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NFPA 801
Facilities Handling Radioactive Materials
1991 Edition

NFPA

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

The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

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MGR FM-90

NFPA 801

Recommended Fire Protection Practice for

Facilities Handling Radioactive Materials

1991 Edition

This edition of NFPA 801, *Recommended Fire Protection Practice for Facilities Handling Radioactive Materials*, was prepared by the Technical Committee on Atomic Energy and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 12-14, 1990 in Miami, FL. It was issued by the Standards Council on January 11, 1991, with an effective date of February 8, 1991, and supersedes all previous editions.

The 1991 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 801

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

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

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

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

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

This latest 1991 edition is a total revision of the document and includes 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.

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

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

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Recommended Fire Protection Practice for

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

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

Chapter 1 Introduction

1-1 Scope.

1-1.1 This recommended practice covers fire protection practices intended to reduce the risks of fire and explosions at facilities handling radioactive materials. The recommendations are applicable to all locations where radioactive materials may be stored, handled, or used, including hospitals, laboratories, and industrial properties.

1-1.2 The objective of this practice is to reduce personal hazards, property damage, and process interruption resulting from fire and explosion. Radioactive contamination may or may not be a factor in these risks.

1-1.3 This recommended practice does not apply to research or power reactors that are covered by NFPA 802, *Recommended Fire Protection Practice for Nuclear Research Reactors*, and NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants.*

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

1-3 Definitions.

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

Approved. Acceptable to the "authority having jurisdiction."

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

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, 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 designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Beta Particle. An elementary particle emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to $1/1837$ 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 may 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. (Any material that does not comply with the definition of either noncombustible or limited combustible.)

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

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

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

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

Fire Barrier. Those components of construction (walls, floors, or floor/ceiling assemblies and their supports, including beams, joists, columns, penetration seals or closures, fire doors, and fire dampers) that are rated by approval laboratories in hours of resistance to fire and are used to prevent the spread of fire.

Fire Hazard Analysis. The objective of the fire hazard analysis is to determine the potential of a fire at any location and to evaluate that the resultant possibility of injury to people or damage to buildings or equipment 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 Risk Analysis. The objective of the fire risk analysis is 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.

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 all handling of items inside the box is carried out through long rubber or neoprene gloves sealed to ports in the walls of the enclosure. The operator places hands and forearms in the gloves from the room side of the box in order to be physically separated from the glove box environment but able 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 and viewing the work through special leaded glass or liquid filled windows or with 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 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. As applied to a building construction material, a material, not complying with the definition of noncombustible material, that, in the form in which it is used, has a potential heat value not exceeding 3500 Btu per lb (8141 kJ/kg) and complies with one of the following paragraphs (a) or (b). Materials subject to increase in combustibility or flame spread rating beyond the limits herein established through the effects of age, moisture, or other atmospheric condition should be considered combustible.

(a) Materials having a structural base of noncombustible material, with a surfacing not exceeding a thickness of $^1/_8$ in. (3.2 mm) that has a flame spread rating not greater than 50.

(b) Materials, in the form and thickness used, other than as described in (a), having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion and of each composition that surfaces that would be exposed by cutting through the material on any plane would have neither a flame spread rating greater than 25 nor evidence of continued progressive combustion.

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

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

Noncombustible. A material that, in the form in which it is used and under the conditions anticipated, will not aid combustion or add appreciable heat to an ambient fire. Where tested in accordance with ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C* (1382°F), materials conforming to the criteria contained in Section 7 of the referenced standard should be considered as noncombustible.

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 (alpha and beta particles, free neutrons, cosmic radiation, etc.). 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 in any one hour a dose in excess of 5 millirem or in any 5 consecutive days a dose in excess of 100 millirems.

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

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

Units. Metric units in this document are in accordance with the International System of Units, which is officially abbreviated SI in all languages. For a full explanation see the *Metric Practice Guide*, ASTM E380 (ANSI Z210.1).

Chapter 2 Administrative Controls

2-1 General.

2-1.1 This chapter 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.

2-1.2 The intent of this chapter can be met by incorporating the features of this chapter in the facility operating procedures or otherwise as determined by management.

2-1.3 The facilities' administrative controls should be reviewed and updated periodically.

2-2 Management Policy and Direction.

2-2.1 Corporate management should 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 as determined by the fire hazard analysis.

2-2.2 Proper preventive maintenance of operating equipment as well as adequate facility personnel training are important aspects of a viable fire prevention program.

2-3* Fire Hazard Analysis.

2-3.1 A documented evaluation should be initiated early in the design process or when configuration changes are made to ensure that the fire prevention and fire protection recommendations as described in this document have been evaluated in view of the facility's specific considerations regarding design, layout, and anticipated operating requirements. The evaluation should consider acceptable means for separation or control of common and special 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 hazard analysis should be performed for all areas of the facility. The objective of the fire hazard analysis is to determine the potential of a fire at any location and to evaluate whether the resultant possibility of injury to people or damage to buildings or equipment is within acceptable limits.

2-3.3 A fire risk analysis may also be performed. The objective of the fire risk analysis is 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.

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

(a) Firesafety information for all employees and contractors. This information should include familiarization with fire prevention procedures, emergency alarms and procedures, and how to report a fire.

(b) Documented facility inspections should be conducted on at least a monthly basis including provisions for remedial action to correct conditions that increase fire hazards.

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

(d) Control of flammable and combustible liquids and gases in accordance with the applicable National Fire Codes.®

(e) Control of ignition sources including but not limited to grinding, welding, and cutting. (*See NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes.*)

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

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

2-5 Testing, Inspection, and Maintenance.

2-5.1 Upon installation, all fire protection systems should be inspected and tested in accordance with the applicable National Fire Codes.

2-5.2 All fire protection systems and equipment should be periodically inspected, tested, and maintained in accordance with the applicable National Fire Codes.

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

2-6 Impairments.

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

(a) Identification and tracking of impaired equipment.

(b) Identification of personnel to be notified.

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

2-6.2 Impairments to fire protection systems should be as short in duration as practical. If the impairment is planned, all necessary parts and personnel should 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 should be expedited.

