NFPA®

850

Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

2020

NFPA®

See ALERT

IMPORTANT NOTICES AND DISCLAIMERS CONCERNING NFPA® STANDARDS

NFPA® codes, standards, recommended practices, and guides ("NFPA Standards"), of which the document contained herein is one, are developed through a consensus standards development process approved by the American National Standards Institute. This process brings together volunteers representing varied viewpoints and interests to achieve consensus on fire and other safety issues. While the NFPA administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in NFPA Standards.

The NFPA disclaims liability for any personal injury, property, or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on NFPA Standards. The NFPA also makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

In issuing and making NFPA Standards available, the NFPA is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the NFPA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

The NFPA has no power, nor does it undertake, to police or enforce compliance with the contents of NFPA Standards. Nor does the NFPA list, certify, test, or inspect products, designs, or installations for compliance with this document. Any certification or other statement of compliance with the requirements of this document shall not be attributable to the NFPA and is solely the responsibility of the certifier or maker of the statement.

REVISION SYMBOLS IDENTIFYING CHANGES FROM THE PREVIOUS EDITION

Text revisions are shaded. A Δ before a section number indicates that words within that section were deleted and a Δ to the left of a table or figure number indicates a revision to an existing table or figure. When a chapter was heavily revised, the entire chapter is marked throughout with the Δ symbol. Where one or more sections were deleted, a • is placed between the remaining sections. Chapters, annexes, sections, figures, and tables that are new are indicated with an ***N***.

Note that these indicators are a guide. Rearrangement of sections may not be captured in the markup, but users can view complete revision details in the First and Second Draft Reports located in the archived revision information section of each code at www.nfpa.org/docinfo. Any subsequent changes from the NFPA Technical Meeting, Tentative Interim Amendments, and Errata are also located there.

See ALERT

ALERT: THIS STANDARD HAS BEEN MODIFIED BY A TIA OR ERRATA

Users of NFPA codes, standards, recommended practices, and guides ("NFPA Standards") should be aware that NFPA Standards may be amended from time to time through the issuance of a Tentative Interim Amendment (TIA) or corrected by Errata. An official NFPA Standard at any point in time consists of the current edition of the document together with any TIAs and Errata then in effect.

To determine whether an NFPA Standard has been amended through the issuance of TIAs or corrected by Errata, go to www.nfpa.org/docinfo to choose from the list of NFPA Standards or use the search feature to select the NFPA Standard number (e.g., NFPA 13). The document information page provides up-to-date document-specific information as well as postings of all existing TIAs and Errata. It also includes the option to register for an "Alert" feature to receive an automatic email notification when new updates and other information are posted regarding the document.

ISBN: 978-145592509-4 (Print)
ISBN: 978-145592593-3 (PDF)

ADDITIONAL IMPORTANT NOTICES AND DISCLAIMERS CONCERNING NFPA® STANDARDS

Updating of NFPA Standards

Users of NFPA codes, standards, recommended practices, and guides ("NFPA Standards") should be aware that these documents may be superseded at any time by the issuance of a new edition, may be amended with the issuance of Tentative Interim Amendments (TIAs), or be corrected by Errata. It is intended that through regular revisions and amendments, participants in the NFPA standards development process consider the then-current and available information on incidents, materials, technologies, innovations, and methods as these develop over time and that NFPA Standards reflect this consideration. Therefore, any previous edition of this document no longer represents the current NFPA Standard on the subject matter addressed. NFPA encourages the use of the most current edition of any NFPA Standard [as it may be amended by TIA(s) or Errata] to take advantage of current experience and understanding. An official NFPA Standard at any point in time consists of the current edition of the document, including any issued TIAs and Errata then in effect.

To determine whether an NFPA Standard has been amended through the issuance of TIAs or corrected by Errata, visit the "Codes & Standards" section at www.nfpa.org.

Interpretations of NFPA Standards

A statement, written or oral, that is not processed in accordance with Section 6 of the Regulations Governing the Development of NFPA Standards shall not be considered the official position of NFPA or any of its Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

Patents

The NFPA does not take any position with respect to the validity of any patent rights referenced in, related to, or asserted in connection with an NFPA Standard. The users of NFPA Standards bear the sole responsibility for determining the validity of any such patent rights, as well as the risk of infringement of such rights, and the NFPA disclaims liability for the infringement of any patent resulting from the use of or reliance on NFPA Standards.

NFPA adheres to the policy of the American National Standards Institute (ANSI) regarding the inclusion of patents in American National Standards ("the ANSI Patent Policy"), and hereby gives the following notice pursuant to that policy:

NOTICE: The user's attention is called to the possibility that compliance with an NFPA Standard may require use of an invention covered by patent rights. NFPA takes no position as to the validity of any such patent rights or as to whether such patent rights constitute or include essential patent claims under the ANSI Patent Policy. If, in connection with the ANSI Patent Policy, a patent holder has filed a statement of willingness to grant licenses under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license, copies of such filed statements can be obtained, on request, from NFPA. For further information, contact the NFPA at the address listed below.

Law and Regulations

Users of NFPA Standards should consult applicable federal, state, and local laws and regulations. NFPA does not, by the publication of its codes, standards, recommended practices, and guides, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

NFPA Standards are copyrighted. They are made available for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of safe practices and methods. By making these documents available for use and adoption by public authorities and private users, the NFPA does not waive any rights in copyright to these documents.

Use of NFPA Standards for regulatory purposes should be accomplished through adoption by reference. The term "adoption by reference" means the citing of title, edition, and publishing information only. Any deletions, additions, and changes desired by the adopting authority should be noted separately in the adopting instrument. In order to assist NFPA in following the uses made of its documents, adopting authorities are requested to notify the NFPA (Attention: Secretary, Standards Council) in writing of such use. For technical assistance and questions concerning adoption of NFPA Standards, contact NFPA at the address below.

For Further Information

All questions or other communications relating to NFPA Standards and all requests for information on NFPA procedures governing its codes and standards development process, including information on the procedures for requesting Formal Interpretations, for proposing Tentative Interim Amendments, and for proposing revisions to NFPA standards during regular revision cycles, should be sent to NFPA headquarters, addressed to the attention of the Secretary, Standards Council, NFPA, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101; email: stds_admin@nfpa.org.

For more information about NFPA, visit the NFPA website at www.nfpa.org. All NFPA codes and standards can be viewed at no cost at www.nfpa.org/docinfo.

NFPA® 850

Recommended Practice for

Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

2020 Edition

This edition of NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*, was prepared by the Technical Committee on Electric Generating Plants. It was issued by the Standards Council on November 4, 2019, with an effective date of November 24, 2019, and supersedes all previous editions.

This document has been amended by one or more Tentative Interim Amendments (TIAs) and/or Errata. See “Codes & Standards” at www.nfpa.org for more information.

This edition of NFPA 850 was approved as an American National Standard on November 24, 2019.

Origin and Development of NFPA 850

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. Begun early in 1980, the first edition of NFPA 850 was officially released in 1986 as the *Recommended Practice for Fire Protection for Fossil Fueled Steam Electric Generating Plants.*

The second edition of NFPA 850 was issued in 1990 under the revised title of *Recommended Practice for Fire Protection for Fossil Fueled Steam and Combustion Turbine Electric Generating Plants.* This second edition incorporated a new Chapter 6 on the identification and protection of hazards for combustion turbines.

In 1991 the committee changed its name to the Technical Committee on Electric Generating Plants. This simplified name was made to reflect the committee’s scope to cover all types of electric generating plants except nuclear.

The 1992 edition of NFPA 850 incorporated a new Chapter 7 on alternative fuel electric generating plants. As part of these changes, the document title was revised to the *Recommended Practice for Fire Protection for Electric Generating Plants.* Various other technical and editorial changes were also made.

The 1996 edition of the standard added a new Chapter 8 on fire protection for high voltage direct current (HVDC) converter stations. In addition, the title was changed to *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations* to incorporate the new chapter.

The 2000 edition revised the application of the document to apply to existing facilities, as it is a good industry practice. Chapter 2 was reorganized to be specific to a fire risk control program. The document also clarified that a single water tank is not a reliable water supply, the spacing of hydrants, and lock-out of five suppression systems, and additional requirements were added for water mist fire suppression systems.

The 2005 edition of NFPA 850 underwent a complete revision to comply with the *Manual of Style for NFPA Technical Committee Documents.* Chapter 2 now contains mandatory references and Chapter 3 now contains definitions, and the subsequent chapters were renumbered.

Additional changes included revised figures in Chapter 5 that are intended to further clarify existing requirements and the addition of new annex material on fire protection requirements.

The 2010 edition of NFPA 850 included a chapter containing recommendations for a fire protection design process and fire protection design basis documentation (the new Chapter 4). The chapter on fire risk control program was moved to Chapter 16. New chapters on wind turbine generating facilities, solar thermal power generation, geothermal power plants, and integrated gasification combined cycle (IGCC) generating facilities (Chapters 10–13) were added.

The use of compressed air-foam systems and fast-depressurization systems were recognized, and recommendations for the use of these systems included.

The 2015 edition underwent a significant revision with the merger of NFPA 851. The recommendations contained in NFPA 850 and 851 were aligned, and a new chapter (Chapter 14) was created to provide recommendations specific to hydroelectric generating plants. Recommendations for aerosol extinguishing systems were added. Recommendations for active carbon injection systems were added to Chapter 7, and Chapter 11 was expanded to provide recommendations for fire and life safety involving photoelectric solar power plants.

The 2020 edition of NFPA 850 has undergone a complete reorganization. Information is now grouped in a more logical layout that helps users navigate the document more quickly. New chapters on flywheel energy systems and compressed air energy storage (CAES) have been added to address technologies used in the industry.

Technical Committee on Electric Generating Plants

Mark S. Boone, *Chair*
Dominion Energy, VA [U]

Steven M. Behrens, AXA XL Risk Consulting/ Global Asset Protection Services, LLC, CT [I]
Daryl C. Bessa, F. E. Moran, Inc. Special Hazard Systems, IL [IM]
Donald C. Birchler, FP&C Consultants, MO [SE]
James Casey, Marsh Risk Consulting, OH [I]
Stanley J. Chingo, NISYS Corporation, GA [SE]
Tom V. Clark, AEGIS Insurance Services, Inc., NJ [I]
Larry M. Danner, GE Power & Water, SC [M]
Russell A. Deubler, HSB Professional Loss Control, NH [I]
Laurie B. Florence, UL LLC, IL [RT]
Brian T. Ford, Tennessee Valley Authority, TN [U]
Ismail M. Gosla, Fluor Corporation, CA [SE]
Daniel D. Groff, AIG Energy and Engineered Risk, PA [I]
Paul Hayes, American Fire Technologies, NC [IM]
Fred L. Hildebrandt, Amerex/Janus Fire Systems, IN [M]
Rep. Fire Suppression Systems Association
Rickey L. Johnson, Liberty International Underwriters, NY [I]
David E. Kipley, JENSEN HUGHES, IL [SE]
Rep. JENSEN HUGHES
Clinton Marshall, FM Global, MA [I]
Rep. FM Global
Steve Maurer, Fuelcell Energy Inc., CT [M]
Joseph L. Navarra, Exelon Corporation/Pepco, DC [M]
Eric Prause, Doosan Fuel Cell America, CT [M]
Scot Pruett, Black & Veatch Corporation, KS [SE]
Karen I. Quackenbush, Fuel Cell & Hydrogen Energy Association, DC [M]
Ronald Rispoli, Entergy Corporation, AR [U]
Richard Ryan, Rodeo/Hercules Fire Protection District, CA [E]
Donald Struck, Siemens Fire Safety, NJ [M]
Rep. National Electrical Manufacturers Association
Leo Subbarao, Fire Department City of New York, NY [E]
Robert D. Taylor, PRB Coal Users Group, IN [U]
Robert Vincent, Shambaugh & Son, L.P., IN [IM]
Rep. National Fire Sprinkler Association

Alternates

James Bouche, F. E. Moran, Inc., IL [IM]
(Alt. to Daryl C. Bessa)
Larry Dix, Global Asset Protection Services, LLC, NY [I]
(Alt. to Steven M. Behrens)
Byron E. Ellis, Entergy Corporation, LA [U]
(Alt. to Ronald Rispoli)
William G. Gurry, Marsh Risk Consulting, CA [I]
(Alt. to James Casey)
Kelvin Hecht, Doosan Fuel Cell America, CT [M]
(Alt. to Eric Prause)
John Nathan Ihme, GE, SC [M]
(Alt. to Larry M. Danner)
Jay Keller, Fuel Cell And Hydrogen Association, CA [M]
(Alt. to Karen I. Quackenbush)
Regina M. Loschiavo, HSB Munich Re, NC [I]
(Alt. to Russell A. Deubler)
Dennis P. Mason, AEGIS Insurance Services, MI [I]
(Alt. to Tom V. Clark)
Timothy Pope, Amerex/Janus Fire Systems, IN [M]
(Alt. to Fred L. Hildebrandt)
Larry D. Shackelford, Southern Company, AL [U]
(Voting Alt.)
James H. Sharp, Siemens Energy, FL [M]
(Alt. to Donald Struck)
Blake M. Shugarman, UL LLC, IL [RT]
(Alt. to Laurie B. Florence)
Todd E. Stinchfield, FM Global, RI [I]
(Alt. to Clinton Marshall)
Andrew Wolfe, JENSEN HUGHES, MD [SE]
(Alt. to David E. Kipley)
Johnny Chung-Hin Young, Contra Costa County Fire District, CA [E]
(Alt. to Richard Ryan)

Nonvoting

Thomas C. Clayton, Overland Park, KS [SE]
(Member Emeritus)
Leonard R. Hathaway, The Villages, FL [I]
(Member Emeritus)

Brian J. O'Connor, NFPA Staff Liaison

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

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

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.

Contents

NFPA 850

Recommended Practice for

Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

2020 Edition

IMPORTANT NOTE: This NFPA document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading "Important Notices and Disclaimers Concerning NFPA Standards." They can also be viewed at www.nfpa.org/disclaimers or obtained on request from NFPA.

UPDATES, ALERTS, AND FUTURE EDITIONS: New editions of NFPA codes, standards, recommended practices, and guides (i.e., NFPA Standards) are released on scheduled revision cycles. This edition may be superseded by a later one, or it may be amended outside of its scheduled revision cycle through the issuance of Tentative Interim Amendments (TIAs). An official NFPA Standard at any point in time consists of the current edition of the document, together with all TIAs and Errata in effect. To verify that this document is the current edition or to determine if it has been amended by TIAs or Errata, please consult the National Fire Codes® Subscription Service or the "List of NFPA Codes & Standards" at www.nfpa.org/docinfo. In addition to TIAs and Errata, the document information pages also include the option to sign up for alerts for individual documents and to be involved in the development of the next edition.

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

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. 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 shall be sent to the technical committee responsible for the source document.

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

Chapter 1 Administration

1.1 Scope. This document provides recommendations for fire prevention and fire protection for electric generating plants and high voltage direct current converter stations, except as follows: Advanced light water reactor electric generating plants are addressed in NFPA 804; nuclear power plants are addressed in NFPA 805; and fuel cells are addressed in NFPA 853.

1.2 Purpose.

1.2.1 This document is prepared for the guidance of those charged with the design, construction, operation, and protection of electric generating plants and high voltage direct current converter stations that are covered by the scope of this document.

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 as shown 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, in the event of fire, should be controlled. 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 ensuring 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 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 on 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 following the methodology described in Chapter 4 and documented in the Fire Protection Design Basis document.

Δ **1.4 Equivalency.**

N **1.4.1** 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.

1.4.2 Equivalency should be demonstrated following the methodology described in Chapter 4 and documented 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 SI10, *American National 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.

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

NFPA 1, *Fire Code,* 2018 edition.
NFPA 2, *Hydrogen Technologies Code,* 2020 edition.
NFPA 10, *Standard for Portable Fire Extinguishers,* 2018 edition.
NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2016 edition.
NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2018 edition.
NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 2018 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2019 edition.
NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2019 edition.
NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2017 edition.
NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems,* 2019 edition.
NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 2017 edition.
NFPA 18A, *Standard on Water Additives for Fire Control and Vapor Mitigation,* 2017 edition.
NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* 2019 edition.
NFPA 22, *Standard for Water Tanks for Private Fire Protection,* 2018 edition.
NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* 2019 edition.
NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2020 edition.
NFPA 30, *Flammable and Combustible Liquids Code,* 2018 edition.
NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages,* 2018 edition.
NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 2020 edition.
NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines,* 2018 edition.
NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2019 edition.
NFPA 54, *National Fuel Gas Code,* 2018 edition.
NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2020 edition.
NFPA 56, *Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems,* 2020 edition.
NFPA 58, *Liquefied Petroleum Gas Code,* 2020 edition.
NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG),* 2019 edition.
NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2018 edition.
NFPA 69, *Standard on Explosion Prevention Systems,* 2019 edition.
NFPA 70®, National Electrical Code®, 2020 edition.
NFPA 72®, National Fire Alarm and Signaling Code®, 2019 edition.
NFPA 75, *Standard for the Fire Protection of Information Technology Equipment,* 2020 edition.
NFPA 77, *Recommended Practice on Static Electricity,* 2019 edition.
NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2019 edition.
NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures,* 2017 edition.
NFPA 85, *Boiler and Combustion Systems Hazards Code,* 2019 edition.
NFPA 86, *Standard for Ovens and Furnaces,* 2019 edition.
NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* 2018 edition.
NFPA 90B, *Standard for the Installation of Warm Air Heating and Air-Conditioning Systems,* 2018 edition.
NFPA 92, *Standard for Smoke Control Systems,* 2018 edition.
NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations,* 2017 edition.
NFPA *101®, Life Safety Code®,* 2018 edition.
NFPA 110, *Standard for Emergency and Standby Power Systems,* 2019 edition.
NFPA 120, *Standard for Fire Prevention and Control in Coal Mines,* 2020 edition.
NFPA 204, *Standard for Smoke and Heat Venting,* 2018 edition.
NFPA 214, *Standard on Water-Cooling Towers,* 2016 edition.
NFPA 220, *Standard on Types of Building Construction,* 2018 edition.
NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations,* 2019 edition.
NFPA 252, *Standard Methods of Fire Tests of Door Assemblies,* 2017 edition.
NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source,* 2019 edition.
NFPA 257, *Standard on Fire Test for Window and Glass Block Assemblies,* 2017 edition.
NFPA 259, *Standard Test Method for Potential Heat of Building Materials,* 2018 edition.
NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas,* 2017 edition.
NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas,* 2017 edition.
NFPA 501A, *Standard for Fire Safety Criteria for Manufactured Home Installations, Sites, and Communities,* 2017 edition.
NFPA 600, *Standard on Facility Fire Brigades,* 2020 edition.
NFPA 601, *Standard for Security Services in Fire Loss Prevention,* 2020 edition.
NFPA 652, *Standard on the Fundamentals of Combustible Dust,* 2019 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2020 edition.

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities,* 2020 edition.

NFPA 701, *Standard Methods of Fire Tests for Flame Propagation of Textiles and Films,* 2019 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* 2017 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2019 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 2020 edition.

NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants,* 2020 edition.

NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants,* 2020 edition.

NFPA 853, *Standard for the Installation of Stationary Fuel Cell Power Systems,* 2020 edition.

NFPA 1142, *Standard on Water Supplies for Suburban and Rural Fire Fighting,* 2017 edition.

NFPA 1143, *Standard for Wildland Fire Management,* 2018 edition.

NFPA 1144, *Standard for Reducing Structure Ignition Hazards from Wildland Fire,* 2018 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems,* 2019 edition.

NFPA 1901, *Standard for Automotive Fire Apparatus,* 2016 edition.

NFPA 1962, *Standard for the Care, Use, Inspection, Service Testing, and Replacement of Fire Hose, Couplings, Nozzles, and Fire Hose Appliances,* 2018 edition.

NFPA 1971, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting,* 2018 edition.

NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services,* 2019 edition.

NFPA 1982, *Standard on Personal Alert Safety Systems (PASS),* 2018 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2018 edition.

NFPA 2010, *Standard for Fixed Aerosol Fire-Extinguishing Systems,* 2020 edition.

NFPA 5000®, Building Construction and Safety Code®, 2018 edition.

NFPA Fire Protection Handbook, 2008, 20th edition.

2.3 Other Publications.

2.3.1 API Publications. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005-4070.

API 500, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division I and Division II*, 2012.

API 505, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0 and Zone 2*, 2018.

API 537, *Flare Details for Petroleum, Petrochemical, and Natural Gas Industries*, 2017.

API 2218, *Fireproofing Practices in Petroleum and Petrochemical Processing Plants*, 2013.

API RP 521, *Guide for Pressure Relieving and Depressurizing Systems*, 2007.

API RP 941, *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants*, 2016.

Δ **2.3.2 ASME Publications.** American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

ASME B31.1, *Power Piping*, 2018.

ASME B31.3, *Process Piping*, 2018.

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

ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*, 2018.

ASTM D448, *Standard Classification for Sizes of Aggregate for Road and Bridge Construction*, 2017.

ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 2019a.

ASTM E108, *Standard Test Methods for Fire Tests of Roof Coverings*, 2017.

ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, 2018ce1.

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 2019.

ASTM E814, *Standard Test Method for Fire Tests of Penetration Firestop Systems*, 2017.

ASTM E1248, *Standard Practice for Shredder Explosion Protection*, 2017.

ASTM E1725, *Standard Test Methods for Fire Tests of Fire-Resistive Barrier Systems for Electrical System Components*, 2014e1.

ASTM SI10, *American National Standard for Use of the International System of Units (SI): The Modern Metric System*, 2016.

2.3.4 IEC Publications. International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

IEC 62305, *Protection Against Lightning*, 2010.

2.3.5 IEEE Publications. IEEE, Three Park Avenue, 17th Floor, New York, NY 10016-5997.

IEEE C2, *National Electrical Safety Code*, 2017.

IEEE C37.20.7, *Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults*, 2007.

IEEE 484, *Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*, 2002.

IEEE 634, *Standard for Cable-Penetration Fire Stop Qualification Test*, 2004.

IEEE 979, *Guide for Substation Fire Protection*, 2012.

IEEE 980, *Guide for Containment and Control of Oil Spills in Substations*, 2013.

IEEE 1202, *Standard for Flame-Propagation Testing of Wire and Cable*, 2006.

N **2.3.6 SFPE Publications.** Society of Fire Protection Engineers, 9711 Washingtonian Blvd, Suite 380, Gaithersburg, MD 20878.

Engineering Guide to Fire Risk Assessment, 2006.

SFPE Handbook of Fire Protection Engineering, edition.

Δ **2.3.7 UL Publications.** Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 263, *Standard for Fire Tests of Building Construction and Materials*, 2011, revised 2018.

UL 723, *Test for Surface Burning Characteristics of Building Materials*, 2008, revised 2018.

UL 790, *Tests for Fire Resistance of Roof Covering Materials* 2004, revised 2014.

UL 900, *Standard for Safety Test Performance of Air Filters*, 2004, revised 2015.

UL 1479, *Standard for Fire Tests of Through-Penetration Firestops*, 2003, revised 2015.

UL 1709, *Standard for Rapid Rise Fire Tests of Protection Materials for Structural Steel*, 2017.

2.3.8 US Government Publications. US Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

OSHA 29 CFR 1910.146, "Permit Required Confined Space Standard," U.S. Department of Labor, 2010.

Title 29, CFR, Part 1910.156, "Fire Brigades," 2008.

2.3.9 Other Publications.

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

•

Δ **2.4 References for Extracts in Recommendations Sections.**

NFPA 30, *Flammable and Combustible Liquids Code,* 2018 edition.

NFPA 101®, *Life Safety Code®*, 2018 edition.

NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials,* 2020 edition.

NFPA 5000®, *Building Construction and Safety Code®,* 2018 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 Alternative Fuels. Solid fuels such as municipal solid waste (MSW), refuse derived fuel (RDF), biomass, rubber tires, and other combustibles that are used instead of fossil fuels (gas, oil, or coal) in a boiler to produce steam for the generation of electrical energy.

3.3.2 Biomass. A boiler fuel manufactured by means of a process that includes storing, shredding, classifying, and conveying of forest and agricultural byproducts (e.g., wood chips, rice hulls, sugar cane).

3.3.3 Combustible. Capable of undergoing combustion.

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

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

3.3.6 Fast Depressurization System. A passive mechanical system designed to depressurize oil-filled equipment such as transformers, current-limiting reactors, bushing cable boxes, or load tap changers a few milliseconds after the occurrence of an internal electrical arc.

3.3.7 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.

3.3.8 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*,** 2018]

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

3.3.10 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 D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester.* [**30,** 2018]

3.3.11 Fire Prevention. Measures directed toward avoiding the inception of fire. [**801,** 2020]

3.3.12 Fire Protection. Methods of providing for fire control or fire extinguishment. [**801,** 2020]

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

3.3.14 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.

3.3.15 Fluid.

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

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

3.3.16 Fossil Fueled. Fuel containing chemical energy, which has been formed from animal and plant matter over many years (i.e., oil, coal, and natural gas) that are used in a boiler to produce steam for the generation of electrical energy.

3.3.17 High-Voltage Direct Current (HVDC) Converter Station. A facility that functions as an electrical rectifier (ac-dc) or an inverter (dc-ac) to control and transmit power in a high-voltage network. There are two types of HVDC valves — the mercury arc valve and the present-day technology solid state thyristor valve. Both types of valves present a fire risk due to high-voltage equipment that consists of oil-filled converter transformers, wall bushings, and capacitors in addition to various polymeric components.

N **3.3.18 Hybrid Fire-Extinguishing System.** A fire-extinguishing system capable of delivering hybrid media at the specified design rate and proportion.

N **3.3.19 Hybrid Media.** An extinguishing media created by the simultaneous discharge of water and an inert gas agent in a controlled proportion from a common discharge device that results in an oxygen concentration less than 18 percent.

N **3.3.20 Idling.** A condition of the flywheel energy system where the flywheel is rotating but not providing energy to external loads.

3.3.21 Interior Finish. The exposed surfaces of walls, ceilings, and floors within buildings. [**5000,** 2018]

Δ **3.3.21.1** ***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 E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or 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.

Δ **3.3.21.2** ***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 E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or 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.

Δ **3.3.22 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 3500 Btu/lb (8141 kJ/kg), where tested in accordance with NFPA 259 and complies with (a) or (b): (a) materials having a structural base of noncombustible material, with a surfacing not exceeding a thickness of 0.127 in. (3.2 mm) 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 are considered combustible.)

3.3.23 Liquid.

3.3.23.1 ***Combustible Liquid.*** Any liquid that has a closed-cup flash point at or above 100°F (37.8°C). *(See NFPA 30.)*

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

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

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

3.3.24 Mass Burn. A process in which municipal solid waste is hauled directly to a tipping floor or storage pit and then is used as a boiler fuel without any special processing.

3.3.25 Municipal Solid Waste (MSW). Solid waste materials consisting of commonly occurring residential and light commercial waste.

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

3.3.27 Rating.

3.3.27.1 ***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 and NFPA 257 as applicable.

