NFPA 851
Recommended Practice for Fire Protection for Hydroelectric Generating Plants

1996 Edition

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

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This edition of NFPA 851, *Recommended Practice for Fire Protection for Hydroelectric Generating Plants*, was prepared by the Technical Committee on Electric Generating Plants and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 13-15, 1995, in Chicago, IL. It was issued by the Standards Council on January 12, 1996, with an effective date of February 2, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 851 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 851

The Committee on Non-Nuclear Power Generating Plants was organized in 1979 to have primary responsibility for documents on fire protection for non-nuclear electric generating plants. The Hydroelectric Subcommittee was formed in 1982 to write this document. The first edition of NFPA 851 was issued in 1987 and revised in 1992. The 1996 edition contains minor changes to clarify the life safety recommendations and generator windings protection.

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

Committee Scope: This Committee shall have primary responsibility for documents on fire protection for electric generating plants and high voltage direct current (HVDC) converterstations, except for electric generating plants using nuclear fuel.

Contents

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

Information on referenced publications can be found in Chapter 7.

Chapter 1 Introduction

1-1 Scope. This document provides recommendations (not requirements) for fire prevention and fire protection for hydroelectric generating plants. The term "hydroelectric generating plant" also may be referred to as "station," "project," "unit(s)," "facility," or "site."

1-2 Purpose.

1-2.1 This document provides guidance for those charged with the design, construction, and operation of hydroelectric generating plants.

1-2.2 This document provides fire prevention and fire protection recommendations primarily to safeguard physical property and continuity of power production, but its application can also enhance safety of site personnel. This document is not intended to restrict new technologies or alternate arrangements.

1-3 Application.

1-3.1 This document is intended for use by persons knowledgeable in the application of fire protection to hydroelectric generating plants.

1-3.2 The recommendations contained in this document are intended for new installations only, as the application to existing installations might not be practicable.

1-3.3 It should be recognized that rigid uniformity of generating station design and operating procedures does not exist and that each facility will have its own special conditions that impact on the nature of the installation. Many of the specific recommendations herein may require modification after due consideration of all local factors involved. Individual generating units, particularly those of less than 25 MW, should be given a cost-benefit analysis to determine the extent to which fire protection is justified.

1-4 Definitions.

Approved.* Acceptable to the authority having jurisdiction.

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

Combustible. Any material that does not comply with the definition of either noncombustible or limited combustible.

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C). (*See NFPA 30 , Flammable and Combustible Liquids Code.*)

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

Fire Loading. The amount of combustibles present in a given area, expressed in Btu/ft^2 (kJ/m^2).

Fire Point. The lowest temperature at which a liquid in an open container will give off sufficient vapors to burn once ignited. It is generally slightly above the flash point.

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

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

Fire Protection Rating. The time, in minutes or hours, that materials and assemblies used as opening protection have withstood a fire exposure as established in accordance with test procedures of NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, and NFPA 257, *Standard for Fire Tests of Window Assemblies*, as applicable.

Fire Rated Penetration Seal. An opening in a fire barrier for the passage of pipe, cable, duct, etc., that has been sealed so as to maintain a barrier rating.

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

Flammable Liquid. Any liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psia (276 kPa) absolute pressure at 100°F (37.8°C). (*See NFPA 30, Flammable and Combustible Liquids Code.*)

High Fire Point Liquid. A combustible dielectric liquid listed as having a fire point of not less than 572°F (300°C).

Interior Finish. The exposed interior surfaces of buildings including, but not limited to, fixed or movable walls and partitions, columns, and ceilings. Interior finish materials are grouped in the following classes:

Class A Interior Finish. Materials having flame spread 0—25, smoke developed 0—450 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.* Includes any material classified at 25 or less on the flame spread test scale and 450 or less on the smoke test scale when any element thereof, when tested, does not continue to propagate fire.

Class B Interior Finish. Materials having flame spread 26—75, smoke developed 0—450 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.* Includes any material classified at more than 25, but not more than 75, on the flame spread test scale and 450 or less on the smoke test scale.

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

Less Flammable Liquid. A combustible dielectric liquid listed as having a fire point of not less than 572°F (300°C).

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/lb (8.14×10^6 J/kg) (see NFPA 259, *Standard Test Method for Potential Heat of Building Materials*), and complies with one of the following paragraphs (a) or (b).

(a) Materials having a structural base of noncombustible material with a surfacing not exceeding a thickness of $^1/_8$ in. (3.175 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 such composition that the 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 as tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.*

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 are considered combustible.

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.

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. Materials when tested in accordance with ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750° C*, and conforming to the criteria contained in Section 7 of the referenced standard shall be considered noncombustible.

Nonflammable Fluid. A nonflammable dielectric fluid that does not have a flash point and is not flammable in air.

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

1-5 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 ASTM E380/ANSI Z210.1, *Metric Practice Guide.*

Chapter 2 Administrative Controls

2-1 General.

2-1.1 This chapter provides recommended criteria for the development of administrative procedures and controls necessary for the execution of the fire prevention and fire protection activities and practices for hydroelectric generating plants.

2-1.2 The administrative controls recommended in this chapter should be reviewed and updated periodically.

2-1.3 The intent of this chapter can be met by incorporating the features of this chapter in the plant's operating procedures or otherwise as determined by plant management.

2-2 Management Policy and Direction.

2-2.1 Corporate management should establish a policy and institute a program to promote the conservation of property and continuity of operations as well as protection of safety to life by adequate fire prevention and fire protection measures at each facility.

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

2-3 Fire Risk Evaluation. A Fire Risk Evaluation should be initiated early in the design process to ensure that the fire prevention and fire protection recommendations as described in this document have been evaluated in view of the plant's specific considerations regarding design, layout, and anticipated operating requirements. The evaluation should result in a list of recommendations based on acceptable means for separation or control of common and special hazards, the control or elimination of ignition sources, and the suppression of fires.

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

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

(b) Documented plant inspections including provisions for remedial actions 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 appropriate NFPA standards.

(e) Control of ignition sources to include smoking, grinding, welding, and cutting. (*See NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes.*)

(f) Fire prevention surveillance. (*See NFPA 601, Standard for Security Services in Fire Loss Prevention.*)

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

2-5 Testing, Inspection, and Maintenance.

2-5.1 Upon installation, all fire protection systems should be preoperationally inspected and tested in accordance with applicable NFPA standards. Where appropriate standards do not exist, inspection and test procedures outlined in the purchase and design specifications should be followed.

2-5.2 All fire protection systems and equipment should be periodically inspected, tested, and maintained in accordance with applicable *National Fire Codes®*. (*See Table 2-5.2 for guidance.*)

Table 2-5.2 Reference Guide for Fire Equipment Inspection, Testing, and Maintenance

Item	NFPA No.
Supervisory and Fire Alarm Circuits	72
Fire Detectors	72
Manual Fire Alarms	72
Sprinkler Water Flow Alarms	13/72
Sprinkler and Water Spray Systems	15/13
Foam Systems	11A/11C/16
Halogenated Agent, Chemical, & CO_2 Systems	12/12A/17
Fire Pumps & Booster Pumps	20
Water Tanks & Alarms	13/22/72
P.I.V.s and O.S. & Y. Valves	13/72
Fire Hydrants and Associated Valves	13/24
Fire Hose and Standpipes	14/1962
Portable Fire Extinguishers & Hose Nozzles	10/1962
Fire Brigade Equipment	1971/1972/1973/1974
Fire Doors	80
Smoke Vents	204M
Emergency Lighting	70
Radio Communication Equipment	1221

NOTE: Inspection intervals for unattended plants may be permitted to be extended to normal plant inspections.

2-5.3 Testing, inspection, and maintenance should be documented with written procedures, results, and follow-up actions recorded.

2-6 Impairments.

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

(a) Identification and tracking of impaired equipment.

(b) Identification of personnel to be notified (e.g., plant fire brigade chief, public fire department, etc.).

(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 impairment is not planned, or when a system has discharged, the repair work or system restoration should be expedited.

2-6.3 Proper reinstallation after maintenance or repair should be performed to ensure proper systems operation. Once repairs are complete, tests that will ensure proper operation and restoration of full fire protection equipment capabilities should be made. Following restoration to service, the parties previously notified of the impairment should be advised. The latest revision of the design documents reflecting as-built conditions should be available to ensure that the system is properly reinstalled (e.g., drawings showing angles of nozzles).