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

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

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

(b) Notification of personnel identified in the plan.

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

(d) Coordination with security forces, radiation protection personnel, or other designated personnel to admit public fire department and other emergency response agencies.

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

NOTE: Recommendations contained in NFPA 600, *Recommendations for Organization, Training and Equipment of Private Fire Brigades*, and OSHA 1910.156 should be consulted for additional information.

(f) Requirements for periodic drills and exercises to verify adequacy of the fire emergency plan. Practice sessions should be coordinated around previously developed valid emergency scenarios particular to the facility.

(g) Fire prevention surveillance. (*See NFPA 601, Standard for Guard Service in Fire Loss Prevention.*)

2-8 Fire Emergency Organization.

2-8.1 A fire emergency organization should 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 should determine the composition of the fire emergency organization.

2-8.3 The fire emergency organization training, including special fire fighting conditions unique to facilities handling radioactive materials, should be identified in the fire emergency plan.

NOTE: Recommendations contained in NFPA 600, *Recommendations for Organization, Training and Equipment of Private Fire Brigades*, and OSHA 1910.156 should be consulted for additional information.

2-8.4 Fire emergency organizations should conduct drills at least quarterly, and they should be critiqued by competent individuals. The drill critique should be documented, and recommendations for improvements should be implemented. Practice sessions should be coordinated around previously developed valid emergency scenarios particular to the facility.

Chapter 3 General Facility Design

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

(a) Limits on the 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 should be located or segregated from other important buildings or operations.

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

3-3* The facility should be designed to provide construction that will confine a potential radiation contamination incident and should include surface finishes that are easy to clean.

3-4* Fire Area Determination. The facility should be subdivided into separate fire areas as determined by the fire hazard analysis for the purposes of limiting the spread of fire, protecting personnel, and limiting the resultant consequential damage to the facility. Fire areas should 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 should be fire resistive or noncombustible (Type I or Type II according to NFPA 220, *Standard on Types of Building Construction*).

3-6* Openings in Fire Barriers.

3-6.1 All openings in fire barriers (which may also serve as radiation shields, HVAC air envelopes, or flood or watertight enclosures) should be protected consistent with the designated fire resistance rating of the barrier.

3-6.2 For fire doors and windows, see NFPA 80, *Standard for Fire Doors and Windows.*

3-7 Shielding.

3-7.1 Any permanent or temporary shielding materials should be noncombustible.

3-7.2 Where combustible materials are used, appropriate protection should be provided as determined by the fire hazard analysis.

3-8 Interior Finish.

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

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

3-9 Heating, Ventilating, and Air Conditioning.

3-9.1 Introduction. Ventilation of a nuclear facility involves balanced air differentials between building areas, comfort ventilation, and heat removal from areas where heat is generated by equipment. This need also includes fire area isolation and smoke removal equipment, as well as equipment for filtering radioactive gases.

3-9.2 The ventilation system should be arranged such that the area containing dispersable radioactive materials remains at an air (or other atmosphere) pressure less than that of adjoining areas of the facility before and during any fire incident, including during and following any actuation of fire protection systems.

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

3-9.4 The design of the ventilation should 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*, NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*, and NFPA 204M, *Guide for Smoke and Heat Venting*.

3-9.5 Self-cleaning filters that pass through a viscous liquid yield a radioactive sludge requiring disposal. Therefore, such systems should generally be avoided in areas where radioactive materials are handled. Such filter systems may require additional fire protection features because of the combustible nature of the liquid.

3-9.6 The use of filters of low combustibility, such as those that comply with Underwriters Laboratories Inc. Standards No. 900 and 586, is recommended. Their use reduces the likelihood of the spread of contamination by fire. Roughing filters, where necessary, should be constructed of materials that will not contribute to the fire hazard. Careful attention should be given to the disposal of filters, especially if they are loaded with materials having any significant degree of combustibility. The use of combustible filters introduces a serious fire hazard into the ventilating system and requires automatic sprinklers or other special fire protection. In the absence of protection systems within the ducts and for the filter banks, fires in combustible filters become extremely difficult to extinguish.

3-9.7 All HEPA filtration systems should be analyzed in the fire hazard analysis. Those with a leading surface area greater than 16 sq ft (1.49 m^2) should have automatic fire detection and suppression. Smaller filter systems may require detection and suppression systems to preclude filter media being damaged from hot gases and flame.

3-9.8 Fresh air inlets should be located to reduce the possibility of radioactive contaminants being introduced. Such inlets should be located where it would be most unlikely for radioactive contaminants to be present. For example, they should not be located near storage areas of combustible radioactive waste material that, upon ignition, could discharge radioactive combustion products that may be picked up by the ventilating system.

3-9.9 Smoke, corrosive gases, and the nonradioactive substances that might be freed by the fire should be vented from their place of origin directly to a safe location. Radioactive materials that might be released by the fire should be confined, removed from the exhaust ventilation air stream, or released under controlled conditions.

3-9.10 Ventilation systems designed to exhaust smoke or corrosive gases should be evaluated to ensure that inadvertent operation or failures will not violate the controlled areas of the facility design.

3-9.11 Smoke ventilation should be provided for fire areas based upon the fire hazard analysis.

NOTE 1: Separate smoke ventilation systems are preferred; however, smoke venting can be integrated into normal ventilation systems using automatic or manually positioned dampers and motor speed control.

NOTE 2: The lack of smoke and heat venting in areas of relatively high combustible loading can result in significant damage to structural components.

NOTE 3: Automatic or manual actuation of smoke and heat venting will be determined by the fire hazard analysis.

3-9.12 Smoke ventilation from areas that may contain radioactive substances should not be ventilated outside the building. These smoke ventilation systems should be connected to treatment systems to preclude release of radioactive substances.

3-9.13 Enclosed stairwells should be designed to minimize smoke infiltration during a fire.

NOTE: Stairwells serve as escape routes and fire fighting access routes. Suitable methods of ensuring a smoke-free stairwell include pressurization of stairwells (*see NFPA 90A, Chapter 4 and Appendix*) and the construction of smokeproof towers. (*See 5-2.3 of NFPA 101, Life Safety Code.*)

3-9.14 When natural-convection ventilation is used, the smoke and heat venting should be provided in accordance with the fire hazard analysis.

