NFPA® 851

Recommended Practice for Fire Protection for Hydroelectric Generating Plants

2010 Edition

NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471
An International Codes and Standards Organization

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NFPA® 851

Recommended Practice for

Fire Protection for Hydroelectric Generating Plants

2010 Edition

This edition of NFPA 851, *Recommended Practice for Fire Protection for Hydroelectric Generating Plants*, was prepared by the Technical Committee on Electric Generating Plants. It was issued by the Standards Council on October 27, 2009, with an effective date of December 5, 2009, and supersedes all previous editions.

This edition of NFPA 851 was approved as an American National Standard on December 5, 2009.

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 contained minor changes to clarify the life safety recommendations and generator windings protection. The 2000 edition editorially revised Chapter 2 to be consistent with NFPA 850, *Recommended Practice for Fire Protection of Electric Generating Plants and High Voltage Direct Current Converter Stations*. In addition, the document was revised to clarify the requirements for fire suppression systems for generator windings of different composition.

The 2005 edition of NFPA 851 was restructured to conform to the requirements of the *Manual of Style for NFPA Technical Committee Documents*. There were changes made to clarify existing recommendations under 5.2.2.3 and 5.2.2.4 using new artwork. Other changes included coordination of similar recommendations from NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*.

The 2010 edition of NFPA 851 now includes a chapter containing recommendations for a fire protection design process and a fire protection design basis document (new Chapter 4). An annex has been added showing an example of a Fire Protection Design Basis document. The chapter on Fire Risk Control Program has been moved to a new Chapter 9.

The use of compressed air foam systems and fast-depressurization systems has been recognized, and recommendations for the use of these systems are now included.

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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) converter stations, except for electric generating plants using nuclear fuel.

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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 Annex A.

Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in the recommendations sections of this document are given in Chapter 2 and those for extracts in the informational sections are given in Annex E. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text should be sent to the technical committee responsible for the source document.

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

Chapter 1 Administration

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 can 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 hazard control recommendations for the safety of construction and operating personnel, the physical integrity of plant components, and the continuity of plant operations. Specific concerns are generalized and categorized in 1.2.2.1 through 1.2.2.4.

1.2.2.1 Protection of Plant Personnel. Risk of injury and loss of life should be controlled in the event of fire. Specific criteria should be established for means of egress. When for plant safety and emergency response reasons personnel are not able to evacuate immediately, specific criteria for assuring their safety until they can evacuate and safe passage to egress routes should be established.

1.2.2.2 Assets Protection. The large capital costs of the structures, systems, and components for the facilities addressed in this recommended practice create financial risks for the owners, investors, and financiers. Specific criteria should be established for the mitigation of the risks from fires exposing these assets.

1.2.2.3 Business Interruption. The ability of these facilities to generate and transmit electricity is important not only to the owners of the facilities but also to the consumers of that energy, including the public. Specific criteria for managing the effects of fire on the ability to generate and transmit its power should be developed, based on economic and societal considerations.

1.2.2.4 Environmental Protection. Fires in these facilities have the potential of creating environmental impact, by damaging pollution control systems and components and by creating unwanted releases to the environment from the fire and fire-fighting activities. Specific criteria should be established to control the impact of fire and fire-fighting activities on the environment.

1.3 Application.

1.3.1 This document is intended for use by persons knowledgeable in the application of fire protection for electric generating plants and high voltage direct current converter stations.

1.3.2 The recommendations contained in this document are intended for new installations, as the application to existing installations might not be practicable. However, the recommendations contained in this document represent good industry practice and should be considered for existing installations.

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 the nature of the installation. Many of the specific recommendations herein might require modification after due consideration of all applicable factors involved. This modification should be made only after the methodology described in Chapter 4 and provided in the fire protection design basis document has been followed.

1.4 Equivalency. Nothing in this recommended practice is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this recommended practice.

1.4.1 Equivalency should be demonstrated following the methodology described in Chapter 4 and provided in the fire protection design basis document.

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 SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System.*

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this recommended practice and should be considered part of the recommendations of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 10, *Standard for Portable Fire Extinguishers,* 2010 edition.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2010 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2008 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 2009 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2010 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2010 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2007 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems,* 2007 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 2009 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* 2010 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection,* 2008 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* 2010 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2008 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 2008 edition.

NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages,* 2008 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 2006 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines,* 2010 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2009 edition.

NFPA 54, *National Fuel Gas Code,* 2009 edition.

NFPA 58, *Liquefied Petroleum Gas Code,* 2008 edition.

NFPA 72®, National Fire Alarm and Signaling Code, 2010 edition.

NFPA 75, *Standard for the Protection of Information Technology Equipment,* 2009 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2010 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures,* 2007 edition.

NFPA 85, *Boiler and Combustion Systems Hazards Code,* 2007 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* 2009 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air-Conditioning Systems,* 2009 edition.

NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations,* 2008 edition.

NFPA *101®, Life Safety Code®,* 2009 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems,* 2010 edition.

NFPA 120, *Standard for Fire Prevention and Control in Coal Mines,* 2010 edition.

NFPA 204, *Standard for Smoke and Heat Venting,* 2007 edition.

NFPA 220, *Standard on Types of Building Construction,* 2009 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations,* 2009 edition.

NFPA 251, *Standard Methods of Tests of Fire Resistance of Building Construction and Materials,* 2006 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies,* 2008 edition.

NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source,* 2006 edition.

NFPA 257, *Standard on Fire Test for Window and Glass Block Assemblies,* 2007 edition.

NFPA 259, *Standard Test Method for Potential Heat of Building Materials,* 2008 edition.

NFPA 501A, *Standard for Fire Safety Criteria for Manufactured Home Installations, Sites, and Communities,* 2009 edition.

NFPA 551, *Guide for the Evaluation of Fire Risk Assessments,* 2010 edition.

NFPA 600, *Standard on Industrial Fire Brigades,* 2010 edition.

NFPA 601, *Standard for Security Services in Fire Loss Prevention,* 2010 edition.

NFPA 701, *Standard Methods of Fire Tests for Flame Propagation of Textiles and Films,* 2010 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2010 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 2008 edition.

NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants,* 2010 edition.

NFPA 1143, *Standard for Wildland Fire Management,* 2009 edition.

NFPA 1144, *Standard for Reducing Structure Ignition Hazards from Wildland Fire,* 2008 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems,* 2010 edition.

NFPA 1901, *Standard for Automotive Fire Apparatus,* 2009 edition.

NFPA 1962, *Standard for the Inspection, Care, and Use of Fire Hose, Couplings, and Nozzles and the Service Testing of Fire Hose,* 2008 edition.

NFPA 1971, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting,* 2007 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2008 edition.

NFPA Fire Protection Handbook, 20th edition.

2.3 Other Publications.

2.3.1 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D 92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester,* 2003.

ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials,* 2009.

ASTM E 108, *Standard Test Method for Fire Tests of Roof Coverings,* 2007.