2-7 Fire Emergency Plan. A written fire emergency plan should be developed, and, as a minimum, this plan 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 or other designated personnel to admit public fire department and control traffic and personnel.

(e) Fire extinguishment activities.

(f) Periodic drills to verify viability of the plan.

(g) Control room operator(s) activities during fire emergencies. Approved breathing apparatus should be readily available in the control room area.

2-8 Fire Brigade.

2-8.1 The size of the plant and its staff, the complexity of fire-fighting problems, and the availability and response time of a public fire department should determine the requirements for a fire brigade.

2-8.2* If a fire brigade is provided, its organization and training, including special fire-fighting conditions unique to hydroelectric plants, should be outlined in written procedures.

2-8.3 Cable tray fires, unique to hydroelectric generating plants, should be handled like any fire involving energized electrical equipment. It may not be practical or desirable to deenergize the cables involved in the fire. Water is the most effective extinguishing agent for cable insulation fires but should be applied with an electrically safe nozzle. Some cables [polyvinyl chloride (PVC), Neoprene, or Hypalon] can produce dense smoke in a very short time. In addition, PVC liberates hydrogen chloride (HCl) gas. Self-contained breathing apparatus should be used by personnel attempting to extinguish cable tray fires.

Chapter 3 General Plant Design

3-1 Plant Arrangement.

3-1.1 Fire Area Determination.

3-1.1.1 The hydroelectric generating plant should be subdivided into separate fire areas as determined by the Fire Risk Evaluation for the purposes of limiting the spread of fire, protecting personnel, and limiting the resultant consequential damage to the plant. Fire areas should be separated from each other by approved fire barriers, spatial separation, or other approved means.

3-1.1.2 Determination of fire area boundaries should be based on consideration of the following: types, quantity, density, and locations of combustible material; location and configuration of plant equipment; consequences of losing plant 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 two hours fire resistance rating. 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.) Unless consideration of the above factors indicates otherwise, it is recommended that fire area boundaries be provided as follows:

(a) To separate cable spreading room(s) and cable tunnel(s) from adjacent areas.

(b) To separate the control room, computer room, or combined control/computer room from adjacent areas. Where the 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 room and relay room, 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.

(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 oil storage and purification rooms from adjacent areas.

(k) To separate fan rooms and plenum chambers from adjacent areas (fire dampers may not be advisable in emergency ventilation ducts — see Section 3-4).

(l) To separate office areas from adjacent areas.

(m) To separate telecommunication rooms from adjacent areas.

(n) To separate the intake hoist housing from generator floor area and from adjacent areas.

(o) To separate the tailrace service gallery from turbine/generator floors and governor hydraulic equipment.

3-1.2 Outdoor Oil-Insulated Transformers.

3-1.2.1 Outdoor oil-insulated transformers should be separated from adjacent structures and from each other by firewalls, spatial separation, or other approved means for the purpose of limiting the damage and potential spread of fire from a transformer failure.

3-1.2.2 Determination of the type of physical separation should be based on consideration of the following:

(a) type and quantity of oil in the transformer,

(b) size of a postulated oil spill (surface area and depth),

(c) type of construction of adjacent structures,

(d) power rating of the transformer,

(e) fire suppression systems provided, and

(f) type of electrical protective relaying provided.

3-1.2.3 Unless consideration of the factors in 3-1.2.2 indicates otherwise, it is recommended that any oil-insulated transformer containing 500 gal (1893 L) or more of oil be separated from adjacent noncombustible or limited combustible structures by a 2-hr rated firewall or by spatial separation in accordance with Table 3-1.2.3. Where a firewall is provided between structures and a transformer, it should extend vertically and horizontally as indicated in Figure 3-1.2.3.

NOTE: As a minimum, the firewall should extend at least 1 ft (0.31 m) above the top of the transformer casing and oil conservator tank and at least 2 ft (0.61 m) beyond the width of the transformer and cooling radiators.

Table 3-1.2.3
Outdoor Oil-Insulated Transformer Separation Criteria

Transformer Oil Capacity	Minimum (Line-of-Sight) Separation without Firewall
Less than 500 gal (1893 L)	See 3-1.2.2
500 gal to 5000 gal (1893-18,925 L)	25 ft (7.6 m)
over 5000 gal (18,925 L)	50 ft (15 m)

3-1.2.4 Unless consideration of the factors in 3-1.2.2 indicates otherwise, it is recommended that adjacent oil-insulated transformers containing 500 gal (1893 L) or more of oil be separated from each other by a 2-hr rated firewall or by spatial separation in accordance with Table 3-1.2.3. Where a firewall is provided between transformers, it should extend at least 1 ft (0.31 m) above the top of the transformer casing and oil conservator tank and at least 2 ft (0.61 m) beyond the width of the transformer and cooling radiators.

3-1.2.5 Where a firewall is provided, it should be designed to withstand the effects of exploding transformer bushings or lightning arrestors.

NOTE: A higher noncombustible shield may be permitted to be provided to protect against the effects of an exploding transformer bushing.

3-1.2.6 Where a firewall is not provided, the edge of the postulated oil spill (i.e., containment basin, if provided) should be separated by a minimum of 5 ft (1.5 m) from the exposed structure to prevent direct flame impingement on the structure.

3-1.2.7 Outdoor transformers insulated with a less flammable liquid should be separated from each other and from adjacent structures that are critical to power generation by firewalls or spatial separation based on consideration of the factors in 3-1.2.2, 3-1.2.5, and 3-1.2.6.

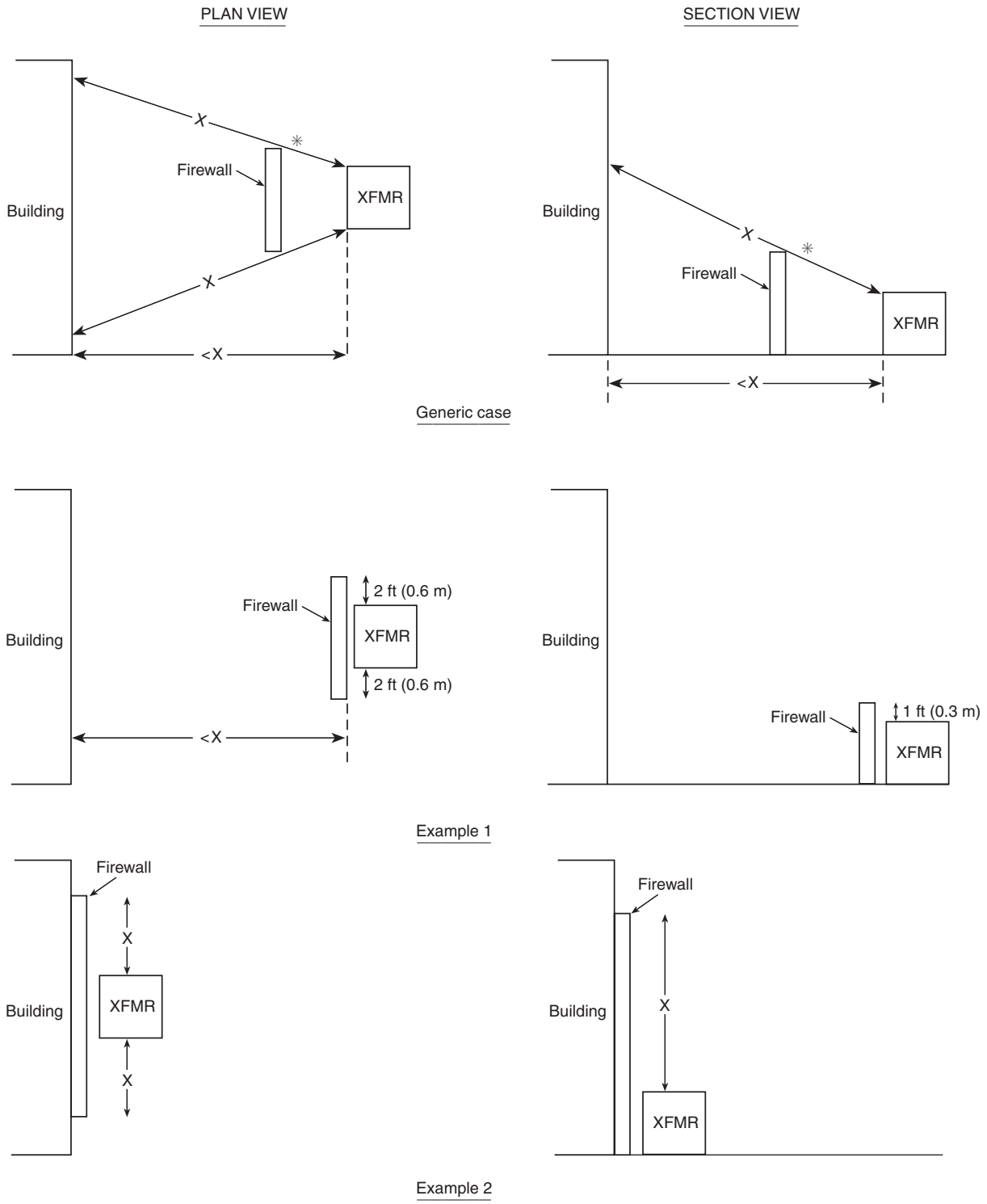
3-1.3 Indoor Transformers.