3.3.27.2 ***Fire Resistance Rating.*** The time, in minutes or hours, that materials or assemblies have withstood a fire exposure as determined by the tests, or methods based on tests, as prescribed in *NFPA 5000.* [**5000,** 2018]

3.3.28 Refuse Derived Fuel (RDF). A boiler fuel manufactured by means of a process that includes storing, shredding, classifying, and conveying of municipal solid waste.

N **3.3.29* Spin Down.** Shutdown condition of the flywheel energy system, where energy is being dissipated and the flywheel rotor is slowing down to a stop.

3.3.30 Stakeholder. An individual, a 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 Fire Protection Design Basis Document should be a living document that continues to evolve, as the plant design is refined, and it should be maintained and revised for the life of the plant. The Fire Protection Design Basis Document is key to the management of change process *(see 5.4.3)*.

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 Stakeholders establish goals and objectives and evaluate whether the recommendations of NFPA 850 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 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 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 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) Fuel types and volatility
(4) Plant layout and geographic location
(5) Equipment availability/redundancy
(6) Availability of water supply
(7) Capability of emergency responders
(8) Storage configuration (short term and long term)
(9) Historical loss information/lessons learned/fire reports *(See Annex B and Annex D.)*

4.4 Fire Protection Design Basis Process.

4.4.1 Stakeholder establishes goals and objectives and evaluates whether the recommendations of NFPA 850 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 layout is not acceptable, a fire risk evaluation should be developed to ensure objectives are met, and then return to the review process.

4.4.3 Each hazard/area is reviewed against the goals and objectives and NFPA 850. If the hazards control is not acceptable, then a fire risk evaluation should be developed to ensure objectives are met, and then return to the review process.

4.4.4 A DBD is developed.

4.4.5 As the project evolves, the DBD should be reviewed and updated as necessary to incorporate changes and revisions. *(See Figure 4.4.5.)*

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/prevention design basis for achieving the fire hazard control objectives agreed upon by the stakeholders, including the following:

(1) Identify assumptions (including items in 4.3.2).
(2) Identify source documents.
(3) Identify each hazard, identify which fire prevention/protection features are to be provided or omitted, and summarize 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.

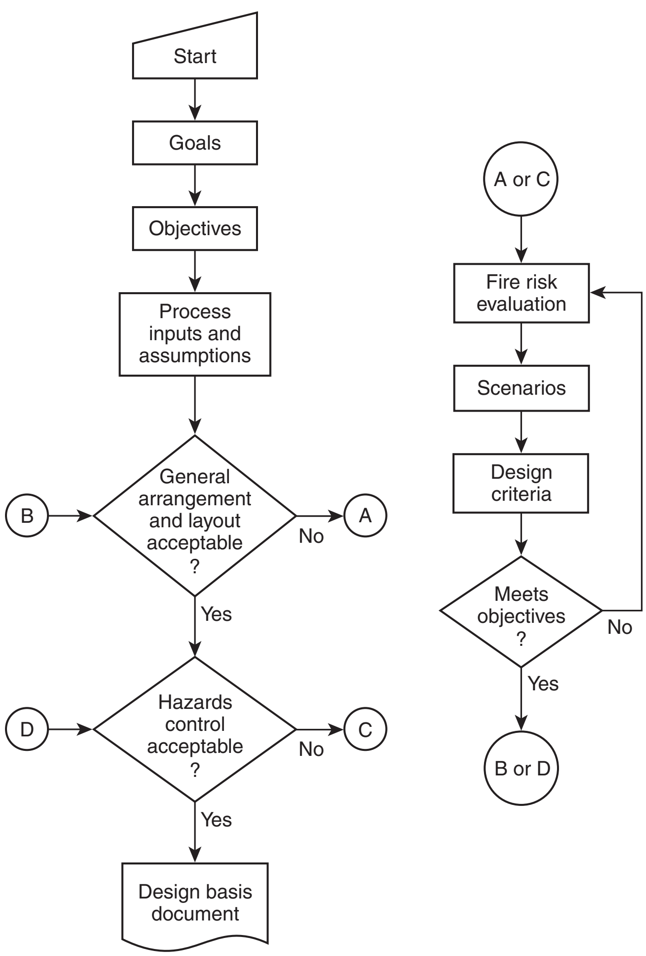


FIGURE 4.4.5 Fire Protection Design Basis Process Flow Chart.

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 and also addressing containment and drainage. A sample table of contents for the DBD is contained in Annex E.

Chapter 5 Fire Risk Control Program

5.1 General.

5.1.1 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 electric generating plants and high voltage direct current converter stations.

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

5.1.3 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.

5.2 Management Policy and Direction.

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

5.2.2 Proper preventive maintenance of operating equipment and adequate operator training are critical aspects of an effective fire prevention program. See Annex D for examples of operator errors causing significant property loss.

Δ **5.3 Fire Risk Control Program.**

N **5.3.1** A written plant fire prevention program should be established and, at a minimum, should include the following:

(1) Fire safety information for all employees and contractors. This information should include, at a minimum, familiarization with fire prevention procedures, plant emergency alarms and procedures, and how to report a fire. This should be included in employee/contractor orientation.
(2) Documented, regularly scheduled plant inspections, including provisions for handling remedial actions to correct conditions that increase fire hazards.

(3) A description of general housekeeping practices and the control of transient combustibles. Fire experience has shown that transient combustibles can be a significant factor during a fire situation, especially during outages.
(4) Control of flammable and combustible liquids and gases in accordance with appropriate NFPA standards.
(5) Combustible dust, as applicable, in accordance with NFPA 652.
(6) Control of ignition sources including smoking, grinding, welding, and cutting. *(See NFPA 51B.)*
(7) Fire prevention surveillance. *(See NFPA 601.)* Operational experience has demonstrated that roving operators and other plant personnel have been key factors in detection of fires and unsafe conditions. It is important that they be properly trained to observe and react to incipient fire situations. These should be reported to the control room operator for evaluation to determine what action is to be taken.
(8) A fire report, including an investigation and a statement on the corrective action to be taken *(see Annex B)*.
(9) Fire hazards of materials located in the plant or storage areas identified in accordance with NFPA 704 and applicable material safety data sheets (MSDS).

N **5.3.2** A regular housekeeping program should be established to maintain combustible and other materials in designated storage areas.

5.4 Fire Protection Program.

5.4.1 Testing, Inspection, and Maintenance.

5.4.1.1 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.

5.4.1.2* All fire protection systems and equipment should be periodically inspected, tested, and maintained in accordance with applicable *National Fire Codes. (See Table 5.4.1.2 for guidance.)*

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

5.4.2 Impairments.

5.4.2.1 A written procedure should be established to address impairments to fire protection systems and other plant systems that impact the level of fire hazard (e.g., dust collection systems, HVAC systems). As a minimum this procedure should address the following:

(1) Identify equipment not available for service
(2) Identify personnel to be notified (e.g., plant fire brigade leader, public fire department, plant fire protection coordinator, control room operator)
(3) Increase fire surveillance as needed *[see 5.3.1(6)]*
(4) Provide additional protected measures as necessary (e.g., temporary water supplies, additional hose)

5.4.2.2 Impairment to fire protection systems should be as short in duration as practical. If the impairment is planned, all necessary parts and manpower 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.

Δ **Table 5.4.1.2 Reference Guide for Fire Equipment Inspection, Testing, and Maintenance**

Item	NFPA Document No.
Supervisory and fire alarm circuits	72
Fire detectors	72
Manual fire alarms	72
Sprinkler water flow alarms	25/72
Sprinkler and water spray systems	25/72
Foam systems	11/16/25
Halogenated agent, chemical and CO_2 systems	12/12A/17/2001
Fire pumps and booster pumps	25/72
Water tanks and alarms	25/72
PIVs and OS & Y valves	25/72
Fire hydrants and associated valves	13/24
Fire hose and standpipes and hose nozzles	25/1962
Water additives	18A
Portable fire extinguishers	10
Fire brigade equipment	1971/1981/1982
Fire doors and dampers	80/90A
Smoke vents	204
Emergency lighting	110
Radio communication equipment	1221
Audible and visual signals	72
Water mist fire protection systems	750

5.4.2.3 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).

Δ **5.4.3 Management of Change.** A system should be implemented that would ensure that the appropriate individual(s) with fire protection responsibility are made aware of new constructions, modifications to existing structures, changes to operating conditions, or other action that could impact the fire protection of the plant. The Fire Protection Design Basis Document and the appropriate procedures and programs discussed in this chapter might need to be revised to reflect the impact of this action.

5.4.4* 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 employees and visitors 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 and identification of fire water application concerns on operating equipment
(6) Periodic drills to verify viability of the plan
(7) Control room operator(s) and auxiliary operator(s) activities during fire emergencies
(8) Procedures for grounding, isolating, or discharging of energy sources
(9) Procedures for maintaining appropriate clearances to high-voltage electrical systems
(10) Timely communication of all fire events to the responding fire brigade and the fire department

N **5.4.4.1** Emergency preplanning for the fire brigade and the fire department should include manual fire-fighting equipment utilization and deployment training.

N **5.4.4.2 Unattended Facilities.**

N **5.4.4.2.1** Power generating plants that are operated unattended or with minimal staffing present special fire protection concerns.

N **5.4.4.2.2** 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.

N **5.4.4.2.3** 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 11.5.4)*.

5.4.5 Emergency Response Personnel.

5.4.5.1 The size of the plant and its staff, the complexity of fire-fighting problems, and the availability of a public fire department should determine the requirements for emergency response personnel or fire brigade.

5.4.5.2 An emergency response team can be provided to facilitate response to emergencies such as fire. Activities can include incident command, incipient fire-fighting, escorting fire department personnel, first aid, HazMat First Responder duties, and so forth. The organization and responsibilities should be clearly identified.

5.4.5.3* If a fire brigade is provided, its organization and training should be identified in written procedures. NFPA 600 and OSHA standard 29 CFR 1910.156, "Fire Brigades," should be consulted for determining operation limitations.

5.4.6* Special Fire-Fighting Conditions. Electric generating plants present unique fire-fighting challenges. This information might be useful in fire preplanning. It could also be utilized in the education and training of both on-site and off-site fire-fighting personnel who would respond in the event of a fire emergency.

5.4.6.1 Turbine Lubricating Oil Fires. A critical aspect of responding to turbine lubricating oil fires is minimizing the size and duration of the oil spill. The need for lubrication to protect the turbine-generator bearings and shaft should be balanced against the fire damage from allowing the oil leak to continue. The following steps can be useful in minimizing fire damage and should be considered during preplanning and training for emergency conditions:

(1) Tripping the turbine
(2) Breaking condenser vacuum
(3) Emergency purging of the generator
(4) Shut down main and backup oil pumps

Shutting down oil pumps can cause additional mechanical damage to the turbine depending on rotating speed. However, it can be effective in mitigating the overall damage due to fire. *(See Annex D.)* When ac oil pumps are shut down, dc or backup pumps will start on low pressure. The dc or backup oil pumps will also have to be secured, which usually requires more than operating a switch.

5.4.6.2 Regenerative Air Heaters. Since laboratory tests and reported incidents indicated a rapid increase in temperature to the 2800°F–3000°F (1537°C–1648°C) range in an air preheater fire, great care should be given to manual fire fighting. Large amounts of water will be needed to cool and extinguish a preheater fire. Fire preplanning should be accomplished to ensure use of an adequate number of access doors and safe access to the doors.

N **5.4.6.3 Scrubbers.**

N **5.4.6.3.1 Fire Protection.** A fire protection system should be provided during outages for absorber vessels containing combustible packing or lining and should include the following:

(1) The fire protection system can be the spray system designed for normal scrubber operation or a specially designed fire protection system. Water spray systems should be designed such that spray patterns cover the lining and packing. Where scrubber spray systems are used for fire protection, system components internal to the scrubber should be noncombustible. The water supply should be from a reliable source available during the outage.
(2) A fire protection system should be provided in the duct systems during maintenance operations. A fixed protection duct system on the scaffolding is recommended. The duct system should be designed to protect the work platform and twice the area that can be reached by workers on the platform.
(3) Due to the unique design and operating features of scrubbers, fire protection designers should consult with the scrubber manufacturer for guidance as to material selection for internal fire protection systems and specific protection design features.
(4) Standpipes should be provided such that 1½ in. (3.8 cm) hose is available at scrubber access hatches that are open during outages.
(5) The introduction of combustible materials into the scrubber should be limited and controlled during maintenance and inspection outages.

N **5.4.6.3.2** During outages, all of the following should be done:

(1) Cutting, welding, and other hot work is the most likely cause of ignition. *(See also NFPA 51B.)* At a minimum, strict work controls should be enforced. Packing should be covered with fire-resistant blankets over sheet metal. Blankets should be kept wet. A charged hose and fire watch should be provided at the work area.
(2) The scrubber reservoir should be maintained full if possible or returned to service as quickly as possible during an outage.
(3) The absorber inlet and outlet damper should be closed during cutting, welding, or other hot work to reduce the

induced draft. When the scrubber outlet damper is open, no hot work should be permitted in the downstream duct or stack.

5.4.6.4 Electrostatic Precipitators. Once a fire is detected, the unit should go into emergency shutdown immediately. It should be recognized that during operation the atmosphere in the precipitator is oxygen-deficient and opening doors or running system fans following a fuel trip could cause conditions to worsen (increased potential for backdraft explosion). Once the flow of air and fuel to the fire has been stopped and the electrostatic precipitator has been shut down and de-energized, the precipitator doors can be permitted to be opened and water hoses employed if necessary.

5.4.6.5 Cable Trays. Cable tray fires 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.

5.4.6.6 Hydrogen System. Hydrogen has a relatively large flammability range (4 to 75 percent by volume) in air. The explosive range (for deflagrations and detonations) is narrower than the flammability range, but hydrogen explosions can occur inside turbine halls in the event of accidental release and delayed ignition. Under most conditions, it is safer to allow a hydrogen fire to burn in a controlled manner until such time as the gas source can be shut off. Extinguishing the fire while gas is still escaping could allow an explosive mixture to be generated. The Fire Protection Design Basis Document should include provisions so that hydrogen supplies can be shut off from a readily accessible location outside the fire area if called for in an emergency situation.

5.4.6.7* Fuel Storage and Handling.

5.4.6.7.1 Once the location and extent of a fire in a solid-fuel storage pile have been determined, the fuel should be dug out and the heated fuel removed. Because moisture accelerates oxidation, water used for fire-fighting can aggravate the situation if the seat of the fire is not reached. Water additives should be considered, to break the water tension and improve penetration.

Δ **5.4.6.7.2** Clearly marked access panels in equipment should be provided for manual fire-fighting. Combustible dust presents both a fire and explosion hazard. Combustible, finely divided material is easily ignited. However, there is a possibility that a deep-seated hard-to-extinguish fire can occur. Application of an extinguishing agent that disturbs dust deposits could result in a dust explosion.

N **5.4.6.7.3** The facility personnel should ensure that fuel is continuously moved to the processing or storage areas. Vehicles loaded with fuel materials should not be parked in the building during idle periods.

5.4.6.8 Coal Pulverizers. *(See 9.5.4 of NFPA 85.)* Additional information can be obtained from published manufacturer's instructions.

5.5 Identification of Fire Hazards of Materials. Materials located in the plant or storage areas should be identified in accordance with NFPA 704 and the applicable SDS.

Chapter 6 General Plant Design

6.1 Plant Arrangement.

6.1.1 Fire Area Determination.

6.1.1.1 The electric generating plant and the high voltage direct current converter station should be subdivided into separate fire areas as determined by the Fire Protection Design Basis Document for the purpose 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 fire barriers, spatial separation, or other approved means.

6.1.1.2 Determination of fire area boundaries should be based on consideration of the following:

(1) Types, quantity, density, and locations of combustible material
(2) Location and configuration of plant equipment
(3) Consequence of losing plant equipment
(4) Location of fire detection and suppression systems

Δ **6.1.1.3*** Unless consideration of the factors of 6.1.1.2 indicates otherwise or if adequate spatial separation is provided as permitted in 6.1.1.5, it is recommended that fire area boundaries be provided to separate the following:

(1) Cable spreading room(s), and cable tunnel(s) and high-voltage lead shafts from adjacent areas
(2) Control room, computer room, or combined control/computer room from adjacent areas
(3) Rooms with major concentrations of electrical equipment, such as a switchgear room or relay room, from adjacent areas
(4) Battery rooms from associated battery chargers, equipment, and adjacent areas
(5) Maintenance shop(s) from adjacent areas
(6) Main fire pump(s) from reserve fire pump(s) where these pumps provide the only source of fire protection water
(7) Fire pumps from adjacent areas
(8) Warehouses from adjacent areas
(9) Emergency generators, combustion turbines, and other internal combustion engines from each other and from adjacent areas
(10) Fossil-fuel-fired auxiliary boiler(s) from adjacent areas
(11) Fuel oil pumping, fuel oil heating facilities, or both, used for continuous firing of the boiler from adjacent areas
(12) Storage areas for flammable and combustible liquid tanks and containers from adjacent areas
(13) Office buildings from adjacent areas
(14) Telecommunication rooms, supervisory control and data acquisition (SCADA) rooms, and remote terminal unit (RTU) rooms from adjacent areas
(15) Adjacent turbine generators beneath the underside of the operating floor
(16) Between the boiler house and the areas of the fuel handling system above the bin, bunker, or silo

(17) Fan rooms and plenum chambers from adjacent areas [fire dampers might not be advisable in emergency ventilation ducts *(see Section 6.4)*]
(18) Switchgear area and sulfur hexafluoride (SF_6) switchyard area from adjacent areas

6.1.1.4 Fire barriers separating fire areas should be a minimum of 2-hour fire resistance rating.

6.1.1.5 If a fire area is defined as a detached structure, it should be separated from other structures by an appropriate distance as determined by NFPA 80A evaluation.

N **6.1.1.6** Particular care should be practiced with respect to adequate spatial separation and protection from wildland fires as well as the control of vegetation. Guidance regarding vegetation clearance, separation distance, and emergency planning can be found in NFPA 1143 and NFPA 1144.

6.1.2 Openings in Fire Barriers.

Δ **6.1.2.1*** All openings in fire barriers should be provided with fire door assemblies, fire dampers, through 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. Through penetration fire stops for electrical and piping openings should be listed or should meet the requirements for an "F" rating when tested in accordance with ASTM E814, *Standard Test Method for Fire Tests of Penetration Firestop Systems.* Other test methods for qualifications of penetration seals, such as IEEE 634, *Standard for Cable-Penetration Fire Stop Qualification Test,* or UL 1479, *Standard for Fire Tests of Through-Penetration Firestops,* are permitted to be considered for this application.

6.1.2.2 Fire door assemblies, fire dampers, and fire shutters used in 2-hour–rated fire barriers should be listed and approved for a minimum 1½ hour fire rating. *(See NFPA 80.)*

6.1.3 Hydrogen Storage. Hydrogen storage facilities should be separated from adjacent areas. *(See NFPA 2.)*

6.1.4 Outdoor Oil-Insulated Transformers.

6.1.4.1 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.

6.1.4.2 Determination of the type of physical separation to be used between transformers, control equipment, and building structures should be based on a detailed analysis 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) Type and amount of exposed equipment, including high line structures, motor control center (MCC) equipment, breakers, other transformers, and so forth.
(5) Power rating of the transformer
(6) Fire suppression systems provided
(7) Type of electrical protective relaying provided
(8) Availability of replacement transformers (long lead times)
(9)* The existence of fast depressurization systems

Once this analysis has been completed, any decisions made as a result should be included as part of the Fire Protection Design Basis Document.

6.1.4.3* Unless consideration of the factors in 6.1.4.2 indicates otherwise, it is recommended that any oil-insulated transformer, including the edge of the postulated oil spill, be separated from adjacent structures by a 2-hour-rated firewall or by spatial separation in accordance with Table 6.1.4.3. Where a firewall is provided between structures and a transformer, it should extend vertically and horizontally as indicated in Figure 6.1.4.3.

6.1.4.4 Unless consideration of the factors in 6.1.4.2 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 6.1.4.3. When the oil containment, as shown in Figure 6.1.4.4, consists of a large, flat concrete containment area that holds several transformers and other equipment in it without the typical pit containment areas, specific containment features to keep the oil in one transformer from migrating to any other transformer or equipment should be provided. Subsection 6.5.6 can be used for guidance. Where a firewall is provided between transformers, it should extend at least 1 ft (0.31 m) above the top of the transformer casing and oil conservator tank and at least 2 ft (0.61 m) beyond the width of the transformer and cooling radiators, or to the edge of the containment area, whichever is greater. *(See Figure 6.1.4.4 for an illustration of the recommended dimensions for a firewall.)*

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

•

6.1.4.6 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 6.1.4.2 and 6.1.4.5.

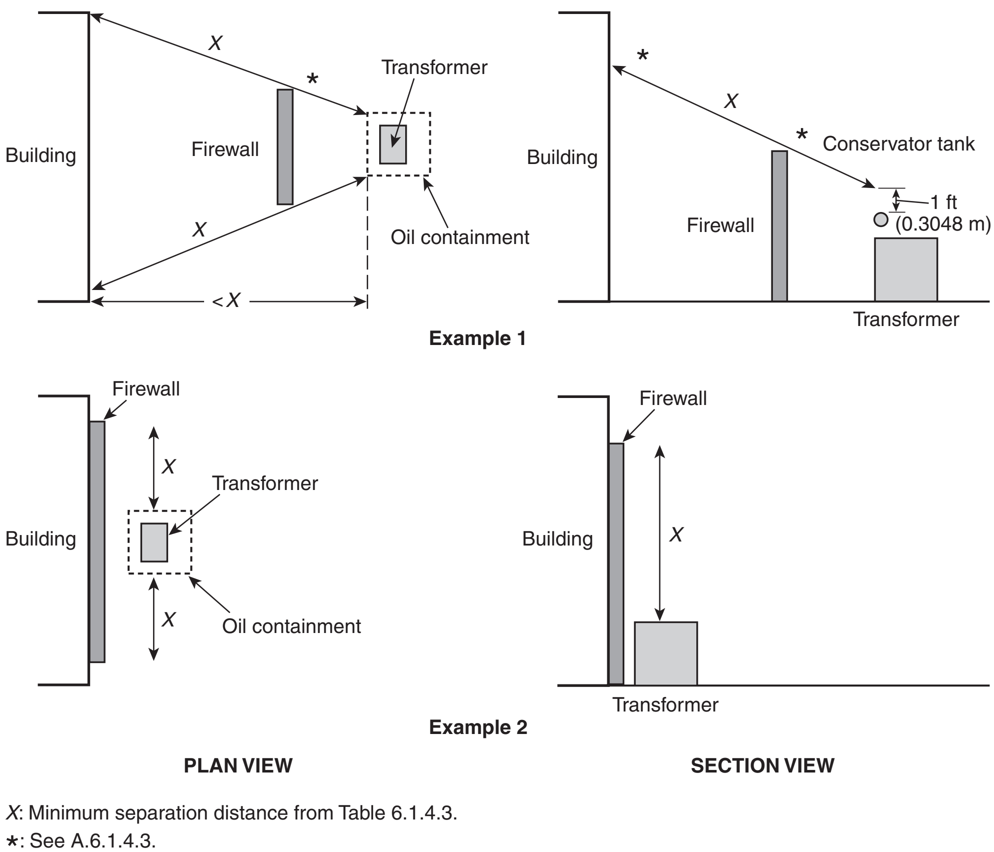
6.1.5 Indoor Transformers and Other Oil-Filled Electrical Equipment.

6.1.5.1 Dry-type transformers and other non-oil-filled electrical equipment are preferred for indoor installations. Dry-type capacitors or capacitors filled with a less flammable liquid should be considered to minimize the fire risk associated with oil-filled equipment.

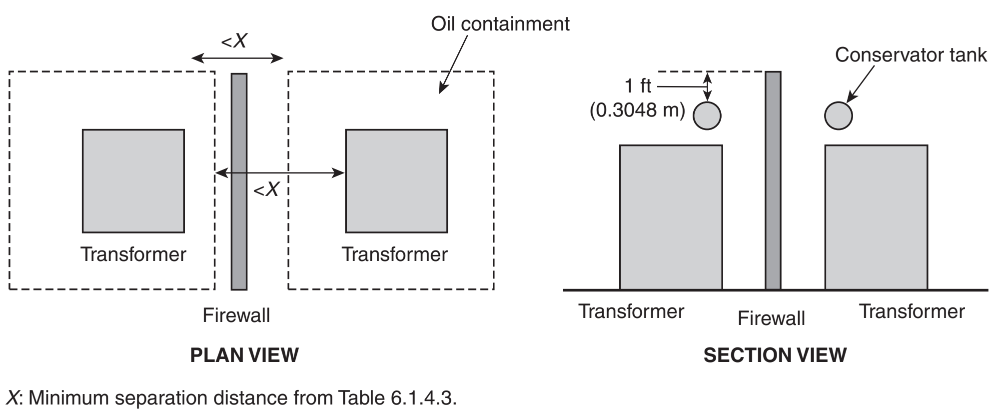
6.1.5.2* Oil-insulated transformers or other oil-filled electrical equipment of greater than 100 gal (379 L) oil capacity installed indoors should be separated from adjacent areas by fire barriers of 3-hour fire resistance rating.

Δ **Table 6.1.4.3 Outdoor Oil-Insulated Transformer Separation Criteria**

Transformer Oil Capacity		Minimum (Line-of-Sight) Separation Without Firewall	
gal	L	ft	m
<500	<1893	5	1.5
500–5000	1893–18,925	25	7.6
>5000	>18,925	50	15



Δ **FIGURE 6.1.4.3 Illustration of Oil-Insulated Transformer Separation Recommendations.**



Δ **FIGURE 6.1.4.4 Outdoor Oil-Insulated Transformer Separation Criteria.**

6.1.5.3 Transformers having a rating greater than 35 kV, insulated with a less flammable liquid or nonflammable fluid, and installed indoors should be separated from adjacent areas by fire barriers of 3-hour fire resistance rating.

6.1.5.4 Where transformers or other oil-filled electrical equipment are protected by an automatic fire suppression system, the fire barrier fire resistance rating should be permitted to be reduced to 1 hour.

N **6.1.5.5** 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, according to the hazard analysis, to warrant a fixed fire suppression system, automatic fire detection should be considered *(see 7.7.2)*.

6.1.6* General Substation Arrangement. The following documents should be considered for arrangement and protection of substations and switchyards:

(1) IEEE 979, *Guide for Substation Fire Protection*
(2) IEEE 980, *Guide for Containment and Control of Oil Spills in Substations*

6.2 Life Safety.

6.2.1 For life safety considerations for electric generating plants included in the scope of this document, see NFPA *101.*

6.2.2* Structures should be classified as follows, as defined in NFPA *101*:

(1) General areas should be considered as special-purpose industrial occupancies.
(2) Open structures and underground structures (e.g., tunnels) should be considered as occupancies in special structures. Temporary occupancies and means of egress inside the structures and piers of large "bulb" hydroelectric units should be evaluated based on occupancies in special structures.
(3) General office structures should be considered as business occupancies.
(4) Warehouses should be considered as storage occupancies.
(5) Fuel preparation and handling facilities (e.g., enclosed crusher houses, transfer houses, and conveyors) should be considered special-purpose industrial occupancies.
(6) Scrubber buildings should be considered as special-purpose industrial occupancies.