ASTM E 814, *Fire Tests of Through-Penetration Fire Stops,* Rev B-94.

ASTM SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System,* 1997.

2.3.2 IEEE Publications. Institute of Electrical and Electronics Engineers, Three Park Avenue, 17th Floor, New York, NY 10016-5997.

IEEE 383, *Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations*, 2003.

IEEE 484, *Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations*, 2002.

2.3.3 SFPE Publications. Society of Fire Protection Engineers, 7315 Wisconsin Avenue, Suite 1225 W, Bethesda, MD 20814.

SFPE Engineering Guide to Fire Risk Assessment, 2006.

SFPE Handbook of Fire Protection Engineering, 4th edition.

2.3.4 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

ANSI/UL 723, *Test for Surface Burning Characteristics of Building Materials,* 2008.

UL 790, *Standard Test Methods for Fire Tests of Roof Coverings*, 2004.

2.3.5 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Recommendations Sections.

NFPA 30, *Flammable and Combustible Liquids Code,* 2008 edition.

NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products,* 2007 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials,* 2007 edition.

NFPA *101*®, *Life Safety Code*®, 2009 edition.

NFPA 220, *Standard on Types of Building Construction,* 2009 edition.

NFPA 306, *Standard for the Control of Gas Hazards on Vessels,* 2009 edition.

NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials,* 2008 edition.

NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations,* 2010 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter apply to the terms used in this recommended practice. Where terms are not defined in this chapter or within another chapter, they should be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary,* 11th edition, is the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

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

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

3.2.5 Recommended Practice. A document that is similar in content and structure to a code or standard but that contains only nonmandatory provisions using the word "should" to indicate recommendations in the body of the text.

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

3.3 General Definitions.

3.3.1 Combustible. Capable of undergoing combustion.

3.3.2 Compressed Air Foam (CAF). A homogenous foam produced by the combination of water, foam concentrate, and air or nitrogen under pressure.

3.3.3 Fast Depressurization System. A passive mechanical system designed to depressurize the transformer a few milliseconds after the occurrence of an electrical fault.

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

3.3.5 Fire Barrier. A continuous membrane or a membrane with discontinuities created by protected openings with a specified fire protection rating, where such membrane is designed and constructed with a specified fire resistance rating to limit the spread of fire, that also restricts the movement of smoke. [***101***, 2009]

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

3.3.7 Fire Point. The lowest temperature at which a liquid will ignite and achieve sustained burning when exposed to a test flame in accordance with ASTM D 92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester.* [**30,** 2008]

3.3.8 Fire Prevention. Measures directed toward avoiding the inception of fire. [**801,** 2008]

3.3.9 Fire Protection. Methods of providing for fire control or fire extinguishment. [**801,** 2008]

3.3.10 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 on Fire Test for Window and Glass Block Assemblies*, as applicable. [**850,** 2010]

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

3.3.12 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 Resistance of Building Construction and Materials*. [**220,** 2009]

3.3.13 Fire Risk Evaluation. An evaluation of the plant-specific considerations regarding design, layout, and anticipated operating requirements. The evaluation should result in a list of recommended fire prevention features to be provided 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.

3.3.14 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 as Class A Interior Finish and Class B Interior Finish.

3.3.14.1 ***Class A Interior Finish.*** Materials having a flame spread index of 0–25 and a smoke developed index of 0–450 when tested in accordance with ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Test for Surface Burning Characteristics of Building Materials*. Includes any material with a flame spread index of 25 or less and with a smoke developed index of 450 or less when any element thereof, when tested, does not continue to propagate fire.

3.3.14.2 ***Class B Interior Finish.*** Materials having a flame spread index of 26–75 and a smoke developed index of 0–450 when tested in accordance with ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Test for Surface Burning Characteristics of Building Materials*. Includes any material with a flame spread index of 26 or more but not more than 75 and with a smoke developed index of 450 or less.

3.3.15 Limited Combustible. A building construction material not complying with the definition of noncombustible material that, in the form in which it is used, has a potential heat value not exceeding 8141 kJ/kg (3500 Btu/lb), where tested in accordance with NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, and complies with (a) or (b): (a) materials having a structural base of noncombustible material, with a surfacing not exceeding a thickness of 3 mm (⅛ in.) that has a flame spread index not greater than 50; and (b) materials, in the form and thickness used, other than as described in (a), having neither a flame spread index greater than 25 nor evidence of continued progressive combustion and of such composition that surfaces that would be exposed by cutting through the material on any plane would have neither a flame spread index greater than 25 nor evidence of continued progressive combustion. (Materials subject to increase in combustibility or flame spread index beyond the limits herein established through the effects of age, moisture, or other atmospheric condition shall be considered combustible.) [**33,** 2007]

3.3.16 Liquid.

3.3.16.1 ***Combustible Liquid.*** Any liquid that has a closed-cup flash point at or above 37.8°C (100°F). [**306,** 2009]

3.3.16.2 ***Flammable Liquid.*** A liquid that has a closed-cup flash point below 37.8°C (100°F) and a maximum vapor pressure of 2068 mm Hg (40 psia) at 37.8°C (100°F). [**30B,** 2007]

3.3.16.3 ***High Fire Point Liquid.*** A combustible dielectric liquid listed as having a fire point of not less than 572°F (300°C). [**850,** 2010]

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

3.3.17 Noncombustible. Not capable of igniting and burning when subjected to a fire.

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

3.3.19 Stakeholder. An individual, group of individuals, or an organization that is perceived to affect or be affected by the fire hazards associated with the facility being evaluated. Stakeholders include all those who have a financial, personnel safety, public safety, or regulatory interest in the fire risk, such as the public (e.g., neighbors, community groups, first responders), employees, owner/investor(s), operator, insurer, regulator(s), and design team.

Chapter 4 Fire Protection Design Process

4.1 General.

4.1.1 The fire protection design process should be initiated under the direction of someone experienced in the area of fire protection engineering and having extensive knowledge and experience in power plant operation of the type of plant under consideration.

4.1.2 The creation of the fire protection design basis should be initiated as early in the plant design process as practical to ensure that the fire prevention and fire protection recommendations as described in this document have been evaluated in view of the plant-specific consideration regarding design, layout, and anticipated operating requirements.

4.1.3 Applicable process safety management (PSM) techniques should be considered.

4.1.4 The purpose of the fire protection design basis document (DBD) is to provide a record of the decision-making process in determining the fire prevention and fire protection for specific hazards.

4.1.5 The DBD should be a living document that evolves as the plant design is refined and that will be maintained and revised for the life of the plant.

4.2 Stakeholders.

4.2.1 The stakeholders with an interest in the scope and applicability of the fire protection design should be identified early in the process.

4.2.2 The stakeholders establish goals and objectives and evaluate whether or not the recommendations of NFPA 851 are adequate to meet those goals and objectives. The criteria for acceptability of the level of fire protection should consider the perspective of the various stakeholders.