3-1.3.1 Dry-type transformers are preferred for indoor installations.

3-1.3.2 Oil-insulated transformers of greater than 100 gal (379 L) oil capacity installed indoors should be separated from adjacent areas by fire barriers of 3-hr fire resistance rating.

NOTE: Where multiple transformers of less than 100 gal (379 L) capacity each are located within close proximity, additional fire protection could be required based on the Fire Risk Evaluation.

3-1.3.3 Transformers insulated with less flammable liquids, having a rating above 35 KV and installed indoors, should be separated from adjacent areas by fire barriers of 3-hr fire resistance rating.



Notes:
X = Minimum separation distance from Table 3-1.2.3.
✳ = See Note in 3-1.2.3.

Figure 3-1.2.3 Illustration of oil-insulated transformer separation recommendations.

3-1.3.4 Where transformers are protected by an automatic fire suppression system, the fire barrier fire resistance rating may be permitted to be reduced to 1 hr.

3-1.4 Circuit Breakers.

3-1.4.1 The preferred location for oil circuit breakers is outdoors. Consideration should be given to dry or gas-cooled circuit breakers for indoor applications.

3-1.4.2 Oil-cooled circuit breakers should be separated from adjacent areas by fire barriers having a 3-hr fire resistance rating.

3-1.5 Openings in Fire Barriers.

3-1.5.1 All openings in fire barriers should be provided with fire door assemblies, fire dampers, penetration seals (fire stops), or other approved means having a fire protection rating consistent with the designated fire resistance rating of the barrier. Windows in fire barriers (e.g., control rooms or computer rooms) should be provided with a fire shutter or automatic water curtain. Penetration seals provided for electrical and piping openings should be listed or should meet the requirements for an "F" rating when tested in accordance with ASTM E814, *Fire Tests of Through-Penetration Fire Stops*. Other test methods for qualifications of penetration seals, such as IEEE 634, *Testing Fire Rated Penetration Seals*, may be permitted to be considered for this application.

NOTE: Listed penetration seals for large diameter piping might not be commercially available. In such instances the design should be similar to listed configurations.

3-1.5.2 Fire door assemblies, fire dampers, and fire shutters used in 2-hr rated fire barriers should be rated not less than $1^1/_2$ hr. (*See NFPA 80, Standard for Fire Doors and Fire Windows.*)

3-2 Life Safety.

3-2.1 For life safety for hydroelectric generating plants, see *NFPA 101®*, *Life Safety Code®*.

3-2.2 Structures should be classified as follows, as defined in *NFPA 101, Life Safety Code*:

(a) General areas should be considered as special purpose industrial occupancies.

NOTE 1: Hydroelectric powerhouse structures protected in accordance with this document meet the intent of *NFPA 101, Life Safety Code*, for additional travel distances for fully sprinklered facilities.

NOTE 2: *NFPA 101* allows additional means of egress components for special purpose industrial occupancies. These areas may be permitted to be provided with fixed industrial stairs, fixed ladders (see ANSI A1264.1, *Safety Requirements for Workplace Floor and Well Openings, Stairs, and Railing Systems*, and ANSI A14.3, *Standard for Safety Requirements for Fixed Ladders*), or alternating tread devices (see *NFPA 101*). Examples of these spaces include catwalks, floor areas, or elevated platforms that are provided for maintenance and inspection of in-place equipment.

NOTE 3: *NFPA 101* allows spaces not subject to human occupancy because of the presence of machinery or equipment to be excluded from egress capacity requirements. Examples of these spaces include:

(1) Turbine scroll cases;

(2) Generators;

(3) Access tunnels for dam inspections;

(4) Entry into draft tubes; or

(5) Penstocks.

(b) Temporary occupancies and means of egress inside the structures and piers of large "bulb" units should be evaluated based on occupancies in special structures.

(c) Open structures and underground structures (e.g., tunnels) should be considered as occupancies in special structures.

(d) General office structures should be considered as business occupancies.

(e) Warehouses should be considered as storage occupancies.

3-3 Building Construction Materials.

3-3.1 Construction materials being considered for hydroelectric generating plants should be selected based on the Fire Risk Evaluation using the following standards:

(a) NFPA 220, *Standard on Types of Building Construction;*

(b) NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials;*

(c) NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source;*

(d) NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials;*

(e) NFPA 259, *Standard Test Method for Potential Heat of Building Materials.*

3-3.2 Building components for all powerhouse and subsurface structures should be of noncombustible or limited combustible materials, except as noted in 3-3.3.

3-3.3 Roof coverings should be Class A in accordance with NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*. Metal roof deck construction, where used, should be Class I listed or approved.

3-3.4 Interior Finish.

3-3.4.1 Cellular or foam plastic materials should not be used in interior finish in buildings critical to the generation processes or in subsurface structures.

3-3.4.2 Interior finish in buildings critical to power generation should be Class A.

3-3.4.3 Interior finish in buildings not critical to the generation processes should be Class A or Class B.

3-4 Smoke and Heat Venting, Heating, Ventilating, and Air Conditioning.

3-4.1 Smoke and Heat Venting.

3-4.1.1 Smoke and heat vents are not substitutes for normal ventilation systems unless designed for dual usage, and should not be used to assist such systems for comfort ventilation. Smoke and heat vents should not be left open where they can sustain damage from high wind conditions. They should be included in surveillance programs to ensure availability in emergency situations.

3-4.1.2 Heat vents should be provided for areas identified by the Fire Risk Evaluation. Where heat vents are provided, heat generated under fire conditions should be vented from its place of origin directly to the outdoors.

3-4.1.3 Smoke venting should be provided for areas identified by the Fire Risk Evaluation. Where smoke venting is provided, smoke should be vented from its place of origin in a manner that does not interfere with the operation of the plant.

3-4.1.3.1 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. (*See NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems, and NFPA 204M, Guide for Smoke and Heat Venting.*) Smoke venting also may be permitted to be accomplished through the use of portable smoke ejectors.

3-4.1.3.2 Consideration should be given to smoke venting for the following areas: control room, cable spreading room(s), and switchgear room.

3-4.1.3.3 In the areas with gaseous fire extinguishing systems, the smoke ventilation system should be properly interlocked to ensure the effective operation of the gaseous fire extinguishing systems.

3-4.1.3.4 Smoke removal system dampers, where installed, are normally operable only from an area immediately outside of, or immediately within, the fire area served since it is desired to have entry into, and inspection of, the fire area by fire-fighting personnel prior to restoring mechanical ventilation to the fire area. Smoke removal system dampers may be permitted to be operable from the control room if provisions are made to prevent premature operation. This can be accomplished using thermal interlocks or administrative controls.

3-4.1.4 The fan power supply wiring and controls for smoke exhaust should be located external to the fire area served by the fan or be installed in accordance with the Fire Risk Evaluation.