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

3-9.15 The ventilation system should be designed, located, and protected such that airborne corrosive products will not be circulated.

3-9.16 The power supply and controls for mechanical ventilation systems should be located outside the fire area served by the system or protected from fire damage.

3-9.17 Duct Systems.

3-9.17.1 If plastic ducts are used, they should be listed fire retardant types.

3-9.17.2 Ventilation ducts passing through fire areas that they do not serve should not degrade the fire integrity of the fire rated enclosure.

NOTE: Fire dampers or fire doors compatible with the rating of the barrier may be required at the duct penetrations to the fire area.

3-9.17.3 Fire dampers should be provided to resist the passage of smoke, heat, or flame through ventilation ducts from one area to another.

3-9.17.4 Approved fire dampers having a rating of 1½ hr should be installed where ventilation ducts penetrate fire barriers having a required fire resistance rating of 2 hr or less. Where ventilation ducts penetrate required 3-hr fire barriers, approved fire dampers having a fire protection rating of 3 hr should be installed.

Exception: Fire dampers are not required for ventilation duct penetrations where shutdown of the ventilation system is not allowed.

3-9.17.5 Fire dampers should be equipped with thermal elements. The closure of fire dampers should be guaranteed by mounting the damper directly into the separating wall or by protecting the duct up to the damper according to the fire resistance of the separating wall structure.

3-9.17.6 Interconnections of individual fire areas via the ventilation system should be avoided insofar as possible. Where this is not possible, the necessary precautions should be taken to prevent the spread of smoke and fire by such routes.

3-9.18 Fire suppression systems should be installed to protect filters that collect combustible material, unless the elimination of such protection is justified by the fire hazard analysis.

3-10 Drainage.

CAUTION: For facilities handling special nuclear materials, areas where water can accumulate should be analyzed for criticality potential.

3-10.1 Provisions should 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 to reduce the potential for flooding of equipment and without endangering other areas (*see Appendix A of NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection*). Drainage and prevention of equipment flooding should be accomplished by one or more of the following:

(a) Floor drains.

(b) Floor trenches.

(c) Open doorways or other wall openings.

(d) Curbs for containing or directing drainage.

(e) Equipment pedestals.

(f) Pits, sumps, and sump pumps.

3-10.2 Drainage Design.

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

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

(b) The maximum design volume of discharge from the expected number of fire hose lines operating for a minimum of 20 min.

(c) The maximum design volume of discharge from the fixed fire suppression system(s) operating for a minimum of 20 min.

(d) For outdoor installations, credible environmental discharge such as rain or snow should be considered.

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

3-10.3 Floor drainage from areas containing flammable or combustible liquids should 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 should be provided with adequate seals, or the fire suppression system should be sized to compensate for the loss of fire suppression agent through the drains.

3-11 Emergency Lighting.

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

3-11.2 Emergency lighting should be provided for critical operations areas.

3-12 Lightning Protection. Lightning protection, where required, should be provided in accordance with NFPA 78, *Lightning Protection Code.*

3-13 Light and Power.

3-13.1 Lights, ventilation, and operation of much remote-controlled equipment are dependent upon a reliable source of electrical power. Location of transformers, switches, and control panels well away from "high activity" areas helps to provide that maintenance work can be done without direct exposure to radiation from such areas. The need for effective ventilation during and immediately after an emergency such as a fire is of considerable importance. An auxiliary power system should be available to provide temporary lighting, ventilation, and radiation monitoring equipment in those facilities where the radioactive materials being handled are potentially dangerous to personnel.

3-13.2 It is important that electrical equipment be selected for its ease of decontamination and early restoration to service in those areas where a contamination is considered likely. Electrical conduits leading to or from "hot" areas should be internally sealed to prevent the spread of radioactive materials. Only utilities required for operation within hot areas should enter the hot area.

3-13.3 Less hazardous dielectric fluids should 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 should be installed in accordance with NFPA 70, *National Electrical Code.*®

3-14 Storage.

3-14.1 General. Except for those amounts needed for immediate or continuous use, chemicals, materials, and supplies should be in separate storerooms and not in areas where work with radioactive materials is conducted.

3-14.2 Storage of Radioactive Materials.

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

3-14.2.2 Special consideration should 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 should be designed with the peculiar characteristics of the gases in mind. Special noncombustible storage facilities located remotely from the main facility may be necessary in some cases.

3-14.2.3 Care should be exercised in selecting the locations for the storage of radioactive waste material. Such material should not be located near the fresh air intakes to the heating, ventilation, and air conditioning systems nor the air intakes for air compressors. Should the products of combustion of waste materials containing long-lived and high activity radioactive materials be dispersed through heating, ventilation, and air conditioning or compressed air systems, a decontamination problem of serious magnitude could result.

Chapter 4 General Fire Protection Systems and Equipment

4-1* General Considerations.

4-1.1 A fire hazard analysis should 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 should be provided unless the hazard analysis in Section 2-3 dictates otherwise. Special hazards may require additional fixed protection systems as indicated by the fire hazard analysis.

4-1.3* Where fissile materials may be present, thus creating a potential criticality hazard, combustible materials should be excluded. If combustible materials are unavoidably present in quantity sufficient to constitute a fire hazard, water or other suitable extinguishing agent should be provided for fire fighting purposes. Fissile materials should be arranged such that neutron moderation and reflection by water will not present a criticality hazard.

4-2 Water Supply.

4-2.1* The water supply for the permanent fire protection installation should be based on the largest fixed fire suppression system demand plus the maximum hose stream demand as well as any normally anticipated service water demand, if any, as determined by the fire hazard analysis. The fire protection water supply system should 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 When an auxiliary supply is required by the fire hazard analysis, each supply should be capable of meeting the recommendations in 4-2.1.