4.3 Inputs to the Design Process.

4.3.1 General Inputs. In addition to the guidelines in this document, the following list should be reviewed for applicability:

(1) Codes
  (a) Building codes — state and local
  (b) Fire codes — state and local

(2) Standards
  (a) Industry standards
  (b) Utility company standards
  (c) Insurance requirements
  (d) Applicable NFPA documents *(See Chapter 2.)*
(3) Regulations
  (a) Environmental
  (b) OSHA
(4) Other references
  (a) *SFPE Handbook of Fire Protection Engineering* and SFPE journals
  (b) *SFPE Engineering Guide to Fire Risk Assessment* (Chapters 14 and 15)
  (c) Best practices: EEI, EPRI, IEEE
  (d) *NFPA Fire Protection Handbook*
  (e) NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants* (Performance-Based Criteria in Chapter 4)
(5) Design documents
(6) Stakeholder inputs

4.3.2 Project-Specific Inputs. Each facility will have its own special conditions that will have an impact on the nature of the installation. Many of the specific criteria herein might require modification due to the consideration of all project-specific factors involved. The project-specific inputs utilized in the design basis process include but are not limited to the following:

(1) Base load/peaking unit
(2) Personnel levels
  (a) Unattended
  (b) Low level of occupancy
  (c) High level of occupancy
(3) Plant layout and geographic location
(4) Dam structural stability
(5) Equipment availability/redundancy
(6) Capability of emergency responders
(7) Storage configuration (short term and long term)
(8) Historical loss information/lessons learned/fire reports *(See Annex B.)*

4.4 Fire Protection Design Basis Process. See Figure 4.4 for a flow chart of the fire protection design basis process.

4.4.1 The stakeholders establish goals and objectives and evaluates whether the recommendations of NFPA 851 are adequate to meet those goals and objectives. The criteria for acceptability of the level of fire protection should consider the perspective of the various stakeholders.

4.4.2 The general arrangement and plant layout should be provided to clearly reflect the separation of hazards. If the layout is not acceptable, a fire risk evaluation should be developed to ensure objectives are met, and then the layout returned to the review process.

4.4.3 Each hazard/area is reviewed against the goals and objectives and against NFPA 851. If the hazards control is not acceptable, then a fire risk evaluation should be developed to ensure objectives are met, then returned to the review process.

4.4.4 The design basis document is developed.

4.4.5 As the project evolves, the DBD should be reviewed and updated as necessary to incorporate changes and revisions.

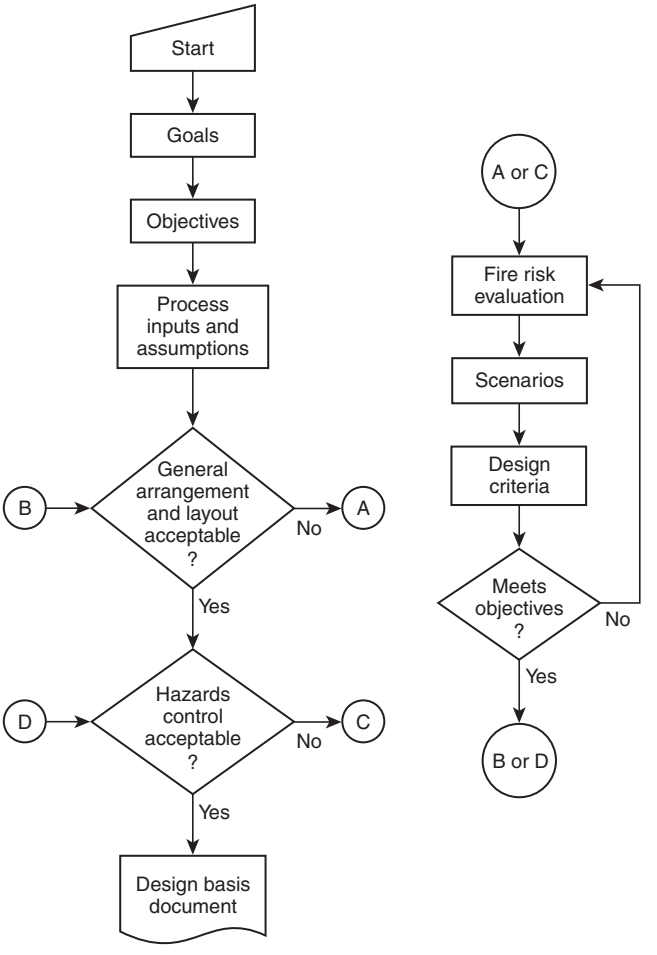


FIGURE 4.4 Fire Protection Design Basis Process Flow Chart.

4.5 Fire Protection Design Basis Document (Deliverables).

4.5.1 The scope of the DBD is to establish the fire protection design criteria for the facility. The development of the DBD will be an iterative process. The DBD will be revised as the design progresses, based on dialogue among the stakeholders. The DBD should outline the fire protection and prevention design basis for achieving the fire hazard control objectives agreed upon by the stakeholders. The outline should include the following:

(1) Identify assumptions (including items in 4.3.2).
(2) Identify source documents.
(3) *Identify each hazard, fire prevention and protection features that are to be provided or omitted, and a summary of the decision-making process.
(4) Identify where operational and administrative controls are assumed to be in place to mitigate the need for fire protection features.

4.5.2 During the various stages of the design development and the development of the DBD, assumptions will be made when inadequate or insufficient information is available. These assumptions should be clearly identified and documented in accordance with Section 4.5. As additional information becomes available, the assumptions should be updated or replaced with actual

design information and the DBD should be amended as necessary to reflect the more definitive information.

4.5.3 The process identified in 4.5.1 and 4.5.2 should be documented. The format of the document is a statement on general fire protection philosophy for the facility and a comparison of the facility fire protection features to the guidelines in the design chapters. For example, protection of oil hazards, as well as containment and drainage, are addressed. A sample table of contents for the DBD is contained in Annex D.

Chapter 5 General Plant Design

5.1 Plant Arrangement.

5.1.1 Fire Area Determination.

5.1.1.1 The hydroelectric generating plant should be subdivided into separate fire areas as determined by the fire protection design basis 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.

5.1.1.2 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 2-hour 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:

(1) To separate cable spreading room(s), cable tunnel(s), and high voltage lead shafts from adjacent areas.
(2) 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.
(3) To separate rooms with major concentrations of electrical equipment, such as switchgear room and relay room, from adjacent areas.
(4) To separate battery rooms from associated battery charging equipment and from adjacent areas.
(5) To separate maintenance shop(s) from adjacent areas.
(6) To separate main fire pump(s) from reserve fire pump(s), where these pumps provide the only source of water for fire protection.
(7) To separate fire pumps from adjacent areas.
(8) To separate warehouses and combustible storage areas from adjacent areas.
(9) To separate emergency generators from each other and from adjacent areas.
(10) To separate oil storage and purification rooms from adjacent areas.
(11) To separate fan rooms and plenum chambers from adjacent areas [fire dampers might not be advisable in emergency ventilation ducts *(see Section 5.4)*.]
(12) To separate office areas from adjacent areas.
(13) To separate telecommunication rooms, supervisory control and data acquisition (SCADA) rooms, and remote terminal unit (RTU) rooms from adjacent areas.
(14) To separate the intake hoist housing from generator floor area and from adjacent areas.
(15) To separate dam and spillway hoists, including the main power and backup power bus, from adjacent areas such as spillway electrical distribution rooms.
(16) To separate the tailrace service gallery from turbine/generator floors and governor hydraulic equipment.
(17) To separate switchgear area and sulfur hexafluoride (SF_6) switchyard area from adjacent areas.