3-4.1.5 Ventilation exhaust systems, particularly those for subsurface portions of underground facilities, should have fans able to continuously exhaust smoke and chemical fumes that can result from fires or from extinguishing of fires. The design and selection of the fans and other elements of the system should take into account additional ventilation needs for removing smoke and high temperature gases. Therefore the fan and its associated components, along with any ductwork, should be capable of handling high temperatures without deforming. The specific weight and volume of the heated air during a fire and the climatic conditions should also be considered. Total fan capacity should be provided so that ventilation requirements can be met with the largest fan out of service.

NOTE: When fire heats air and introduces products of combustion into the air in tunnels and in underground hydroelectric plants, the ventilation conditions that existed while the air was cold are altered. Frictional resistance to flow of heated air containing products of combustion is much greater than frictional resistance to flow of cold air that does not contain products of combustion. In the event of mild heating, increased resistance to flow would decrease the rate of ventilation. Then, after the fire is contained and the air is cooled, the air and smoke could be evacuated. Therefore, considerations for the health and safety of people underground should cause the designers to increase the rate of evacuating hot air containing smoke. As the fire underground increases the temperature of the air, ventilation flow can be reversed. The cooler ventilating air may flow in one direction occupying much of the lower spaces of tunnels while plumes of heated air flow rapidly outward from the area of the fire beneath the tunnel ceiling in the opposite direction from, and above, the mass of cooler air. The designer should then consider the stratification of air flow, the numerous nodes or junctures between tunnels and shafts, the likely frictional resistances with and without fire, and the placement and capacities of the fans and fire stops.

Some useful information is available in the proceedings of Session XI, *Fires*, of the 2nd International Mine Ventilation Congress. The designer is advised to be thoroughly familiar with Chapter 41, Fire and Smoke Control, in the *ASHRAE Handbook*.

3-4.2 Normal Heating, Ventilating, and Air Conditioning Systems.

3-4.2.1 For normal heating, ventilating, and air conditioning systems, see NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, or NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, as appropriate.

3-4.2.2 Air conditioning for the control room should provide a pressurized environment to preclude the entry of smoke in the event of a fire outside the control room.

3-4.2.3 Plastic ducts, including listed fire-retardant types, should not be used for ventilating systems. Listed plastic fire-retardant ducts with appropriate fire protection may be permitted to be used in areas with corrosive atmospheres.

3-4.2.4 Fire dampers (doors) compatible with the rating of the barrier should be provided at the duct penetrations to the fire area (*see Section 3-1*) unless the duct is protected throughout its length by a fire barrier equal to the rating required of fire barrier(s) penetrated.

3-4.2.5 Smoke dampers, where installed, should be installed in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems.*

3-4.2.6 The fresh air supply intakes to all areas should be located remotely from the exhaust air outlets and smoke vents of other fire areas to minimize the possibility of drawing products of combustion into the plant.

3-4.2.7 Fire hazards should not be located in the principal access or air supply (e.g., conduits, shafts, tunnels) in order to avoid loss of fresh air in the event of a fire.

3-5 Drainage.

3-5.1 Provisions should be made in all fire areas of the plant for removal of all liquids directly to safe areas or for containment in the fire area without 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.

NOTE: Draining the space above the turbine head cover by gravity may not be possible. Both ac and dc drainage pumps discharging into piping leading to the station sump are often provided with suctions in the well where the shaft first extends above the gland seal. In addition, gravity drainage may be impossible from some of the enclosed volumes of "bulb" units. In such cases, accumulated liquids from oil spills and from fire suppression should be pumped to sumps or to other containment volumes.

3-5.2 The provisions for drainage 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 liquid or combustible liquid, or both, in the area.

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

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

NOTE: The provisions for drainage and any associated drainable facilities (pits, sumps, drains to downstream surge chamber and/or tail tunnels or tailrace, and sump pumps) for underground power plants should be sized to accommodate the discharge from the maximum expected discharge of fixed fire suppression system(s) operating for a minimum of two hours.

3-5.3 Floor drainage from areas containing flammable or combustible liquids should be trapped to prevent the spread of burning liquids beyond the fire area.

3-5.4 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.

3-5.5 Drainage facilities should be provided for outdoor oil-insulated transformers, or the ground should be sloped such that oil spills will flow away from buildings, structures, and adjacent transformers. Unless drainage from oil spills is accommodated by sloping the ground around transformers away from structures or adjacent equipment, consideration should be given to providing curbed areas or pits around transformers. The pit or drain system or both should be sized in accordance with 3-5.2. The curbed area or pit may be permitted to be filled with uniformly graded, crushed stone as a means of minimizing ground fires.

3-5.6 For facilities consisting of more than one generating unit, a curb or trench drain should be provided on solid floors where the potential exists for an oil spill, such that oil released from an incident on one unit will not expose an adjacent unit.

3-5.7 For environmental reasons, liquid discharges resulting from oil spills or operation of a fire suppression system may have to be treated (e.g., oil separation).

3-5.8 An emergency power supply should be provided for principal drainage pumps in situations where flooding would be dangerous.

3-6 Emergency Lighting.

3-6.1 Emergency lighting should be provided for means of egress in accordance with *NFPA 101, Life Safety Code.*

3-6.2 Emergency lighting should be provided for critical plant operations areas.

3-7 Lightning Protection. Lightning protection, where required, should be provided in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems.*

Chapter 4 General Fire Protection Systems and Equipment

4-1 General Considerations. All fire protection systems, equipment, and installations should be dedicated to fire protection purposes.

4-2 Water Supply.

4-2.1 Hydroelectric plants are commonly located in remote areas adjacent to rivers or at the base of lakes. Fire protection water supplies may be permitted to be limited to the water from the river, lake, reservoir, or private tank(s). Consideration should be given to the special problems for this type of water supply (i.e., freezing, low flow, heavy sediment) associated with requirements for the fire protection systems, equipment, and installation.

4-2.2 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 of not less than 500 gpm (31.5 L/sec) for a two-hour duration.

4-2.3 If a single water supply is utilized, two independent connections should be provided. If a situation can arise in which the primary water supply can become unavailable (e.g., dewatering of penstocks), an auxiliary supply should be provided. Each supply should be capable of meeting the requirements in 4-2.2.

4-2.3.1 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 requirements determined by 4-2.2 with the largest pump out of service.

4-2.3.2 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 stations, see Section 4-9.

4-2.3.3 If tanks are of dual-purpose use, a standpipe or similar arrangement should be provided to dedicate the amount determined by 4-2.2 for fire protection use only. (*See NFPA 22, Standard for Water Tanks for Private Fire Protection.*)

4-2.3.4 Where tanks are used, they should be filled from a source capable of replenishing the 2-hour supply for the fire protection requirement in an 8-hour period. The 8-hour (time) requirement for refilling may be permitted to be extended if the initial supply exceeds the minimum storage requirement on a volume per time ratio basis. It is normally preferred for the refilling operation to be accomplished on an automatic basis.

4-2.4 Each water supply should be connected to the station supply main by separate connections, arranged and valve controlled to minimize the possibility of multiple supplies being impaired simultaneously.

4-2.5 In some rivers and tributaries, the existence of microorganisms limits the use of raw water for fire protection without treatment. Consideration of water quality can prevent long-term problems relating to fire protection water supply.

4-2.6 Upstream water is frequently the fire protection water supply. Water for fire suppression should not be taken downstream from any closure device in a penstock, flume, or forebay.

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 by one of the following methods:

(a) Electrical supervision with audible and visual signals in the main control room or other constantly attended location.

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

(c) Sealing of valves. This option should be followed only when valves are within fenced enclosures under the control of the property owner.

4-4 Supply Mains and Hydrants.

4-4.1 Supply mains and fire hydrants should be installed on the plant site. (*See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*)

4-4.1.1 Remotely located plant-related facilities should be reviewed on an individual basis to determine the need for fire protection. If excessively long extensions of underground fire mains are necessary for fire protection at these locations, it may be permitted to supply this need from an available service main in the immediate area.

4-4.1.2 The supply mains should be looped and of sufficient size to supply the flow requirements determined by 4-2.2 to any point in the loop considering the most direct path to be out of service. Pipe sizes should be designed to encompass any anticipated expansion and future water demands.

4-4.1.3 Indicator control valves should be installed to provide adequate sectional control of the fire main loop to minimize plant protection impairments.