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

4-2.2.2 Fire pumps should be automatic starting with manual shutdown. The manual shutdown should be at the pump controllers only. (*See NFPA 20, Standard for the Installation of Centrifugal Fire Pumps.*)

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

4-2.2.3 If tanks are of dual-purpose use, they should be arranged to provide the amount determined by 4-2.1 for fire protection use only. (*See NFPA 22, Standard for Water Tanks for Private Fire Protection.*)

4-2.2.4 Where tanks are used, they should be filled from a source capable of replenishing the supply for the fire protection requirements in an 8-hr period. The 8-hr (time) requirement for refilling may be extended if the initial supply exceeds the recommendations of paragraph 4-2.1. It is normally preferred for the refilling operation to be accomplished on an automatic basis.

4-2.3 If multiple water supplies are used, each water supply should be connected to the fire main by separate connections, 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 should be under a periodic inspection program (*see Chapter 2*) and should be supervised as recommended in NFPA 26, *Recommended Practice for Supervision of Valves Controlling Water Supplies for Fire Protection*, or 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. (*See NFPA 72 series standards.*)

(b) Locking valves open. Keys should be made available only to authorized personnel.

4-4 Supply Mains and Hydrants.

4-4.1 Supply mains and fire hydrants as required by the fire hazard analysis should be installed on the facility site.

(*See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*)

4-4.1.1 When required by the fire hazard analysis, the supply mains should be looped and of sufficient size to supply the flow recommendations as determined by 4-2.1.

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

4-4.2 Each hydrant should 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 When required by the fire hazard analysis, standpipe and hose systems should be installed. (*See NFPA 14, Standard for the Installation of Standpipe and Hose Systems.*)

4-5.2 The standpipe piping should be capable of providing minimum volume and pressure for the most hydraulically remote hose stations.

4-5.3 Hose station location should take into account safe egress for personnel operating hose lines.

4-5.4 Spray nozzles having shutoff capability and listed for use on electrical equipment should be provided on hoses located in areas near energized electrical equipment.

4-6 Portable Fire Extinguishers. For first aid fire protection, suitable fire extinguishers should 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 should be provided in all areas of the facility as determined by the fire hazard analysis. The applicable NFPA standards should be used for the design of the fire suppression systems. Refer to the following NFPA documents:

NFPA 11, *Standard for Low Expansion Foam and Combined Agent Systems*

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

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

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

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

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

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

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

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

NFPA 16A, *Recommended Practice 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.*

4-7.2 Selection of the extinguishing agent system should be based upon:

(a) Type of hazard.

(b) Effect of agent discharge on equipment.

(c) Health hazards.

(d) Cleanup after agent discharge.

(e) Effectiveness of agent in suppressing fire.

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

(g) Availability of agent.

(h) Criticality safety.

(i) Environmental impact.

4-8 Fire Signaling Systems.

4-8.1 Fire detection and automatic fixed fire suppression systems should be equipped with local audible and/or visual signals with annunciation on the main fire control panel or at another constantly attended location (*see NFPA 72 series standards*). Audible fire alarms should be distinctive from other facility system alarms.

4-8.2 Automatic fire detectors should be installed in accordance with NFPA 72E, *Standard on Automatic Fire Detectors*, and as required by the fire hazard analysis.

4-8.3 The fire signaling system for the facility communication system should provide the following:

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

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

(c) Two-way communications for the facility emergency organization if required by the fire hazard analysis (*see Sections 2-3 and 2-7*).

(d) Means to notify the public fire department.

4-9 Unattended Facilities.

4-9.1 Facilities that are operated unattended or with minimal staffing present special fire protection concerns.

4-9.2 Consideration should be given both to the delayed response time for the fire brigade or public fire fighting personnel and to the lack of personnel available to alert others on site to a fire condition.

4-9.3 The fire hazard analysis should address delayed response and lack of communication. This may establish the need to provide additional fire protection measures to prevent a major fire spread prior to the arrival of fire fighting personnel.

4-9.4 Remote annunciation of the fire signaling panels should be transmitted to one or more constantly attended locations.

Chapter 5 Special Radiation Facilities and Equipment

5-1 General. The principal fire hazards to be encountered in special radiation facilities will vary with the particular occupancy. In general, the recommendations described in this recommended fire protection practice apply to all facilities handling radioactive materials. Special occupancy fire hazards associated with particular operations are described in this chapter along with the special fire protection methods that apply to those hazards, except nuclear power plants and nuclear research reactors.

5-2* Hospitals.

5-2.1 Radioactive materials may be used in hospitals for a variety of purposes, including biomedical tracers, disease therapy, and laboratory analysis.

5-2.2 Fire Protection. Radioactive materials used in hospitals are rarely a fire hazard in 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. Therefore, the appropriate form of fire protection for areas in which radioactive materials are present should be based primarily on the usual fire hazard analysis factors. Additional precautions may need to be taken if the radioactive materials are stored or used in ways that might make them more susceptible to release from their containers.

5-3 Fuel Fabrication Facilities.

5-3.1 Special hazards related to fire problems should be controlled by at least one of the following: location, safe operating procedures, fixed protection systems, inerting, or any other methods accepted by the authority having jurisdiction. In the following sections, special hazards associated with uranium fuel processing and fabrication are discussed.

5-3.2 Combustible gases, such as hydrogen, ethylene, propane, acetylene, and natural gas, present both fire and explosion hazards. They should only be used in accordance with operating controls and limits recommended by the applicable NFPA standards. In enclosed spaces in which combustible gas could accumulate outside of the storage vessels, piping, and utilization equipment, combustible-gas analyzers should be installed appropriate to the gas being used. The analyzer should be set to alarm at a concentration no higher than 25 percent of the lower explosive limit.

5-3.3 Industrial furnaces using a special atmosphere should be installed and operated in accordance with NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere.*

5-3.4 Flammable and combustible liquids should be used in accordance with NFPA 30, *Flammable and Combustible Liquids Code.* In enclosed spaces in which vapors could accumulate outside of the storage vessels, piping, and utilization equipment, combustible-vapor analyzers should be installed appropriate to the vapors generated. The analyzer should be set to alarm at a concentration no higher than 25 percent of the lower explosive limit.

5-3.5 Solvents.