5.1.2 Outdoor Oil-Insulated Transformers.

5.1.2.1 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.

5.1.2.2 Determination of the type of physical separation should be based on consideration of the following:

(1) Type and quantity of oil in the transformer
(2) Size of a postulated oil spill (surface area and depth)
(3) Type of construction of adjacent structures
(4) Power rating of the transformer
(5) Fire suppression systems provided
(6) Type of electrical protective relaying provided
(7)*Fast depressurization systems

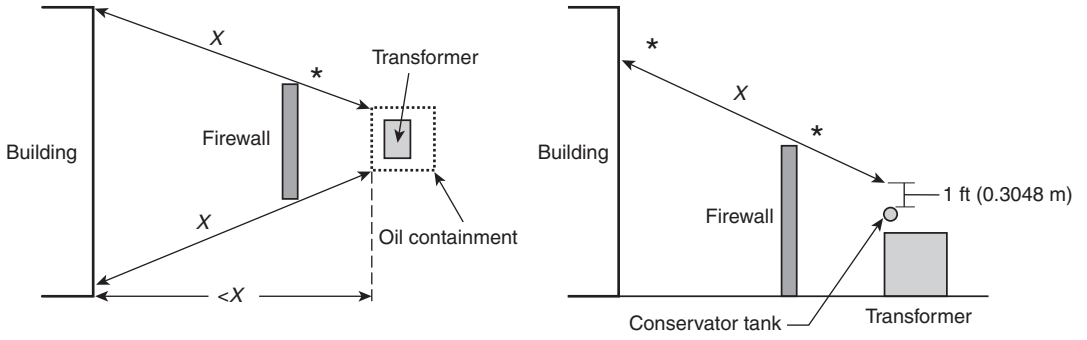
5.1.2.3* Unless consideration of the factors in 5.1.2.2 indicates otherwise, it is recommended that any oil-insulated transformer containing 500 gal (1893 L) or more of oil be separated from adjacent noncombustible or limited combustible structures by a 2-hour rated firewall or by spatial separation in accordance with Table 5.1.2.3. Where a firewall is provided between structures and a transformer, it should extend vertically and horizontally as indicated in Figure 5.1.2.3.

5.1.2.4 Unless consideration of the factors in 5.1.2.2 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-hour rated firewall or by spatial separation in accordance with Table 5.1.2.3. Where a firewall is provided between transformers, it should extend at least 1 ft (0.3048 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. *(See Figure 5.1.2.4 for an illustration of the recommended dimensions for a firewall.)*

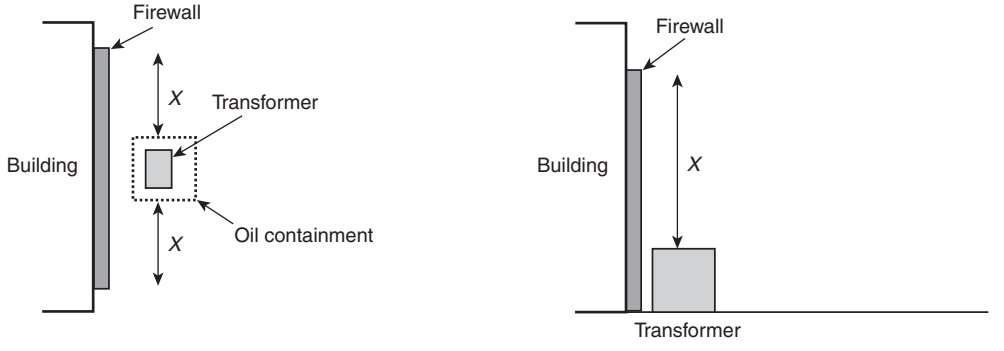
5.1.2.5* Where a firewall is provided, it should be designed to withstand the effects of exploding transformer bushings or lightning arresters.

5.1.2.6 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.

5.1.2.7 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 5.1.2.2, 5.1.2.5, and 5.1.2.6.



Example 1



Example 2

PLAN VIEW SECTION VIEW

X = Minimum separation distance from Table 5.1.2.3.
* See A.5.1.2.3.

FIGURE 5.1.2.3 Illustration of Oil-Insulated Transformer Separation Recommendations.

Table 5.1.2.3 Outdoor Oil-Insulated Transformer Separation Criteria

Transformer Oil Capacity		Minimum (Line-of-Sight) Separation Without Firewall	
gal	**L**	**ft**	**m**
<500	<1,893	See 5.1.2.2.	
500–5,000	1,893–18,925	25	7.6
>5,000	>18,925	50	15.2

5.1.3 Indoor Transformers.

5.1.3.1 Dry-type transformers are preferred for indoor installations.

5.1.3.2* 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-hour fire resistance rating.

5.1.3.3 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-hour fire resistance rating.

5.1.3.4 Where transformers are protected by an automatic fire suppression system, the fire barrier fire resistance rating can be permitted to be reduced to 1 hour.

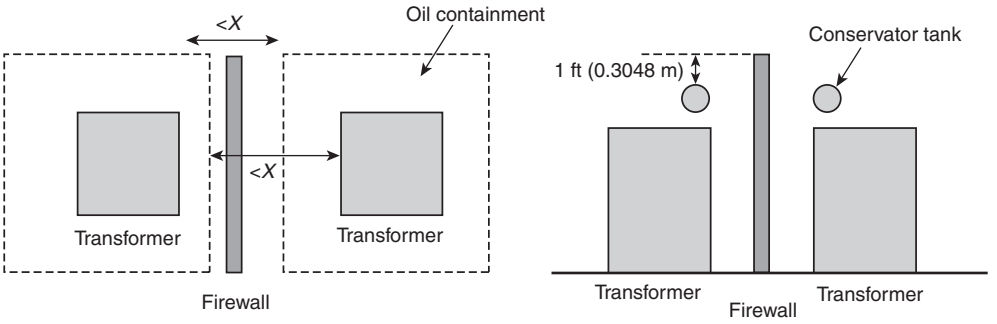
5.1.4 Circuit Breakers.

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

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

5.1.5 Openings in Fire Barriers.

5.1.5.1* 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 E 814, *Fire Tests of Through-Penetration Fire Stops*. Other test methods for qualifications of penetration seals can be permitted to be considered for this application.



X = Minimum separation distance from Table 5.1.2.3.