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

4-4.3 It may be necessary for the fire department to draft from the river or lake adjacent to the plant. However, the terrain and elevation above the water supply may make it difficult for drafting. Consideration should be given to installing a dry hydrant with adequate fire apparatus access that will take suction from the river above the hydroelectric plant.

4-5 Standpipe and Hose Systems.

4-5.1 Standpipe and hose systems should be installed. (*See NFPA 14, Standard for the Installation of Standpipe and Hose Systems.*) The standpipe and hose system is an extension of the fire main and hydrant system. The hose stations should be capable of delivering the hose stream demand for the various hazards in buildings.

4-5.2 Fire main connections for standpipes should be arranged so that a fire main break can be isolated without interrupting service simultaneously to both fixed protection and hose connections protecting the same hazard or area. For the important hazards the arrangement should permit operation of at least two hose lines on a fire. For areas of high water demand, the installation should meet the requirements for a Class III system. (*See NFPA 14, Standard for the Installation of Standpipe and Hose Systems.*) For other areas, a Class II system may be permitted to suffice.

4-5.3 The standpipe piping should be capable of providing minimum volume and pressure for the highest hose stations.

4-5.4 Due to the open arrangement of these plants, the locations of hose stations should take into account safe egress for personnel operating hose lines.

4-5.5 Spray nozzles having shutoff capability and listed for use on electrical equipment should be provided on hoses located in areas near energized electrical equipment.

4-5.6 Hose Threads. Hose threads on hydrants and standpipe systems should be compatible with fire hose used by the responding fire departments.

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 — General Requirements.

4-7.1 Fire suppression systems and equipment should be provided in all areas of the plant as identified in Chapter 5 or as determined by the Fire Risk Evaluation. Fixed suppression systems should be designed in accordance with the following codes and standards unless specifically noted otherwise:

NFPA 11, *Standard for Low-Expansion Foam*

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

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

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

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

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

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

NFPA 231, *Standard for General Storage*

NFPA 231C, *Standard for Rack Storage of Materials.*

4-7.2 The selection of extinguishing agent should be based on:

(a) Type of hazard.

(b) Effect of agent discharge on equipment.

(c) Health hazards.

NOTE: Personnel hazards created by the discharge of CO_2 should be considered in the design of the system. The design should take into account the immediate release of CO_2 into the protected area and the possibility of CO_2 leakage, migration, and settling into adjacent areas and lower elevations of the plant. See NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, for hazards to personnel. As a minimum, if CO_2 systems are provided, they should be provided with an odorizer for alerting personnel, and breathing apparatus should be provided for operators in areas that cannot be abandoned.

4-7.3 Fire Suppression System Safety Considerations. It is imperative that safety in the use of any fire suppression system be given proper consideration and that adequate planning be done to ensure safety of personnel.

Potential safety hazards could include impingement of high velocity discharge on personnel, loss of visibility, hearing impairment, reduced oxygen levels that will not support breathing, toxic effects of the extinguishing agent, and electric conductivity of water-based agents.

NFPA standards for the extinguishing systems used should be carefully studied and the personnel safety provisions followed. Evacuation of a protected area is recommended before any special extinguishing system discharges. Alarm systems that are audible above machinery background noise, or that are visual or olfactory or a combination, should be used where appropriate. Personnel warning signs are necessary. (*See NFPA 12, Standard on Carbon Dioxide Extinguishing Systems, and NFPA 12A, Standard on Halon 1301 Fire Extinguishing Systems.*)

4-8 Fire Signaling Systems.

4-8.1 Fire detection and automatic fixed fire suppression systems should be equipped with local audible and visual signals with annunciation in the main control room or another constantly attended location. (*See NFPA 72 , National Fire Alarm Code.*)

4-8.1.1 Audible fire alarms should be distinctive from other plant system alarms.

4-8.1.2 Special consideration should be given to alerting personnel in confined spaces, such as in scroll/spiral cases or draft tubes, that a fire alarm system has been activated.

4-8.2 Automatic fire detectors should be installed in accordance with NFPA 72, *National Fire Alarm Code.*

4-8.3 The fire signaling system or plant communication system should provide the following:

(a) Manual fire alarm devices (e.g., pull boxes or page party stations) installed in all occupied buildings. Manual fire alarm devices should be installed for remote yard hazards as identified by the Fire Risk Evaluation.

(b) Plant-wide audible fire alarm or voice communication systems, or both, for purposes of personnel evacuation and alerting of plant emergency organization. The plant public address system, if provided, should be available on a priority basis.

(c) Two-way communications for the plant emergency organization during emergency operations.

(d) Means to notify the public fire department.

4-9 Unattended Plants.

4-9.1 Hydroelectric plants 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 of the fire brigade or public fire-fighting personnel (which can be several hours) and to the lack of personnel available to alert others on site to a fire condition.

4-9.3 The Fire Risk Evaluation 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. The delayed response by personnel to the site may necessitate automatic shutoff of fire pumps.

4-9.4 If automatic water-based fire suppression systems are utilized, a cycling deluge valve should be considered. The arrangement will depend on the type of system and the hazard protected. Thermal detection is recommended. (System design should be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, or NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection.*)

4-9.5 Remote annunciation of the fire signaling panel to one or more constantly attended location is critical for emergency response. The fire signaling panel should be located at the entry to the plant.

4-9.6 An emergency lighting system for critical operating areas that depends on batteries or fuel supplies should be manually operated from a switch at the entry to the plant. The emergency lighting may be permitted to consist either of fixed units or of portable lights. (*See 3-6.2.*)

4-9.7 It is important that the responding fire brigade or public fire-fighting forces be familiar with access, plant fire protection systems, emergency lighting, specific hazards, and methods of fire control. This should be reflected in the plant fire emergency plan. (*See Section 2-7.*)

4-9.8 The air supply and exhaust systems for the plant should be automatically shut down in the event of a fire. Manual override should be located at the entry to the plant so that emergency responders can activate these controls upon arrival.

Chapter 5 Identification and Protection of Hazards

5-1 General. The identification and selection of fire protection systems should be based on the Fire Risk Evaluation. This chapter identifies fire and explosion hazards in hydroelectric generating stations and specifies the recommended protection criteria unless the Fire Risk Evaluation indicates otherwise.

5-2 Turbine-Generator Hydraulic Control and Lubricating Oil Systems.

5-2.1 Hydraulic Control Systems.

5-2.1.1 Hydraulic control systems should use a listed fire-resistant fluid.

5-2.1.2 Determination of the need for fire-resistant fluid should be based on the quantity of fluid involved in the system, whether or not equipment that utilizes this fluid will operate hot or be exposed to external sources of ignition, and whether exposure problems are created for adjacent equipment by the use of nonfire-resistant fluid.

5-2.1.3 If a listed fire-resistant fluid is not used, hydraulic control equipment should be protected. Fire extinguishing systems, where installed for hydraulic control equipment, should include protection for reservoirs, other equipment, valves, and associated piping.

5-2.2 Wherever possible, oil piping should be welded and flanged to minimize the possibility of an oil leak due to severe vibration.

5-2.3 Oil piping should be routed away, or be shielded from, electrical equipment or other sources of ignition.

5-2.4 Fixed fire protection for this equipment, where provided, should be as follows:

(a) Automatic wet pipe sprinkler systems utilizing a design density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) for the entire hazard area (*see 3-5.3*).

(b) Automatic foam-water sprinkler systems providing a density of 0.16 gpm/ft^2 (0.11 L/sec-m^2).

(c) Gaseous extinguishing systems of either the local application or total flooding types. Safety considerations associated with these extinguishing agents should be evaluated prior to the selection of gas-type protection systems.

NOTE: When areas or rooms are located beneath areas protected by CO_2 (or other extinguishing gases), consideration should be given in the design for the possible settling of the gas to lower levels and its effect on personnel who may be in these areas.

5-2.5 Consideration for protection of horizontal and vertical turbine bearings should be made based on the Fire Risk Evaluation.

5-2.6 Curbs [minimum 6 in. (0.15 m) high] or drains or both should be provided for the oil storage and oil purification areas in accordance with Chapter 3.