6.2.3 In the event of a plant fire, egress of occupants in control facilities can be delayed due to emergency shutdown procedures. *(See 40.2.5.1.2 of NFPA 101.)* Control facilities should have a means of egress that is separated from other plant areas to facilitate a delayed egress.

6.2.4 In the event of a plant fire, explosion, or other incident that would require evacuation of a turbine hall or boiler house (or any other occupied area) during an outage, evacuation plans and emergency plans in general should be developed that would take into consideration the increased occupancy load in these areas.

6.3 Building Construction Materials.

Δ **6.3.1** Construction materials being considered for electric generating plants and high-voltage direct current converter stations should be selected based on the Fire Protection Design Basis Document and on consideration of the following standards:

(1) NFPA 220
(2) ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, or UL 263, *Standard Test Methods for Fire Tests of Building Construction and Materials*
(3) NFPA 253
(4) NFPA 259
(5) ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or UL 723, *Test for Surface Burning Characteristics of Building Materials*

6.3.2 Construction materials used in the boiler, engine, or turbine-generator buildings or other buildings critical to power generation or conversion should meet the definition of *noncombustible* or *limited combustible*, except for the following:

(1) Roof coverings, which should be as outlined in 6.3.4
(2) Limited use of translucent reinforced plastic panels as allowed by the Fire Protection Design Basis Document

6.3.3 The use of material that does not meet the definition of *noncombustible* or *limited combustible*, such as translucent reinforced plastic panels, is permitted in limited applications if the Fire Protection Design Basis Document and/or fire risk evaluation demonstrate that the material is acceptable.

6.3.4 Roof covering should be Class A in accordance with ASTM E108, *Standard Test Methods for Fire Tests of Roof Coverings*, or UL 790, *Tests for Fire Resistance of Roof Covering Materials.* Metal roof deck construction, where used, should be "Class I" or "fire classified."

6.3.5 Interior Finish.

6.3.5.1 Cellular or foamed plastic materials (as defined in Annex A of NFPA *101*) should not be used as interior finish.

6.3.5.2 Interior finish in buildings critical to power generation or conversion should be Class A.

6.3.5.3 Interior finish in buildings not critical to power generation or conversion should be Class A or Class B.

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

6.4.1* Smoke and Heat Venting.

6.4.1.1 General.

6.4.1.1.1 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.

6.4.1.1.2 Smoke and heat vents should not be left open where they can sustain damage from high wind conditions.

6.4.1.1.3 Smoke and heat vents should be included in preventative maintenance or surveillance programs to ensure availability in emergency situations.

N **6.4.1.1.4*** Ventilation exhaust systems, particularly those for subsurface portions of underground facilities, should have fans able to operate continually to 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. Total fan capacity should be provided so that ventilation requirements can be met with the largest fan out of service. The specific weight and volume of the heated air during a fire and the climatic conditions should also be considered.

6.4.1.2 Heat Vents.

6.4.1.2.1 Heat vents should be provided for areas identified by the Fire Protection Design Basis Document. Where heat vents are provided, heat generated under fire conditions should be vented from its place of origin directly to the outdoors.

6.4.1.2.2 Heat vents in the boiler and turbine building are permitted to be provided through the use of automatic heat vents or windows at the roof eave line. Heat venting in areas of high combustible loading can reduce damage to structural components. *(See NFPA 204.)*

6.4.1.3 Smoke Vents.

6.4.1.3.1 Smoke venting should be provided for areas identified by the Fire Protection Design Basis Document. 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.

6.4.1.3.2* 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, NFPA 92, and NFPA 204.)* Smoke venting also is 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.

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

6.4.1.3.4 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 system.

6.4.1.3.5 Smoke removal system dampers, where installed, normally are 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 firefighting personnel prior to restoring mechanical ventilation to the fire area. Smoke removal system dampers are permitted to be operable from the control room if provisions are made to prevent premature operation, which can be accomplished using thermal interlocks or administrative controls.

6.4.1.3.6 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 Protection Design Basis Document.

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

6.4.2.1 For normal heating, ventilating, and air-conditioning systems, see NFPA 90A or NFPA 90B as appropriate.

6.4.2.2 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.

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

6.4.2.4 Fire dampers (doors) compatible with the rating of the barrier should be provided at the duct penetrations in accordance with NFPA 90A to the fire area unless the duct is protected throughout its length by a fire barrier equal to the rating required of fire barrier(s) penetrated *(see Section 6.1)*.

6.4.2.5 Smoke dampers, where installed, should be installed in accordance with NFPA 90A.

6.4.2.6 The fresh air supply intakes to all areas should either be located so as to minimize the possibility of drawing products of combustion into the plant, or be provided with automatic shutdown or closure on detection of smoke. Separation from exhaust air outlets, smoke vents from other areas, and outdoor fire hazards should all be considered. For unattended or hydroelectric generating stations, manual override should be located at the entry to the plant so that emergency responders can activate these controls upon arrival.

N **6.4.2.7** 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.

6.5 Containment and Drainage.

6.5.1* Provisions should be made in all fire areas of the plant for removal of 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.)* 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
(7) Porous ground surfaces such as stone or soil

Δ **6.5.1.1*** The provisions for drainage and any associated drainage facilities should be sized to accommodate all of the following:

(1) The spill of the largest single container of any flammable or combustible liquids in the area
(2) The maximum expected number of fire hose operating for a minimum of 10 minutes
(3) The maximum design discharge of fixed fire suppression systems operating for a minimum of 10 minutes

N **6.5.1.2** Independent of the above, the drainage systems should consider the maximum water introduced by the washdown systems. If this amount exceeds the drainage required for fire protection, it should govern the sizing of the drainage system. Additional precautions should be taken for belowgrade areas to prevent damage of equipment due to water buildup.

N **6.5.1.3** A means to direct leaking flammable fluid away from important equipment and structures should be provided. Sloping the ground to channel leaking fluid to safe areas and curbs to prevent flow toward equipment are some methods that can be used.

N **6.5.1.4** An emergency power supply should be provided for principal drainage pumps in areas where flooding would be dangerous.

6.5.2 The drainage system for continuous fuel oil-fired boilers should consist of curbs and gutters arranged to confine the area of potential fuel oil discharge. Consideration also should be given to providing the same measures for any boilers using oil for ignition. Walking surfaces in the vicinity of burners should be made impervious to oil leakage by the use of checkered steel plate, sheet metal drip pans, or other means. Curbs in passageways should have ramps or steps or be otherwise constructed to present no obstacle to foot traffic. Gutter outlet pipes and all other drains should be trapped to prevent the passage of flames and permit the flow of oil. A clearance between the boiler front and the walk structure is required for the differential movement where the heated boiler elongates. This clearance space in the vicinity of the burners should be flashed and counter-flashed with sheet metal or otherwise arranged to allow movement and to redirect dripping oil, which can impinge on the boiler face.

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

6.5.4 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.

6.5.5 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 6.5.1.1. If a layer of uniformly graded stone is provided in the bottom of the curbed area or pit as a means of minimizing ground fires, the following should be addressed:

(1) Sizing of the pit should allow for the volume of the stone, keeping the highest level of oil below the top of the stone.
(2) The design should address the possible accumulation of sediment or fines in the stone.
(3) Overflow of the containment pit and/or curbing should be considered in reviewing drainage pathways away from critical structures. Common containment pits for multiple transformers should be avoided.

6.5.5.1 Rock-Filled Pits. Where rock-filled pits are used, the rock should periodically be loosened and turned as necessary to prevent filling of void spaces by dirt, dust, or silt. The frequency is dependent on area of the country and location near manufacturing facilities that generate dust or fly ash.

6.5.5.2 Open Pits. Where an open pit is used, one of the following forms of protection should be provided:

(1) Automatic sprinkler or water spray protection should be provided for the pit area designed to a discharge density of 0.15 gal/min·ft^2 (6 mm/min) over the area of the pit.
(2) A 12 in. (30 cm) thick layer of rock located between steel grating should be provided at the top of the pit. The rock used should be 1.5 in. (3.8 cm) or larger washed and uniformly sized rock (size No. 2, ASTM D448, *Standard Classification for Sizes of Aggregate for Road and Bridge Construction*).

6.5.6 For facilities consisting of more than one generating unit that are not separated by a fire barrier *[see 6.1.1.3(15)]*, provisions such as a sloped floor, 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 in one unit will not expose an adjacent unit.

6.5.7 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).

6.6 Emergency Lighting.

6.6.1 Emergency lighting should be provided for means of egress. *(See NFPA 101.)*

6.6.2 Emergency lighting should be provided for critical plant operations areas. A normally unattended site emergency lighting system for critical operating areas that depends on batteries or fuel supplies should be manually operated from a switch at the entry to the plant. The emergency lighting can be permitted to consist either of fixed units or of portable lights.

6.7 Lightning Protection. Lightning protection should be provided for those structures having a risk index (R) of 4 or greater when evaluated in accordance with NFPA 780.

Chapter 7 General Fire Protection Systems and Equipment

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

7.2 Water Supply.

7.2.1* The water supply for the permanent fire protection installation should be based on providing a 2-hour supply for all of the following:

(1) Either of the following, whichever is greater:
  (a) The largest fixed fire suppression system demand
  (b) Any fixed fire suppression system demands that could reasonably be expected to operate simultaneously during a single event [e.g., turbine underfloor protection in conjunction with other fire protection system(s) in the turbine area, coal conveyor protection in conjunction with protection for related coal handling structures during a conveyor fire, adjacent transformers not adequately separated according to 6.1.4]
(2) The hose stream demand of not less than 500 gpm (1893 L/min)
(3) Incidental water usage for non–fire protection purposes

7.2.2* At least one reliable water supply should be provided. The Fire Protection Design Basis Document should identify the need for multiple supply sources. Factors to consider should include the following:

(1) Reliability of source
(2) Capacity of source
(3) Reliance on water-based fire protection systems
(4) Availability of alternate and backup sources
(5) Consequences of a loss in terms of property and generation

7.2.2.1* Potential sources to be considered include tanks, ponds, rivers, municipal supplies, and cooling tower basins.

7.2.3 Each water supply should be connected to the station supply main or yard main by separate connections arranged and valve controlled to minimize the possibility of multiple supplies being impaired simultaneously.

7.2.3.1 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 recommendations in 7.2.2.

7.2.4 Consideration of water quality can prevent long-term problems relating to fire protection water supply. For example, in some rivers and tributaries the existence of microorganisms limits the use of raw water for fire protection without treatment. Demineralized water and ash water should not be considered for use as a fire protection water source due to excessive corrosion and erosion characteristics.

7.2.5 Fire Pumps.

7.2.5.1 Where multiple fire pumps are required by the Fire Protection Design Basis Document, 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 7.2.1 with the largest pump out of service.

7.2.5.2 Fire pumps should be automatic starting with manual shutdown, except as allowed in NFPA 20. The manual shutdown should be at the pump controllers only.

7.2.6 Water Supply Tanks.

7.2.6.1 If tanks are of dual-purpose use, a standpipe or similar arrangement should be provided to dedicate the amount determined by 7.2.1 for fire protection use only. *(See NFPA 22.)*

7.2.6.2 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 normally is preferred for the refilling operation to be accomplished on an automatic basis.

7.3 Valve Supervision. All fire protection water supply and system control valves should be under a periodic inspection program *(see Chapter 5)* and should be supervised by one of the following methods:

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

7.4 Supply Mains, Yard Mains, Hydrants, and Building Standpipes.

7.4.1 Supply Mains, Yard Mains, and Hydrants.

7.4.1.1 Supply mains, yard mains, and outdoor fire hydrants should be installed on the plant site. *(See NFPA 24.)* Hydrant spacing in main plant areas should be a maximum of 300 ft (91.4 m). Hydrant spacing in remote areas such as long-term solid-fuel storage should be a maximum of 500 ft (152.4 m).

N **7.4.1.2** Consideration should be given to the placement of hydrants and monitors about the area to provide strategic coverage of all flammable or combustible liquids piping. Based on the completed Fire Protection Design Basis Document, an alternative could be the use of fire/water trucks if the site water supply so dictates.

7.4.1.3 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. Where common supply piping is provided for service water and fire protection water supply, it should be sized to accommodate both service water and fire protection demands.

7.4.1.4 The supply mains should be looped around the main power block and should be of sufficient size to supply the flow requirements determined by 7.2.1 to any point in the yard 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.

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

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

7.4.1.7 Interior fire protection loops are considered an extension of the yard main and should be provided with at least two valved connections to the yard main with appropriate sectional control valves on the interior loop.

7.4.1.8 It might be necessary for the fire department to draft from a body of water 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.

7.4.2 Standpipe and Hose Systems.

7.4.2.1 Standpipe and hose systems should be installed in buildings and structures where deemed necessary by the Fire Protection Design Basis. *(See NFPA 14.)* The standpipe and hose system is an extension of the yard fire main and hydrant system. The hose stations should be capable of delivering the hose stream demand for the various hazards in buildings.

7.4.2.2 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. Choice of Class I, Class II, or Class III systems should be determined by a Fire Protection Design Basis. *(See NFPA 14.)*

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

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

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

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

7.5 Portable Fire Extinguishers. For first aid fire protection, suitable fire extinguishers should be provided. *(See NFPA 10.)*

7.6 Fire Suppression Systems and Equipment — General Requirements.

Δ **7.6.1** Fire suppression systems and equipment should be provided in all areas of the plant as identified in subsequent chapters or as determined by the Fire Protection Design Basis Document. Fixed suppression systems should be listed and sized for the application and designed, installed, and commissioned in accordance with the manufacturer's recommendations and the following codes and standards unless specifically noted otherwise:

(1) NFPA 11
(2) NFPA 12
(3) NFPA 13
(4) NFPA 15
(5) NFPA 16
(6) NFPA 17
(7) NFPA 18A
(8) NFPA 20
(9) NFPA 24
(10) NFPA 25
(11) NFPA 214
(12) NFPA 750
(13) NFPA 2001
(14) NFPA 2010

N **7.6.2*** Fire suppression and fire-extinguishing systems should be sized to be capable of providing protection for as long as the hazards of hot metal surfaces above the autoignition temperature (AIT) and uncontrolled combustible liquid flow exist (consult manufacturer for cooldown times or obtain machine-specific data).

Δ **7.6.3** The selection of an extinguishing agent or a combination of extinguishing agents should be based on the following:

(1) The type of hazard
(2) The effect of agent discharge on equipment
(3) The health hazards and ability to remove the agent, the toxic gases, and the combustion products from these structures following system actuation
(4) Need for and ability to minimize agent leakage by sealing of electrical enclosures as well as room integrity and automatic closing of ventilation dampers and doors, as applicable, and automatic shutdown of fans
(5) Extinguishing agent discharge should be based on concentration while hazard is above the autoignition temperature
(6)* Potential for causing flooding or environmental damage

N **7.6.4** 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 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.

N **7.6.5 Automatic Sprinkler and Water Spray Systems.**

N **7.6.5.1** Automatic sprinkler and water spray systems, including systems with water additives, where provided, should follow the recommendations in Chapter 9 and the following criteria:

(1) If permitted by the turbine configuration, water spray nozzles provided to protect the combustion turbine power bearing housings behind the exhaust duct should be directed based on unit geometry to avoid possible water damage.
(2)* Depending on unit packaging arrangement, consideration should be given to closing the fuel valves automatically on water flow. This action should not be taken for ICE emergency power supply systems (e.g., hospital emergency power).
(3) Turbochargers on ICEs constitute a part of the hazard, and protection should be provided.

N **7.6.6* Total Flooding Gaseous Systems.** Where total flooding gaseous agent systems are used, the system should be listed and installed in accordance with NFPA 12, NFPA 12A, or NFPA 2001, and the manufacturer's installation procedures.

N **7.6.6.1** Where total flooding gaseous systems are used, the engine enclosure should be arranged for minimum leakage by automatic shutdown of fans and automatic closing of doors, ventilation dampers, and other openings. CT or ICE compartments are designed to be capable of nominally airtight closure. During operation there is, however, a need for substantial amounts of secondary cooling (compartment ventilation) air. This air can be moved through the compartments by fans or venturi action from the CT or ICE air. This air flow will not stop immediately upon shutdown, and, therefore, it should be considered in the extinguishing system design.

N **7.6.6.2** Maintenance of total flooding systems is particularly critical. The integrity of the enclosure to be flooded and the interlocks between the fire system and associated equipment, such as the ventilation system dampers, should be maintained. The enclosure's integrity should be verified whenever it has been disassembled or modified. This can be done by a door fan test or other quantified means of detecting leakage. The leakage test should be conducted at least every 5 years. Maintenance and testing of the fire protection system should be conducted as defined in the applicable suppression standard.

N **7.6.6.3** It should be noted that deep-seated fires, such as oil-soaked insulation, can be present and will require manual extinguishment after the gaseous system soak time.

N **7.6.6.4** Provisions should be made to safely remove the gas and potential toxic combustion by-products from the enclosure following gaseous system actuation.

N **7.6.7 Total Flooding Water Mist Systems.**

N **7.6.7.1** Where total flooding water mist systems are used, the system should be installed in accordance with NFPA 750 and should be listed for the application. The system should be installed in accordance with the manufacturer's installation procedures.

N **7.6.7.2** The enclosure should be arranged for minimum leakage by automatic shutdown of fans and automatic closing of the doors, ventilation dampers, and other openings. Where equipment is operating, there is a need for substantial amounts of secondary cooling (e.g., compartment ventilation) air. This air flow will not stop immediately upon shutdown, and, therefore, it should be considered in the extinguishing system design.

N **7.6.8 Hybrid Fire-Extinguishing Systems.**

N **7.6.8.1** Where hybrid fire-extinguishing systems are used, the system should be installed in accordance with the listed configuration and the manufacturer's design and installation procedures.

N **7.6.8.2** The enclosure should be arranged for minimum leakage by automatic shutdown of fans and automatic closing of doors, ventilation dampers, and other openings. Where equipment is operating, there is a need for substantial amounts of secondary cooling (e.g., compartment ventilation) air. This airflow will not stop immediately upon shutdown, and therefore, it should be considered in the extinguishing system design.

N **7.6.9 Localized Extinguishing Systems.**

N **7.6.9.1** Where units are not enclosed and a first level of protection is desired that will operate before sprinklers, or where sprinklers are not installed, a localized extinguishing system might be appropriate. Such a system should be of a listed local application type such as water mist, compressed air foam, carbon dioxide, or dry chemical.

N **7.6.9.2** Discharge rates and duration of discharge should be such that cooling and shutdown occur to prevent reignition of the fire. System operation should be arranged to close fuel valves.

N **7.6.9.3** The positioning of local application nozzles should be such that maintenance access to the turbine or engine is not obstructed.

N **7.6.10 High-Expansion Foam Systems.** Where provided, high-expansion foam systems should be installed in accordance with the requirements of NFPA 11.

N **7.6.11 Compressed Air Foam Systems.** Where provided, compressed air foam systems should be installed in accordance with the requirements of NFPA 11.

N **7.6.12 Fixed Aerosol Fire-Extinguishing Systems.** Where provided, fixed aerosol fire extinguishing systems should be installed in accordance with the requirements of NFPA 2010.

7.6.13 Fire Suppression System Safety Considerations.

7.6.13.1 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.

7.6.13.2 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, breakdown products of the extinguishing agent, and electric conductivity of water-based agents.

7.6.13.3 When working in areas (e.g., combustion turbine compartments) where actuation of the fire protection system could affect personnel safety, the fire extinguishing system should be locked out to prevent discharge of the system. A trouble indication should be provided when the system is locked out.

7.6.13.4 NFPA standards for the extinguishing systems used should be carefully studied and the personnel safety provisions followed. *(See NFPA 12.)*

7.6.13.4.1 Evacuation of a protected area is recommended before any special extinguishing system discharges.

7.6.13.4.2 Alarm systems that are audible above machinery background noise or that are visual or olfactory or a combination should be used where appropriate.

7.6.13.4.3 Personnel warning signs should be used as necessary.

7.6.13.4.4 Retroactive requirements for enhancing the safety of existing CO_2 systems are detailed in NFPA 12 paragraphs 4.3.2 (safety signs), 4.3.3.6 and 4.3.6.6.1 (lockout valves), and 4.5.6.1 (pneumatic time delays and pneumatic predischarge alarms).

7.7 Fire-Signaling Systems.

7.7.1 The type of protective signaling system for each installation and area should be determined by the Fire Protection Design Basis Document in consideration of hazards, arrangement, and fire suppression systems. Fire detection and automatic fixed fire suppression systems should be equipped with local audible and visual signals with annunciation in a constantly attended location, such as the main control room. Audible fire alarms should be distinctive from other plant system alarms. *(See NFPA 72.)*

7.7.2 Automatic fire detectors should be installed in accordance with *NFPA 72*.

7.7.3 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 or in other special cases (e.g., confined spaces, scroll/spiral cases, draft tubes) to alert personnel that a fire alarm system has been activated as identified by the Fire Protection Design Basis Document.
(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. Remote annunciation of the fire-signaling panel to one or more constantly attended locations is critical for emergency response.
(5) At unattended plants, the fire-signaling panel should be located at the entry.

N **7.7.4** Annunciation of fire-signaling systems to a constantly attended location is critical for emergency response. The location and design of fire-signaling systems, including emergency shutdown stations and their interfaces with facility control and information systems, should be considered.

N 7.7.5 Vapor or Gas Detection.

N 7.7.5.1 Vapor detection should be provided to allow early warning for equipment subject to leaks of flammable fluid or vapors so corrective action can be taken.

N 7.7.5.1.1 Vapor detection systems should alarm at a constantly attended location, such as the control room. The following should be considered:

(1) Alarm from one detector should be investigated immediately.
(2) Consideration should be given to automatic equipment shutdown in the event two detectors alarm simultaneously.

N 7.7.5.1.2 For unattended plants, vapor detection should provide for automatic shutdown and notification.

N 7.8 Commissioning and Maintenance.

N 7.8.1 Fire protection systems should be functionally tested to verify operation, integrity, and flow of the nozzles at the completion of commissioning activities and any time maintenance requires disassembly of the fire protection system.

N 7.8.2 Maintenance and testing of the fire protection system should be conducted as defined in the applicable standard.

Chapter 8 Fire Protection for the Construction Site

8.1 Introduction.

8.1.1 Although many of the activities on electric generating plant and HVDC converter station construction sites are similar to the construction of other large industrial plants, an above average level of fire protection is justified due to life safety consideration of the large number of on-site personnel, high value of materials, and length of the construction period. Consideration of fire protection should include safety to life and potential for delays in construction schedules and plant startup, as well as protection of property.

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. Chapter 8 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 the internal program as necessary using the measures outlined in this recommended 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 Protection Design Basis Document of the construction site and construction activities at any construction site. *(See Chapter 4.)*

8.2.4 Written procedures should be established for the new construction site, including major construction projects in existing plants. Such procedures should be in accordance with Sections 5.3 and 5.4, and 5.4.2, 5.4.4, and 5.4.5.

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.)*

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 guard service rounds are 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 are permitted to be omitted after the first round indicated in 8.2.5.1.

8.2.6 Construction schedules 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 9.

8.2.7 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.

8.2.8 Construction and installation of fire barriers and protective opening devices (i.e., fire doors, dampers) should be given priority in the construction schedule.

8.3 Site Clearing, Excavation, Tunneling, and Construction Equipment.

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. 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 and maintained in a designated area.

8.3.1.4 Each site utility vehicle should be equipped with at least a 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 should obtain all appropriate permits prior to the start of work. *(See Section 8.2.)*

8.3.1.7 Local conditions can 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. Inspections 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 1.2.)*

8.3.2.5 Construction Equipment. Construction equipment should meet the requirements of NFPA 120.

8.4 Construction Warehouses, Shops, and Offices.

8.4.1 All structures that are to be retained as part of the completed plant should be constructed of materials as indicated in Chapter 6 and should be in accordance with other recommendations 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 of their exposure to major plant buildings or other important structures. For guidance in separation and protection, see NFPA 80A and NFPA 1144.

8.4.3 Large central office facilities can be of substantial value and contain high-value computer equipment, irreplaceable construction records, or other valuable contents, the loss of which can result in significant construction delays. An analysis of fire potential should be performed. This analysis can indicate a need for automatic sprinkler systems or other protection, fire/smoke detection, subdividing the complex to limit values exposed by one fire, or a combination of the above.

8.4.4 Warehouses that contain high value equipment (as defined by the individual responsible for fire prevention and fire protection), or where the loss of or damage to contents would cause a delay in startup dates of the completed plant, should be arranged and protected as indicated in 8.4.4 through 8.4.10. 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.

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

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

8.4.4.3 Air-supported structures sometimes are used to provide temporary warehousing space. Although the fabric envelope can be a fire-retardant material, the combustibility of contents and the values 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 be used only for noncombustible storage. An additional factor to consider is that relatively minor fire damage to the fabric envelope can leave the contents exposed to the elements.

8.4.5 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.

8.4.6 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 conditions applies:

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

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

8.4.7.1 Mobile buildings should be installed and located according to the requirements of NFPA 501A. Insulating materials utilized in mobile buildings should be noncombustible.

8.4.7.2 Construction camp buildings should be designed and installed in accordance with NFPA *101*.

8.4.8 Fire alarms should be connected to a constantly attended central location. All premise fire alarm systems should be installed, tested, and maintained as outlined in *NFPA 72*. An alternative to remote alarms would be audible and visual alarms that would alert site/security personnel to abnormal conditions.

8.4.8.1 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 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 The handling, storage, and dispensing of flammable liquids and gases should meet the requirements of NFPA 30, NFPA 58, and NFPA 30A.

8.4.10 Vehicle repair facilities should meet the requirements of NFPA 30A.

8.4.11 Construction kitchens should be protected in accordance with NFPA 96.

8.5 Construction Site Lay-Down Areas.

8.5.1 Fire hydrant systems with an adequate water supply should be provided in lay-down areas where the need is determined by the individual responsible for fire prevention and fire protection.

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 hose, extinguishers, and hydrants.

8.6 Temporary Construction Materials.

8.6.1 Noncombustible or fire-retardant scaffolds, form work, decking, and partitions should be used both inside and outside of permanent buildings where a fire could cause substantial damage or delay construction schedules. Consideration should be given to providing sprinkler protection for combustible form work where a fire could cause substantial damage or construction delays.

8.6.1.1 The use of noncombustible or fire-retardant concrete form work is especially important for large structures (e.g., turbine-generator pedestal) where large quantities of forms are used.

8.6.1.2 The use of listed pressure-impregnated fire-retardant lumber or listed fire-retardant coatings generally would be 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., concrete forms), the fire retardant used should be suitable for this exposure. Fire-retardant coatings are not acceptable on walking surfaces or surfaces subject to mechanical damage.

8.6.2 Tarpaulins and plastic films should be of listed weather-resistant materials and meet the performance criteria of NFPA 701.