5-3.5.1 When 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. When a flammable or combustible solvent is used, it should be handled in a system that does not allow uncontrolled release of vapors. Approved operating controls and limits should be established. An approved fixed system for fire extinguishing should be installed or its absence justified to the satisfaction of the authority having jurisdiction.

5-3.5.2 Solvent distillation and recovery equipment for flammable or combustible liquids should be isolated from areas of use by 3-hr fire barriers. Explosion-relief panels should be provided for solvent recovery areas.

5-3.6 During scrap recovery using nitric acid, experience and experiments have confirmed that exothermic reactions of distinctive violence can occur between tributylphosphate and uranyl nitrate or between tributylphosphate and nitric acid or both. In order to ensure the safe operation of such process evaporators (i.e., Plutonium Uranium Reduction and Extraction – PUREX), means should be provided to prevent entry of excess amounts of water-soluble quantities into the evaporators.

5-3.7 Fines and cuttings from materials such as zirconium constitute a pyrophoric hazard. Operating controls and limits for the handling of pyrophoric materials should be established to the satisfaction of the authority having jurisdiction. A supply of an appropriate extinguishing medium should be available in all areas where fines and cuttings of such material are present. For operations involving zirconium, guidance is provided by NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium.*

5-4 Fuel Reprocessing.

5-4.1 Fuel reprocessing facilities involve the storage and handling of large quantities of flammable and combustible liquids and gases, solid and liquid oxidizing agents, combustible metals, and pyrophoric materials.

5-4.1.1 Flammable and combustible liquids should be stored and handled in accordance with NFPA 30, *Flammable and Combustible Liquids Code.*

5-4.1.2 Flammable and combustible gases should be stored and handled in accordance with NFPA 43C, *Code for the Storage of Gaseous Oxidizing Materials*, 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*, and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

5-4.1.3 Solid and liquid oxidizing agents should be stored and handled in accordance with NFPA 43A, *Code for the Storage of Liquid and Solid Oxidizers*.

5-4.1.4 Combustible metals should be stored and handled in accordance with NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium*, 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*.

5-4.1.5 Nuclear reprocessing facilities and nuclear fuel fabrication facilities have similar fire hazards. See Section 5-3 for guidance that may also be applicable to reprocessing facilities.

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

5-5.1 All glove boxes, hoods, cells, and caves should be provided with a means of fire detection if used in the handling of pyrophoric materials, oxidizers, or if organic liquids are used.

5-5.2 Fire suppression should be provided in all glove boxes, cells, hoods, and caves that may contain combustible metals or organic liquids in quantities that could be expected to cause a breach of integrity. The preferred method of suppression is an automatic sprinkler system, although other methods of suppression would also be acceptable where installed in accordance with the proper NFPA standard.

5-5.3 Hot Cells.

5-5.3.1 Construction of hot cells should be noncombustible. Liquid filled windows should contain a noncombustible medium, such as zinc bromide solution.

5-5.3.2 Where hydraulic fluids are used in master slave manipulators, less hazardous hydraulic fluids should be used.

5-5.3.3 Combustible concentrations inside the cells shall be kept to a minimum. Where combustibles are present, a fixed extinguishing system should be installed in the cell. If explosive concentrations of gases or vapors are present, an inert atmosphere should be provided.

5-5.3.4 Noncombustible filters should be used, or a fire suppression system should be provided. (See also Section 3-8.)

5-5.3.5 A documented daily housekeeping inspection should be made for each hot cell.

5-5.4* Glove Boxes.

5-5.4.1 The glove box and window should be of noncombustible construction.

5-5.4.2 The gloves should be limited to the minimum number necessary to perform the operations. When the gloves are not used, they should be tied outside the box. When the gloves are no longer needed for operations, the gloves should be removed and glove port covers installed.

5-5.4.3 The concentration of combustibles should be kept to a minimum. Where combustibles are present, a fire suppression system or fixed inerting system should be provided. If fixed extinguishing systems are utilized, the internal pressurization must be calculated in order to prevent gloves from failing or being blown off.

5-5.4.4 Fire dampers should be provided for glove boxes that are operated in series.

5-5.4.5 Noncombustible filters should be used, or a fire suppression system should be provided.

5-5.4.6 A documented daily housekeeping inspection should be made for each glove box.

5-6 Laboratories. Fire protection for laboratories is covered by NFPA 45, *Standard on Fire Protection of Laboratories Using Chemicals*. The same fire protection principles apply to laboratories handling radioactive materials.

5-7 Ovens and Furnaces. Ovens and furnaces are used in nuclear applications that may require fire protection features as determined by the fire hazard analysis. Combustion safeguards and controls are not unique to the nuclear application and are covered by the following NFPA documents:

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

NFPA 85A, *Standard for Prevention of Furnace Explosions in Fuel-Oil and Natural Gas-Fired Single Burner Boiler-Furnaces*

NFPA 85B, *Standard for Prevention of Furnace Explosions in Natural Gas-Fired Multiple Burner Boiler-Furnaces*

NFPA 85D, *Standard for Prevention of Furnace Explosions in Fuel Oil-Fired Multiple Burner Boiler-Furnaces*

NFPA 85E, *Standard for Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces*

NFPA 86, *Standard for Ovens and Furnaces*

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

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

Chapter 6 Referenced Publications

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

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

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition

NFPA 11, *Standard for Low Expansion Foam and Combined Agent Systems*, 1988 edition

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1988 edition

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1989 edition

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1989 edition

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

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1989 edition

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1990 edition

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

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

NFPA 16A, *Recommended Practice for the Installation of Closed-Head Foam-Water Sprinkler Systems*, 1988 edition

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1990 edition

NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*, 1990 edition

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1990 edition

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1987 edition

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1987 edition

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

NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition

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

NFPA 43C, *Code for the Storage of Gaseous Oxidizing Materials*, 1986 edition

NFPA 45, *Standard on Fire Protection of Laboratories Using Chemicals*, 1986 edition