5-2.7 Fire extinguishing systems, where installed for lube oil systems employing combustible-type oil, should include protection for the reservoirs, pumps, and all oil lines, especially where unions exist on piping and beneath any shielded area where flowing oil can collect. Facilities not provided with curbs or drains should extend coverage for a distance of 20 ft (6 m) from the oil lines, when measured from the outermost oil line.

5-2.8 Clean or dirty oil storage areas should be protected based on the Fire Risk Evaluation. This area generally represents the largest concentrated oil storage in the plant. The designer should consider, as a minimum, the installation of fixed automatic fire protection systems, and the ventilation and drainage requirements in Chapter 3.

5-3 Generator Windings.

5-3.1 Protection of generator windings should be provided by gaseous extinguishing systems, waterspray rings, or both. Consideration for protection should be given to the composition of the winding insulation and the rating of the generator.

5-3.2 Gaseous suppression systems should be actuated by protective relays or fire detection systems or both.

5-3.3 Waterspray rings should be manually actuated or automatically actuated by an interlocked system that requires the unit to be tripped.

5-4 Control, Computer, and Communication Rooms.

5-4.1 Control, computer, and telecommunication rooms should meet applicable requirements of NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment.*

5-4.2 A smoke detection system should be installed throughout these rooms including walk-in-type consoles, above suspended ceilings where combustibles are installed, and below raised floors. Where the only combustibles above the false ceiling are cables in conduit and the space is not used as a return air plenum, smoke detectors may be permitted to be omitted from this area.

5-4.3 A preaction sprinkler system for the computer or telecommunications rooms should be considered during the Fire Risk Evaluation. In addition, gaseous extinguishing systems should be considered for areas beneath raised floors that contain cables or for areas or enclosures containing equipment that is of high value or is critical to power generation. Individual equipment or cabinet protection could be considered in lieu of total flooding systems.

5-4.4 Cable raceways not terminating in the control room should not be routed through the control room.

5-5 Cable Concentrations.

5-5.1 Consideration should be given to the use of fire-retardant cable insulation such as the types that pass the flame propagation test of the Institute of Electrical and Electronics Engineers (IEEE-383).

5-5.2 Areas with significant concentrations of combustible cable jacketing or oil-filled cable should be protected with automatic sprinkler or water spray systems. However, if water-type systems cannot be used, foam or gaseous extinguishing systems should be provided.

5-5.3 Sprinkler or water spray systems should be designed for a density of 0.30 gpm/ft^2 (0.20 L/sec-m^2) over 2500 ft^2 (232 m^2). This coverage is for area protection. Individual cable tray tier coverage could be required based on the Fire Risk Evaluation.

5-5.4 Cable with Fire-Retardant Coatings.

5-5.4.1 A suitable alternative for combustible jacket cable automatic protection would be cable with fire-retardant coatings. The method of protection should be based on the Fire Risk Evaluation.

5-5.4.2 Care should be exercised in selection of fire-retardant coatings to ensure that derating of the cable is considered. Consideration should also be given to the ability to add or remove cables and to make repairs to cables protected with fire-retardant coatings.

5-5.5 Grouped electrical cables should be routed away from exposure hazards or protected as required by the Fire Risk Evaluation. In particular, care should be taken to avoid routing cable trays near sources of ignition or flammable or combustible liquids. Where such routing is unavoidable, cable trays should be designed and arranged to prevent the spread of fire.

5-6 Cable Tunnels.

5-6.1 Where protection is required by the Fire Risk Evaluation, cable tunnels should be protected by automatic water spray, automatic wet pipe sprinkler, or foam systems. Automatic sprinkler systems should be designed for a density of 0.30 gpm/ft^2 (0.20 L/sec-m^2) over 2500 ft^2 (232 m^2) or the most remote 100 linear ft (30 m) of cable tunnel up to 2500 ft^2 (232 m^2).

5-6.2 Portable high-expansion foam generators may be permitted to be used to supplement fixed fire protection system(s). (*See NFPA 11C , Standard for Mobile Foam Apparatus.*)

5-6.3 Ventilation and drainage should be provided for these areas in accordance with Chapter 3.

5-7 Transformers. Oil-filled main, station service, and startup transformers should be protected with automatic water spray or foam-water spray systems.

5-8 Indoor Oil-Filled Electrical Equipment. Automatic sprinkler, foam-water, and water spray systems should be considered for oil-filled electrical equipment. Where the hazard is not great enough to warrant a fixed fire suppression system, automatic fire detection should be considered. (*See 4-8.2.*)

5-9 Battery Rooms. Battery rooms should be provided with ventilation to limit the concentration of hydrogen to one percent by volume. For further information, refer to ANSI/IEEE 484, *Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations.*

5-10 Switchgear and Relay Rooms. Switchgear rooms and relay rooms should be provided with smoke detection systems.

5-11 Emergency Generators.

5-11.1 The installation and operation of emergency generators should be in accordance with NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines.*

5-11.2 Emergency generators located within main plant structures should be protected by automatic sprinkler, water spray, foam-water sprinkler, or gaseous-type extinguishing systems. Sprinkler and water spray protection systems should be designed for a 0.25 gpm/ft^2 (0.17 L/sec-m^2) density over the fire area.

5-11.3 Where gaseous suppression systems are used on combustion engines, which can be required to operate during the system discharges, consideration should be given to the supply of engine combustion air and outside air for equipment cooling.

5-12 Air Compressors. Automatic sprinkler protection, with a density of 0.25 gpm/ft^2(0.17 L/sec-m^2) over the postulated oil spill, should be considered for air compressors containing a large quantity of oil. Where the hazard is not great enough to warrant a fixed fire suppression system, automatic fire detection should be considered. (*See 4-8.2.*)

5-13 Hydraulic Systems for Gate and Valve Operators. Hydraulic control systems should use a listed fire-resistant fluid. Automatic sprinkler protection designed for a density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) over the fire area should be considered for hydraulic systems not using a listed fire-resistant fluid. Where the hazard is not great enough to warrant a fixed fire suppression system, automatic fire detection should be considered. (*See 4-8.2.*)

5-14 Fire Pumps. Rooms housing diesel-driven fire pumps should be protected by automatic sprinkler, water spray, or foam-water sprinkler systems. If sprinkler and water spray protection systems are provided they should be designed for a density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) over the fire area. For automatic foam-water sprinkler systems, a density of 0.16 gpm/ft^2 (0.11 L/sec-m^2) should be provided.

5-15 Storage Rooms, Offices, and Shops. Automatic sprinklers should be provided for storage rooms, offices, and shops containing combustible materials that present an exposure to surrounding areas that are critical to plant operations. (*For oil storage rooms, see 5-2.8.*)

5-16 Warehouses. Automatic sprinklers should be provided for warehouses that contain high-value equipment and combustible materials that are critical to power generation or that constitute a fire exposure to other important buildings.

5-17 Auxiliary Heating. The storage and piping systems of fuels in the gaseous or liquefied state should comply with NFPA 31, *Standard for the Installation of Oil Burning Equipment*; NFPA 54, *National Fuel Gas Code*; NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*; and NFPA 8501, *Standard for Single Burner Boiler Operation*, as applicable.

5-18 Garages. Vehicle repair facilities should meet the requirements of NFPA 88B , *Standard for Repair Garages.*

Chapter 6 Fire Protection for the Construction Site

6-1 Introduction.

6-1.1 Although many of the activities in hydroelectric generating plant construction are similar to the construction of other large industrial plants, sites for hydroelectric generating plants are frequently located in remote areas with restricted access and limited construction space. Congested or distant construction facilities may be required, and specialized activities such as deep excavation and tunneling may be encountered. An above average level of construction fire protection is justified due to the life safety consideration of the large number of on-site personnel, high value of materials, and length of construction period.

6-1.2 Major construction projects in existing plants present many of the hazards associated with new construction while presenting additional exposures to the existing facility. The availability of the existing plant fire protection equipment and the reduction of fire exposure by construction activities are particularly important.

6-1.3 For fire protection for plants and areas under construction, see NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations.* This chapter addresses concerns not specifically considered in NFPA 241.

6-2 Administration.

6-2.1 The responsibility for fire prevention and fire protection for the entire site during the construction period should be clearly defined. The administrative responsibilities should be to develop, implement, and periodically update as necessary the measures outlined in this practice.