8.7 Underground Mains, Hydrants, and Water Supplies.

8.7.1 General.

8.7.1.1 Where practical, the permanent underground yard system, fire hydrants, and water supply (at least one water source), as indicated in Chapter 7, 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. If there is a possibility that the temporary system will be used for the life of the plant, then the temporary system should meet the requirements indicated in Chapter 7.

8.7.1.2 The necessary reliability of construction water supplies, including redundant pumps, arrangement of power supplies, and use of combination service water and construction fire protection water, should be determined by the individual responsible for fire prevention and fire protection.

8.7.2 Hydrants should be installed, as indicated in Chapter 7, in the vicinity of main plant buildings, important warehouses, office or storage trailer complexes, and important outside structures with combustible construction or combustible concrete form work (e.g., cooling towers). Where practical, the underground main should be arranged 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.

8.7.3* A fire protection water supply should be provided on the construction site and should be capable of furnishing the largest of the following for a minimum 2-hour duration:

(1) 750 gpm (2839 L/min)
(2) The in-service fixed water extinguishing system with the highest water demand and 500 gpm (1893 L/min) for hose streams

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

8.7.3.2 Fixed systems should be provided as soon as construction allows, and 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 will 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. When using construction water in permanent systems, adequate strainers should be provided to prevent clogging of the system by foreign objects and dirt.

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

8.8 Manual Fire-Fighting Equipment.

8.8.1* First aid fire-fighting equipment should be provided, in accordance with NFPA 600 and NFPA 241.

8.8.2 Portable fire extinguishers of suitable capacity should be provided in accordance with NFPA 10 as follows:

(1) Where flammable liquids are stored or handled
(2) Where combustible materials are stored
(3) Where temporary oil- or gas-fired equipment is used
(4) Where a tar or asphalt kettle is used
(5) Where welding, grinding, or open flames are in use

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

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

Δ Chapter 9 Fuels, Common Equipment, and Protection

9.1 General. The identification and selection of fire protection systems should be based on the Fire Protection Design Basis Document. This chapter identifies fire and explosion hazards in fossil fueled electric generating stations and specifies the recommended protection criteria unless the Fire Protection Design Basis Document indicates otherwise.

•

9.2 Flammable Gases.

Δ **9.2.1*** The storage and associated piping systems for gases should comply with NFPA 2, NFPA 54, NFPA 55, NFPA 56, NFPA 58, NFPA 59A, and ASME B31.1, *Power Piping*.

9.2.2 The plant's fuel gas shutoff valve should be located in a remote area and accessible under emergency conditions. The valve should be provided with both manual and automatic closing capabilities locally, and remote closing capability from the control room. The valve should be arranged to fail closed on the loss of power or pneumatic control.

9.2.3 Electrical equipment in areas with potentially hazardous atmospheres should be designed and installed in compliance with Articles 500 and 501 of *NFPA 70*, NFPA 497, and IEEE C2, *National Electrical Safety Code*.

N **9.2.4* Piping Underground Beneath Buildings.** Gas piping greater than 125 psi should not be located underneath buildings. Where gas piping greater than 125 psi must be installed underground beneath buildings, the piping should be either of the following:

(1) Encased in an approved conduit designed to withstand the imposed loads and installed in accordance with 9.2.4.1 or 9.2.4.2
(2) A piping/encasement system listed for installation beneath buildings

N **9.2.4.1 Conduit with One End Terminating Outdoors.** The conduit should extend into an accessible portion of the building and, at the point where the conduit terminates in the building, the space between the conduit and the gas piping should be sealed to prevent the possible entrance of any gas leakage. Where the end sealing is of a type that retains the full pressure of the pipe, the conduit should be designed for the same pressure as the pipe. The conduit should extend at least 4 in. (100 mm) outside the building, be vented outdoors above finished ground level, and be installed so as to prevent the entrance of water and insects.

N **9.2.4.2 Conduit with Both Ends Terminating Indoors.** Where the conduit originates and terminates within the same building, the conduit should originate and terminate in an accessible portion of the building and should not be sealed.

9.2.5* Inerting. Prior to introducing fuel gas to, or removing fuel gas from, the fuel gas piping, inerting should be performed and gas piping should also be inerted prior to maintenance, modifications, or repair.

9.2.6* Maintenance, Modification, and Repair. The hazards associated with flammable gases, including those hazards arising from toxic constituents in the gas and asphyxiants, should be considered when performing maintenance, modifications, or repairs.

9.2.6.1 When performing maintenance, modification, or repair of piping that contains a flammable gas that has toxic constituents, or when inerting fuel gas piping with asphyxiants, the area should be ventilated or considered a confined space as regulated by U.S. Department of Labor, OSHA 29 CFR 1910.146, "Permit Required Confined Space Standard."

•

9.3 Combustible Liquids.

9.3.1 Combustible liquid storage, pumping facilities, and associated piping should comply with NFPA 30, NFPA 31, NFPA 85, and ASME B31.1, *Power Piping*.

9.3.2 Internal tank heaters needed to maintain combustible liquid pumpability should be equipped with temperature-sensing devices that alarm in a constantly attended area prior to the overheating of the combustible liquid.

9.3.3 External tank heaters should be interlocked with a flow switch to shut off the heater if combustible liquid flow is interrupted.

9.3.4 Tank filling operations should be monitored to prevent overfilling.

9.3.5 While combustible liquid unloading operations are in progress, the unloading area should be manned by personnel properly trained in the operation of pumping equipment, valving, and fire safety.

9.3.6 Pump installations should not be located within tank dikes.

9.3.7 Electrical equipment in areas with potentially hazardous atmospheres should be designed and installed in compliance with NFPA 30, NFPA 497, Articles 500 and 501 of *NFPA 70*, and IEEE C2, *National Electrical Safety Code*.

Δ **9.3.8** To prevent hazardous accumulations of flammable vapors, ventilation for indoor pumping facilities for combustible liquids at or above their flash point should provide at least 1 cfm of exhaust air per ft^2 of floor area ($0.30\ m^3/min/m^2$), but not less than 150 ft^3/min ($0.071\ m^3/sec$). Ventilation should be accomplished by mechanical or natural exhaust ventilation arranged in such a manner to include all floor areas or pits where flammable vapors can collect. Exhaust ventilation discharge should be to a safe location outside the building.

9.3.9 Fire Protection.

9.3.9.1 Indoor combustible liquid pumping or heating facilities, or both, should be protected with automatic sprinklers, water spray, water mist system, hybrid fire-extinguishing systems, water-based systems with water additives, foam-water sprinklers, compressed air foam systems, or gaseous total flooding system installed in accordance with their listing. Local application dry chemical systems are permitted to be used in areas that normally do not have re-ignition sources, such as steam lines or hot boiler surfaces.

9.3.9.2 The provisions of foam systems for combustible liquid outdoor storage tank protection should be considered in the Fire Protection Design Basis Document. The Fire Protection Design Basis Document should regard exposure to other combustible liquid storage tanks and important structures, product value, and resupply capability, as well as the anticipated response and capabilities of the local fire brigade.

9.3.9.3 Outdoor combustible liquid handling and storage areas should be provided with hydrant protection in accordance with Section 7.4.

•

N 9.4 Flammable Liquids.

9.4.1 The storage and associated piping systems for flammable liquids should comply with NFPA 30, ASME B31.1, *Power Piping*, and ASME B31.3, *Process Piping*.

N **9.4.2** Tank filling operations should be monitored to prevent overfilling.

N **9.4.3** While flammable liquid unloading operations are in progress, the unloading area should be manned by personnel properly trained in the operation of pumping equipment, valving, and fire safety.

N **9.4.4** Pump installations should not be located within tank dikes.

N **9.4.5** Use of double mechanical seals on pumps to reduce potential sources of leaks should be considered.

N **9.4.6** Pressure relief should be provided for any section of the system containing a low-vapor-pressure flammable fluid that can be isolated between two valves.

N **9.4.7** Relief valves should discharge at a location that will limit fire exposure to critical equipment.

N **9.4.8** Electrical equipment in areas with potentially hazardous atmospheres should be designed and installed in compliance with NFPA 30, Articles 500 and 501 of *NFPA 70*, NFPA 497, and IEEE C2, *National Electrical Safety Code*.

N **9.4.9** Emergency isolation valve(s) in the piping arrangement to reduce size of possible flammable fluid release should be provided. The following should be considered:

(1) Actuators for remote-operated emergency isolation valves should be pneumatically or electrically powered. The preferred method would be to provide “fail safe valve(s)” that close on loss of instrument air or electrical power.
(2) If pneumatic power is required to close the valve(s), the air lines and fittings should be of stainless steel construction and electrically operated valves and associated cabling should be provided with fireproofing having a 15-minute rating.
(3) Remote actuation stations are ideally located in a constantly attended control room but, if locating them such is not possible or practical, they should be located at least 50 ft (15.2 m) away from anticipated leak points.

N **9.4.10** To prevent hazardous accumulations of flammable vapors, ventilation for indoor facilities for flammable liquids should provide at least 1 cfm of exhaust air per ft^2 of floor area ($0.30\ m^3/min/m^2$), but not less than 150 ft^3/min ($0.071\ m^3/sec$). Ventilation should be accomplished by mechanical or natural exhaust ventilation arranged in such a manner to include all floor areas or pits where flammable vapors can collect. Exhaust ventilation discharge should be to a safe location outside the building.

N 9.4.11 Fire Protection.

N **9.4.11.1** Protection of pumps, associated piping, and fittings using automatic water-spray systems should be considered if either of the following applies:

(1) They are located in an area exposing other equipment.
(2) They cannot be remotely isolated.

N **9.4.11.2** For the equipment and ground area where flammable fluids could flow and expose critical equipment, consideration should be given to protection by fixed water spray fire protection systems or monitor nozzles, which will help in fire fighting and exposure control. The following should be considered:

(1) Adjustable monitor nozzles should be used with flow rates of a minimum of 500 gpm (1893 L/min) that will overlap at least one other spray pattern from another monitor nozzle.
(2) Consider the prevailing winds when locating monitor nozzles. It should be assumed that due to seasonal changes in wind direction there will be times when some monitor nozzles will be downwind and not accessible due to the vapor cloud or heat generated from a fire.
(3) Fixed water spray systems should be designed in accordance with NFPA 15.

N **9.4.11.3** Supports for process structures to prevent collapse of these units in the event of a pool fire should be protected. One or more of the following should be considered:

(1) Steel protected with a 2-hour rated coating (listed in accordance with UL 1709, *Standard for Rapid Rise Fire Tests of Protection Materials for Structural Steel*) acceptable for outdoor use
(2) Water spray on the columns in accordance with NFPA 15

N 9.5 Solid Fuels.

N 9.5.1 Fuel Receiving and Storage Areas.

N **9.5.1.1** The fuel receiving and storage areas, whether indoors or outdoors, should be designed in accordance with the following:

(1) NFPA 1 *(see Section 10.15 and Chapter 33)*
(2) NFPA 80A
(3) NFPA 652
(4) NFPA 1144

9.5.1.2* Fuel storage piles can be subject to fires caused by spontaneous heating.

Δ **9.5.1.3** For fuels subject to spontaneous ignition, there are measures that should be taken to lessen the likelihood of storage pile fires. These measures are dependent on the type of fuel. Among the more important are the following:

(1) Short duration, active, or “live” storage piles should be worked to prevent dead pockets, a potential source of spontaneous heating.
(2) Storage piles should not be located above sources of heat, such as steam lines, or sources of air, such as manholes.
(3) Fuel placed in long-term storage should be piled in layers, appropriately spread, and compacted prior to the addition of subsequent layers to reduce air movement and to minimize water infiltration into the pile.
(4) Different types of fuel that are not chemically compatible should not be stored in long-term storage piles.

(5) Access to storage piles should be provided for fire-fighting operations and for pulling out hot pockets. Where storage barns or domes are used to enclose storage piles, the design of the structure should include dedicated space to allow small vehicles to access all areas of the fuel pile. The design should prevent stored fuel from encroaching on the dedicated space.

N **9.5.1.4** Specific hot-load unloading areas should be designated and separated from other areas (preferably outdoors) so that loads containing smoldering or other suspect constituents can be segregated. Such areas should be properly monitored and equipped to promptly extinguish incipient fires before recombining.

N **9.5.1.5*** Where overhead cranes are used to load inside feed hoppers from inside the storage pits, the following should be considered:

(1) Locating the pulpit so that operator safety is not compromised
(2) The ability to have a clear and unobstructed view of all storage and charging areas

Δ **9.5.1.6** Where fuel storage barns or domes are used to enclose storage piles, the fire detection, fire protection, fire alarm, dust collection, dust suppression, explosion venting, and housekeeping recommendations contained herein for fuel handling areas and structures should be considered. The plant-specific features provided for the fuel barn/dome should be as determined during the Fire Protection Design Process. *(See Chapter 4.)*

Δ **9.5.2 Bins, Bunkers, and Silos.**

9.5.2.1* Storage structures should be of noncombustible construction and designed to minimize corners, horizontal surfaces, or pockets that cause fuel to remain trapped and present a potential for spontaneous combustion. Bins, bunkers, and silos should be designed with access ports to allow manual fire-fighting activities such as the use of a piercing rod hand line for delivery of fire-fighting agents with water. Access ports should be provided around the bunker or silo to allow direct attack on the fire using the piercing rod. Silos greater than 50 ft (15.2 m) in height should be provided with access ports at multiple elevations.

9.5.2.2* During planned outages, fuel bins, bunkers, or silos should be emptied to the extent practical.

9.5.2.3* The period of shutdown requiring emptying of the bins depends on the spontaneous heating characteristics of the fuel. Spontaneous heating can be slowed by minimizing air flow through the bins by such means as inerting, filling the bins with high-expansion foam, or sealing the surface of the fuel with an appropriate binder/sealer designed for this purpose.

9.5.2.4* During idle periods, flammable gas levels, CO levels, and temperatures should be monitored.

9.5.2.5 Once spontaneous heating develops to the fire stage, it becomes very difficult to extinguish the fire short of emptying the bin, bunker, or silo. Therefore, provisions for emptying the bin, bunker, or silo should be provided. This unloading process might take the form of conveyors discharging to a stacking out pile. Another method would be to use flanged openings for removing the fuel if adequate planning and necessary equipment have been provided. Removing hot or burning fuel can lead to a dust explosion if a dust cloud develops. Proper preplanning should be developed to prevent a dust cloud, such as covering the fuel with a blanket of high-expansion foam, water mist, water spray with fire-fighting additives, dust suppression, or dust collection.

Δ **9.5.2.6* Bin, Bunker, or Silo Fires.**

N **9.5.2.6.1** If fire occurs, manual actions for suppression and extinguishment should be initiated. The following fire-fighting strategies have been successfully employed (depending on the specific circumstances and type of fuel used):

(1) Use of fire-fighting additives such as Class A foams, penetrants, or wetting agents and water additives
(2) Injection of inert gas
(3) Emptying the bin, bunker, or silo to a safe location (inside or outside the powerhouse) and removing the debris

Δ **9.5.2.6.2** The following fire-fighting strategies should be taken into consideration:

(1) Water has been used successfully to control fires. However, the possibility of an explosion exists under certain circumstances if the water reaches the fuel in a hot spot. Therefore, water is not a recommended fire-fighting strategy for these types of fire events. The amount of water delivered in a stream can create structural support problems. However, use of fire-fighting additives with water can be highly effective for fuel fires, especially sub-bituminous coal fires and, potentially, fires involving other type of fuels. This use of fire-fighting additives typically results in significantly less water being delivered due to the enhanced fire suppression properties of the agent and subsequent shorter delivery period.
(2) Steam-smothering has also been used to control fires on marine vessels. All openings need to be sealed prior to the introduction of steam, which is rarely possible at electric generating plants due to the relatively porous nature of the equipment. The use of steam introduces high temperature and moisture that could increase the possibility of spontaneous combustion; therefore, this strategy is not recommended.
(3) Locating hot spots and extinguishing them before the fuel leaves the bin, bunker, or silo is an accepted practice. The fuel hot spots are detected and extinguished. If additional hot spots are detected as the fuel drops down, fuel flow should be stopped and the hot spots extinguished. If the hot spots are exposed during the lowering of the fuel, potential for dust explosions is increased.

Δ **9.5.2.7** Care should be taken where working in enclosed areas near fuel bins, bunkers, or silos in confined areas because spontaneous heating can generate gases that are both toxic and explosive. Fixed or portable carbon monoxide monitoring should be provided to detect spontaneous heating and hazardous conditions.

9.5.2.8 Dusttight barriers should be provided between the boiler house and the areas of the fuel handling system above the bin, bunker, or silo.

Δ **9.5.2.9** It might not be practical to install explosion vents on a bin, bunker, or silo. Typical designs do not have sufficient area above the fuel level for properly designed explosion vents. Vents would present an exposure hazard to any personnel in adjacent areas *(see NFPA 652)*. If explosion vents are considered, they should be designed in accordance with NFPA 68.

9.5.3* Dust Suppression and Control.

Δ **9.5.3.1*** Dust generated due to fuel handling can constitute a fire and explosion hazard that should be identified and, if needed, controlled by one or more of the following methods:

(1) A dust collection system
(2) A dust suppression system
(3) An open-air construction
(4) Passive design features of the conveyor chutes and dust hoods to minimize generation of dust and spillage of fuel at the transfer points
(5) Routine cleaning of fuel handling areas

N **9.5.3.2** The frequency of cleaning activities is plant specific based on refueling activities, type of fuel, space construction features, and so on. Dust accumulation on overhead beams and joists contributes significantly to the secondary dust cloud. Other surfaces, such as the tops of ducts and large equipment, can also contribute significantly to the dust cloud potential. Due consideration should be given to dust that adheres to walls, because it is easily dislodged. Attention and consideration should also be given to other projections such as light fixtures, which can provide surfaces for dust accumulation.

9.5.3.3* Where dust collection or suppression systems are installed to prevent hazardous dust concentration, appropriate electrical and mechanical interlocks should be provided to prevent the operation of fuel handling systems prior to the starting and sustained operation of the dust control equipment.

9.5.3.4 Dust suppression systems usually consist of spray systems using water, surfactants, binders, or a combination of these to reduce the dust generation of fuel handling operations. The sprays are normally applied at or near those locations where the fuel is transferred from one conveyor to another and at stack-out points.

Δ **9.5.3.5** Dust collectors should be located outside. For dust collection systems provided for handling combustible dusts, see NFPA 652. Other recommendations for reducing the probability of explosion and fire from combustible dust are as follows:

(1) Fans for dust collectors should be installed downstream of the collectors so that they handle only clean air.
(2) For dust collectors vented to the outside, see NFPA 68. Explosion suppression systems are permitted to be provided for dust collection systems that cannot be safely vented to the outside. *(See NFPA 69.)*
(3) Dust collection hoppers should be emptied prior to shutting down dust removal systems to reduce the likelihood of collector fires originating from spontaneous heating in the dust hopper.
(4) Dust collectors should not discharge into inactive fuel storage bins, bunkers, or silos.
(5) High-level detection with an annunciator alarm should be provided for the dust hoppers.
(6) Monitoring and trending for carbon monoxide should be provided for dust collectors to detect spontaneous combustion.
(7) Dust collected in a dust collection system, baghouse, or cyclone should be discharged downstream of the collection system, back to the conveying system, or back to the residue or waste stream.

9.5.3.6 Cleaning methods such as vigorous sweeping of dust or blowing down with steam or compressed air should not be used because these methods can produce an explosive atmosphere. Preferred cleaning methods would use appropriate portable or fixed pipe vacuum cleaners of a type approved for dust hazardous locations or low-velocity water spray nozzles and hose.

Δ **9.5.4 Conveyors.**

9.5.4.1 Conveyor belts should be of material designed to resist ignition. U.S. Mine Safety and Health Administration and Canadian Bureau of Mines Standards for fire-retardant conveyor belt materials should be used as a guide. However, "fire-retardant" belt materials will burn and therefore might require additional fire protection.

9.5.4.2 Each conveyor system should be arranged to automatically shut off driving power in the event of belt slowdown of greater than 20 percent or misalignment of belts. In addition, a complete belt interlock shutdown system should be provided so that, if any conveyor stops, the power to all conveyor systems feeding that belt would be shut down automatically.

9.5.4.3 Hydraulic systems should use only listed fire-retardant hydraulic fluids. Where unlisted hydraulic fluids must be used, consideration should be given to protection by a fire suppression system.

Δ **9.5.4.4** Foreign materials pose a threat to shredders, crushers, pulverizers, and feeders by interrupting the flow of fuel or by causing sparks capable of igniting dust/air mixtures. Methods of removing tramp metals and other foreign materials include magnetic separators, pneumatic separators, and screens. Means for removing such foreign material should be provided as early in the fuel handling process as possible.

9.5.4.5 Prior to extended idle periods, the conveyor system should be cleared of fuel if subject to spontaneous combustion.

N **9.5.4.6** Conveyors handling noncombustible materials are typically components of FGD systems and fluidized bed boiler systems. Materials typically include limestone and gypsum. These conveyors should meet the recommendations of 9.5.4.1 through 9.5.4.3, 9.5.5.1, 9.5.6.1 through 9.5.6.4, and 9.5.6.6.

9.5.5 Fuel Conveying and Handling Structures.

9.5.5.1 Fuel conveying and handling structures and supports should be of noncombustible construction.

9.5.5.2 The accumulation of combustible dust in enclosed buildings can be reduced by designing structural members such that their shape or method of installation minimizes the surface area where dust can settle. Consideration should be given to installing structural members exterior to the enclosure. Access should be provided to facilitate cleaning of all areas.

9.5.5.3 Explosion venting for enclosed structures should comply with NFPA 68.

9.5.5.4 Provisions should be made for de-energizing both lighting and electrical power circuits without requiring personnel to enter dust-producing sections of the plant during emergencies.

9.5.5.5 Areas of the fuel handling system requiring heat should use approved heaters suitable for hazardous areas. The heating equipment should be kept free of dusts and should be designed to limit surface temperature below the autoignition temperature of the material and dust.

Δ **9.5.5.6** Electrical equipment within fuel handling areas with potential for combustible dust generation should be approved for use in hazardous locations Class II, Division 1 or Division 2. *(See Article 502 of NFPA 70 and NFPA 499.)* Electrical equipment subject to accumulations of methane gas or carbon monoxide should also be listed and installed, as appropriate, for use in hazardous locations Class I, Division 2, Group D. *(See Articles 500 and 501 of NFPA 70, NFPA 497, and Section 127 of IEEE C2, National Electrical Safety Code.)*

9.5.5.7 Static electricity hazards should be minimized by the permanent bonding and grounding of all conductive equipment, including duct work, pulleys, take-up reels, motor drives, dust collection equipment, and vacuum cleaning equipment. *(See NFPA 77.)*

9.5.6 Fire Protection.

9.5.6.1 Automatic sprinkler or water spray fixed systems should be provided for fuel handling structures that are critical to power generation and subject to accumulations of fuel or fuel dust. Automatic sprinkler systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) density over a 2500 ft^2 (232 m^2) area. If water spray fixed systems are used to protect structures, the same densities should be used.

9.5.6.2* Automatic sprinkler or water spray fixed systems should be provided for coal conveyors that are critical to continuous power generation. System coverage should include transfer points (tail dust hoods and head chutes). Sprinklers should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) density over 2000 ft^2 (186 m^2) of enclosed area or the most remote 100 linear ft (30 m) of conveyor structure up to 2000 ft^2 (186 m^2). For water spray design criteria, see NFPA 15. Water spray systems should be considered for enclosed conveyors that are inclined because of the greater potential for rapid fire spread.

Δ **9.5.6.2.1** If a sprinkler system is used to protect the conveyor, particular care should be exercised in locating closed sprinkler heads so that they will be in the path of the heat produced by the fire and still be in a position to provide good coverage of all belt surfaces along the conveyor. *(See NFPA 15.)* The conveyor width and other sprinkler obstructions should be considered in protection of the return belt and other floor level equipment. *(See NFPA 13 for positioning of sprinklers to avoid obstructions.)* Where sprinklers cannot provide adequate coverage due to obstructions, a water spray system using above- and below-belt nozzles should be considered instead of a sprinkler system.

9.5.6.2.2 Conveyors that are below grade or enclosed are extremely hazardous to maintenance or fire-fighting personnel in the event of a fire. Automatic water spray or sprinkler systems should be provided for these conveyors even though they might not be critical to plant operations.

9.5.6.2.3 Actuation of water spray or sprinkler systems should shut down the conveyor belt involved and all conveyor belts feeding the involved belt.

9.5.6.2.4 The sprinkler or water system control valve should be located in an area or enclosure separate from the hazard.

9.5.6.2.5 Dust collectors and fans should automatically shut down along with other related equipment upon detection of fire.

9.5.6.2.6 Draft barriers installed at the end and midpoints of enclosed conveyors and between separate sprinkler and water spray systems where the length of the conveyor requires multiple systems should be considered in the Fire Protection Design Basis Document. Draft barriers will improve the response time of installed automatic sprinkler or detection systems and minimize the chimney effects in the event of fire.

9.5.6.3 Stacker-reclaimer and barge/ship unloader conveyors present unique fire protection concerns. Protection of the equipment and safety of the personnel is made more difficult due to the movement-in-place capabilities of the equipment and its mobility and movement along a fixed rail system. Provision of hydrants in the area might not be sufficient protection primarily due to the extreme delay in response in the event of fire emergency and the difficulty in reaching all areas involved in a fire with hand-held hose equipment.

9.5.6.4 Consideration should be given to the installation of an automatic water spray or sprinkler system over the conveyor belt and striker plate areas within the stacker-reclaimer. The water supply could be from a 3000 gal to 5000 gal (11,355 L to 18,925 L) capacity pressure tank located on-board. A fire department pumper connection should be provided so connection can be made to the fire hydrants in the area during down or repair periods to provide a more adequate water supply. Consideration should be given to protecting enclosed electrical control cabinets by a pre-engineered fixed automatic gaseous-type suppression system activated by a fixed temperature detection system.

9.5.6.5* Bag-type dust collectors, baghouses, and cyclone-type separators that are located inside buildings or structures should be protected with automatic sprinkler or water spray systems inside of the collectors.

9.5.6.5.1 Sprinklers for bag-type dust collectors, baghouses, and cyclone-type separators should be designed for ordinary-hazard systems. Sprinkler and water spray systems should be designed for a density of 0.20 gpm/ft^2 (8.1 mm/min) over the projected plan area of the dust collector. Use of fire-fighting additives should be considered for dust collectors used for materials that are subject to spontaneous combustion (e.g., sub-bituminous coal dust collectors).

9.5.6.5.2 Protection inside dust collectors should include the clean air plenum and the bag section. If the hopper is shielded from water discharge, sprinklers also should be provided in the hopper section.

Δ **9.5.6.5.3** Consideration should be given to providing automatic sprinkler systems for bag-type dust collectors, baghouses, and cyclone-type separators located outdoors with the following characteristics:

(1) Are in continuous operation
(2) Process large amounts of combustible dust
(3)* Have limited access for manual fire-fighting
(4) Are critical to plant operation

•

9.5.6.6 Consideration should be given to providing detection-only systems on noncritical conveyors to facilitate a manual response.

•

9.6 Hydraulic Control System.

9.6.1 The hydraulic control system should use a listed fire-resistant fluid.

N 9.6.1.1* 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.