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

NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, 1989 edition

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1989 edition

NFPA 54, *National Fuel Gas Code*, 1988 edition

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1989 edition

NFPA 70, *National Electrical Code*, 1990 edition

NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*, 1990 edition

NFPA 72E, *Standard on Automatic Fire Detectors*, 1990 edition

NFPA 72G, *Guide for the Installation, Maintenance, and Use of Notification Appliances for Protective Signaling Systems*, 1989 edition

NFPA 72H, *Guide for Testing Procedures for Local, Auxiliary, Remote Station and Proprietary Protective Signaling Systems*, 1988 edition

NFPA 78, *Lightning Protection Code*, 1989 edition

NFPA 80, *Standard for Fire Doors and Windows*, 1990 edition

NFPA 85A, *Standard for Prevention of Furnace Explosions in Fuel-Oil and Natural Gas-Fired Single Burner Boiler-Furnaces*, 1987 edition

NFPA 85B, *Standard for Prevention of Furnace Explosions in Natural Gas-Fired Multiple Burner Boiler-Furnaces*, 1989 edition

NFPA 85D, *Standard for Prevention of Furnace Explosions in Fuel Oil-Fired Multiple Burner Boiler-Furnaces*, 1989 edition

NFPA 85E, *Standard for Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces*, 1985 edition

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

NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, 1987 edition

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

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1989 edition

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, 1989 edition

NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*, 1990 edition

NFPA *101*, *Life Safety Code*, 1991 edition

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

NFPA 220, *Standard on Types of Building Construction*, 1985 edition

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium*, 1987 edition

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

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

NFPA 600, *Recommendations for Organization, Training and Equipment of Private Fire Brigades*, 1986 edition

NFPA 601, *Standard for Guard Service in Fire Loss Prevention*, 1986 edition

NFPA 802, *Recommended Fire Protection Practice for Nuclear Research Reactors*, 1988 edition

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, 1988 edition

6-1.2 Other Publications.

6-1.2.1 ANSI Publication. American National Standards Institute Inc., 1450 Broadway, New York, NY 10018.

ANSI Z210.1 (*See ASTM E380.*)

6-1.2.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

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

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

6-1.2.3 OSHA Publication. Occupational Safety and Health Administration, 200 Constitution Avenue, N.W., Washington, DC 20210.

OSHA 1910.156, *Fire Brigades*, 1981

6-1.2.4 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 586, *Standard for Test Performance of High Efficiency Particulate, Air Filter Units*, Sixth Edition

UL 900, *Standard for Test Performance of Air Filter Units*, Fifth Edition

Appendix A

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

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

Various types of emitted radiation are capable of causing damage to living tissue. Especially during fire conditions, vapors and smoke may be formed that could 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, especially because radioactivity is not detectable by any of the human senses.

Additional specific requirements for light water nuclear power reactors are delineated in NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*; and recommendations for research reactors are described in NFPA 802, *Recommended Fire Protection Practice for Nuclear Research Reactors.*

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

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

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

(2) List the codes and standards that will be used for the design of the fire protection systems. Include the published standards of the National Fire Protection Association. Select the specific sections and paragraphs, not general items.

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

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

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

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

(7) Consider the qualifications required for the personnel performing the inspection checks and the frequency of testing to maintain a reliable alarm detection system.

(8) The features of building and facility arrangements and the structural design features generally define the methods for fire prevention, fire extinguishing, fire control, and control of hazards created by fire. Fire barriers,

egress, fire walls, and the isolation and containment features that should be provided for flame, heat, hot gases, smoke, and other contaminants should be carefully planned. Outline the drawings and list of equipment and devices that are needed to define the principal and auxiliary fire protection systems.

(9) Prepare a list of the dangerous and hazardous combustibles and the maximum amounts estimated to be present in the facility. Evaluate where these will be located in the facility.

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

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

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

(13) Analyze what is available in the form of "back-up" or "public" fire protection to be considered for the installation. Review the "back-up" fire department, equipment, manpower, special skills, and training required.

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

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

(16) Review the qualification requirements for the fire protection engineer or consultant who will assist in the design and selection of equipment. This person will also inspect and test the completed physical aspects of the system and develop the complete fire protection program for the operating facility.

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

A-3-1 Special Considerations. The design and installation of such service facilities as light and power, heating and ventilation, storage, and waste disposal at facilities not handling radioactive materials may present no unusual problems. The introduction of radioactive materials into a facility presents additional hazards to both personnel and property, which warrants special consideration of these services. Inadequate attention to the design features of service facilities has unfortunately contributed to the extent of decontamination found to be necessary following fires and explosions. It is considered good practice to analyze the design of each service for the purpose of determining what effect the service would have upon the spread of contamination following a fire or criticality accident. An appraisal of the seriousness of contamination spread may then be used to determine the necessity for modifying the design of the service facility under consideration.

A-3-2.2 A breakdown in an air cleaning system can be more serious if the discharged air can immediately be drawn 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 a study of the possible results of a contamination incident indicates that this is justified. In order to avoid unnecessary complication of accidents, such facilities should be located away from those handling explosives or flammable materials.

A-3-3 Planning for Decontamination. The extent to which decontamination might be necessary depends upon the amount of radioactive material being released, its half-life, type of radiation emitted, and its chemical and physical form. Taking all of these 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. All these factors tend to raise costs and thus justify capital expenditures to reduce them to a minimum through good emergency planning procedures.

A-3-4 Determination of fire area boundaries should be based on consideration of the following types, quantity, density, and locations of combustible material and radioactive materials; location and configuration of equipment; consequences of losing equipment; location of fire detection and suppression systems; and personnel safety/exit requirements. It is recommended that most fire barriers separating fire areas be of 3-hr fire resistance rating unless a fire hazard 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 are typically 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 need not 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 maintenance shop(s) from adjacent areas.