6-2.2 The responsibility for fire prevention and fire protection programs among various parties on site should be clearly delineated. The fire protection program that is to be followed and the owner's right to administration and enforcement should be established.

6-2.3 The fire prevention and fire protection program should include a Fire Risk Evaluation of the construction site and construction activities at any construction camp. (*See Chapter 2.*)

6-2.4 Written administrative procedures should be established for the construction site, and such procedures should, as a minimum, be in accordance with Sections 2-4, 2-5, and 2-7.

6-2.5 Security guard service, including recorded rounds, should be provided through all areas of construction during times when construction activity is not in progress. (*See NFPA 601, Standard for Security Services in Fire Loss Prevention.*)

6-2.5.1 The first round should be conducted one-half hour after the suspension of work for the day. Thereafter, rounds should be made every hour.

6-2.5.2 Where partial construction activities occur on second and third shifts, the security service rounds may be permitted to be modified to include only unattended or sparsely attended areas.

6-2.5.3 In areas where automatic fire detection or extinguishing systems are in service, with alarm annunciation at a constantly attended location, or in areas of limited combustible loading, rounds may be permitted to be omitted after the first round indicated in 6-2.5.1.

6-2.6 Construction should be coordinated so that planned permanent fire protection systems are installed and placed in service as soon as possible, at least prior to the introduction of any major fire hazards identified in Chapter 5. In-service fire detection and fire extinguishing systems provide important protection for construction materials, storage, etc., even before the permanent hazard is present. Temporary fire protection systems may be warranted during certain construction phases. The need and type of protection should be determined by the individual responsible for fire prevention and fire protection. Construction and installation of fire barriers and fire doors should be given priority in the construction schedule.

6-3 Site Clearing, Excavation, and Tunneling.

6-3.1 Site Clearing.

6-3.1.1 Prior to clearing forest and brush covered areas, the owner should ensure that a written fire control plan is prepared and that fire-fighting tools and equipment are made available as recommended by NFPA 295, *Standard for Wildfire Control*. Contact should be made with local fire and forest agencies for current data on restrictions and fire potential and to arrange for necessary permits.

6-3.1.2 All construction vehicles and engine-driven portable equipment should be equipped with effective spark arrestors. Vehicles equipped with catalytic converters should be prohibited from wooded and heavily vegetated areas.

6-3.1.3 Fire tools and equipment should be used for fire emergencies only and should be distinctly marked.

6-3.1.4 Each site utility vehicle should be equipped with at least one fire-fighting tool, portable fire extinguisher, or backpack pump filled with 4 gal to 5 gal (15 L to 19 L) of water.

6-3.1.5 Cut trees, brush, and other combustible spoil should be disposed of promptly.

6-3.1.6 Where it is necessary to dispose of combustible waste by onsite burning, designated burning areas should be established with approval by the owner and should be in compliance with federal, state, and local regulations and guidelines. The contractor should coordinate burning with the agencies responsible for monitoring fire danger in the area and obtain all appropriate permits prior to the start of work. (*See Section 6-2.*)

6-3.1.7 Local conditions may require the establishment of fire breaks by clearing or use of selective herbicides in areas adjacent to property lines and access roads.

6-3.2 Excavation and Tunneling.

6-3.2.1 Construction activities related to tunnels, shafts, and other underground excavations are strictly regulated by federal and state agencies. Fire prevention consists of adequate ventilation, good housekeeping, and limiting the types of fuel, explosives, and combustibles underground as well as adjacent to entrances and ventilation intakes. Inspection of site conditions and the testing of air quality should be assigned to qualified personnel specifically trained in the use of those instruments specified by the regulating agency.

6-3.2.2 Pre-excavation geologic surveys should include tests for carbonaceous or oil-bearing strata, peat, and other organic deposits that can be a source of combustible dusts or explosive gases.

6-3.2.3 The use of vehicles and equipment requiring gasoline, liquefied petroleum gas, and other fuels in excavations with limited air circulation should be restricted.

6-3.2.4 A general plan of action for use in times of emergency should be prepared for every underground excavation. (*See Section 6-2.*)

6-3.3 Construction Equipment. Construction equipment should meet the requirements of NFPA 121, *Standard on Fire Protection for Self-Propelled Mobile Surface Mining Equipment*, and NFPA 512, *Standard for Truck Fire Protection*.

6-4 Construction Warehouses, Shops, Offices, and Construction Camps.

6-4.1 All structures that are to be retained as part of the completed plant should be constructed of materials as required in Chapter 3 and should comply with other requirements of this document for the completed plant.

6-4.2 Construction warehouses, offices, trailers, sheds, and other facilities for the storage of tools and materials should be located with consideration for their exposure to major plant buildings or other important structures. These buildings should be located according to the requirements of NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, and NFPA 299, *Standard for Protection of Life and Property from Wildfire*, as applicable.

6-4.3 Mobile homes should be installed and located according to the requirements of NFPA 501A, *Standard for Fire Safety Criteria for Manufactured Home Installations, Sites, and Communities*. Insulating materials utilized in mobile homes should be noncombustible.

6-4.4 Large central office or storage facilities, where provided, should be located so as not to expose major plant buildings or other important structures. These facilities can be of substantial value, containing high value computer equipment, irreplaceable construction records, or other valuable contents, the loss of which could result in significant construction delays. The Fire Risk Evaluation may indicate a need for auto-

matic sprinklers or other protection, the desirability of subdividing the complex to limit values exposed by one fire, or a combination of the above.

6-4.5 Construction camps comprised of mobile buildings arranged with the buildings adjoining each other to form one large fire area should be avoided. If buildings cannot be adequately separated, consideration should be given to installing fire walls between units or installing automatic sprinklers throughout the buildings.

6-4.6 Construction camp buildings should be designed and installed in accordance with *NFPA 101, Life Safety Code.*

6-4.7 Area fire alarms should be connected to a constantly attended central location such as a fire station or site manager's office with monitoring and central alarm control. Dormitory buildings and bunkhouses should be provided with smoke detection throughout. The alarm panels for the individual buildings served should be located at the entrance to the building. Detector installation should conform to NFPA 72, *National Fire Alarm Code.*

6-4.8 The location for central alarm control should be provided with the following:

(a) Remote fire pump start button.

(b) Manual siren start/stop button.

(c) Provision for alerting the fire crew by VHF radio, fire alert paging, etc.

(d) Monitors for communication between security guard and fire crew at place of fire.

(e) Radio link between security guards' office and the respective fire department.

6-4.9 Warehouses and shops can contain materials whose loss or damage would cause a delay in startup or severe financial loss. Although some of these structures are considered to be temporary and will be removed upon completion of the plant, the fire and loss potential should be thoroughly evaluated and protection provided where warranted. Where the Fire Risk Evaluation indicates a need for protection for warehouses and shops the following guidelines should apply.

6-4.9.1 Building construction materials should be noncombustible or limited combustible. (*See Chapter 3.*)

6-4.9.2 Automatic sprinkler systems should be designed and installed in accordance with the applicable NFPA standards. Waterflow alarms should be provided and located so as to be monitored at a constantly attended location as determined by the individual responsible for fire prevention and fire protection.

6-4.9.3 Air-supported structures are sometimes used to provide temporary warehousing space. Although the fabric envelope may be a fire-retardant material, the combustibility of contents and their value should be considered, as with any other type of warehouse. Because it is impractical to provide automatic sprinkler protection for them, air-supported structures should only be used for noncombustible storage. An additional consideration is that relatively minor fire damage to the fabric envelope can leave the contents exposed to the elements.

6-4.10 Temporary enclosures, including trailers, inside permanent plant buildings should be prohibited except where permitted by the individual responsible for fire prevention and fire protection. Where the floor area of a combustible enclosure exceeds 100 ft^2(9.3 m^2) or where the occupancy presents a fire exposure, the enclosure should be protected with an approved automatic fire extinguishing system.

6-4.11 Storage of construction materials, equipment, or supplies that are either combustible or in combustible packaging should be prohibited in main plant buildings unless:

(a) An approved automatic fire extinguishing system is in service in the storage area, or

(b) The loss of the materials or loss to the surrounding plant area would be minimal, as determined by the individual responsible for fire prevention and fire protection.