9.6.1.2 If a listed fire-resistant fluid is not used, hydraulic equipment, reservoirs, coolers, and associated oil-filled equipment should be provided with automatic sprinkler, water spray protection, water additive, gaseous extinguishing, or hybrid extinguishing systems, or compressed air foam systems. For water sprinkler and spray systems, protection should be over oil-containing equipment and for 20 ft (6.1 m) beyond in all directions. For water sprinkler and spray systems, a density of 0.25 gpm/ft^2 (10.2 mm/min) should be provided. Compressed air foam systems should be designed and installed in accordance with NFPA 11 and its listing for the specific hazards and protection objectives specified in the listing.

9.6.1.3 Fire extinguishing systems, where required for hydraulic control equipment, should include reservoirs and stop, intercept, and reheat valves.

•

N **9.6.1.4** Wherever possible, oil piping should be welded and flanged to minimize the possibility of an oil leak due to severe vibration.

9.7 Electrical Equipment.

N **9.7.1** Electrical equipment in areas with potentially hazardous atmospheres should be designed and installed in compliance with Article 500 of *NFPA 70* and IEEE C2, *National Electrical Safety Code*. Alternatively, if switchgear buildings, motor control centers, and control rooms could be exposed to a flammable vapor cloud, they should be pressurized using air from a safe location to prevent vapor entry. Pressure should be monitored, with alarm on loss of pressure to a constantly attended location.

9.7.2 Control, Distributed Control System (DCS), and Telecommunication Rooms.

9.7.2.1* Control, DCS, or telecommunications buildings, rooms, and enclosures should meet the applicable requirements of NFPA 75.

9.7.3 A smoke detection system should be installed throughout buildings, rooms, or enclosures, 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 are permitted to be omitted from this area.

Δ **9.7.4** Automatic sprinkler protection, hybrid fire-extinguishing, or automatic water mist fire protection systems for DCS or telecommunications buildings, rooms, or enclosures should be considered in the Fire Protection Design Basis Document. In addition, total flooding gaseous fire-extinguishing systems should be considered for areas above and below 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 and cabinet protection could be considered in lieu of total flooding systems.

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

•

9.7.6 Cable Spreading Room and Cable Tunnels.

9.7.6.1 Cable spreading rooms, cable tunnels, and other rooms with significant concentrations of combustible cable jacketing or oil-filled cable should be protected with automatic sprinkler, water spray, water mist, hybrid fire-extinguishing, or automatic gaseous extinguishing 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 m) of cable tunnels up to 2500 ft^2 (232 m^2).

9.7.6.2 This coverage is for area protection. Individual cable tray tier coverage could be required based on the fire risk evaluation. If water-type systems cannot be used, foam or gaseous systems should be provided. Cable spreading rooms and cable tunnels should be provided with an early warning fire detection system.

N **9.7.6.3** Portable high-expansion foam generators can be used to supplement fixed fire protection systems. *(See NFPA 1901.)*

9.7.7 Grouped Electrical Cables or Areas with High Cable Concentrations.

9.7.7.1 Consideration should be given to the use of fire-retardant cable insulation such as those passing the flame propagation test in IEEE 1202, *Standard for Flame-Propagation Testing of Wire and Cable*. Grouped electrical cables should be routed away from exposure hazards or protected as required by the Fire Protection Design Basis Document. In particular, care should be taken to avoid routing cable trays near sources of ignition or flammable and combustible liquids. Where such routing is unavoidable, cable trays should be designed and arranged to prevent the spread of fire.

N **9.7.7.2** In areas where there is the potential for flammable or combustible liquid pool fires, electrical power, control, and instrument cabling required for safe shutdown of critical equipment during emergency plant shutdown should be routed outside the fire area. If routed through the fire area, it should be protected with fireproofing material in accordance with ASTM E1725, *Standard Test Methods for Fire Tests of Fire-Resistive Barrier Systems for Electrical System Components*, or API 2218, *Fireproofing Practices in Petroleum and Petrochemical Processing Plants.*

9.7.7.3 Cable trays subject to accumulation of combustible dust or the spread of an oil spill should be covered by sheet metal. Where potential oil leakage is a problem, solid-bottom trays should be avoided. Changes in elevation can prevent oil travel along cables in a tray.

9.7.7.4 The Fire Protection Design Basis Document should consider the provision of fire suppression systems or fire-retardant cable coatings, or both, for protection of cable concentrations from exposure fires. Care should be exercised in the selection of fire-retardant coatings to ensure that derating of the cable is considered. Consideration also should be given to the ability to add or remove cables and to make repairs to cables protected with fire-retardant coatings.

•

N **9.7.7.5** In plants where the potential for hazardous atmospheres are present, arc-resistant switchgear *(see IEEE C37.20.7, Guide for Testing Metal-Enclosed Switchgear Rated up to 38 kV for Internal Arcing Faults)* should be used.

Δ **9.7.8* 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, *Recom-*

mended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications.

9.7.9* Transformers. Oil-filled main, station service, and startup transformers not meeting the separation or fire barrier recommendations in 6.1.4 or as determined by the Fire Protection Design Basis Document should be protected with automatic water spray, systems with water additives, or foam-water spray systems.

9.7.10* Substations and Switchyards. Substations and switchyards located at the generating facility and utilizing combustible oil–filled equipment should be protected by the yard fire hydrant system where practical. Spatial separation of transformers and other equipment containing over 500 gal (1893 L) of oil should be in accordance with 6.1.4. Consideration should be given to water spray protection of transformers critical to the transmission of the generated power.

•

9.8 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 Section 9.9.)*

9.9 Oil Storage Areas. Clean or dirty oil storage areas should be protected based on the Fire Protection Design Basis Document. This area generally represents the largest concentrated oil storage in the plant. The designer should consider, as a minimum, the installation of fixed automatic fire protection systems and the separation, ventilation, and drainage requirements in Chapter 6.

•

9.10 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.

9.11 Fire Pumps. Rooms housing diesel-driven fire pumps should be protected in accordance with NFPA 20.

9.12 Cooling Towers. Cooling towers of combustible construction that are essential to continued plant operations should be protected by automatic sprinkler or water spray systems in accordance with NFPA 214.

9.13 Auxiliary Boilers.

Δ **9.13.1** Auxiliary boiler-furnaces, their fuel burning systems, combustion products removal systems, and related control equipment should be designed, installed, and operated in accordance with 12.3.1.

9.13.2 Oil-fueled auxiliary boilers installed within main plant structures should be protected by automatic sprinkler, water spray, or foam-water sprinkler systems, or compressed air foam systems. A sprinkler system is preferred throughout the auxiliary boiler room on a 0.25 gpm/ft^2 (10.2 mm/min) density. As a minimum, sprinkler, water spray protection, or systems with water additives should be provided as outlined in 12.3.1.1. Compressed air foam systems should be designed and installed in accordance with NFPA 11 and their listing for the specific hazards and protection objectives specified in the listing.

9.14 Vehicle Repair Facilities. Vehicle repair facilities should meet the requirements of NFPA 30A.

N **9.15 Air Compressors.** Automatic sprinkler protection designed for a density of 0.25 gm/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 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 7.7.2)*.

Δ Chapter 10 Turbines, Generators, and Internal Combustion Engines

10.1 General.

10.1.1 Chapter 10 identifies fire and explosion hazards of combustion turbine (CT), steam turbine (ST), and internal combustion engine (ICE) electric generating units and specifies recommended protection criteria.

10.1.2 It should be recognized that some CT generating facilities consist of manufactured modules wherein construction consists of siting these modules, providing fuel supply, essential services, and interconnections to the electric system, while other facilities consist of buildings specifically designed and built or modified for the CT generator and its auxiliaries. Therefore, some recommendations might be more suitable for one type of plant than another.

N **10.1.3** ST generating facilities consist of turbine assemblies and auxiliary equipment wherein construction consists of incorporating these items into a boiler or HRSG steam system. Although the typical installation is in an open area within a dedicated turbine building, outdoor installations with weather enclosures for the turbine are known and acoustic enclosures might be incorporated for indoor units. As for the CT installations, some recommendations might be more suitable for one type of plant than another.

10.1.4* Modern ICE generating equipment is typically provided as a complete package requiring only a fuel source and electrical connections to the system to be powered. The installations should be either fixed/permanent or installed as a portable/temporary power source. The recommendations of this chapter should be applied to fixed nonresidential installations only.

10.1.5 Compressors and regulating stations installed on-site should be protected in accordance with the recommendations of Chapter 10.

•

Δ **10.2 Application of Chapters 4 Through 9.** The recommendations contained in Chapters 4 through 9 can apply to turbine electric generating units. The Fire Protection Design Basis Document will determine which recommendations apply to any specific CT, ST, and ICE electric generating units. This determination is done by evaluating the specific hazards that exist in the facility and evaluating the level of acceptable risk for the facility. For large CT or ST units, or combined cycle plants, it is expected that most of the recommendations will apply, but for individually packaged CT and ICE units, many of the recommendations will not apply since the hazards described might not exist (e.g., small units might not have a cable spreading room or a warehouse).

•

Δ 10.3 Turbine and Internal Combustion Engine Generators.

10.3.1 General.

10.3.1.1 The installation and operation of CT and ICE generators should be in accordance with this chapter and NFPA 37.

10.3.1.2 Site-specific design considerations or manufacturer's typical design will govern what equipment has enclosures or how many separate enclosures will be provided for the CTs, STs, or ICEs. The CT generator is frequently supplied as a complete power plant package with equipment mounted on skids or pads and provided with metal enclosures forming an all-weather housing. In addition to being weathertight, the enclosures are designed to provide thermal and acoustical insulation. ST generators are typically supplied as components that are incorporated into the power plant design and installed in an open room or separate building. Metal acoustic enclosures are available as options for some ST generators. Smaller ICE plants might involve enclosures for equipment, but more commonly engine generators are installed in a row in an open room or hall.

10.3.1.3* The fire and explosion hazards associated with CT, ST, and ICE electric generator units are as follows:

(1) Flammable and combustible fuels
(2) Hydraulic and lubricating oils
(3) Electrical and control equipment
(4) Filter media
(5) Combustible enclosure insulation
(6) Internal explosions in CTs
(7) Crankcase explosions in ICEs

10.3.1.4 Prevention of External Fires.

10.3.1.4.1* Piping systems supplying flammable and combustible liquids and gases should be designed to minimize oil and fuel piping failures as follows:

(1) If rigid metal piping is used, it should be designed with freedom to deflect with the unit, in any direction. This recommendation also should apply to hydraulic lines that are connected to accessory gearboxes or actuators mounted directly on the unit. Properly designed metallic hose is an alternative for fuel, hydraulic, and lube oil lines in high vibration areas, between rigid pipe supply lines and manifolds in and at the points of entry at the engine interface.
(2) Rigid piping connected directly to the unit should be supported such that failures will not occur due to the natural frequency of the piping coinciding with the rotational speed of the machine. Care should be taken in the design of pipe supports to avoid vibrations induced by other equipment that can excite its natural frequency.
(3) Welded pipe joints should be used where practical. Threaded couplings and flange bolts in fuel and oil piping should be assembled using a torque wrench and torqued to the manufacturer's requirements. Couplings should have a positive locking device to prevent unscrewing.
(4) Instrumentation tubing, piping, and gauges should be protected from accidental mechanical damage. Liquid level indicators should be listed and protected from impact.
(5) Where practical, lubricating oil lines should use guarded pipe construction with the pressure feed line located inside the return line or in a separate shield pipe drained to the oil reservoir and sized to handle the flow from all oil pumps operating at the same time. If this is not practical, noncombustible coverings (e.g., piping sleeves and/or tubing and flange guards) should be used to reduce the possibility of oil atomization and contact with hot surfaces with subsequent spray fires.
(6) If practical, fluid piping should be clear of, shielded from, or routed below steam piping, hot metal parts, electrical equipment, or other sources of ignition to preclude leaked fluid dripping on the equipment.
(7) Insulation with impervious lagging should be provided for steam piping or hot metal parts under or near oil piping or turbine bearing points.

N **10.3.1.4.2*** All areas beneath the turbine-generator operating floor that are subject to oil flow, oil spray, or oil accumulation should be protected by an automatic sprinkler or foam-water sprinkler system. This coverage normally includes all areas beneath the operating floor in the turbine building. The sprinkler system beneath the turbine-generator should take into consideration obstructions from structural members and piping and should be designed to a density of 0.30 gpm/ft^2 (12.2 mm/min) over a minimum application of 5000 ft^2 (464 m^2).

N **10.3.1.4.3** Lubricating oil lines above the turbine operating floor should be protected with an automatic sprinkler system covering those areas subject to oil accumulation, including the area within the turbine lagging (skirt). The automatic sprinkler system should be designed to a density of 0.30 gpm/ft^2 (12.2 mm/min).

N **10.3.1.4.4*** Protection for pedestal-mounted turbine generators with no operating floor can be provided by recommendations in 10.3.1.4 and by containing and drainage of oil spills and providing local automatic protection systems for the containment areas. In this type of layout, spray fires from lube oil and hydrogen seal oil conditioning equipment and from control oil systems using mineral oil, if released, could expose building steel or critical generating equipment. Additional protection such as enclosing the hazard, installing a noncombustible barrier between the hazard and critical equipment, or use of a water spray system over the hazard should be considered.

N **10.3.1.4.5*** Foam-water sprinkler systems installed in place of automatic sprinklers should be designed in accordance with NFPA 16, including the design densities specified in Chapter 9.

N **10.3.1.4.6** Electrical equipment in the area covered by a water or foam-water system should be of the enclosed type or otherwise protected to minimize water damage in the event of system operation.

10.3.1.4.7* In many units the lubricating oil is used for both lubrication and hydraulic control. For combined systems, a listed fire-resistant fluid should be considered. If separate systems are used, the hydraulic control system should use a listed fire-resistive hydraulic fluid, and a listed fire-resistant fluid should be considered for the lubricating system.

•

10.3.1.4.8 For recommendations regarding containment and drainage of liquids, see Section 6.5.

10.3.1.4.9 In order to prevent conditions that could cause a fire while the unit is operating, control packages should include the parameter monitoring and shutdown capabilities described in Chapter 9 of NFPA 37.

N **10.3.1.5 Lubricating Oil Systems.**

N **10.3.1.5.1*** Use of a listed fire-resistant (i.e., less hazardous or less flammable) lubricating oil should be considered. The use of a listed fire-resistant fluid as a turbine-generator lubricating oil could eliminate the need for fire protection beneath the operating floor, at lubricating oil lines, lubricating oil reservoirs, and turbine-generator bearings to mitigate the hazard posed solely by pool and three-dimensional fires involving lubrication oil. Protection against pool and three-dimensional fires in accordance with 10.3.1.4.4 should be installed if the hydrogen seal oil system does not use listed fire-resistant fluids. Generator bearings for seal oil systems not using listed fire-resistant fluids should be protected in accordance with 10.3.3.1. Stakeholders should be involved in the decision-making process before eliminating fire protection for the turbine lubrication oil hazard.

N **10.3.1.5.2** Lubricating oil storage, pumping facilities, and associated piping should comply with NFPA 30.

N **10.3.1.5.3** Lubricating oil reservoirs should be provided with a vapor extractor vented to a safe outside location.

N **10.3.1.5.4** Curbing or drainage or both should be provided for the lubricating oil reservoir in accordance with Section 6.5.

N **10.3.1.5.5** All oil piping serving the turbine, ICE, or generator should be designed and installed to minimize the possibility of an oil fire in the event of severe turbine vibration. *(See NFPA 30.)*

N **10.3.1.5.6** Remote operation from the control room of the condenser vacuum break valve and shutdown of the lubricating oil pumps should be provided. Breaking the condenser vacuum markedly reduces the rundown time for the machine and thus limits oil discharge in the event of a leak. See the discussion in 5.4.6.1 on fire emergency planning involving turbine lubricating oil fires.

N **10.3.1.5.7** Cable for operation of lube oil pumps should be protected from fire exposure. Protection can consist of separation of cable for ac and dc oil pumps or 1-hour fire resistive coating (derating of cable should be considered).

N **10.3.1.5.8 Fire Protection.**

N **10.3.1.5.8.1*** Lubricating oil reservoirs and handling equipment should be protected in accordance with 10.3.1.4.2. If the lubricating oil equipment is in a separate room enclosure, protection can be provided by a total flooding gaseous extinguishing system or a hybrid fire extinguishing system.

10.3.1.6 Inlet Air System.

Δ **10.3.1.6.1*** Air filters and evaporative cooling media should be constructed from less flammable materials whenever practical. UL 900, *Standard for Safety Test Performance of Air Filters,* can be used as guidance.

10.3.1.6.2 Manual fire-fighting equipment should be available to personnel performing maintenance on air filters.

10.3.1.6.3 Access doors or hatches should be provided for manual fire fighting on large air filter structures.

10.3.1.7 Starting Equipment for CTs. Where ICEs or torque converters are used, fire protection should be provided based on consideration of the factors in 10.3.2.2.1.

•

N **10.3.2 Combustion Turbines.**

N **10.3.2.1** Combustible gas detector(s) should be considered for the CT enclosures.

Δ **10.3.2.2 Fire Protection.**

Δ **10.3.2.2.1** Determination of the need for fire suppression for combustion turbines should be based on consideration of the value of the unit, consequences of loss of the unit, and vulnerability of adjacent structures and equipment to damage. *(See Chapter 7 for general fire protection methods guidance.)*

N **10.3.2.2.1.1** Fire system operation should be arranged to close the fuel valves.

•

Δ **10.3.2.3 Prevention of Internal Explosions in Combustion Turbines.**

10.3.2.3.1* Combustion turbines should have a proof-of-flame detection system in the combustion section to detect flameout during operation or ignition failure during startup. In the case of flameout, the fuel should be rapidly shut off. If ignition is not achieved within a normal startup time, then the control system should abort the startup and close the fuel valves.

10.3.2.3.2 Two safety shutoff valves in series on the main fuel line should be used to minimize the likelihood of fuel leaking into the engine. On gas systems an automatic vent to the outside atmosphere should be provided between the two valves.

Δ **10.3.3 Steam Turbines.** Steam turbines and their associated hazards should be designed and protected in accordance with an appropriate method selected from Section 9.6 and considering the guidance provided in 10.3.1.4.2 through 10.3.1.4.8.

N **10.3.3.1* Bearings.**

N **10.3.3.1.1*** Turbine bearings should be protected with an automatic closed-head sprinkler system utilizing directional nozzles or water spray or water mist systems. Automatic actuation is more reliable than manual action. Water spray and sprinkler systems for turbine-generator bearings should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over the protected area of all bearings.

N **10.3.3.1.2** Where enclosures are provided, compressed air foam systems and hybrid fire-extinguishing systems can be considered.

N **10.3.3.1.3*** Accidental water discharge on bearing points and hot turbine parts should be considered. If necessary, these areas can be permitted to be protected by shields and encasing insulation with metal covers.

N **10.3.4 Internal Combustion Engines.**

N **10.3.4.1** Combustible gas detector(s) should be considered for the ICE enclosures.

N **10.3.4.2 Fire Protection.**

N **10.3.4.2.1** Determination of the need for fire suppression for the internal combustion engine should be based on consideration of the value of the unit, consequences of loss of the unit, and vulnerability of adjacent structures and equipment to damage. *(See Chapter 7 for general fire protection methods guidance.)*

10.3.4.3 Fire system operation should be arranged to close the fuel valves except for ICE emergency power supply systems (e.g., hospital emergency power).

• **10.3.4.4** In the event of a problem with older ICEs, shutdown might be difficult. Several different methods, operating independently, should be provided. These methods can include centrifugally tripped (overspeed condition) spring-operated fuel rack closure, governor fuel rack closure, electropneumatic fuel rack closure, or air inlet guillotine–type air shutoff.

10.3.5 Generators.

N **10.3.5.1* Hydrogen Cooled Generators.**

N **10.3.5.1.1** Bulk hydrogen systems supplying one or more generators should have automatic valves located at the supply and operable either by "dead man" type controls at the generator fill point(s) or operable from the control room. This would minimize the potential for a major discharge of hydrogen in the event of a leak from piping inside the plant. Alternatively, vented guard piping can be used in the building to protect runs of hydrogen piping.

N **10.3.5.1.2** Routing of hydrogen piping should avoid hazardous areas and areas containing critical equipment.

N **10.3.5.1.3** Hydrogen cylinders and generator hydrogen fill and purge manifold should be located remote from the turbine generator.

N **10.3.5.1.4** For electrical equipment in the vicinity of the hydrogen handling equipment, see Article 500 of *NFPA 70* and Section 127 of IEEE C2, *National Electrical Safety Code.*

N **10.3.5.2 Hydrogen Seal Oil System.**

N **10.3.5.2.1** Redundant hydrogen seal oil pumps with separate power supplies should be provided for adequate reliability of seal oil supply.

N **10.3.5.2.2** Where feasible, electrical circuits to redundant pumps should be run in buried conduit or provided with fire-retardant coating if exposed in the area of the turbine generator to minimize possibility of loss of both pumps as a result of a turbine generator fire.

N **10.3.5.2.3** Hydrogen seal oil units should be protected in accordance with an appropriate method selected from Section 7.6 and considering the guidance provided in 10.3.1.4.2 through 10.3.1.4.6.

N **10.3.5.3** Curbing or drainage or both should be provided for the hydrogen seal oil unit in accordance with Section 6.5.

N **10.3.5.4** A flanged spool piece or equivalent arrangement should be provided to facilitate the separation of hydrogen supply where the generator is opened for maintenance.

N **10.3.5.5** For electrical equipment in the vicinity of the hydrogen handling equipment, including detraining equipment, seal oil pumps, valves, and so forth, see Article 500 of *NFPA 70* and Section 127 of IEEE C2, *National Electrical Safety Code.*

N **10.3.5.6** Control room alarms should be provided to indicate abnormal gas pressure, temperature, and percentage of hydrogen in the generator.

N **10.3.5.7** Hydrogen lines should not be piped into the control room.

N **10.3.5.8** The generator hydrogen dump valve and hydrogen detraining equipment should be arranged to vent directly to a safe outside location. The dump valve should be remotely operable from the control room or an area accessible during a machine fire.

10.3.5.9 Fire protection should be provided in accordance with an appropriate method selected from Section 7.6 and considering the guidance provided in 10.3.3.1 for turbine bearings and 10.3.1.4.2 through 10.3.1.4.5 for oil piping or any area where oil can flow, accumulate, or spray.

N **10.3.5.9.1 Exciter.** The area inside a directly connected exciter housing should be protected with a total flooding automatic carbon dioxide system.

10.3.5.10* Air-cooled generators should be tightly sealed against the ingress of moisture in the event of discharge (accidental or otherwise) of a water spray system. Sealing should be positive, such as by a gasket or grouting, all around the generator housing.

•

N **10.3.6 Emergency Generators.**

N **10.3.6.1** The installation and operation of emergency generators should be in accordance with NFPA 37.

N **10.3.6.2 Fire Protection.**

N **10.3.6.2.1** Emergency generators located within main plant structures should be protected in accordance with NFPA 37.

N **10.3.6.2.2** Where gaseous suppression systems are used on combustion engines that 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.

10.4 Combined Cycle Units.

Δ **10.4.1 Heat Recovery Steam Generators.** Heat recovery steam generators using supplemental firing should be designed and protected in accordance with 12.3.1. *(See NFPA 85 for additional requirements.)*

N Chapter 11 Alternative Fuels

N **11.1* General.** Chapter 11 identifies fire and explosion hazards of alternative-fuel-fired electric generating plants and specifies recommended protection criteria common to all such plants regardless of the fuel.

N **11.1.1** The major fire and explosion hazards associated with mass burn units' power boilers are as follows:

(1) Sourcing, receipt, handling, and storage of large quantities of alternative fuels
(2) Unsuitable waste entering the facility, such as certain hydrocarbons, flammable liquids, metal dusts, acetylene, explosives, and so on
(3) Hydraulic and lubricating oils associated with the processing equipment
(4) Improperly maintained electrical equipment
(5) Large amounts of fuel accumulating in unsuitable areas as a result of spillage or handling
(6) Inadequate dust control

N **11.1.2*** Hose stations designed in accordance with NFPA 14 should be located throughout fuel materials storage areas (e.g., tipping building), charging floors, firing floors, hydraulic areas, and residue buildings. Due to the high frequency of use, the following points should be considered:

(1) Location and physical protection so as to avoid potential damage due to traffic patterns
(2) Size and number to be determined for unique plant geometry (e.g., push walls)
(3) Ease of use, maintenance, and storage, such as through the use of continuous-flow, noncollapsible hose reels
(4) Protection from freezing in unheated areas

N **11.2 Application of Chapters 4 Through 10.** The recommendations contained in Chapters 4 through 10 can apply to alternative-fuel facilities. The Fire Protection Design Basis Document should determine which recommendations apply to any specific alternative fuel facility. This determination is done by evaluating the specific hazards that exist in the facility and evaluating the level of acceptable risk for the facility. For most alternative-fuel facilities, it is expected that most of the recommendations will apply, although there could be particular recommendations will not apply because the hazards described might not exist.

N **11.3 Design and Equipment Arrangement.**

N **11.3.1** Fire areas should be separated from each other by approved means. In addition to the applicable recommendations in 6.1.1.2 and 6.1.1.3, it is recommended that, as a minimum, fire area boundaries be provided to separate initial fuel receiving, processing, and storage areas.

N **11.3.2** The refuse pit is normally enclosed on three sides, up to the charging level, by reinforced concrete walls. The thickness of the walls vary with facility design, but should provide a minimum of 2-hour fire separation.

N **11.3.3** Exposed steel columns located at the front of the refuse pit should be protected against structural damage caused by heat (i.e., fire). This protection could include concrete encasement, water spray, or other suitable alternatives and should extend from the base of the column to the roof of the refuse pit enclosure. Care should be taken to protect fireproofing from mechanical damage.

N **11.3.4** Overhead cranes are often used to mix and stock the refuse within the pit. Undesirable waste (e.g., large items such as refrigerators) is often separated from the waste stock by the crane operator for offsite disposal or for shredding/processing *(see 11.5.5)* prior to replacement into the waste stock. All other items are loaded directly into boiler feed hoppers without processing. In addition, the acceptable method for extinguishment of small fires is also direct loading of the smoldering refuse into the hoppers by the crane operator. The following considerations should be given with respect to the crane operator's pulpit:

(1) Locating the pulpit such that operator safety is not compromised
(2) Ability to have a clear and unobstructed view of all storage and charging areas
(3) Providing self-contained breathing apparatus (SCBA) for operator egress
(4) Providing direct communication with the boiler control room and floor manager
(5) Ability to activate fire protection equipment

N **11.3.5** Mass burn facilities utilizing hammermills and flail mills should refer to the criteria in 11.5.2.

N **11.4 Risk Considerations for MSW.**

N **11.4.1 General.** This section identifies fire and explosion hazards that are unique to the use of MSW as a boiler fuel by means of a process that includes the hauling of MSW directly to a tipping floor or storage pit and burning without any special processing. MSW is municipal solid waste consisting of commonly occurring residential and light commercial waste.