FIGURE 5.1.2.4 Outdoor Oil-Insulated Transformer Separation Criteria.

5.1.5.2 Fire door assemblies, fire dampers, and fire shutters used in 2-hour rated fire barriers should be rated not less than 1½ hours. *(See NFPA 80, Standard for Fire Doors and Other Opening Protectives.)*

5.2 Life Safety.

5.2.1 For life safety for hydroelectric generating plants, see NFPA *101*, *Life Safety Code*.

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

(1)*General areas should be considered as special purpose industrial occupancies.
(2) Temporary occupancies and means of egress inside the structures and piers of large "bulb" units should be evaluated based on occupancies in special structures.
(3) Open structures and underground structures (e.g., tunnels) should be considered as occupancies in special structures.
(4) General office structures should be considered as business occupancies.
(5) Warehouses should be considered as storage occupancies.

5.3 Building Construction Materials.

5.3.1 Construction materials being considered for hydroelectric generating plants should be selected based on the fire risk evaluation using the following standards:

(1) NFPA 220, *Standard on Types of Building Construction*
(2) NFPA 251, *Standard Methods of Tests of Fire Resistance of Building Construction and Materials*
(3) NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*
(4) NFPA 259, *Standard Test Method for Potential Heat of Building Materials*
(5) ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Test for Surface Burning Characteristics of Building Materials*

5.3.2 Building components for all powerhouse and subsurface structures should be of noncombustible or limited combustible materials, except as noted in 5.3.3.

5.3.3 Roof coverings should be Class A in accordance with ASTM E 108, *Standard Test Methods for Fire Tests of Roof Coverings*, or UL 790, *Standard Test Methods for Fire Tests of Roof Coverings*. Metal, roof deck construction, where used, should be Class I listed or approved.

5.3.4 Interior Finish.

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

5.3.4.2 Interior finish in buildings critical to power generation should be Class A.

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

5.4 Smoke and Heat Venting, Heating, Ventilating, and Air Conditioning.

5.4.1 Smoke and Heat Venting.

5.4.1.1 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.

5.4.1.2 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.

5.4.1.3 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.

5.4.1.3.1* Separate smoke management or 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 204, Standard for Smoke and Heat Venting.)* Smoke venting also can be permitted to be accomplished through the use of portable smoke ejectors. A smoke management system should be utilized to mitigate the effects of smoke and heat during the early stages of a fire.

5.4.1.3.2 Consideration should be given to smoke venting for the following areas: control room, cable spreading room(s), switchgear room, and sensitive electronic equipment rooms.

5.4.1.3.3 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.

5.4.1.3.4 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 can 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.

5.4.1.4 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.

5.4.1.5* 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.

5.4.2 Normal Heating, Ventilating, and Air-Conditioning Systems.

5.4.2.1 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.

5.4.2.2 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.

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

5.4.2.4 Fire dampers (doors) compatible with the rating of the barrier should be provided at the duct penetrations to the fire area *(see Section 5.1)* unless the duct is protected throughout its length by a fire barrier equal to the rating required of fire barrier(s) penetrated.

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

5.4.2.6 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.

5.4.2.7 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.

5.5 Containment and Drainage

5.5.1* 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 Annex 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:

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

5.5.2* The provisions for drainage and any associated drainage facilities (pits, sumps, and sump pumps) should be sized to accommodate all of the following:

(1) The spill of the largest single container of any flammable liquid or combustible liquid, or both, in the area
(2) The maximum design volume of discharge from the expected number of fire hose lines operating for a minimum of 10 minutes
(3) The maximum design volume of discharge from the fixed fire suppression system(s) operating for a minimum of 10 minutes

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

5.5.4 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.

5.5.5 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 5.5.2. The curbed area or pit can be permitted to be filled with uniformly graded crushed stone as a means of minimizing ground fires.

5.5.6 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.

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

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

5.6 Emergency Lighting.

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

5.6.2 Emergency lighting should be provided for critical plant operations areas.

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

Chapter 6 General Fire Protection Systems and Equipment

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

6.2 Water Supply.

6.2.1 Hydroelectric plants are commonly located in remote areas adjacent to rivers or at the base of lakes. Fire protection water supplies can 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.

6.2.2 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 (1890 L/min) for a 2-hour duration.

6.2.3 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 6.2.2.

6.2.3.1 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 6.2.2 with the largest pump out of service.

6.2.3.2* 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 Stationary Pumps for Fire Protection.)*

6.2.3.3 If tanks are of dual-purpose use, a standpipe or similar arrangement should be provided to dedicate the amount determined by 6.2.2 for fire protection use only. *(See NFPA 22, Standard for Water Tanks for Private Fire Protection.)*

6.2.3.4 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 can 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.

6.2.4 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.

6.2.5 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.

6.2.6 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.

6.3 Valve Supervision. All fire protection water system control valves should be under a periodic inspection program *(see Chapter 9)* and should be supervised by one of the following methods:

(1) Electrical supervision with audible and visual signals in the main control room or other constantly attended location.
(2) Locking valves open. Keys should be made available only to authorized personnel.
(3) Sealing of valves. This option should be followed only when valves are within fenced enclosures under the control of the property owner.

6.4 Supply Mains and Hydrants.

6.4.1 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.)*

6.4.1.1 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 can be permitted to supply this need from an available service main in the immediate area.

6.4.1.2 The supply mains should be looped and of sufficient size to supply the flow requirements determined by 6.2.2 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.

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

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

6.4.3 It can 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 can 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.

6.5 Standpipe and Hose Systems.

6.5.1 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.

6.5.2 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 can be permitted to suffice.

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

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

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

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

6.6 Portable Fire Extinguishers. For first aid fire protection, suitable fire extinguishers should be installed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.*

6.7 Fire Suppression Systems and Equipment — General Requirements.

6.7.1 Fire suppression systems and equipment should be provided in all areas of the plant as identified in Chapter 7 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:

(1) NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*
(2) NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*
(3) NFPA 13, *Standard for the Installation of Sprinkler Systems*
(4) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*
(5) NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*
(6) NFPA 750, *Standard on Water Mist Fire Protection Systems*
(7) NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*

6.7.2 The selection of an extinguishing agent should be based on the following:

(1) Type of hazard
(2) Effect of agent discharge on equipment
(3) Health hazards

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. At 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.

6.7.3 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.)*

6.8 Fire Signaling Systems.

6.8.1 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 and Signaling Code.)*

6.8.1.1 Audible fire alarms should be distinctive from other plant system alarms.

6.8.1.2 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.

6.8.2 Automatic fire detectors should be installed in accordance with *NFPA 72, National Fire Alarm and Signaling Code.*

6.8.3 The fire signaling system or plant communication system should provide the following:

(1) 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.
(2) 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.
(3) Two-way communications for the plant emergency organization during emergency operations.
(4) Means to notify the public fire department.

6.9 Unattended Plants.

6.9.1 Hydroelectric plants that are operated unattended, or with minimal staffing, present special fire protection concerns.

6.9.2 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.

