areas

A-2-9.3 Prefire plans should be made available to offsite fire departments as appropriate.

A-3-1 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-3-3 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-3-4 Determination of fire area boundaries should be based on consideration of the following:

(a) Types, quantities, density, and locations of combustible materials and radioactive materials
(b) Location and configuration of equipment
(c) Consequences of inoperable equipment
(d) Location of fire detection and suppression systems
(e) Personnel safety/exit requirements

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

(a) To separate manufacturing areas and radioactive materials storage areas from each other and from adjacent areas
(b) To separate control rooms, computer rooms, or combined control/computer rooms from adjacent areas. Where a control room and computer room are separated by a common wall, the wall might not be required to have a fire resistance rating.
(c) To separate rooms with major concentrations of electrical equipment, such as switchgear rooms and relay rooms, from adjacent areas
(d) To separate battery rooms from adjacent areas
(e) To separate a maintenance shop(s) from adjacent areas
(f) To separate the main fire pump(s) from the reserve fire pump(s), where these pumps provide the only source of water for fire protection
(g) To separate fire pumps from adjacent areas
(h) To separate warehouses and combustible storage areas from adjacent areas
(i) To separate emergency generators from each other and from adjacent areas
(j) To separate fan rooms and plenum chambers from adjacent areas
(k) To separate office areas from adjacent areas

A-3-6.1 Fire barriers also serve as radiation shields, ventilation barriers, and flood or watertight enclosures; these concerns also should be taken into consideration.

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

A-3-9.1 In addition, see NFPA 204M, *Guide for Smoke and Heat Venting.*

A-3-9.4 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-3-9.5 Exception. The use of filters of low combustibility, such as those that comply with UL 586, *Standard for Test Performance of High Efficiency Particulate, Air Filter Units,* and UL 900, *Standard for Test Performance of Air Filter Units,* is recommended. Their use reduces the likelihood of the spread of contamination by fire. In the absence of protection systems within the ducts and for the filter banks, fires in combustible filters become extremely difficult to extinguish.

A-3-9.6.3 Where the detection system activates a suppression system, the selection of the detectors should minimize false actuations.

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

A-3-9.7.4 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-3-9.7.6 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-3-9.7.7 Where mechanical ventilation is used, 300 ft^3/min (8.5 m^3/min) is equal to 1 ft^2 (0.09 m^2) of natural-convection vent area.

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

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

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

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

A-3-13.4 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-3-14.2.2 Special noncombustible storage facilities remotely located from the main facility might be necessary.

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

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

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

A-4-2.1 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-4-2.2.2 For further information, see NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps.* For unattended facilities, see Section 4-9 of this document.

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

A-4-2.2.4 The 8-hour requirement for refilling can be extended if the initial supply exceeds the recommendations of 4-2.1. The preferred method for the refilling operation is automatic.

A-4-3 All fire protection water system control valves should be supervised.

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

A-4-9 Facilities that 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 of a fire condition.

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

A-5-2 Radioactive materials are used in hospitals for a variety of purposes, including biomedical tracers, disease therapy, and laboratory analysis. General fire protection requirements for hospitals should be in accordance with NFPA 99, *Standard for Health Care Facilities.* Radioactive materials used in hospitals rarely constitute a fire hazard themselves. Most often, the fire hazard associated with these materials is contamination of personnel, equipment, buildings, or the environment as a result of fire damage to containers and the subsequent release of radioactive materials.

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

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

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

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

A-5-3.2.5.1 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-5-3.2.5.2 Explosion-relief panels should be provided for solvent recovery areas.

A-5-3.2.5.3 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-5-3.2.5.4 Fines and cuttings from materials, such as zirconium, constitute a pyrophoric hazard.

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

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

A-5-4.6.2 Where high reliability is needed, the circuit should be arranged to produce the alarm signal even if a broken wire or a ground accidentally occurs. Under these conditions, the arrangement of circuit and parts should be such that an audible signal cannot be silenced without a corresponding visual signal.

A-5-4.6.3 The prime concern in the reactor facility is directed towards those circuits and systems essential to continued operation of the reactor and particularly to those essential to a safe shutdown under emergency conditions. The possible effects of heat, smoke, and corrosive gases on the operation of control systems and equipment require attention to features of good design and fire protection so as to minimize interference with operation of these systems. If a fire involving a reactor control system causes reactor shutdown, the need for continued cooling of fuel elements will be reduced but will not, in most cases, be eliminated. For these reasons, special care is devoted to redundancy of systems, emergency power supplies, separation, physical protection, and reliability.

A-5-4.6.4 Because of the prime importance that much of the electrical equipment be adequate to ensure continuity of operations, at least to the extent of ensuring safe shutdown conditions, protection of cables, separation of redundant circuits, protection of penetrations (particularly through fire-rated partitions), and adequacy of alarms and interlocks are essential. Extreme care in the layout and in the selection of materials and components is needed during the design phase to minimize the fire loading and fire exposures to critical components. The smoke and toxic products of combustion developed in most electrical fires, together with the smaller number of people available for emergency response (as compared to a manufacturing facility), increase the need for automatic protection systems in critical areas.