N **11.4.2 Fire Protection.**

N **11.4.2.1* General.** The tipping/receiving building should be provided with automatic sprinkler protection throughout. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 130 ft^2 (12 m^2). High-temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used. If the tipping/receiving floor is to be used as the charging storage area, additional protection should be provided in accordance with 11.4.2.2.2.

N **11.4.2.2* The MSW Storage Pit, Charging Floor, and Grapple Laydown Areas.**

N **11.4.2.2.1** Automatic sprinkler protection should be provided throughout the refuse enclosure to protect the entire roof area against structural damage. Systems should be designed for a minimum of 0.20 gpm/ft^2 (8.1 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of pit/floor area with the protection area per sprinkler not to exceed 100 ft^2 (9.3 m^2). High-temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used. Exposed steel column protection, where provided, should be designed in accordance with NFPA 15 and can be connected to the overhead sprinkler system. Due to the distance between the bottom of the refuse pit and the sprinkler system, manual hoses and monitor nozzles should be considered as the primary means of fighting a MSW storage pit fire.

N **11.4.2.2.2** In addition to sprinkler protection, the storage pit should be provided with monitor nozzle protection designed to furnish a minimum of 250 gpm (946 L/min) at 100 psi (689 kPa) at the tip. Monitors should be located so as to allow for coverage of all pit areas with at least two streams operating simultaneously. Due to frequency of use and potential for operator fire exposure, oscillating monitor nozzles with manual override should be provided.

N **11.4.2.3 Harsh Environments.** Particular care should be taken in the selection of fire detection devices in consideration of harsh and dusty environments and high air flows.

N **11.4.2.4 Explosion Suppression.** MSW facilities utilizing hammermills and flail mills for processing of oversize bulky waste should follow the recommendations of 11.5.3.

N **11.5 Risk Considerations for RDF.**

N **11.5.1** This section identifies fire and explosion hazards that are unique to the processing of MSW into RDF. RDF is a boiler fuel manufactured by means of a process that includes storing, shredding, classifying, and conveying the waste to a fuel storage area. It is then conveyed to the boiler through a metering device.

N **11.5.2** There is a potential fire and explosion hazard with the use of hammermills and flail mills and associated dust collection equipment. During the size-reduction process, flammable or explosive materials in the waste stream can be ignited.

N **11.5.2.1 Shredder Location.**

N **11.5.2.1.1** The primary shredder should be located within an enclosure of damage-limiting construction. It is preferable that the enclosure be detached from the main building. Other alternatives include the following:

(1) Outside of, but sharing a common wall with, the main building
(2) Inside of the main building, along an outside wall

N **11.5.2.1.2** In view of the difficulties in preventing and controlling all types of shredder explosions, it is important to isolate the shredder and surrounding enclosure from vulnerable equipment and occupied areas in the plant. Consideration should be given to the protection of operating personnel or visitors from the potential blast zone.

N **11.5.2.2** Secondary shredders do not exhibit as significant a fire and explosion potential as primary shredders. Where specific designs do not eliminate the potential for explosions in the secondary shredder, the recommendations in 11.5.3 should be referenced.

N **11.5.2.3*** Shredders, shredder enclosures, and openings into the enclosure should be designed so that, by a combination of venting and wall strength, they will resist a postulated worst-credible-case explosion. Consideration should be given to a substantial increase in explosive pressure as a result of venting of shredders into a combustible vapor–air mixture within the enclosure. It is recommended that designers have specialized experience in the analysis of such hazards, including specifying and constructing of explosion venting and shredder enclosures.

N **11.5.2.4** Platforms at intermediate elevations should be of open grating to reduce obstructions to the effective vent area.

N **11.5.2.5** Electrical equipment located inside the shredder enclosure should be rated for use in both hazardous vapor and dust atmospheres in accordance with Articles 500 and 501 of *NFPA 70*.

N **11.5.2.6** Service panels or controls for the shredder should be located so as not to expose operating personnel to the blast zone.

N **11.5.2.7** Explosion venting should be sized using properties based on hydrogen as described in NFPA 68. Where ducts are used to vent explosions to the outside, consideration should also be given to increased pressure caused by the length of the vent duct. If the vent area available is inadequate for sufficient explosion venting because of the height of the vent stack or other factors, an explosion suppression system in the shredder should be used to augment the venting arrangement. *(See 11.5.5.)*

N **11.5.2.8** Where access door assemblies are provided for primary shredder enclosure, they should be kept secured to prevent unauthorized access when the equipment is operating. The access door assemblies should have the same pressure rating as the enclosure.

N **11.5.3 Prevention of Fires and Explosions in RDF Units.**

N **11.5.3.1** The process should be designed to minimize the production of dust. Dust collected in a dust collection system, baghouse, or cyclone should be discharged downstream of the collection system, back to the conveying system, or back to the residue or waste stream. *(For additional guidance, see 9.5.3.)*

N **11.5.3.2*** Radiation imaging equipment (e.g., x-ray) should be considered as a means to detect tanks or containers that could contain flammable materials. The detection equipment should be arranged to monitor waste on the conveyor before it enters the shredder. An image of what is seen in the waste is transmitted to an operator. If a tank-shaped object is observed, the conveyor should be stopped and the tank removed.

N **11.5.3.3** A combustible gas detection system should be considered as a supplemental explosion protection measure. Anticipated flammable vapors can include a wide variety of flammable materials and the selected gas detection device should take this into consideration.

N **11.5.3.3.1** The location of sensors or sampling lines should be based on site-specific conditions, including air flow rates through the shredder and associated components located upstream and downstream of the shredder.

N **11.5.3.3.2** The combustible gas detection system should be arranged with alarm annunciation at 25 percent of the calibrated lower explosive limit (LEL) and interlocks at 50 percent of the LEL. Interlocks that should be considered include area evacuation; shutdown of shredder, associated conveyors, and dust collection systems; and operation of fire or explosion suppression systems.

N **11.5.4 Fire Protection.**

N **11.5.4.1*** The actuation of a fire suppression system should cause equipment it protects to shut down. With the shutdown of the equipment, the upstream feed conveyors should also shut down to stop feeding combustible material to the fire, while downstream conveyors should be stopped to prevent the spread of the fire. A manual override should be provided.

N **11.5.4.2** Classifiers/trommels, such as rotating screens, should be provided with water spray protection to prevent fire from propagating downstream through the screen. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) of the entire screen area with nozzles no more than 10 ft (3.0 m) on center. Consideration should be given to avoiding physical damage from mobile equipment operation in the area and from the material being processed.

N **11.5.4.3*** The tipping/receiving building should be provided with automatic sprinkler protection throughout. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area, with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2). High-temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used.

N **11.5.4.4*** The processing building should be provided with automatic sprinkler protection throughout. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area, with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2).

N **11.5.4.5** Where an RDF plant has a tipping floor and pit, it should be protected with monitor nozzle coverage that aligns with the recommendations of 11.4.2.2.2.

N **11.5.4.6** The RDF storage building should be provided with automatic sprinkler protection throughout. Systems should be designed for a minimum of 0.35 gpm/ft^2 (14.3 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area, with the protection area per sprinkler not to exceed 100 ft^2 (9.3 m^2). High-temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used. Storage heights in excess of 20 ft (6.1 m) will require higher design densities.

N **11.5.4.7** The RDF boiler feed system area, including bins, hoppers, chutes, conveyors, and so forth, should be considered for automatic sprinkler protection. Where provided, the systems should be designed for a minimum of 0.20 gpm/ft^2 (8.1 mm/min) over the most remote 2000 ft^2 (186 m^2) (increase by 30 percent for dry pipe systems) of floor area, with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2). Internal, as well as external, protection also should be considered depending upon specific equipment design, ceiling heights, and accessibility for manual fire-fighting.

N **11.5.4.8** Shredder enclosures should be provided with automatic sprinkler or water spray protection. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area, with the protection area per sprinkler not to exceed 100 ft^2 (9.3 m^2). Water spray protection should also be provided within the shredder housings at intake and discharge chutes and within vent shafts.

N **11.5.4.9** The environment should be considered in selecting detection devices. Heat detection is most reliable under conditions encountered in process areas. Smoke detection should not be used in process areas. If flame detectors are used, an air sweep of the lens should be provided.

N **11.5.5 Explosion Suppression.**

N **11.5.5.1** Explosion suppression systems should be considered for protection of shredders. If such systems are selected, they should be designed and installed by qualified individuals using listed components. *(See NFPA 69 and ASTM E1248, Standard Practice for Shredder Explosion Protection.)*

N **11.5.5.2** Explosion suppression system detectors and agent distribution should cover the entire shredder volume and all contiguous areas, including inlet and discharge conveyors, reject chutes, and dust collection systems.

N **11.5.5.3*** The explosion suppression system equipment and associated mountings should be inspected periodically. Extinguisher and detector ports should be cleaned frequently to ensure successful operation.

N **11.5.5.4** Pressure sensors should be located in areas of the shredder where they will not be plugged. If there is a delay in operation of the suppression system, there could be an increase in pressure above what would be expected in an unsuppressed explosion.

N **11.6 Risk Considerations for Biomass Fuels.**

N **11.6.1** This section identifies fire and explosion hazards that are unique to the processing of forest and agricultural by-products (e.g., wood chips, rice hulls, sugar cane) into boiler fuel manufactured by means of a process that can include, but is not limited to, storing, shredding, classifying, and conveying the biomass to a fuel storage area and conveying it from the storage area to feed the boiler through a metering device. In general, biomass fuels are such that fires of low to moderate intensity would be expected. There can be cases, however, where fuel type and processing will present a greater fire hazard and so require a higher level of protection.

N **11.6.2** Where process or handling equipment involves biomass materials with particle size less than 80 mesh and with moisture content less than 30 percent by volume, a potential explosion hazard exists. *(See NFPA 68, NFPA 69, and NFPA 664.)*

N **11.6.3** Biomass units utilizing equipment capable of producing explosive concentrations of gases or dusts as described in 11.6.2 should be provided with explosion venting or explosion suppression systems. *(For further guidance, see NFPA 68, NFPA 69, and NFPA 664.)*

N **11.6.4*** Biomass storage buildings should be provided with automatic sprinklers throughout. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.2 mm/min) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area, with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2).

N **11.7 Risk Considerations for Tire Derived Fuels.**

N **11.7.1 General.**

N **11.7.1.1*** This section identifies fire and explosion hazards that are unique to the processing of rubber tires as a primary or secondary boiler fuel by means of a process that can include, but is not limited to, storing, shredding, and conveying the rubber tires to a fuel storage area (and conveying it from the storage area to fuel the boiler).

N **11.7.1.2** There are several inherent fire hazards associated with scrap tires, whether outside or inside a building. Once tires are ignited, the fire develops rapidly, and it is difficult to extinguish. The tires will generate a large amount of black smoke. In addition, as the tires burn they generate oil that can spread and increase the size of the fire.

N **11.7.1.3** For tire plant processes that generate dust explosion potential, refer to NFPA 68, NFPA 69, and NFPA 652.

N **11.7.2 Fire Protection.**

N **11.7.2.1** For the water supply and fire protection requirements of outdoor storage of scrap rubber tires, see Chapter 33 of NFPA 1.

N **11.7.2.2** The scrap rubber tire pit should be provided with water additive or foam-water spray protection throughout. The system(s) should be designed for a minimum of 0.24 gpm/ft^2 (9.8 mm/min) over the entire pit area, with the protection area per nozzle not to exceed 100 ft^2 (9.3 m^2). Due to the extreme hazard, clearance between the top of storage and foam water spray systems should be minimized.

N **11.7.2.3** In addition to the water additive or foam water spray protection, the storage pit should be provided with monitor nozzle protection designed to furnish a minimum of 250 gpm (946 L/min) at 100 psi (689 kPa) at the tip. Monitors should be located so as to allow for coverage of all pit areas with at least two streams operating simultaneously. Due to the potential for operator fire exposure, oscillating monitor nozzles with manual override should be provided.

N **11.7.2.4** For protection and storage of scrap rubber tires indoors, Section 34.8 of NFPA 1 should be referenced.

N **11.7.2.5** The boiler's tire feed system, including bins, hoppers, and chutes, should be considered for automatic water additive or foam-water protection. Where provided, the system should be designed for a minimum of 0.30 gpm/ft^2 (12.2 mm/min) over the most remote 2500 ft^2 (232 m^2).

N **11.7.2.6** All water spray systems should be capable of remote actuation from the control room or other constantly attended areas. Additionally, local actuation stations should be placed adjacent to the fire areas along lines of egress and in consideration of operator safety and protection from damage due to equipment.

N **11.7.2.7** Scrap rubber tire units utilizing equipment capable of producing explosive concentrations of gases or dusts should be provided with explosion venting or explosion suppression systems. *(For further guidance, see NFPA 68 and NFPA 69.)*

N **11.8 Other Alternative Fuels and Processes.** Other alternative fuels (e.g., culm, peat, gob) are used as boiler fuels. Also, other technologies exist for the utilization and processing of alternative fuels as boiler fuels. Designers should understand the unique characteristics of any particular fuel or technology to properly apply the appropriate portions of this and other applicable documents.

Δ Chapter 12 Power Boilers

Δ **12.1* General.** This chapter identifies fire and explosion hazards associated with electric generating plants utilizing power boilers and specifies recommended protection criteria regardless of the fuel used.

Δ **12.1.1** The major fire and explosion hazards associated with power boilers are as follows:

(1) Sourcing, receipt, handling, and storage of large quantities of fuels
(2) Unsuitable waste entering the facility, such as certain hydrocarbons, flammable liquids, metal dusts, acetylene, explosives, and so on
(3) Hydraulic and lubricating oils associated with the processing equipment
(4) Improperly maintained electrical equipment
(5) Large amounts of fuel accumulating in unsuitable areas as a result of spillage or handling
(6) Inadequate dust control

•

12.1.2* Automatic sprinkler protection should be provided in plastic ducts over 12 in. (300 mm) in diameter whether ducts are located inside or outside the tipping building. Sprinklers should be spaced not more than 12 ft (3.7 m) apart in horizontal ducts and no more than 24 ft (7.32 m) apart in vertical ducts. Water supply should be adequate for a flow rate of 20 gpm (1.26 L/sec) per head.

12.1.3 Automatic sprinklers should be corrosion resistant to withstand corrosion from products of combustion from combustion engine–driven front end loaders and from trash trucks.

12.1.4* Fuel handling structures and conveyors should be protected in accordance with 9.5.6.

•

Δ **12.2 Application of Chapters 4 Through 11.** The recommendations contained in Chapters 4 through 11 can apply to electric generating stations utilizing power boilers. The Fire Protection Design Basis Document will determine which recommendations apply. This is done by evaluating the specific hazards that exist in the facility and determining the level of acceptable risk for the facility. It is expected that most of the recommendations will apply to all units, except as follows:

(1) Where size and specific design eliminate certain hazards (e.g., H_2 seal oil units, cable spreading rooms, or warehouses)
(2) Where the Fire Protection Design Basis Document indicates a single source of water (e.g., a single tank) is considered adequate and reliable

•

N **12.3 Design and Equipment Arrangement.**

N **12.3.1 Steam Generator.** For boiler-furnaces, see NFPA 85.

N **12.3.1.1 Fire Protection.**

N **12.3.1.1.1** Power boiler-furnaces with multiple oil-fired burners or that use oil for ignition should be protected with automatic sprinkler, water spray, water additive, foam, or foam-water sprinkler systems, or compressed air foam systems covering the burner front oil hazard.

N **12.3.1.1.2** Power boiler front fire protection systems should be designed to cover the fuel oil burners and igniters and adjacent fuel oil piping and cable a 20 ft (6.1 m) distance from the burner and igniter, including structural members and walkways at these levels. Additional coverage should include areas where oil can collect. Sprinkler, water spray and water additive systems should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over the protected area. Compressed air foam systems should be designed and installed in accordance with NFPA 11 and their listing for the specific hazards and protection objectives specified in the listing.

12.3.2 Boiler Fuel Feed Equipment.

12.3.2.1 The boiler fuel feed equipment, such as a metering bin, should be of noncombustible material and designed to minimize pockets or corners that would cause combustible material to build up. Video monitoring should be considered for locations not readily visible to plant staff. *(See NFPA 85.)*

12.3.2.2* Access hatches should be provided to allow operating personnel to break up accumulations of combustible material or pluggages. In addition, the hatches should be placed so that the stream from a fire hose can be directed onto a fire that can occur inside the equipment.

•

N **12.3.2.3 Pulverizers.**

N **12.3.2.3.1** For pulverized fuel systems, see NFPA 85.

N **12.3.2.3.2** Carbon monoxide gas detection systems should be considered for pulverizers as an early warning for conditions leading to fires and explosions.

N **12.3.2.3.3** Pulverizer explosion mitigation methods to consider include inerting and temperature control.

N **12.3.2.3.4** Personnel warning systems should be considered during pulverizer startup, shutdown, and trip.

N **12.3.3 Boiler Feed Pumps.**

N **12.3.3.1** Coverage of steam-driven boiler feed pumps should include oil lubrication lines, bearings, and oil reservoirs. Accidental water discharge on bearing points and hot turbine parts should be considered. If necessary, these areas are permitted to be protected by shields and casing insulation with metal covers. Boiler feed pumps that are electric motor-driven, with lubricating or hydraulic oil hazards, can require protection depending on the quantity of oil, oil pressure, or exposure to other equipment.

N **12.3.3.2** Hydraulic and lubricating oil hazards associated with boiler feed pumps that are driven with steam turbines should be protected in accordance with 10.3.1.4.2. The use of a listed fire-resistant lubricant and hydraulic fluid can eliminate the need for fire protection systems.

N **12.3.3.3** Curbing or drainage or both should be provided for the steam-driven boiler feed pump oil reservoirs in accordance with Section 6.5.

N **12.3.4 Flue Gas.**

N **12.3.4.1 Forced Draft, Induced Draft, and Flue Gas Recirculation Fans.**

N **12.3.4.1.1** Coverage of steam-driven fans should include oil lubrication lines, bearings, and oil reservoirs. Accidental water discharge on bearings points and hot turbine parts should be considered. If necessary, these areas can be permitted to be protected by shields and casing insulation with metal covers. Water spray systems for steam turbine–driven forced draft and induced draft fans should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over the oil containment equipment surface. Water spray systems should be designed for 0.25 gpm/ft^2 (10.2 mm/min) for a minimum 20 ft (6.1 m) from the hazard. Compressed air foam systems should be designed and installed in accordance with NFPA 11 and their listing for the specific hazards and protection objectives specified in the listing. Combustible oil hazards associated with forced and induced draft fans driven with steam turbines should be protected with automatic sprinkler, water spray, systems with water additives, foam-water sprinkler systems, or compressed air foam systems.

N **12.3.4.1.2** Forced draft fans, induced draft fans, and flue gas recirculation fans should use a listed fire-resistant fluid for hydraulic drives. Where nonapproved hydraulic fluids are used, protection should be provided as described in 12.3.4.1.1.

N **12.3.5 Regenerative Air Heaters.**

N **12.3.5.1** Fires have occurred in air heaters after the accumulation of appreciable quantities of unburned combustibles on plate surfaces resulting from incomplete combustion of fuel in the boiler. Incomplete combustion is most likely to occur during startup. Incomplete combustion also can occur during load changes, periods of low firing rate, or normal operation due to unstable or over-rich firing.

N **12.3.5.2** Fire-loss experience does not presently indicate the need for special protection for other than regenerative-type air heaters. Regenerative-type air heater fires have occurred when firing on all types of fuel. Fires have occurred most frequently when firing oil or shortly after changing to pulverized coal from oil.

N **12.3.5.3*** Temperature sensors should be provided in the inlet and outlet ducts for both flue gas and air. An alarm should be provided in the control room to alarm when air or flue gas temperatures exceed 50°F (28°C) above normal operating temperature. Temperature sensors alone might not be adequate to provide early warning of a fire in an air heater. In large air heaters, air flow rates are high enough so that a fire will be well developed before the temperature increases enough to alarm and warn the operator. The length of time the operator has to take action is greatly reduced, and severe damage can occur. The installation of a special detection system can allow operators time to quickly detect a fire, isolate the air heater, open drains, and activate the water spray system.

N **12.3.5.4** A minimum of one observation port should be provided in the inlet and/or outlet ducts for both flue gas and air. Large air heaters can require more than one observation port. Observation ports should be placed such that they are accessible for viewing the rotor or stator surface.

N **12.3.5.5** A manual water spray system should be provided to protect the rotor or stator. The water spray system should be capable of being activated from the control room or from the air heater area (control valve should be easily accessible) or both. When the rotor or stator is horizontal, water spray applied to the upper surface can be expected to flow by gravity down over plate surfaces. A minimum density of 0.60 gpm/ft^2 (24.4 mm/min) is recommended. Where the rotor or stator is vertical, water spray should be applied to both sides to obtain adequate penetration. A minimum density of 0.30 gpm/ft^2 (12.2 mm/min) is recommended on both sides. Water wash systems might not be adequate to give full coverage because of rotor drive failure.

N **12.3.5.6** Access hatches for the use of hose streams should be provided. Hatches should be designed for quick access. A minimum of one hatch should be provided per 10 ft (3.0 m) of rotor or stator diameter. For horizontal shaft air heaters, access should be provided on both sides of the rotor or stator. For vertical shaft units, access hatches should be provided above the rotor or stator with one hatch below for units under 20 ft (6.1 m) diameter and two hatches below for units 20 ft (6.1 m) or more in diameter.

N **12.3.5.7** Drainage should be provided to remove suppression water to a safe area. Drains from air heaters, ducts, or both should be accessible or controlled by remotely operated valves.

N **12.3.5.8** A zero speed switch with alarm in the control room should be provided on the rotor shaft or on the output shaft from the fluid coupling or gear reducer. A zero speed alarm warns of stoppage of the rotor or air hoods. This stoppage could be due to failure of the drive motor or coupling that will lead to overheating of a section of the rotor or stator, which can result in a fire. Stoppage also can be caused by high temperatures generated by a fire that has caused the rotor to bind against the housing or the air hoods to bind against the stator.

N **12.3.6 Flue Gas Bag–Type Dust Collectors.**

N **12.3.6.1** Flue gas bag–type dust collectors (also known as fabric filters) can be damaged by overheating or fire. Filter media can be damaged by flue gases entering at a temperature above the operating temperature of the filter media. Fires have been caused by incomplete combustion in the boiler resulting in carryover of burning particulate igniting the filter media and by maintenance operations such as cutting and welding.

N **12.3.6.2** Collectors equipped with bags that have an operating temperature limit exceeding 400°F (204°C) should be subdivided into compartments by noncombustible partitions. The partitions should extend through the flue gas bag area. The filter bag area provided in each compartment should be such that the fabric filter systems will not limit boiler load with one compartment fully isolated to repair damaged filter bags. The pressure drop across the fabric filter system should not increase significantly when one compartment is isolated.

N **12.3.6.3** Collectors equipped with other types of bags should be subdivided into compartments by partitions of 30-minute fire resistance if no automatic sprinkler protection is provided or by noncombustible partitions if sprinklers are provided. Partitions should extend from the hopper, through the bag area, to the clean air plenum. Protection inside dust collectors should include the bag area. The design density should be 0.20 gpm/ft^2 (8.1 mm/min) over the plan area of the dust collector.

N **12.3.6.4** If automatic sprinkler protection is provided, structural design of the collector should take into consideration maximum water loading. A method should be provided for drainage of water from the hoppers.

N **12.3.6.5** Each compartment should be equipped with a heat detection system, arranged to alarm in a constantly attended area at a temperature 50°F (28°C) above normal operating temperature.

N **12.3.6.6** One of the following should be provided to prevent high temperature inlet flue gas from damaging the bags:

(1) Where permitted for emergency conditions, an automatic isolation valve and bypass duct to divert inlet gas streams around the flue gas bag collector
(2) A flue gas tempering water spray system in the duct between the boiler and the flue gas bag collector

N **12.3.6.7** Manual fire-fighting equipment should be available to personnel performing maintenance on a collector. A standpipe system should be provided such that each compartment is accessible by at least one hose system.

N **12.3.6.8** Access doors or hatches for manual fire-fighting and viewing ports should be provided for all compartments.

N **12.3.7 Electrostatic Precipitators.**

N **12.3.7.1** Electrostatic precipitators can be damaged by heat from a fire. High temperatures can warp collecting plates, decreasing collection efficiency. Combustibles can be generated by over-rich boiler-furnace firing. Solid and liquid products of incomplete combustion can be collected on plate surfaces. Ignition can occur by arcing in the electrostatic precipitator.

N **12.3.7.2*** Temperature sensors should be provided in the inlet and outlet ducts. Alarms should be provided in the control room to indicate abnormal operating temperatures.

N **12.3.7.3** Transformer-rectifier sets should use high fire point insulating fluids or should be of the dry type. If mineral oil insulating fluids are used, hydrants or standpipes should be located so that each transformer-rectifier set can be reached by at least one hose stream. In addition, either of the following should be provided:

(1) Automatic sprinkler or automatic water spray protection. Fire protection water spray systems provided for transformer-rectifier sets should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over the exposed surface of the transformer-rectifier set. Automatic sprinkler systems should be designed for a density of 0.25 gpm/ft^2 (10.2 mm/min) over 3500 ft^2 (325 m^2). The drain system should be capable of handling oil spillage plus the largest design water flow from the fire protection system.
(2) Fire barrier(s) or spatial separation in accordance with Chapter 6. *(See 6.1.4 and 6.1.5.)*

N **12.3.8 Scrubbers, Scrubber Buildings, and Exhaust Ducts.**

N **12.3.8.1 General.** Scrubbers are the main component for flue gas desulfurization (FGD) processes, which are frequently used to maintain low sulfur emissions. Auxiliary equipment associated with the FGD process is often enclosed in scrubber buildings constructed around the lower elevations of the scrubber. Some scrubbers are entirely enclosed in the scrubber building as well. Exhaust ducts provide a flow path from the scrubber outlet to the stack. Fires have occurred in scrubbers with combustible lining, combustible packing, or both. The fires occurred during outages and were caused by cutting and welding. Attempts to manually fight the fires were not successful since smoke and heat prevented access to the scrubber. Where scrubbers were located in buildings, there was extensive smoke and heat damage to the building. Fires can also occur in ductwork.

N **12.3.8.2 Scrubber Buildings.**

N **12.3.8.2.1** Buildings should be constructed of materials meeting the criteria outlined in Section 6.3.

N **12.3.8.2.2** Where scrubbers have combustible linings, one of the following methods of protection for the building should be provided:

(1) Automatic sprinkler protection at ceiling level sized to provide 0.20 gpm/ft^2 (8.1 mm/min). The area of operation should be the area of the building or 10,000 ft^2 (930 m^2). Where draft curtains are provided, the area of operation can be reduced to the largest area subdivided by draft curtains.
(2) The roof deck and supporting steel should be protected with a 1-hour fireproof coating. Building columns should be protected with a 2-hour fireproof coating from the roof to 20 ft (6.1 m) below the roof. Columns adjacent to scrubber openings should be protected from the roof to below the scrubber opening. Automatic or remotely actuated heat venting should be provided with a vent area of 1 ft^2 (0.09 m^2) per 50 ft^2 (4.6 m^2) of floor area.