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

Name of Company: ______

Date of Fire: ______ Time of Fire: ______ Operating Facility: ______

Under Construction: ______

Location where fire occurred: ______

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

______

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

______

______

______

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

______

______

______

Types and approximate quantities of portable extinguishing equipment used: ______

______

______

Was fire extinguished with portable equipment only? ______ Public fire department called: ______

Employee Fire Brigade at this location? ______ Qualified for incipient fires? ______

For interior structural fires? ______

Was fixed fire extinguishing equipment installed? ______

Type of fixed extinguishing system? ______

Automatic operation ______, manually actuated ______, or both ______

Specified type of detection devices: ______

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

Did detection devices and extinguishing system function properly? ______

"no," why not? ______

______

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

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

______

______

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

Number of persons injured: ______ Number of fatalities: ______

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

______

______

Submitted by ______ Title ______

Figure A-2-4(f) Sample Fire Report.

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

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 may be present. The intent of this section is to state the recommended fire protection requirements for only those parts or the whole of the facility where the 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 occurring 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 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 bringing about a criticality accident can be calculated in advance. If, in fact, such a hazard exists, combustible material that would require the use of water for fire fighting should be eliminated. If combustible materials are unavoidably present in quantity sufficient to constitute a fire risk, water or other suitable extinguishing agent should be provided for fire fighting purposes. The fissile materials should be so arranged that water moderation and reflection will not present a hazard. In many facilities, fissile materials are stored and handled in sprinklered areas.

A-4-2.1 Consideration of water quality may present long-term problems relating to fire protection water supply. These considerations may include water hardness, corrosiveness, presence of micro-organisms, and others that may be unique to the type of facility.

A-5-2 Biomedical Tracers. Radioactive solutions may be administered intravenously or orally to a patient. The movement of the solution, as indicated 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 comparison to research data on both healthy individuals and those known to have specific diseases, the results can be interpreted to indicate the patient's condition without surgery.

Disease Therapy. Radioactive solutions may be administered intravenously or orally to a patient. 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-5-5.4 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 must be used. These systems are called glove boxes. They may be extensive, with appreciable glass or transparent plastic areas, and present unique fire protection problems. Under normal conditions, the radiation hazard, although present, can be largely protected against. On the other hand, if a "criticality" incident should occur, the type and quantity of radiation emitted create grave hazards to personnel. Even a small fire within a glove box can produce serious consequences if not properly controlled. Fire control systems and procedures for glove boxes should be carefully developed and applied before the boxes are used. Generally such protective systems are custom-designed for each particular application.

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

B-1 General.

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

B-1.1.1 Some radioisotopes occur in nature and may be separated by various physical or chemical processes, and 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. Of themselves, radioactive materials 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 may complicate a fire fighting situation by presenting hazards of which the fire fighter may be unaware and may cause real or imagined hazards to fire fighters, which may inhibit normal fire fighting operations. The dispersal of radioactive materials by fumes, smoke, water, or by the movement of personnel may cause a radiation contamination incident that may contribute greatly 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 upon the extent of loss caused by fire or explosion are:

(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 consequent need for decontamination of buildings, equipment, and materials.

(c) Possible increase in the total damage resulting from contamination of buildings and equipment to the point where they are unusable.

B-2.2 Radioactive materials may be expected to melt, vaporize, become airborne, or oxidize under fire conditions. None of these alterations will slow down or halt the 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 loss and personal injury aggravating characteristics of radioactive materials justify a high degree of protection against fire and explosion at those facilities where this potential exists. The use of least combustible building components and equipment is highly desirable in those areas where radioactive materials are to be stored or used. Some form of automatic protection, such as automatic sprinklers, would be highly advantageous wherever combustibles are encountered. The installation of automatic extinguishing systems will make it less necessary for personnel to expose themselves to possible danger, will start the fire control process automatically, will sound an alarm, and will make efficient use of the available water supply. However, caution should be exercised to ensure that the hazards of criticality and reactivity be 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 may have 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 on hand. Emergency planning is most necessary in order that fire fighters may function at maximum efficiency without exposing themselves to harmful radiation on the one hand and without causing unwarranted fears of radiation hazard to inhibit the fire fighting effort on the other. 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 is determined by the nature of the specific hazard. The radiation hazard can usually be anticipated in emergency planning studies.

B-3 Radiation Hazards and Protection Methods.

B-3.1 Significant levels of radiation exposure may occur under emergency conditions and could cause acute injury or death. However, fire fighter should be aware that radiation exposures that are tolerable in the event of a fire or other accident, especially where rescue operations are called for, are unsuitable for day-in, day-out exposure.

B-3.2 Based on information provided by a health physicist, the level of radiation risk to be assumed should be decided by the officer in charge of the fire fighting operation, based on knowledge and the importance of the operation to be accomplished. In the absence of information from a health physicist, the risk should be assumed to be significant.

B-3.3 Nature of the Hazard of Radioactivity. In order that fire fighting personnel may 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 are generally provided under normal operating conditions at those facilities where this hazard is to be found. While quite brief and simplified, the following paragraphs should assist in identifying for the fire fighter those areas of concern:

(a) For brief definitions of some of the terms used, radioactivity may be defined as the spontaneous emission of rays or particles during change of an atom's nucleus. Radioactive decay means 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 may in turn be radioactive.

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

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

(c) Among the radiations likely to be encountered are alpha particles, beta particles, gamma rays, and neutrons. The first three come from many radioactive materials, but neutrons are likely to be present in the vicinity of nuclear reactors or accelerators only while they are in operation, or 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 (like 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 may be done without the recipient of the injury being aware of it at the time. Because of their relatively high penetrating power, gamma rays and neutrons may be a serious external hazard (i.e., may be very dangerous even when arising from a source outside of the body). Beta particles, being less penetrating, can be somewhat of an external hazard if approached within inches but are mainly an internal hazard; alpha particles, because of their extremely low penetrating power, are entirely an internal hazard (i.e., can only injure the body if emanating from a source within the body after having entered the body by inhalation, ingestion, or a wound).

(e) These radiations are measured in roentgens, a unit representing the amount of radiation absorbed or that will produce a specified effect. Radiation dosages are measured in rems, a dose unit that will produce a specified effect in man. The ultimate effect upon the human body will depend 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.

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

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

B-3.4 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 may be photographic or electronic. Instruments used by personnel for radiation detection or measurement include:

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

(b) Pocket dosimeter — measures gamma radiation.

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

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

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

(f) Proportional counter — measures alpha radiation.