A-5-4.7 As an example, the use of liquid metal as a reactor coolant can require special extinguishing systems not utilizing water. The possibility of water/liquid metal reactions can justify the exclusion of water systems from the area. When such a condition exists, it can impose more severe limitations on the presence of combustible oils, plastics, insulations, and other materials that generally require water for fire extinguishment. Where such mixed hazards exist, it is important that careful consideration be given to the potentials for a failure in one system to cause a failure in the incompatible system. In such cases, either a protection system should be provided that can ensure the extinguishment of fire in either system before it can cause a rupture of the other systems, or a single protection system (such as inerting) should be developed that is adequate for either hazard.

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

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

B-1 General.

B-1.1 Radioactive materials are substances that spontaneously decay, emitting energetic rays or particles in the process. Certain radioactive elements occur in more than one form. The various forms are chemically identical but differ in their atomic weights and are called isotopes. Those that are radioactive are called radioactive isotopes (radioisotopes). It is possible for an element to have one or more nonradioactive (stable) 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.

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

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

B-1.1.3 The presence of radioactive materials can complicate a fire-fighting situation by presenting hazards unknown to the fire fighter and causing real or wrongly anticipated hazards to fire fighters 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.

B-2 Fire Problems.

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

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

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

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

B-2.2 Radioactive materials can be expected to melt, vaporize, become airborne, or oxidize under fire conditions. None of these alterations will slow or halt radioactivity. It is conceivable that certain radioactive materials under fire conditions might be converted to radioactive vapor or oxidized to a radioactive dust or smoke. This dust or smoke could be carried by air currents and subsequently deposited on other parts of the burning buildings or even on neighboring buildings or land. These aggravated loss and personal injury characteristics of radioactive materials justify a high degree of protection against fire and explosion at those facilities where these potential hazards exist. The use of 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.

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

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

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

B-3 Radiation Hazards and Protection Methods.

B-3.1 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.

B-3.2 Nature of the Hazard of Radioactivity. In order that fire-fighting personnel understand how to effectively protect themselves 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:

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

(b) The units for measuring the quantity of radioactivity in the source material are the curie, the millicurie (one one-thousandth 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.

(c) 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).

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

(e) These radiations are measured in roentgens, a unit representing the amount of radiation absorbed or the amount that will produce a specific effect. Radiation doses are measured in rems, a dose unit that will produce a specified effect in humans. The ultimate effect 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.

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

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

(a) *Film badge.* A piece of photographic film that records gamma and beta radiation

(b) *Pocket dosimeter.* Measures gamma radiation

(c) *Geiger-Müller counter.* Measures beta and gamma radiation

(d) *Scintillation counter.* Measures alpha, beta, and gamma radiation

(e) *Ionization chamber.* Measures alpha, beta, and gamma radiation

(f) *Proportional counter.* Measures alpha radiation

(g) *Gamma survey meter.* Measures intensity of gamma radiation

(h) *Thermoluminescent dosimeter (TLD).* A crystal chip that records beta, gamma, and neutron radiation

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

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

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

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

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

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

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

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

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

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

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

B-4 Sealed and Unsealed Radioactive Materials.

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

B-4.2 The protection of properties against the spread of radioactive contamination as the result of fire or explosion is simplified considerably by the fact that many radioactive materials are shipped, stored, and, in some cases, used without ever exposing the radioactive material 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 radioactive isotope contained therein.

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

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

B-5 Applications.

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

B-5.2 Most of the thousands of scientific and industrial uses of radioactive materials take advantage of one or more of the types of radiations emitted; 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.

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

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

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

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

(d) Radioactive materials are being employed in the development of atomic batteries (as isotopic power fuels). The small currents generated are utilized in low-current demand 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.

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

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

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

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

B-6 Nuclear Reactor Fuel Element Manufacture.

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

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

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

B-7 Nuclear Fuel Reprocessing.

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

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

B-8 Particle Accelerators.

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

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

B-8.1.2 Certain target materials become radioactive when bombarded by atomic particles. 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.

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

B-9 Isotope Production Facilities.

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

B-9.2 Isotope Production in Reactors. Radioisotopes are produced in nuclear reactors 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.

B-9.2.1 Activation of isotopes in reactors generally is the result of the exposure of an element to a neutron flux resulting in a transmutation of the element due to neutron capture and alpha, beta, or proton decay.

B-9.2.2 Various radioisotopes are produced as the result of fission of uranium in reactors. These isotopes can be removed from the fuel by chemical extraction following removal of the fuel from the reactor.

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

B-10 Research and Production Reactors.

B-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.

B-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.

B-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.

B-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.

B-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.

B-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.

B-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.

B-10.6 Classification. There is no single system of reactor classification. Reactors are 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).

B-10.7 Hydrogen Explosions.

B-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.

B-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.

B-11 Open Pool Reactor (Swimming Pool Reactor).

B-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.