N **12.3.8.2.3** If a listed less flammable fluid is not used, hydraulic and lubricating oil equipment should be protected as described in 9.6.1.

N **12.3.8.3 Scrubbers.**

N **12.3.8.3.1 Materials of Construction.** Scrubbers, internal piping, and ducts should be constructed of noncombustible materials, or the recommendations of 10.3.5.2.1 and 10.3.5.2.2 should be incorporated. All equipment lined with combustible material should be identified with warning signs or placards.

N 12.3.9 Activated Carbon Injection Systems.

N 12.3.9.1 General. Activated carbon injection (ACI) systems are used on some coal-fired plants to adsorb mercury from the flue gas. Powdered activated carbon (PAC) is stored in silos and pneumatically conveyed to the flue gas duct work and injected into the flue gas stream. Residual PAC (spent) is collected with fly ash in the baghouse ash hoppers.

N 12.3.9.2 Types of Powdered Activated Carbon. Powdered activated carbon (PAC) for use at power plants is typically a steam-activated carbon product. The feedstock varies by manufacturer, but steam-activated carbon is not subject to spontaneous heating. Chemically activated carbon products are subject to spontaneous heating and are not typically used at power plants. The activation method should be identified and considered in the Fire Protection Design Basis Document. PAC products might or might not be combustible or explosible, and testing is recommended for the PAC products specified for the plant-specific ACI system. If the product cannot be identified and tested prior to the design of the ACI system, then the Fire Protection Design Basis Document should consider a worst-case scenario.

N 12.3.9.3 Storage of Powdered Activated Carbon. PAC is typically stored in outdoor silos filled pneumatically by tank truck or rail tank car. Trucks connect to fill connections at grade, and PAC is transported into the top of the silos via a blower on the truck or at the rail car unloading station. In addition to fill piping and instrumentation, there is typically a bin vent filter at the top of the silo (not typically enclosed). The skirt area of the silo below the hopper might contain fluidizing air piping, PAC day bins, piping, instrumentation, etc. Depending on the PAC test results, enclosed areas should be evaluated for the plant's combustible dust program in accordance with NFPA 654.

N 12.3.9.4 Effect of PAC on Fly Ash Properties. Fly ash hoppers downstream of the PAC injection point will contain spent PAC in some percentage. The percentage depends on operating conditions, whether or not the PAC is injected downstream or upstream of an electrostatic precipitator, and whether or not the unit uses other inert materials in the process such as a dry sorbent. If the PAC is determined to be combustible and/or explosible *(see 12.3.9.2)*, then the fly ash/spent PAC mixture in the collection points (e.g., baghouse hoppers) should be evaluated based on the worst-case operating conditions. This could require testing to determine if the mixture is combustible or explosible. The results should be considered in the Fire Protection Design Basis Document.

N 12.3.9.5 Fire Protection. Where fire detection is recommended by the Fire Protection Design Basis Document, carbon monoxide monitors should be located on the clean side of the silo bin vent filters. Upon receipt of an alarm, thermographic cameras should be used to confirm the presence of a fire in the silo. Where fire protection is recommended by the Fire Protection Design Basis Document, one of the following methods of protection should be provided:

(1) A fixed water-based (water, foam-water, water with wetting agents and/or water additives) system that is designed to protect a full silo. However, admitting water into a full PAC silo will create a sludge that is not likely to flow out of a drain connection. The silo design should accommodate removal of this sludge after a fire is suppressed. Structural design should accommodate the added weight of the water. The system could utilize a fixed water supply or be supplied via manual connections located remote from the silos. The silo should be equipped with access platforms for maintenance of nozzles.
(2) A fixed water-based (water, foam-water, water with wetting agents and/or water additives) system that is designed to wash down a nearly empty silo. In this case, the silo design should accommodate removal of the PAC prior to activation of the wash down system. The wash down nozzles could be minimized (e.g., at the top only) to minimize the number of penetrations in the silo. This method minimizes the amount of sludge created by putting water on the PAC.
(3) Low-pressure carbon dioxide (CO_2) can be used to inert the silo. This can be a fixed system with a low-pressure CO_2 storage tank, vaporizer, and distribution piping. The silo manufacturer should be consulted during design of the system to confirm that the silo design pressure is high enough for a CO_2 discharge, and to confirm how many nozzle locations are required to ensure that the CO_2 can permeate the dense PAC in the silo. As an alternate to the fixed low-pressure CO_2 storage tank, the system could utilize a dry-header and fixed vaporizer with connections for a CO_2 tank truck. The silo should be equipped with access platforms for maintenance of nozzles.
(4) Other approved means.

N 12.3.10 Stacks.

N 12.3.10.1 Noncombustible liners should be used where practical. *(See Annex C for fire tests.)*

N 12.3.10.2 Combustibles should not be stored in the stack unless the liner is adequately protected by a fire barrier. The barrier could be either a 2-hour fire barrier or a 1-hour fire barrier if automatic sprinkler protection is provided over the combustible material.

N 12.3.10.3 A fire protection system should be provided for maintenance operations inside combustible stack liners. A fixed protection system installed on scaffolding is recommended. It should be capable of both manual and automatic operation and designed to protect the work platform and twice the area that can be reached by workers on the platform.

N 12.3.10.4 Ignition sources should be eliminated when work is being performed on combustible liners.

N 12.3.10.5 Noncombustible scaffolding should be considered for work on combustible plastic liners.

Δ Chapter 13 Wind Turbines

13.1 General.

13.1.1 Chapter 13 identifies fire and explosion hazards of wind turbine electric generating units and associated wind generating facilities (wind farms) and specifies recommended protection criteria.

13.1.2 Most wind farms consist of a varied number of tower-mounted wind turbine generators with electrical outputs tied together with the electrical power voltage stepped up to match grid voltage. The particular design of the wind turbine generators can vary, as will that of the configuration of the power output circuitry and components. Therefore, some recommendations might be more suitable for one type of wind turbine or wind farm facility than another. Many of the specific guidelines herein might require modification after due consideration of all local factors involved. Given the geographical remoteness of the typical wind farm, the emphasis of this guideline is on prevention of fire by design with the addition of fire suppression equipment to be guided by the Fire Protection Design Basis Document as well as a cost-benefit analysis to determine the extent to which fire protection is justified.

Δ **13.2 Application of Chapters 4 Through 10.** The recommendations contained in Chapters 4 through 10 can apply to wind generating facilities. The Fire Protection Design Basis Document should determine which recommendations apply to any specific wind generating facility. This determination is done by evaluating the specific hazards that exist in the facility and evaluating the level of acceptable risk for the facility. For most wind generating facilities, it is expected that most of the recommendations will apply, although there could be particular wind turbines and output circuit designs for which some of the recommendations will not apply since the hazards described might not exist (e.g., no transformer in the wind turbine nacelle).

Δ **13.3 Design and Equipment Arrangement.**

13.3.1* Site-specific considerations or a manufacturer's typical layout will govern wind turbine generating facility design. This will include the wind turbine design, tower design and heights, tower foundations, power output, and load control circuitry. This will dictate how many separate structures or enclosures will be provided in addition to the wind turbine towers. The wind turbines and associated towers are commonly installed in multiple rows or long strings, depending on the land and wind topography.

13.3.2 Special-purpose electrical heaters can be used in wind turbine nacelles to provide for oil sump and space heating. These heaters should be listed for the type of use in which they are employed.

13.3.3 High speed brakes (if used) can create a large quantity of sparks. The use of shield(s) should be considered to isolate these sparks from combustible equipment components and locations where leaked combustible fluids can accumulate.

13.3.4 Particular care should be practiced with respect to spatial separation and protection from wildland fires as well as the control of vegetation where wind turbines and associated equipment might be located. Guidance regarding vegetation clearance, separation distance, and emergency planning can be found in NFPA 1143 and NFPA 1144.

•

N **13.4 Risk Consideration.**

13.4.1 Adequate separation should be provided between the following, as determined by the Fire Protection Design Basis Document:

(1) Adjacent wind turbine units consistent with land and wind topography constraints
(2) Adjacent structures or exposures, including transformers
(3) Adjacent properties (e.g., aboveground pipelines, tank farms, or natural gas facilities that could present a severe exposure)

13.4.2 Consideration should be given to equipment layout that is adjacent to wind turbines and in line with the planes of the rotating blades and hub in typical wind conditions that have a higher potential for damage from flying debris (such as blade sections on overspeed or ice).

13.4.3 In the event of a problem with a wind turbine generator, automatic shutdowns should be provided that result in stopping of shaft rotation, braking, and isolation of electrical power to the tower and nacelle. Different methods of equipment shutdown and isolation, operating independently, should be provided. These can include blade pitch control and/or hydraulic braking as well as power isolation in concert with electronic control termination.

13.4.3.1 Determination of the need for fire detection/suppression and associated wind turbine safe shutdown sequence for wind generating facilities should be based on the facility design and layout, including specific equipment and components used in producing power within the facility. This should be addressed in the Fire Protection Design Basis Document with regard to the wind turbine and tower as well as power delivery and control circuits. In addition, consideration should be given to the consequences of loss of a wind turbine unit or multiple units as well as the vulnerability of adjacent structures and equipment to damage.

13.4.3.2 Should the Fire Protection Design Basis Document indicated in 13.4.3.1 determine a need for fire detection system(s), the system(s) should be arranged to activate alarms at a constantly attended location or via the provision of remote operator circuits. This applies to nacelles, towers, electrical equipment enclosures, and buildings.

13.4.3.3 Due to the remote location of the majority of onshore wind generating facilities and the lack of abundant water supplies, the use of water-based fire protection systems is unlikely. For off-shore facilities, the same is true because the construction of pumping and fire water distribution systems would be cost prohibitive. If the design of a particular facility does, however, permit the use of water suppression systems, these systems should follow the general recommendations in Chapter 9. If the Fire Protection Design Basis Document indicates a need for fire-fighting capability using water, NFPA 1142 should be consulted.

•

N **13.5 Hazard Protection.**

13.5.1 In general, the principles outlined in NFPA 30 should be applied to gearboxes and lubricating oil sumps, pumps, coolers, filters, and associated piping. As a minimum, piping systems supplying flammable and combustible liquids should be designed to minimize hydraulic and lubricating oil piping failures as follows:

(1) If rigid metal piping is used, it should be designed with freedom to deflect with the gearbox, in any direction, at the interface with the gearbox. This recommendation also should apply to hydraulic lines that are connected to accessory gearboxes or actuators mounted directly in the nacelle. Properly designed metallic hose is an alternative for hydraulic and lube oil lines in high vibration areas to allow relative motion between rigid pipe supply lines and manifolds, and at the points of entry at the gearbox and generator interfaces.
(2) Rigid piping connected directly to the gearbox should be supported such that failures will not occur due to the natural frequency of the piping coinciding with the rotational speed of the gearbox, drive shaft and hub, and generator. Care should be taken in the design of pipe

supports to avoid vibrations induced by other equipment that can excite its natural frequency.

(3) Welded pipe joints are preferred. Threaded couplings and flange bolts in oil piping should be assembled using a torque wrench and torqued to the manufacturer's requirements. Threaded fittings should have a positive locking device to prevent unscrewing.
(4) Instrumentation tubing, piping, and gauges should be protected from accidental mechanical damage. Sight glasses should be listed.
(5) Lubricating oil lines should use “guarded” pipe construction with the pressure feed line located inside the return line. Where guarded pipe construction is not used, piping sleeves should be used to reduce the possibility of oil atomization. All mechanical connections should be guarded.
(6) Containment and drainage should be provided so as to minimize the spread of oil within the nacelle or externally, which poses a risk to equipment or personnel below.
(7) Fluid piping should be routed below all electrical equipment to preclude leaked fluid dripping on the equipment.

13.5.2 For wind turbine generators, the following monitors and/or trip functions should be provided to monitor the operation of wind turbine generators safely, and initiate a safe shutdown of abnormal operating conditions or parameters:

(1) Grid disturbance
(2) Yaw errors or limits
(3) Braking issues
(4) Abnormal vibration
(5) Overspeed (including wind conditions)
(6) Temperature faults
(7) Oil condition (gearbox/lubrication and hydraulic)
(8) Motor protection
(9) Loss of communication between modules or with control center
(10) Blade angles and battery status
(11) Activation of smoke and/or heat detectors within the nacelle

13.5.2.1 Batteries are frequently employed to provide back-up power in the nacelle and hub of a wind turbine proper, and other support structures (e.g., control rooms). Batteries should be provided adequate ventilation and should be kept clean.

13.5.2.2 Lightning protection for blades, nacelles, towers, power lines, transformers, and support structures should be provided in accordance with NFPA 780 or IEC 62305, *Protection Against Lightning*.

•

13.5.3 Fire Protection for Wind Generating Facilities.

13.5.3.1 General.

13.5.3.2 Nacelle Fire Protection.

Δ **13.5.3.2.1** The need for automatic fixed fire protection within the nacelle of a wind turbine generator should be based on the Fire Protection Design Basis Document and associated Fire Risk Evaluation. Fire suppression within sealed electrical enclosures and cabinets is discussed in Chapter 9. A local application system is more appropriate for unsealed electrical enclosures and cabinets within the nacelle and tower. Likewise, a local application extinguishing system might be appropriate for the gearbox lubrication system or hydraulic control system. If used, fire suppression capability should be provided for oil piping or any area where oil can flow, accumulate, or spray. Fire extinguishing systems, where provided for hydraulic control equipment, should include protection of reservoirs, pumps, accumulators, piping, and actuating systems. Listed systems should be used.

13.5.3.2.2* Discharge rates and duration should be such that cooling and shutdown occur to prevent re-ignition of the fire. System operation should be arranged to coincide with automatic shutdown of the wind turbine.

13.5.3.2.3 The positioning of local application nozzles should be such that maintenance access to the wind turbine components within the nacelle is maintained.

•

Δ **13.5.3.2.4** A smoke/fire detection system with occupant notification should be installed throughout the tower and nacelle to provide early warning and alarm functions.

•

Δ Chapter 14 Solar Generation

14.1* General. Chapter 14 covers fire hazards associated with solar power generating stations. The process used in current commercial applications typically involves one of two basic technologies:

(1) Concentrated solar power (CSP), which involves using solar radiation to heat a working fluid which, in turn, is used to generate steam to drive a steam turbine generator.
(2) Photovoltaic (PV) solar power that is associated with the use of PV panels in various arrays to convert energy from the sun to dc electrical energy that is subsequently converted to ac power for delivery to the grid.

14.2 Application of Chapters 4 Through 10. The recommendations contained in Chapters 4 through 10 apply. The Fire Protection Design Basis Document should determine which recommendations apply to any specific facility. This determination is done by evaluating the specific hazards that exist in the facility and evaluating the level of acceptable risk for the facility. The remaining paragraphs in this chapter provide recommendations that are beyond the scope of other chapters in this recommended practice.

•

14.3 Design and Equipment Arrangement.

14.3.1 HTF Pumps and Piping.

Δ **14.3.1.1*** ASME B31.1, *Power Piping*, should be followed in the design of HTF piping systems. Piping and fittings should be properly designed to resist an exposure fire until protection can be achieved by water spray. Careful consideration should be given to the design, application, construction, and installation of connections (rotating ball joint, flexible hose, etc.) employed in areas such as the HTF loop connections of adjacent solar collector assemblies to prevent possible sources of HTF leaks. Gaskets and seals should be compatible with HTF. Flanges and piping connections on HTF systems should have guards.

14.3.1.2 Piping and components containing and using HTF should be located outside.

14.3.1.3 Pressure monitoring with alarm to a constantly attended area upstream of the HTF heat exchanger and on each

HTF loop, and interlocks to shut down pumps or isolate a loop in the event of pressure drop, should be provided.

14.3.1.4 Consideration should be given to the use of remotely operated emergency isolation valve(s) in the piping arrangement to reduce the volume of flammable fluid released. Actuators for remotely operated emergency isolation valves should be controlled pneumatically, electrically, or both.

(1) Pneumatic operation is preferred. This method provides "fail safe valve(s)" that close on loss of instrument air or electrical power. If pneumatic power is required to close the valve(s), the air lines and fittings should be of stainless steel construction.
(2) Electrically operated valves and associated cabling should be provided with fireproofing, allowing cable to remain in service when exposed to a 30-minute UL 1709 time-temperature exposure. Cable for valves that fail in the closed position on loss of power need not be fireproofed.
(3) Remote actuation controls or devices should be located in a constantly attended control room. If not, they should be at least 50 ft (15.2 m) from anticipated leak points.

14.3.1.5 A means to direct leaking HTF away from important equipment and structures should be provided. Sloping the ground to channel leaking HTF to safe areas and curbs to prevent flow toward equipment can be used.

14.3.1.6 Stone or crushed rock surfaces could be an effective fire control measure near high value or critical process equipment *(see 6.5.5)*.

14.3.1.7 HTF piping and component relief valves should be positioned in such a way that discharges of either liquid or vapor occur at a location that will limit fire exposure to critical equipment and/or adjacent equipment or structures.

14.3.1.8 HTF piping should be insulated or routed away from combustible materials.

14.3.1.9 Use of double mechanical seals on pumps to reduce potential sources of leaks should be considered.

14.3.2 HTF Heater Protection.

14.3.2.1 An emergency dump system should be provided to carry HTF to a safe location.

14.3.2.2 An internal fixed fire extinguishing system should be provided for the heater.

14.3.2.3 Burner front fire protection systems should be provided *(see 9.5.1)*.

14.3.2.4 A means should be provided to identify tube rupture, and valving should be provided to isolate the tube or the header supplying HTF to the tube where a significant gravity flow could occur.

14.3.2.5 The fuel supply to the heater should be capable of being remotely shut off or isolated through action taken in the control room or in a constantly attended area.

14.3.2.6 Controls and instrumentation safeguards should be provided for heaters as identified in NFPA 86 and the equipment manufacturer's recommendations. Consideration should be given to include monitoring, alarms, and/or automatic shutdown for the following conditions:

(1) Low HTF flow
(2) High HTF outlet temperature
(3) Low fuel gas pressure or low liquid fuel flow
(4) Flame failure
(5) High exhaust stack temperature

14.4* Risk Considerations.

14.4.1* Photovoltaic (PV) Power. Major hazards associated with PV generating plants are as follows:

(1) Electrical fires associated with failed PV module connections or string cabling
(2) Hydraulic oil fires associated with the hydraulic oil systems used for multi-plane tracker positioning of the PV modules
(3) Inverter, switchgear, and cable fires
(4) Transformer failure fires
(5) Wildland fires around arrays of PV modules and strings

14.4.2 As solar generating stations are typically located in remote areas, NFPA 1142 should be consulted if the design basis indicates the need for water-based fire protection.

14.4.3* Concentrated Solar Power. The major hazards associated with concentrated solar generating plants are as follows:

(1) Release of large quantities of combustible HTF
(2) Shielded fires involving large quantities of HTF in the heater
(3) Lubricating and control oil fires
(4) Switchgear and cable fires
(5) Transformer failure fires
(6) Wildland fires around arrays of solar collection assemblies

14.4.4 Determination should be made with regard to damage that would be caused by a release of HTF. Spacing and design of critical equipment and structures should limit damage in the event of a fire exposure in both the solar field and power generation areas.

14.5 Hazard Protection.

N **14.5.1 Concentrated Solar.**

14.5.1.1 Supports for steam generator heat exchangers, HTF heaters, and other equipment containing liquid hydrocarbon holdup should be protected to prevent structural collapse of these units in event of a pool fire. In addition, protection for supports for adjacent critical equipment, such as pipe supports, within 20 ft to 40 ft (6.1 m to 12.2 m), depending on the Fire Protection Design Basis Document, should be considered. Protect structural supports with either of the following:

(1) A 2-hour fire resistance rating when tested by the UL 1709 time-temperature exposure. If a coating is used for outdoor applications, it should be acceptable for outdoor use.
(2) Water spray protection in accordance with NFPA 15.

14.5.1.2 Equipment such as HTF pumps, surge tank areas, steam generator heat exchanger areas, HTF ullage equipment, and ground area where HTF fluid could spray, flow, or accumulate should be protected by automatic water-based or foam fire protection systems.

•

Δ Chapter 15 Geothermal Generation

Δ **15.1 General.** Chapter15 covers fire and explosion hazards and recommended protection criteria associated with geothermal power plants.

15.2* Application of Chapters 4 Through 10. The recommendations contained in Chapters 4 through 10 apply to all geothermal power plants (direct steam, flash steam, and binary). The Fire Protection Design Basis Document should determine which recommendations apply to any specific facility. This determination is done by evaluating the specific hazards that exist in the facility and evaluating the level of acceptable risk for the facility. The remainder of this chapter provides recommendations that are not included in other chapters in this recommended practice.

•

N **15.3 Design and Equipment Arrangement.**

15.3.1 Binary Plants. Recommendations in this section apply to binary plants.

15.3.1.1* Determination should be made with regard to damage that could be caused by a release of flammable organic fluid as a liquid or as a vapor cloud. Spacing and design of critical equipment and structures should be such so as to limit damage in the event of explosion or fire exposure.

15.3.2 Location.

15.3.2.1 Prevailing wind direction with regard to arrangement of major components should be considered, because this will reduce the possibility of a release exposing critical equipment or adjacent units.

15.3.2.2 Components containing flammable working fluid should be located outside or in adequately ventilated enclosures. Adequate ventilation is considered to be one that limits concentration to less than 25 percent of the LFL.

15.3.2.3 Working fluid pumps should be located so as not to expose critical equipment.

15.3.2.4 Potential fire exposures such as turbine lube oil reservoirs and working fluid storage tanks should be located so as not to expose critical equipment.

•

15.4 Risk Considerations.

Δ **15.4.1 Direct Steam and Flash Steam Geothermal Plants.** In general, risk considerations for direct steam and flash steam geothermal plants are the same as those for conventional steam turbine power plants.

15.4.2 Binary Geothermal Plants. The major hazards associated with binary plants are as follows:

(1) Release of flammable liquid above its boiling point with potential fire exposure to other equipment or a potential vapor cloud explosion
(2) Pool fire from release of flammable liquid
(3) Combustible cooling tower construction
(4) Lubricating and control oil fires
(5) Switchgear and cable fires

Δ **15.5 Hazard Protection.** The Fire Protection Design Basis Document should examine the type of detection needed as well as alarms and emergency shutdown devices (ESDs).

•

Δ Chapter 16 Integrated Gasification Combined-Cycle (IGCC)

16.1* General. Chapter 16 identifies fire and explosion hazards associated with integrated gasification combined-cycle (IGCC) electric generating facilities and specifies recommended protection criteria.

Δ **16.2 Application of Chapters 4 Through 10.** The recommendations contained in Chapters 4 through 10 readily apply to IGCC facilities. With the addition of the different technologies involved in syngas production and the differences in syngas with respect to natural gas, the Fire Protection Design Basis Document should determine which recommendations apply to any specific IGCC facility. This determination is done by evaluating the specific hazards that exist in the facility and evaluating the level of acceptable risk for the facility. For IGCC facilities, it is expected that most of the recommendations will apply, although there could be particular plants for which some of the recommendations will not apply since the hazards described might not exist (e.g., no air separation unit). The user is responsible for determining the properties of the materials used or generated in the facility (vapor density, ignition temperature, LFL, etc.). It is recommended that designers seek guidance from those having specialized experience to understand the unique characteristics of any particular fuel or technology in order to properly apply the appropriate portions of this and other applicable documents.

Δ **16.3* Design and Equipment Arrangement.**

16.3.1 Fuel availability; type of fuel; site-specific considerations, including environmental limits; and an engineering firm's typical layout will govern IGCC facility design. This design will include the choice of fuel and the fuel preparation systems needed, the design and layout of the gasification plant, the need for an air separation unit, and the amount of by-product reclamation systems. This, in turn, will dictate how many separate structures or enclosures will be provided in addition to the power plant's gas turbine(s), HRSG(s), and steam turbine generator(s).

•

16.3.2 Physical separation should be provided between the following as determined by the Fire Protection Design Basis Document:

(1) The feedstock fuel preparation and storage area
(2) The power plant, including switchyard
(3) Gasification plant
(4) Air separation unit
(5) Syngas cleaning/treatment area
(6) Chemical production areas
(7) Adjacent properties (e.g., refinery, process facility, aboveground pipelines, tank farms, or natural gas facilities that could present a severe exposure)

N **16.3.3 Control/Electrical Equipment Enclosures and Buildings.**

16.3.3.1* An analysis of the facility design and layout should be made to determine the most appropriate location for the gasification plant and power plant control rooms, or an integrated control, if applicable. In addition to location, consideration should be given to the need to incorporate blast resistance, building/room pressurization, and fire protection into the building/room design.

•

16.3.4 Consideration should be given to the high temperatures, high pressures, and combustible gases (e.g., hydrogen) content associated with syngas developed in the gasification plant. Proper control of combustible material in and around the gasifier, syngas cooler, and associated piping and vessels is paramount, as is proper area classification and the use of listed electrical equipment.

•

Δ **16.3.5** Due to the hazards involved in the processing, storage, and handing of flammable gas mixtures, many of the requirements of NFPA 54 and NFPA 55 are applicable with respect to the following:

(1) Container, tank, piping, and valve construction safety features
(2) Instrumentation and controls
(3) Electrical equipment classification for hazardous atmospheres
(4) Loading/unloading stations
(5) Equipment spacing
(6) Building construction
(7) Diking, impounding, drainage, and so on
(8) Fire protection, including hose streams, monitor nozzles, fixed water spray, fire extinguishers, and so on

16.3.6 Piping.

16.3.6.1 The principles outlined in NFPA 30 should be applied to gear boxes and lubricating oil sumps, reservoirs, pumps, coolers, filters, and associated piping that are necessary for operation of the fuel preparation systems, air separation unit and other support functions, and the combined-cycle power plant. As a minimum, piping systems supplying flammable and combustible liquids should be designed to minimize hydraulic and lubricating oil piping failures as follows:

(1) Rigid metal piping should be designed with freedom to deflect with the system/component the piping is serving, in any direction, at the interface with the component. Properly designed metallic hose is an alternative for hydraulic and lube oil lines in high vibration areas to allow relative motion between rigid pipe supply lines and manifolds, and at the associated points of entry.
(2) In syngas areas, piping and vessels should be appropriately designed with adequate corrosion allowances. Appropriate maintenance and monitoring frequencies should be identified.
(3) Rigid piping connected directly to pumps, sumps, and gearboxes should be supported such that failures will not occur due to the natural frequency of the piping coinciding with the rotational speed of the gearbox, drive shaft, prime mover, and load. Care should be taken in the design of pipe supports to avoid vibrations induced by other equipment that can excite its natural frequency.
(4) Welded pipe joints should be used where possible. Threaded couplings and flange bolts in oil piping should be assembled using a torque wrench and torqued to the manufacturer's requirements. Threaded fittings should have a positive locking device to prevent unscrewing.
(5) Instrumentation tubing, piping, and gauges should be protected from accidental mechanical damage. Sight glasses should be listed.
(6) Where practical, lubricating oil lines should use “guarded” pipe construction with the pressure feed line located inside the return line. If this not practical, piping sleeves and/or tubing and flange guards should be used to reduce the possibility of oil atomization with subsequent spray fires.
(7) If practical, fluid piping should not be routed above electrical equipment to preclude leaked fluid dripping on the equipment.