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

(h) TLD - Thermoluminescent Dosimeter. A crystal chip that records beta, gamma, and neutrons.

B-3.4.1 Common effects of excessive (200 roentgens or more) nuclear radiation on the body include vomiting, fever, loss of hair, loss of weight, a decrease in the white blood cell count, and an 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-3.4.2 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-3.4.3 The practice of placarding dangerous areas is for the protection of both regular operating personnel and those who, such as fire fighters, may have to deal with an emergency situation. If fire fighters are to have the best protection, they should inspect, long before they are called to any fire, the premises where there may be radiation hazards to consider during fire operations. Also, by frequent follow-up inspections, they should reach an agreement with the emergency director or other personnel directing the facilities as to steps to be taken in case of fire.

B-3.4.4 Fire fighters who may attend fires in properties where there are hazards of radioactivity should be given special training in what to wear for protection and what to do by way of cleanup or decontamination of their persons, clothing, or equipment afterward. In all cases, they should have and be trained in the use of suitable radiation monitoring equipment themselves or have monitoring specialists with them.

B-3.5 Protection from External Radiation. In the case of external nuclear radiation, the dosage, and hence the injury therefrom, may be kept to a minimum in several ways.

B-3.5.1 First, only the smallest possible portion of the body should be exposed (e.g., the hands, rather than the entire body).

B-3.5.2 Second, by efficient organization of the work procedure, the time spent in the hazardous area and thereby, the time of exposure, may be kept to a minimum.

B-3.5.3 Third, the intensity of radiation during exposure may be minimized by maintaining the greatest possible distance (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 for shielding. Radiation intensity decreases (inversely) as the square of the distance from the source only when 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 to 50 ft (9.1 to 15.2 m). The cases in which a fire fighter will encounter a single point source are probably in the minority, and therefore, the conservative statement should be used.

B-3.6 Protection from Internal Radiation. The possibility of radioactive materials entering the body may be reduced by the wearing of protective face masks and clothing while in a hazardous area. These masks should fit properly and be of a type that will prevent the entry of the particular radioactive materials encountered into the lungs or digestive system. Clothing should be of such a nature as to prevent the entry of radioactive materials into the body through wounds, scratches, or skin abrasions. Eating, drinking, smoking, and chewing must be avoided while in, or while awaiting decontamination after being in, radioactive areas.

B-3.6.1 Personnel working with radioisotopes are commonly subjected to routine biomedical checks for possible ingested radioactivity. Where applicable, routine checks are also made to show that a permissible concentration of radioactive material in the body, the air, or elsewhere is not exceeded.

B-3.6.2 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 this kind of biomedical examination.

B-4 "Sealed" and "Unsealed" Radioactive Materials.

B-4.1 For purposes of this publication, 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 and/or is intended to be opened at the facility.

B-4.2 The protection of properties against the spread of radioactive contamination as the result of fire or explosion is considerably simplified by the fact that many radioactive materials are shipped, stored, and in some cases used, without ever exposing the radioactive material itself to air. In many cases the shipping containers, or even the use containers, may have sufficient integrity to withstand a fire or an external explosion. Examples are: metallic cobalt-60 sources tightly encapsulated in steel and sealed sources used in "beta gage" thickness and measuring devices. There have been several instances of stainless steel encapsulated beta gage 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 may not thoroughly consider fire resistance, and it is important to remember that a sealed source may burst if its contents are subject to thermal expansion as a result of exposure to fire.

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

B-5 Applications.

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

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

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

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

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

(c) Certain of the intensive sources of radiation have the ability to ionize gases. One of the important applications is to prevent accumulation of static electricity on moving machinery. Here 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 are also being used as activating agents with self-luminous (phosphorescent) paints and coatings for various markings, emergency lighting, and instrument panels.

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

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

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

B-6 Nuclear Reactor Fuel Element Manufacture.

B-6.1 Certain radioactive nuclides are fissile (fissionable). 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 down of neutrons). Fissile materials to be 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 will often involve 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; 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 may be necessary to protect them from the effects of an otherwise inconsequential fire.

B-7 Nuclear Fuel Reprocessing.

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

B-7.2 The large quantities of highly radioactive materials present require massive shielding for personnel safety, and most chemical processing and maintenance operations are conducted entirely by remote controls. Fire hazards are present during the sawing and chopping of fuel elements containing combustible metals, either in the form of fuel or cladding, and in the chemical processing operation. Specially designed fire detection and control systems are used to protect these operations. Ventilating systems should be arranged so as to maintain their integrity under fire conditions. Such facilities handling large quantities of highly radioactive materials require 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, or bevatrons. The machines are used, as the name implies, to accelerate various charged particles of which atoms are composed to tremendous speeds and consequently, to high energy levels. Radiation machines furnish scientists with atomic particles in the form of a beam that may be utilized for fundamental studies of atomic structure. In addition, they furnish high energy radiation that may be utilized for radiography, therapy, or chemical processing.

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

B-8.1.2 Certain "target" materials become radioactive when bombarded by atomic particles, and for this reason monitoring equipment should be used during fire fighting operations to estimate the radiation hazard. The usual hazard presented by particle accelerators is largely that of electrical equipment. There are, however, some important exceptions to this. 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. Another factor is the possible presence of combustible oils used for insulating and cooling.

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 (e.g., IEEE-383) wiring and interior finishing, and the elimination of as much other combustible material as possible (*see NFPA 220, Standard on Types of Building Construction*). Automatic sprinkler protection should be provided for areas having hazardous amounts of combustible material or equipment. Special fire protection should be provided for any high voltage electrical equipment.

B-9 Isotope Production Facilities.

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

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

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

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

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

Appendix C Referenced Publications

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

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

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1987 edition

NFPA 220, *Standard on Types of Building Construction*, 1985 edition

NFPA 480, *Standard for the Storage, Handling and Processing of Magnesium*, 1987 edition

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

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

NFPA 802, *Recommended Fire Protection Practice for Nuclear Research Reactors*, 1988 edition

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, 1988 edition

C-1.2 Other Publications.

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

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

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

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

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

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