6-4.12 Construction kitchens should have automatic protection installed over the fryers. Guidance is provided in NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations.*

6-4.13 Vehicle repair facilities should meet the requirements of NFPA 88B, *Standard for Repair Garages.*

6-4.14 The handling, storage, and dispensing of flammable liquids and gases should meet the requirements of NFPA 30, *Flammable and Combustible Liquids Code,* NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases,* and NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites.*

6-5 Construction Site Laydown Areas.

6-5.1 Fire hydrant systems with an adequate water supply should be provided in laydown areas where the need is determined by the individual responsible for fire prevention and fire protection. (*See Chapter 4.*)

6-5.2 Combustible materials should be separated by a clear space to allow access for manual fire-fighting equipment (*see Section 6-8*). Access should be provided and maintained to all fire-fighting equipment including fire hoses, extinguishers, and hydrants.

6-6 Temporary Construction Materials.

6-6.1 The use of listed pressure-impregnated fire-retardant lumber or listed fire-retardant coatings would be generally acceptable. Pressure-impregnated fire-retardant lumber should be used in accordance with its listing and manufacturer's instructions. Where exposed to the weather or moisture (e.g., draft tubes, semi-spiral cases), the fire retardant used should be suitable for this exposure. Fire-retardant coatings should not be permitted on walking surfaces or surfaces subject to mechanical damage.

6-6.2 Tarpaulins and plastic films should be of listed weather-resistant and fire-retardant materials. (*See NFPA 701, Standard Methods of Fire Tests for Flame-Resistant Textiles and Films.*)

6-6.3 Consideration should be given to providing sprinkler protection for combustible form work where a fire could cause substantial damage or construction delays.

6-7 Underground Mains, Hydrants, and Water Supplies.

6-7.1 Where practical, the permanent underground yard system, fire hydrants, and water supply (at least one totally reliable source of required capacity), as recommended in Chapter 4, should be installed during the early stages of construction. Where provision of all or part of the permanent underground system and water supply is not practical, temporary systems should be provided. Temporary water supplies should be hydrostatically tested, flushed, and arranged to maintain a high

degree of reliability, including protection from freezing and loss of power. Where using construction water in permanent systems, adequate strainers should be provided to prevent clogging of the system by foreign objects and dirt.

6-7.2 The necessary reliability of construction water supplies, including redundant pumps, arrangement of primary and backup power supplies, and use of combination service water and construction fire protection water, should be reviewed by the individual responsible for fire prevention and fire protection.

6-7.3 Hydrants should be installed, as recommended by Chapter 4, in the vicinity of main plant buildings, important warehouses, office or storage trailer complexes, important outside structures and laydown areas with combustible construction, construction camp complexes, or combustible concrete form work (e.g., draft tube and turbine-generator blockouts). Where practical, the underground main should be arranged utilizing post indicator valves to minimize the possibility that any one break will remove from service any fixed water extinguishing system or leave any area without accessible hydrant protection.

6-7.4 A fire protection water supply should be provided on the construction site and should be capable of furnishing the largest of the following for at least a 2-hour duration:

(a) 750 gpm (47 L/sec), or

(b) The in-service fixed water extinguishing system with the highest water demand plus 500 gpm (32 L/sec) for hose streams.

NOTE 1: The highest water demand should be determined by the hazards present at the stage of construction, which may not correspond with the highest water demand of the completed plant.

NOTE 2: The water supply should be sufficient to provide adequate flow and pressure for hose connections at the highest elevation.

6-7.5 Vehicles, equipment, materials, and supplies should be placed so that access to fire hydrants and other fire-fighting equipment is not obstructed.

6-7.6 Fixed systems should be provided as soon as construction permits. These systems should be provided in continuous operating condition.

6-7.7 As fixed water extinguishing systems are completed, they should be placed in service, even when the available construction phase fire protection water supply is not adequate to meet the system design demand. The extinguishing system can at least provide some degree of protection, especially where the full hazard is not yet present. However, when the permanent hazard is introduced, the water supply should be capable of providing the designed system demand.

6-7.8 On sites where large differences in elevation exist between construction facilities, satisfying pressure requirements at the highest elevation can result in hazardous pressure conditions at the lower elevations unless some approved method of pressure regulation is included in the system. Attempting to compensate for high-pressure conditions by partially opening dry barrel hydrants can result in erosion at the hydrant thrust block and should be avoided.

6-8 Fire Suppression Systems and Equipment.

6-8.1 In general, fire suppression equipment should be:

(a) Provided where risk of fire exists.

(b) Suitable as to type and size for combating any likely fire.

(c) Protected from mechanical damage.

(d) Located for easy access at well-identified stations.

(e) Maintained in good operating condition.

(f) Protected from freezing.

6-8.2 Portable fire extinguishers of suitable capacity should be provided where:

(a) Flammable liquids are stored or handled.

(b) Temporary oil- or gas-fired equipment is used.

(c) A tar or asphalt kettle is used.

(d) lWelding or open flames are in use.

(*See NFPA 10, Standard for Portable Fire Extinguishers.*)

6-8.3 First aid fire-fighting equipment should be provided. (*See NFPA 600, Standard on Industrial Fire Brigades, and NFPA 241, Standard for Safeguarding Construction, Alteration, and Demolition Operations.*)

6-8.4 Hoses and nozzles should be available at strategic locations inside hose cabinets, hose houses, or on dedicated fire response vehicles.

6-8.5 No fire protection equipment or device should be made inoperable or used for other purposes.

6-8.6 If fire hose connections are not compatible with local fire-fighting equipment, adapters should be made available.

Chapter 7 Referenced Publications

7-1 The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of the document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

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

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

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

NFPA 11C, *Standard for Mobile Foam Apparatus*, 1995 edition.

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

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

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

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

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

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

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

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

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

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1995 edition.

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

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 1994 edition.

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

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

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

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

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

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

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

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

NFPA 88B, *Standard for Repair Garages*, 1991 edition.

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

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

NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations*, 1994 edition.

NFPA 101, Life Safety Code, 1994 edition.

NFPA 121, *Standard on Fire Protection for Self-Propelled and Mobile Surface Mining Equipment*, 1996 edition.

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

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

NFPA 231, *Standard for General Storage*, 1995 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 1995 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1993 edition.

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

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

NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*, 1995 edition.

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

NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*, 1993 edition.

NFPA 257, *Standard for Fire Tests of Window Assemblies*, 1996 edition.

NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 1993 edition.

NFPA 295, *Standard for Wildfire Control*, 1991 edition.

NFPA 299, *Standard for Protection of Life and Property from Wildfire*, 1991 edition.

NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites*, 1993 edition.

NFPA 501A, *Standard for Fire Safety Criteria for Manufactured Home Installations, Sites, and Communities*, 1992 edition.

NFPA 512, *Standard for Truck Fire Protection*, 1994 edition.

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

NFPA 601, *Standard for Security Services in Fire Loss Prevention*, 1996 edition.

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

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 1995 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems*, 1994 edition.

NFPA 1962, *Standard for the Care, Use, and Service Testing of Fire Hose Including Couplings and Nozzles*, 1993 edition.

NFPA 1972, *Standard on Helmets for Structural Fire Fighting*, 1992 edition.

NFPA 8501, *Standard for Single Burner Boiler Operation*, 1992 edition.

7-1.2 Other Publications.

7-1.2.1 ANSI Publications. American National Standards Institute Inc., 1450 Broadway, New York, NY 10018.

ANSI A14.3, *Standard for Safety Requirements for Fixed Ladders*, 1984.

ANSI A1264.1, *Safety Requirements for Workplace Floor and Well Openings, Stairs, and Railing Systems*, 1992.

ANSI Z210.1, *Metric Practice Guide*, 1993.

7-1.2.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19105.

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750° C*, Rev A-94.

ASTM E380 (See ANSI Z210.1), 1993.

ASTM E814, *Fire Tests of Through-Penetration Fire Stops*, Rev B-94.

7-1.2.3 IEEE Publications. Institute of Electrical and Electronics Engineers, 345 East 47 St., New York, NY 10070.

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

IEEE 484, *Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations*, 1987.

IEEE 634, *Testing Fire Rated Penetration Seals.*