6.9.3 The fire risk evaluation should address delayed response and lack of communication. This might 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 can necessitate automatic shutoff of fire pumps.

6.9.4 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.)*

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

6.9.6 An emergency lighting system for critical operating areas that depends on batteries or fuel supplies should be manu-

ally operated from a switch at the entry to the plant. The emergency lighting can be permitted to consist either of fixed units or of portable lights. *(See 5.6.2.)*

6.9.7 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 9.4.4.)*

6.9.8 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 7 Identification and Protection of Hazards

7.1 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.

7.2 Turbine-Generator Hydraulic Control and Lubricating Oil Systems.

7.2.1 Hydraulic Control Systems.

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

7.2.1.2 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 non-fire-resistant fluid.

7.2.1.3 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.

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

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

7.2.4* Fixed fire protection for this equipment, where provided, should be as follows:

(1) Automatic wet pipe sprinkler systems utilizing a design density of 0.25 gpm/ft^2 (10.2 mm/min) for the entire hazard area.
(2) Automatic foam-water sprinkler systems providing a density of 0.16 gpm/ft^2 (6.5 mm/min).
(3) 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.
(4) Compressed air foam systems should be designed and installed in accordance with NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, and their listing for the specific hazards and protection objectives specified in the listing.

7.2.5 Consideration for protection of horizontal and vertical turbine bearings should be made based on the fire risk evaluation.

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

7.2.7 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.

7.2.8 Clean or dirty oil storage areas should be protected based on the fire risk evaluation. These areas generally represent 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 5.

7.3 Generator Pit and Windings.

7.3.1* Protection of generator windings consisting of materials that will not extinguish when de-energized should be provided by automatically actuated gaseous extinguishing systems, waterspray rings, or both.

7.3.2 Fire detection in generator winding should be provided.

7.3.3 Protection of generator pits containing auxiliary circuits such as protection current transformers (CTs), neutral transformers, and grounding resistors that are associated with generator protection should be provided by an automatically actuated gaseous extinguishing system or water spray system.

7.3.4 Gaseous suppression systems should be actuated by protective relays, fire detection systems, or both.

7.3.5 Operation of waterspray rings should be interlocked so that the unit will trip before the water spray system activates. Immediately after the generator has been sprayed with a water-based system, it should be mechanically run (electrically isolated and without excitation) for at least 24 hours to avoid creating stator ground faults on both types of winding materials.

7.4 Control, Computer, and Communication Rooms.

7.4.1 Control, computer, and telecommunication rooms should meet applicable requirements of NFPA 75, *Standard for the Protection of Information Technology Equipment.*

7.4.2 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 can be permitted to be omitted from this area.

7.4.3 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.

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7.4.4 Cable raceways not terminating in the control room should not be routed through the control room.

7.5 Cable Concentrations.

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

7.5.2 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.

7.5.3 Sprinkler or water spray systems should be designed for a density of 0.30 gpm/ft^2 (12.2 mm/min) 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.

7.5.4 Cable with Fire-Retardant Coatings.

7.5.4.1 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.

7.5.4.2 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.

7.5.5 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.

7.6 Cable Tunnels.

7.6.1 Where protection is required by the fire risk evaluation, cable tunnels should be protected by automatic water spray, automatic wet pipe sprinkler, or foam-water spray systems. Automatic sprinkler systems should be designed for a density of 0.30 gpm/ft^2 (12.2 mm/min) over 2500 ft^2 (232 m^2) or the most remote 100 linear ft (30.5 m) of cable tunnel up to 2500 ft^2 (232 m^2).

7.6.2 Portable high-expansion foam generators can be permitted to be used to supplement fixed fire protection system(s). *(See NFPA 1901, Standard for Automotive Fire Apparatus.)*

7.6.3 Ventilation and drainage should be provided for these areas in accordance with Chapter 5.

7.7 Transformers. Oil-filled main, station service, and startup transformers not meeting separation or fire barrier recommendations in 5.1.2 or as determined by the fire risk evaluation should be protected with automatic water spray, foam-water spray, or compressed air foam systems.

7.8 Indoor Oil-Filled Electrical Equipment. Automatic sprinkler, foam-water spray, water spray, and compressed air foam 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 6.8.2.)*

7.9 Battery Rooms. Battery rooms should be provided with ventilation to limit the concentration of hydrogen to 1 percent by volume. For further information, refer to IEEE 484, *Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations.*

7.10 Switchgear and Relay Rooms. Switchgear rooms and relay rooms should be provided with smoke detection systems.

7.11 Emergency Generators.

7.11.1 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.*

7.11.2 Emergency generators located within main plant structures should be protected by automatic sprinkler, water spray, foam-water sprinkler, compressed air foam, or gaseous-type extinguishing systems. Sprinkler and water spray protection systems should be designed for a 0.25 gpm/ft^2 (10.2 mm/min) density over the fire area. Compressed air foam systems should be designed and installed in accordance with NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, and their listing for the specific hazards and protection objectives specified in the listing.

7.11.3 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.

7.12 Air Compressors. Automatic sprinkler protection designed for a density of 0.25 gpm/ft^2(10.2 mm/min) over the postulated oil spill or compressed air foam should be considered for air compressors containing a large quantity of oil. Compressed air foam systems should be designed and installed in accordance with NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, and their listing for the specific hazards and protection objectives specified in the listing. Where the hazard is not great enough to warrant a fixed fire suppression system, automatic fire detection should be considered. *(See 6.8.2.)*

7.13 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 (10.2 mm/min) over the fire area or compressed air foam systems should be considered for hydraulic systems not using a listed fire-resistant fluid. Compressed air foam systems should be designed and installed in accordance with NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, and their listing for the specific hazards and protection objectives specified in the listing. Where the hazard is not great enough to warrant a fixed fire suppression system, automatic fire detection should be considered. *(See 6.8.2.)*

7.14 Fire Pumps. Rooms housing diesel-driven fire pumps should be protected by automatic sprinkler, water spray, foam-water sprinkler, or compressed air foam systems. If sprinkler and water spray protection systems are provided, they should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over the fire area. For automatic foam-water sprinkler systems, a density of 0.16 gpm/ft^2 (6.5 mm/min) should be provided. Compressed air foam systems should be designed and installed in accordance with NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, and their listing for the specific hazards and protection objectives specified in the listing.

7.15 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 7.2.8.)*

7.16 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.

7.17 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, *Liquefied Petroleum Gas Code*, and NFPA 85, *Boiler and Combustion Systems Hazards Code*, as applicable.

7.18 Garages. Vehicle repair facilities should meet the requirements of NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages*.

Chapter 8 Fire Protection for the Construction Site

8.1 Introduction.

8.1.1 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 can be required, and specialized activities such as deep excavation and tunneling can 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.

8.1.2 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.

8.1.3 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.

8.2 Administration.

8.2.1 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.

8.2.2 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.

8.2.3 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 9.)*

8.2.4 Written administrative procedures should be established for the construction site, and such procedures should, as a minimum, be in accordance with Section 9.3, 9.4.1, and 9.4.4.

8.2.5 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.)*

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

8.2.5.2 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.

8.2.5.3 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 can be permitted to be omitted after the first round indicated in 8.2.5.1.

8.2.6 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 7. In-service fire detection and fire extinguishing systems provide important protection for construction materials, storage, and so forth, even before the permanent hazard is present. Temporary fire protection systems can 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.

8.3 Site Clearing, Excavation, and Tunneling.

8.3.1 Site Clearing.

8.3.1.1 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 1143, *Standard for Wildland Fire Management*. Contact should be made with local fire and forest agencies for current data on restrictions and fire potential and to arrange for necessary permits.

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

8.3.1.3 Fire tools and equipment should be used for fire emergencies only and should be distinctly marked.

8.3.1.4 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.

8.3.1.5 Cut trees, brush, and other combustible spoil should be disposed of promptly.

8.3.1.6 Where it is necessary to dispose of combustible waste by on-site 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 8.2.)*

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

8.3.2 Excavation and Tunneling.

8.3.2.1 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.

8.3.2.2 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.

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

8.3.2.4 A general plan of action for use in times of emergency should be prepared for every underground excavation. *(See Section 8.2.)*

8.3.3 Construction Equipment. Construction equipment should meet the requirements of NFPA 120, *Standard for Fire Prevention and Control in Coal Mines*.

8.4 Construction Warehouses, Shops, Offices, and Construction Camps.

8.4.1 All structures that are to be retained as part of the completed plant should be constructed of materials as required in Chapter 5 and should comply with other requirements of this document for the completed plant.

8.4.2 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 1144, *Standard for Reducing Structure Ignition Hazards from Wildland Fire*, as applicable.

8.4.3 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.

8.4.4 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 can indicate a need for automatic sprinklers or other protection, the desirability of subdividing the complex to limit values exposed by one fire, or a combination of the above.

8.4.5 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 firewalls between units or installing automatic sprinklers throughout the buildings.

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

8.4.7 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 and Signaling Code*.

8.4.8 The location for central alarm control should be provided with the following:

(1) Remote fire pump start button
(2) Manual siren start/stop button
(3) Provision for alerting the fire crew by VHF radio, fire alert paging, and so forth
(4) Monitors for communication between security guard and fire crew at place of fire
(5) Radio link between security guards' office and the respective fire department

8.4.9 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 guidelines given in 8.4.9.1 through 8.4.9.3 should apply.

8.4.9.1 Building construction materials should be noncombustible or limited combustible. *(See Chapter 5.)*

8.4.9.2 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.

8.4.9.3 Air-supported structures are sometimes used to provide temporary warehousing space. Although the fabric envelope can be a fire-retardant material, the combustibility of its 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.

8.4.10 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.

8.4.11 Storage of construction materials, equipment, or supplies that are either combustible or in combustible packaging should be prohibited in main plant buildings unless one of the following situations applies:

(1) An approved automatic fire extinguishing system is in service in the storage area.
(2) 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.

8.4.12 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.*

8.4.13 Vehicle repair facilities should meet the requirements of NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages.*

8.4.14 The handling, storage, and dispensing of flammable liquids and gases should meet the requirements of NFPA 30, *Flammable and Combustible Liquids Code*, NFPA 58, *Liquefied Petroleum Gas Code*, and NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages.*

8.5 Construction Site Laydown Areas.

8.5.1 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 6.)*

8.5.2 Combustible materials should be separated by a clear space to allow access for manual fire-fighting equipment *(see Section 8.8)*. Access should be provided and maintained to all fire-fighting equipment, including fire hoses, extinguishers, and hydrants.

8.6 Temporary Construction Materials.

8.6.1 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.

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

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

8.7 Underground Mains, Hydrants, and Water Supplies.

8.7.1 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 6, 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.

8.7.2 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.

8.7.3 Hydrants should be installed, as recommended by Chapter 6, 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.

8.7.4* 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:

(1) 750 gpm (2835 L/min)
(2) The in-service fixed water extinguishing system with the highest water demand plus 500 gpm (1890 L/min) for hose streams

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

8.7.6 Fixed systems should be provided as soon as construction permits. These systems should be provided in continuous operating condition.

8.7.7 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.

8.7.8 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.

8.8 Fire Suppression Systems and Equipment.

8.8.1 In general, fire suppression equipment should be as follows:

(1) Provided where risk of fire exists
(2) Suitable as to type and size for combating any likely fire
(3) Protected from mechanical damage
(4) Located for easy access at well-identified stations
(5) Maintained in good operating condition
(6) Protected from freezing

8.8.2 Portable fire extinguishers of suitable capacity should be provided where any of the following conditions exist:

(1) Flammable liquids are stored or handled.
(2) Temporary oil- or gas-fired equipment is used.
(3) A tar or asphalt kettle is used.
(4) Welding or open flames are in use. *(See* NFPA 10, *Standard for Portable Fire Extinguishers.)*

8.8.3 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.)*

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

8.8.5 No fire protection equipment or device should be made inoperable or used for other purposes.

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

Chapter 9 Fire Risk Control Program

9.1 General.

9.1.1 This chapter provides recommended criteria for the development of a fire risk control program that contains administrative procedures and controls necessary for the execution of the fire prevention and fire protection activities and practices for hydroelectric generating plants.

9.1.2 The fire risk control program recommended in this chapter should be reviewed and updated periodically.

9.1.3 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.

9.2 Management Policy and Direction.

9.2.1 Corporate management should establish a policy and institute a comprehensive fire risk control program to promote the conservation of property, continuity of operation, and protection of safety to life by adequate fire prevention and fire protection measures at each facility.

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

9.3 Fire Risk Control Program. A written plant fire prevention program should be established and, as a minimum, should include the following:

(1) Fire safety information for all employees and contractors. This information should familiarize them with, as a minimum, fire prevention procedures, plant emergency alarms and procedures, and how to report a fire.
(2) Documented regularly scheduled plant inspections including provisions for remedial actions to correct conditions that increase fire hazards.
(3) A description of the general housekeeping practices and the control of transient combustibles.
(4) Control of flammable and combustible liquids and gases in accordance with appropriate NFPA standards.
(5) Control of ignition sources including smoking, grinding, welding, and cutting. *(See NFPA 51B, Standard for Fire Prevention During Welding, Cutting, and Other Hot Work.)*
(6) Fire prevention surveillance. *(See NFPA 601, Standard for Security Services in Fire Loss Prevention.)*
(7) Fire report, including an investigation and a statement on the corrective action to be taken. *(See Annex B.)*

9.4 Fire Protection Program.

9.4.1 Testing, Inspection, and Maintenance.

9.4.1.1 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.

9.4.1.2* All fire protection systems and equipment should be periodically inspected, tested, and maintained in accordance with applicable *National Fire Codes®*. *(See Table 9.4.1.2 for guidance.)*

Table 9.4.1.2 Reference Guide for Fire Equipment Inspection, Testing, and Maintenance

Item	NFPA Document
Supervisory and Fire Alarm Circuits	*NFPA 72*
Fire Detectors	*NFPA 72*
Manual Fire Alarms	*NFPA 72*
Sprinkler Water Flow Alarms	NFPA 25, *NFPA 72*
Sprinkler and Water Spray Systems	NFPA 25, *NFPA 72*
Foam Systems	NFPA 11, NFPA 16, NFPA 25
Halogenated Agent, Chemical, and CO_2 Systems	NFPA 12, NFPA 12A, NFPA 17, NFPA 2001
Fire Pumps and Booster Pumps	NFPA 25, *NFPA 72*
Water Tanks and Alarms	NFPA 25, *NFPA 72*
Post-Indicator Valves (PIVs) and Outside Screw and Yoke (OS&Y) Valves	NFPA 25, *NFPA 72*
Fire Hydrants and Associated Valves	NFPA 13, NFPA 24
Fire Hose and Standpipes and Hose Nozzles	NFPA 1962, NFPA 25
Portable Fire Extinguishers	NFPA 10
Fire Brigade Equipment	NFPA 1971
Fire Doors and Dampers	NFPA 80, NFPA 90A
Smoke Vents	NFPA 204
Emergency Lighting	NFPA 110
Radio Communication Equipment	NFPA 1221
Water Mist Fire Protection Systems	NFPA 750

9.4.1.3 Testing, inspection, and maintenance should be documented with written procedures, results, and follow-up corrective actions recorded and tracked for closure.

9.4.2 Impairments.

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

(1) Identification and tracking of impaired equipment
(2) Identification of personnel to be notified (e.g., plant fire brigade chief, public fire department)
(3) Determination of needed fire protection and fire prevention measures
(4) Identification of additional protective measures as necessary (i.e., temporary water supply, additional fire hose)

9.4.2.2 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.

9.4.2.3 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).

9.4.3 Management of Change. A system should be implemented that would ensure that the appropriate individual(s) with fire protection responsibility is made aware of new construction, modifications to existing structures, changes to operating conditions, or other action that could impact the fire protection of the plant. The fire risk evaluation and the appropriate procedures and programs discussed in this chapter might need to be revised to reflect the impact of this action.

9.4.4 Fire Emergency Plan. A written fire emergency plan should be developed, and, as a minimum, this plan should include the following:

(1) Response to fire alarms and fire systems supervisory alarms.
(2) Notification of personnel identified in the plan.
(3) Evacuation of personnel not directly involved in fire-fighting activities from the fire area.
(4) Coordination with security forces or other designated personnel to admit public fire department and control traffic and personnel.
(5) Fire preplanning that defines fire extinguishment activities.
(6) Periodic drills to verify viability of the plan.
(7) Control room operator(s) and auxiliary operator(s) activities during fire emergencies. Approved breathing apparatus should be readily available in the control room area.

9.4.5 Fire Brigade.

9.4.5.1 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.

9.4.5.2* 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.

9.4.5.3 Cable tray fires, unique to hydroelectric generating plants, should be handled like any fire involving energized electrical equipment. It might not be practical or desirable to de-energize 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.

Annex A Explanatory Material

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

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.5.1.2.2(7) Oil-filled transformer explosions and fire can be prevented by the installation of a passive mechanical system designed to depressurize the transformer a few milliseconds after the occurrence of an electrical fault. This fast depressurization can be achieved by a quick oil evacuation triggered by the dynamic pressure peak generated by the short circuit. The protection technology activates within milliseconds, before static pressure increases, thereby preventing transformer explosion and subsequent fire.

A.5.1.2.3 As a minimum, the firewall should extend at least 1 ft (0.3 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.

A.5.1.2.5 A higher noncombustible shield is permitted to protect against the effects of an exploding transformer bushing.

A.5.1.3.2 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.

A.5.1.5.1 Listed penetration seals for large-diameter piping might not be commercially available. In such instances the design should be similar to listed configurations.

A.5.2.2(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.

NFPA *101*, *Life Safety Code*, allows additional means of egress components for special purpose industrial occupancies. These areas can 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, Life Safety Code)*.

Examples of these spaces include catwalks, floor areas, or elevated platforms that are provided for maintenance and inspection of in-place equipment.

NFPA *101*, *Life Safety Code*, 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 the following:

(1) Turbine scroll cases
(2) Generators
(3) Access tunnels for dam inspections
(4) Entry into draft tubes
(5) Penstocks

A.5.4.1.3.1 Where a separate smoke management system is provided, it should be designed for areas that could be damaged indirectly in the event of a fire through either of the following two scenarios:

(1) Exposure to smoke from a fire originating within the rooms themselves
(2) Exposure to smoke in one room from a fire originating in the other room

A smoke management system (ventilation) should be designed to minimize the penetration of smoke into electrical equipment.

A.5.4.1.5 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 can 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 firestops. 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*.

A.5.5.1 Draining the space above the turbine head cover by gravity might 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 might 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.

A.5.5.2 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 2 hours.

A.6.2.3.2 For unattended stations, see Section 6.9.

A.7.2.4 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 might be in these areas.

A.7.3.1 Fires occurring where a generator is in operation are caused by an electrical fault in the generator. Not all faults result in fire. Electrical protection should quickly isolate the generator following detection of a fault. Generator fires are low frequency events. Fires occurring in generators with thermoplastic insulation (i.e., asphalt, cloth ribbon, polyester) have resulted in self-supporting fires. Damage and downtime have been reduced by the use of fire suppression systems.

Fires in generators with thermoset insulation (i.e., fiberglass, epoxy resin) have been less frequent. Incidents have been reported where self-sustaining fire did not occur and operation of a fire suppression system did not result in reduction of damage. There have been other incidents where generator protection schemes failed to isolate the unit electrically (the unit remained energized). This fault energy was high enough to result in a self-sustaining fire. The operation of a fire suppression system limited damage and reduced the amount of time the generator was out of service.

A.8.7.4 The highest water demand should be determined by the hazards present at the stage of construction, which might not correspond with the highest water demand of the completed plant.

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

A.9.4.1.2 Inspection intervals for unattended plants are permitted to be extended to normal plant inspections.

A.9.4.5.2 Recommendations contained in NFPA 600, *Standard on Industrial Fire Brigades*, and 29 CFR 1910, Subparts E and L, should be consulted for additional information.

Annex B Sample Fire Report

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

B.1 Figure B.1 is one example of a typical fire report to be used by the fire brigade after an incident.

SAMPLE FIRE REPORT

Name of company: _____

Date of fire: _____ Time of fire: _____ Operating facility: _____

Under construction: _____

Plant or 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: _____

Specific type of detection devices: _____

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

Did detection devices and extinguishing system function properly? _____

If 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 other utilities who might have similar equipment, structures, or extinguishing systems? _____

_____

_____

Submitted by: _____ Title: _____

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FIGURE B.1 Example of a Fire Report.