16.3.6.2 Piping through which syngas and natural gas is directed should be constructed in accordance with API RP 941, *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants*, and ASME B31.3, *Process Piping*. Specific design considerations should recognize the hazards imposed by the high hydrogen concentration within the syngas that is directed to the combustion turbine(s).

Δ **16.3.6.3** Plant design should address the need for flare stacks as required by the various processes built into the plant design. Guidance on flare stack design can be found in API RP 521, *Guide for Pressure Relieving and Depressurizing Systems*, and API 537, *Flare Details for Petroleum, Petrochemical, and Natural Gas Industries*.

16.4 Risk Considerations.

Δ **16.4.1** The major fire and explosion hazards associated with IGCC facilities being designed and installed today that should be assessed as part of the Fire Protection Design Basis Document are as follows:

(1) Combustible fuels that are stored and processed in the fuel preparation area and subsequently delivered to the combustor
(2) An uncontrolled reaction involving oxygen and synthesis fuel gas (syngas) in the gasifier or downstream equipment, often due to loss of combustible fuel without loss of oxygen or inadequate purge procedures
(3) The high temperatures and pressures produced in the gasifier
(4) Flammable and combustible liquids associated with lubrication and hydraulic oil systems (e.g., compressors, pumps, fans, turbines)
(5) Fuel gas highly enriched in hydrogen moving from the gasifier to the combustion turbine(s)
(6) Natural gas or fuel oil used as an alternative fuel for the combustion turbine(s) in the combined-cycle power plant
(7) Electrical components and wiring
(8) Contaminants in the plant oxygen systems, such as hydrocarbons, residual materials from inadequate cleaning, or inappropriate materials of construction, that result in detonations
(9) Propane or other startup/preheat fuels
(10) Air or oxygen introduced into the flare system

16.4.2 Syngas Within Buildings and Enclosures.

16.4.2.1 When syngas piping and associated appliances are within a building or enclosure, ventilation should be provided. Syngas contains hydrogen. Hydrogen is more likely to leak from pipe fittings than other gases, increasing the fire and explosion hazard that would be encountered whenever such piping and associated metering and control appliances are installed within a building or enclosure.

16.4.2.2 Electrical classification of equipment should be in accordance with one of the following: NFPA 497; API 500, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division I and Division II*; or API 505, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, and Zone 2.*

•

16.5 Hazard Protection.

16.5.1 The Fire Protection Design Basis Document should determine the need for fire detection/suppression for IGCC facilities should be based on the facility design and lay-out, including specific equipment and components used in producing syngas as well as power within the facility. This can require separate fire risk evaluations of the gasification plant, gasifier support systems, and combined-cycle power plant. Fuel preparation and delivery systems are addressed in Chapter 9. The gasification plant analysis should examine the need for and location of gas and other types of detectors as well as alarms and ESDs. The location of a flare stack to safely release any flammable gases in the event of a process upset, gas turbine trip, or safety valve actuation should also be considered. Flash tanks/drums that allow direct venting of syngas or other combustible gases to the atmosphere should not be used.

Δ **16.5.2** The following monitors or trip functions should be considered where appropriate for the equipment design to safely monitor the operations and processes taking place within the facility and initiate a safe shutdown when necessary:

(1) Pressures, temperatures, and flow rates of fuel supplies, reaction enhancers, syngas, and combustion contaminant recovery systems
(2) Combustion safeguards and reaction control system in the gasifier, combustion turbine generator(s), and heat recovery steam generator(s) (if equipped with duct burners)
(3) Combustible gas detection in the event of a fuel gas leak
(4) Flame detection in the event of a fuel gas leak
(5) Carbon monoxide detectors and warning lights to signal the presence of toxic atmosphere
(6) Liquid levels in process vessels

•

16.5.3 An IGCC facility will feature many different processes and fuels in the production of syngas and its use in the combined-cycle power plant; therefore, the Fire Protection Design Basis Document should determine the use of a number of types of fire protection systems, with primary reliance on water-based systems.

Δ **16.5.4** An automatic fire protection system should be provided for the catalytic agent and product storage vessels and tank areas in accordance with the Fire Protection Design Basis Document. Where the hazard is lube oil or hydraulic oil, a listed fire-resistant fluid is an acceptable alternative to fixed fire protection.

16.5.5 Special consideration should be given to the unique geometries associated with some gasifier and syngas cooler designs with respect to fire main and hydrant/monitor coverage.

16.5.6 Structures.

Δ **16.5.6.1** Critical structures within the gasification plant should be protected in accordance with API 2218, *Fireproofing Practices in Petroleum and Petrochemical Processing Plants.*

16.5.6.2 Consideration should be given to any exterior insulation used on structures, vessels, and piping, to minimize any possibility of an external fire hazard on these structures.

•

16.5.7* Prevention of Internal Explosions in Combustion Turbines. In addition to those listed in 10.3.2.3, the precautions in 16.5.7.1 and 16.5.7.2 apply.

16.5.7.1 Where syngas has independent piping to the combustor, a dedicated inert gas purge should be provided for the piping downstream of the last block valve in the control system. Additionally, an inert gas block should be provided between the last block valve and the next valve upstream to prevent the release of unburned syngas into the turbine. This purge and block arrangement prevents possible reignition and/or explosion in the gas turbine.

16.5.7.2 Where common fuel piping system is used for delivering both syngas and a gaseous startup fuel to the combustor, the startup fuel will provide the necessary buffer to prevent unburned syngas from entering the turbine under normal operating conditions. However, in an emergency stop/trip situation, the shutdown occurs without a transfer to the startup fuel, which leaves syngas in the fuel delivery piping. Consequently, an inert purging system is needed to avoid the potential for releasing unburned syngas into the turbine.

Δ Chapter 17 Hydroelectric Generation

17.1 General.

17.1.1 Chapter 17 identifies fire and explosion hazards of hydroelectric generating stations. Such facilities include both dam-type facilities using penstocks to direct water to vertical-type hydro turbine generators and run-of-the-river facilities in which river water is channeled through axial-type hydro turbine generators. In addition, pumped-storage hydro facilities operate as normal vertical (upper storage to lower storage) hydro stations to produce electrical power and pump water from the lower storage to the upper storage. This chapter specifies recommended protection criteria for all three types of hydroelectric stations.

Δ **17.2 Application of Chapters 4 Through 10.** The recommendations contained in Chapters 4 through 10 can apply to hydroelectric generating stations. The Fire Protection Design Basis Document will determine which recommendations apply to any specific hydroelectric generating station. This determination is done by evaluating the specific hazards that exist in the facility and determining the level of acceptable risk for the facility. It is expected that most recommendations will apply to all hydroelectric generating stations.

Δ **17.3 Design and Equipment Arrangement.**

17.3.1 Adequate separation should be provided between the following, as determined by the Fire Protection Design Basis Document:

(1) To separate the intake hoist housing from generator floor area and from adjacent areas
(2) To separate dam and spillway hoists, including the main power and backup power bus, from adjacent areas such as spillway electrical distribution rooms
(3) To separate the tailrace service gallery from turbine/generator floors and governor hydraulic equipment

•

N 17.4 Risk Considerations. (Reserved)

N 17.5 Hazard Protection.

17.5.1 Consideration for protection of horizontal and vertical turbine bearings should be made based on the Fire Protection Design Basis Document.

•

17.5.2 Generator Pit and Windings.

17.5.2.1* Protection of generator windings consisting of materials that will not extinguish when de-energized should be provided by automatically actuated gaseous extinguishing systems, hybrid fire-extinguishing systems, water mist systems, water spray rings, or a combination thereof.

17.5.2.2 Fire detection in generator winding should be provided.

17.5.2.3 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, hybrid fire-extinguishing system, water mist system, or water spray system.

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

17.5.2.5 Operation of water spray 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 (i.e., electrically isolated and without excitation) for at least 24 hours to avoid creating stator ground faults on both types of winding materials.

•

Δ Chapter 18 High-Voltage Direct Current (HVDC) Converter Stations

18.1 General. Chapter 18 identifies the fire hazards and specifies recommended protection criteria for high-voltage direct current (HVDC) converter stations, which include both alternating and direct current converters, static var compensator/static var generator (SVC/SVG) facilities, and variable frequency transformers (VFTs).

Δ 18.2 Application of Chapters 4 Through 9. The recommendations contained in Chapters 4 through 9 can apply to HVDC converter stations and SVC/SVG. The Fire Protection Design Basis Document will determine which recommendations apply to any specific HVDC or SVC/SVG facility. This determination is done by evaluating the specific hazards that exist in the facility and determining the level of acceptable risk for the facility. It is expected that most recommendations will apply to all HVDC, SVC/SVG, and VFT facilities.

18.3 Design and Equipment Arrangement.

18.3.1* Each thyristor valve hall, TSC/TCR valve hall, and VFT hall should be a separate fire area. Each hall should be separated from adjacent fire areas by fire area boundaries in accordance with 6.1.1.3. Unless consideration of the factors of 6.1.1.2 indicates otherwise, it is recommended that fire area boundaries be provided *(see Figure 18.3.1)* to separate the following:

(1) Service building
(2) Main control room
(3) Valve electronics rooms
(4) Valve control and pole control equipment room
(5) VFT rotating transformers
(6) Human–machine interface (HMI) controls room
(7) HVAC equipment rooms
(8) Relay room, SCADA room, and remote terminal unit room (RTU)
(9) Control equipment room
(10) Electrical equipment/switchgear room
(11) 125/250 V dc control relay room
(12) Cable tunnel/vault/room(s)

18.3.2 Converter valves and associated support equipment should use noncombustible or limited-combustible materials. Where noncombustible or limited-combustible materials are not used, fire-retardant separation barriers should be installed between the following equipment areas:

(1) Valve tier levels, by adding to the bottom tray on each level
(2) Valve modules, by adding to the side of each tray section
(3) Grading capacitors, snubber circuits, and power supplies

18.3.3 Smoke or heat vents should be considered in accordance with 6.4.1.

18.3.4 Heating, ventilating, and air-conditioning (HVAC) systems for the valve hall should be provided with fire/smoke dampers arranged to shut down to preclude the entry of smoke from sources outside the valve hall structure. Separate dedicated HVAC and smoke management systems should serve each valve hall.

18.3.5 Outdoor converter transformers and oil-filled smoothing reactor(s) should be arranged in accordance with 6.1.4 and 6.5.5.

18.3.6 Drainage provisions should be provided for indoor and outdoor oil-filled wall bushings. Drainage should be arranged in accordance with Section 6.5. Indoor oil-filled wall bushings should be provided with means to prevent the spread of oil to adjacent equipment. Where the converter bushings penetrate the valve hall, provisions should be made to prevent the oil contents of the transformer from entering the valve hall.

18.3.7 Mercury arc converters should be arranged to minimize the effects of a hazardous material spill or airborne contamination from mercury that could impede fire-fighting efforts and restoration activities.

•

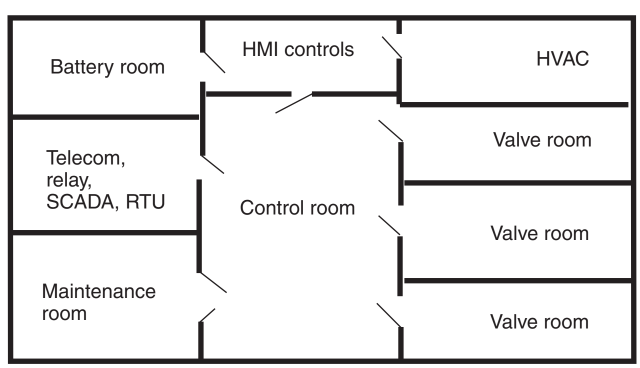


FIGURE 18.3.1 Typical Fire Area Separation for Converter Stations.

18.4 Risk Considerations.

Δ **18.4.1** This section identifies fire hazards that are associated with the operation of HVDC and AC converter stations, SVC/SVG facilities, and VFTs. Conditions that could cause a fire in high-voltage equipment include the following:

(1) Loose electrical connections
(2) Electrical insulation or resistance breakdowns
(3) Overheated components
(4) Water leakage or intrusion (e.g., cooling system malfunction, roof leak)
(5) Foreign objects (e.g., tools, metal scrap, rubbish, vermin)

18.4.2 The hazards that could present a fire risk at converter stations include the following:

(1) Converter valve assemblies
(2) Valve base electronics and thyristor fault monitoring controls
(3) Thyristor switched capacitors (TSC) control equipment
(4) Thyristor controlled reactor (TCR) control equipment
(5) VFT dc drive
(6) Oil-filled wall bushings
(7) Capacitors containing combustible dielectric fluid or polymers
(8) Transformers
(9) Station services and auxiliary high-voltage equipment

18.4.3 Air core reactors should be considered as an alternative to oil-filled reactors to eliminate the fire risk associated with oil-filled equipment.

•

18.5 Hazard Protection.

Δ **18.5.1** Periodic cleaning of the valve and the valve hall structure should be performed in accordance with the manufacturer's instructions for maintaining clean equipment and a clean building environment.

•

18.5.2 Oil-filled wall bushings should be protected with automatic fire suppression system(s). The fire suppression system design should ensure that the fire suppression agent does not affect the converter valve, the arresters, or other energized electrical equipment.

18.5.3 Dry-type ac/dc wall bushings, which do not necessitate fire detection or suppression systems, should be considered to eliminate the fire risk associated with oil-filled equipment.

•

18.5.4* The valve hall should be provided with a very early warning fire detection (VEWFD) system. Consideration should also be given to providing a second reliable fire detection system such as ionization, photoelectric, projected beam, flame detection, or video cameras. The interlock of VEWFD and the redundant fire detection system should be considered to initiate a fast-switch-off or emergency-switch-off of the respective valve group, TSC valves and TCR valves.

18.5.5 For the protection of the converter station equipment and the building, water-based or gaseous agent suppression systems should be considered. The type and design of the suppression systems should be reviewed in consultation with the equipment manufacturer.

•

N Chapter 19 Flywheel Energy Systems

N 19.1 General.

N **19.1.1*** Chapter 19 identifies fire and explosion hazards of flywheel energy systems and associated equipment and specifies recommended protection criteria.

N **19.1.2** The emphasis of this guideline is on prevention of fire by design with the addition of fire suppression equipment to be guided by the Fire Protection Design Basis Document as well as a cost-benefit analysis to determine the extent to which fire protection is justified.

N **19.2 Application of Chapters 4 Through 10.** The recommendations contained in Chapters 4 through 10 can apply to flywheel energy system facilities. The Fire Protection Design Basis Document should determine which recommendations apply to any specific flywheel energy system or facility. This determination is done by evaluating the specific hazards that exist in the facility and evaluating the level of acceptable risk for the facility. For flywheel energy facilities, it is expected that most of the recommendations will apply, although there could be particular flywheel energy systems and output circuit designs for which some of the recommendations will not apply since the hazards described might not exist (e.g., no transformer in the flywheel systems).

N 19.3* Design and Equipment Arrangement.

N **19.3.1*** Site-specific considerations or a manufacturer's typical layout should govern flywheel energy system facility design. This should include the flywheel energy system design and containment system, power output, and load control circuitry. This should dictate how many separate structures or enclosures will be provided.

N **19.3.2** Flywheel energy systems should be provided with a means for containment of the rotating mass to prevent access to the rotating parts and to contain debris that might result from abnormal operating conditions.

N **19.3.3** Special-purpose electrical heaters can be used in flywheel energy systems to provide for oil sump and space heating. These heaters should be listed for the type of use for which they are employed.

N **19.3.4*** The rotor housing should be designed to isolate any potential sparks from combustible equipment components and locations where leaked combustible fluids can accumulate.

N **19.3.5** Particular care should be practiced with respect to spatial separation and protection from wildland fires as well as the control of vegetation where flywheel energy systems and associated equipment might be located. Guidance regarding vegetation clearance, separation distance, and emergency planning can be found in NFPA 1143 and 1144.

N 19.4 Risk Consideration.

N **19.4.1** Adequate separation should be provided between the following, as determined by the Fire Protection Design Basis Document:

(1) Adjacent flywheel energy units consistent with land and wind topography constraints
(2) Adjacent structures or exposures, including transformers
(3) Adjacent properties (e.g., aboveground pipelines, tank farms, or natural gas facilities that could present a severe exposure)

N **19.4.2** In the event of a problem with a flywheel energy system, automatic shutdowns or idling to bring the system to a safe state should be provided that result in slowing/stopping of shaft rotation and/or isolation of electrical power to or from the motor/generator as dependent on the system design. Different methods of equipment shutdown and isolation, operating independently, should be provided. These can include speed control as well as power isolation in concert with electronic control termination.

N **19.4.3** Vacuum or inert gas systems employed to lower friction losses of rotating parts as well as cooling systems to prevent overheating of the flywheel motor/generators and their power converters should be monitored and produce an orderly shutdown (i.e., spin down of the rotor) should these systems not be operating properly or fail.

N **19.4.4** Determination of the need for fire detection/suppression and associated flywheel energy system safe shutdown sequence for flywheel energy system facilities should be based on the facility design and layout, including specific equipment and components used in producing power within the facility. The approach can vary also depending on whether the flywheel energy system is located outdoors or indoors. This should be addressed in the Fire Protection Design Basis Document with regard to the flywheel energy units as well as power delivery and control circuits. In addition, consideration should be given to the consequences of failure of a flywheel energy unit or multiple units as well as the vulnerability of adjacent structures and equipment to damage.

N **19.4.4.1** If the Fire Protection Design Basis Document indicated in Chapter 4 determines a need for a fire detection system(s), the system(s) should be arranged to activate alarms at a constantly attended location or via the provision of remote operator circuits. This applies to flywheel energy units, electrical equipment enclosures, and buildings.

N **19.4.4.2** For remote location of flywheel energy facilities where there is a lack of abundant water supplies, the use of water-based fire protection systems is unlikely. If the design of a particular facility does, however, permit the use of water suppression systems, these systems should follow the general recommendations in Chapter 7. If the Fire Protection Design Basis Document indicates a need for fire-fighting capability using water, NFPA 1142 should be consulted.

N **19.5 Hazard Protection.**

N **19.5.1** In general, the principles outlined in NFPA 30 should be applied to gearboxes and lubricating or coolant oil sumps, pumps, coolers, filters, and associated piping. As a minimum, piping systems supplying flammable and combustible liquids should be designed to minimize hydraulic and lubricating oil piping failures as follows:

(1) If rigid metal piping is used, it should be designed with freedom to deflect with the gearbox, in any direction, at the interface with the gearbox. This recommendation also should apply to hydraulic lines that are connected to accessory gearboxes or actuators mounted directly in the nacelle. Properly designed metallic hose is an alternative for hydraulic and lube oil lines in high vibration areas to allow relative motion between rigid pipe supply lines and manifolds and at the points of entry at the gearbox and system interfaces.
(2) Rigid piping connected directly to the gearbox should be supported such that failures will not occur due to the natural frequency of the piping coinciding with the rotational speed of the gearbox, drive shaft and hub, and flywheel energy system. Care should be taken in the design of pipe supports to avoid vibrations induced by other equipment that can excite its natural frequency.
(3) Welded pipe joints are preferred. Threaded couplings and flange bolts in oil piping should be assembled using a torque wrench and torqued to the manufacturer's requirements. Threaded fittings should have a positive locking device to prevent unscrewing.
(4) Instrumentation tubing, piping, and gauges should be protected from accidental mechanical damage. Sight glasses should be listed.
(5) Lubricating oil lines should use "guarded" pipe construction with the pressure feed line located inside the return line. Where guarded pipe construction is not used, piping sleeves should be used to reduce the possibility of oil atomization. All mechanical connections should be guarded.
(6) Containment and drainage should be provided so as to minimize the spread of oil within the flywheel energy system or externally, which poses a risk to equipment.
(7) All fluid piping should be routed below all electrical equipment to preclude leaked fluid dripping on the equipment.

N **19.5.2*** Flywheel energy systems are to be provided with a means of containment for the rotating portion of the system to prevent exposure to sparks, projectiles, and so forth, in the event of a mechanical failure of the rotor and/or bearing assembly. In addition, the analysis of the flywheel system should document that the rotor assembly has a sufficient margin of safety factor between the strength of the rotor assembly design and the stresses to the system that occur under maximum normal operating conditions.

N **19.5.3** For flywheel energy systems, monitors and/or trip functions should be provided to monitor and control the operation of flywheel energy systems safely and initiate a safe state (e.g., spin down, idling condition) dependent on the system design, for abnormal operating conditions or parameters as noted in the following list:

(1) Grid disturbance
(2) Abnormal condition (e.g., locking up, breakage, bearing damage) of rotor and/or bearings
(3) Abnormal vibration
(4) Loss of vacuum
(5) Loss of cooling
(6) Overheating of rotor assembly
(7) Overspeed
(8) Temperature faults (of critical components)
(9) Loss of/faulted magnetic field for magnetic bearings
(10) Oil condition (gearbox/lubrication and hydraulic)
(11) Motor-generator protection
(12) Loss of communication between flywheel energy units of a system or with control center
(13) Battery status
(14) Activation of smoke or heat detectors or sensors detecting abnormal conditions within the flywheel energy system

N **19.5.4** Electrical power delivery and control systems as well as communications systems, including cabling, wiring, insulation, fans/motors, and cabinetry, should meet the applicable industry design standards for the use intended and duty cycle specified. Such standards should be applied to systems within the flywheel energy unit as well as those associated with moving power from the flywheel energy units to the grid. As such, this includes power cables and lines, transformers, and power conditioning systems and/or components. Electrical equipment faults are the most likely source of ignition for combustible materials. Electrical equipment should consist of listed arc-resistant switchgear.

N **19.5.5** Materials of construction should be noncombustible whenever possible. Such principles should be applied to flywheel energy unit enclosures, O&M/control buildings, and other support structures such as relay houses, switchyard control buildings, and power conditioning buildings.

N Chapter 20 Compressed Air Energy Storage (CAES)

N **20.1 General.**

N **20.1.1** Chapter 20 identifies fire and explosion hazards of compressed air energy storage (CAES) systems and associated equipment and specifies recommended protection criteria.

N **20.1.2** CAES systems are power generation systems that store compressed air in large reservoirs, typically underground caverns such as salt domes, and use the compressed air as an energy source to drive a turbine-generator to produce power for peaking purposes.

N **20.1.2.1** The generator is typically a dual function motor-generator unit that can be reversed to drive the compressors during the nonpeak power periods and then returned to the generator mode to produce power when using the compressed air to drive the turbine unit.

N **20.1.2.2** During operation the compressed air is released from the reservoir where the air temperature is increased by heat exchangers and fuel-fired heaters.

N **20.2 Application of Chapters 4 Through 10.** The recommendations contained in Chapters 4 through 10 can apply to CAES system facilities. The Fire Protection Design Basis Document should determine which recommendations apply to any specific CAES system facility. This determination is done by evaluating the specific hazards that exist in the facility and evaluating the level of acceptable risk for the facility. For CAES system facilities, it is expected that most of these recommendations will apply.

N **20.3 Design and Equipment Arrangement.** Site-specific considerations or a manufacturer's typical layout will govern CAES system facility design. If on-site heaters are used to heat the air prior to compression, there are other considerations that might need to be addressed based on how the air is heated. If fuel-fired heaters are used, other NFPA codes and standards relative to the fuel used should apply.

N **20.4 Risk Consideration.** Adequate separation and containment should be provided as determined by the Fire Protection Design Basis Document. Areas that should be addressed include the following:

(1) Flammable and combustible liquids storage and containment
(2) Adjacent structures or exposures, including transformers
(3) Adjacent properties, including aboveground pipelines, tank farms, other generation units or natural gas, or other fuel facilities that could present an exposure hazard

N **20.5 Hazard Protection.**

N **20.5.1** The need for automatic fixed fire protection within a CAES unit should be based on the Fire Protection Design Basis Document. Areas recommended for fire suppression and/or detection systems include the following:

(1) Rotating equipment lubricating oil systems above and below the operating floor
(2) Lubricating oil storage tanks or room enclosures with oil storage tanks
(3) Motor/generator or turbine bearings
(4) Hydraulic control systems
(5) Control, computer, and communications rooms
(6) Cable spreading rooms and cable tunnels
(7) Grouped electrical cables — cable trays
(8) Switchgear and relay rooms
(9) Battery rooms
(10) Maintenance equipment shop
(11) Warehouse storage locations

N **20.5.2** Discharge rates and duration should be such that cooling and shutdown occur to prevent re-ignition of the fire. Densities should be in accordance with Chapter 7.

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.

N **A.3.3.29 Spin Down.** A complete stop of the flywheel rotor cannot occur instantaneously because of the high kinetic energy of the rotor, but rather occurs over time due to a gradual slowdown to a stop as a result of friction forces acting on the rotor.

N **A.4.3.2 Fire Protection Operation.** With few exceptions, fire protection systems should be automatically actuated to ensure prompt operation. Manually activated systems could cause delays in response times unacceptable for most hazards.

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.

Unattended Facilities. Facilities that are operated unattended present special fire protection concerns.

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 to a fire condition.

The Fire Protection Design Basis Document should address delayed response and lack of communication. This analysis can establish the need to provide additional fire protection measures to prevent a major fire spread prior to the arrival of fire-fighting personnel.

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 unattended plant.

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 coordinating effort should be reflected in the plant fire emergency plan. *(See Section 5.4.)*

A.5.4.1.2 Inspection intervals for unattended plants can be permitted to be extended to normal plant inspections.

A.5.4.4 Emergency conditions can warrant that breathing apparatus be readily available in the control room. Self-contained breathing apparatus should be considered for activities outside the control room.

A.5.4.5.3 Recommendations contained in NFPA 600 and 29 CFR 1910, Subparts E and L should be consulted for additional information.

N **A.5.4.6** Power generation plants with unique hazards, such as IGCC, and binary geothermal plants require special response considerations and training for personnel expected to respond. The Fire Protection Design Basis Document can establish the need to provide additional fire protection measures to prevent a major fire spread prior to the arrival of fire-fighting personnel.

It is important that the responding fire brigade and public fire department be familiar with access to and movement around the facility site and specific hazards with respect to the gasification plant and its support systems as well as the power plant. This coordinating effort is essential and should be reflected in the plant's fire emergency plan.

N **A.5.4.6.7** NFPA 652 should be consulted for appropriate fuel handling and hazard management practices. Also refer to 9.5.2.2 and 9.5.2.3 for appropriate fire prevention practices.

A.6.1.1.3 Where the control room and computer room are separated by a common wall, the wall need not have a fire resistance rating. Consideration should be given to equipment layout that is adjacent to and in line with the planes of turbine and compressor disks or other rotating equipment that have a higher potential for damage from flying debris.

A.6.1.2.1 Listed penetration seals for large diameter piping might not be commercially available. In such instances the design should be similar to listed configurations.

Listed penetration seals for the internals of nonsegregated phase bus ducts and isolated phase bus ducts can be excluded.

A.6.1.4.2(9) Oil-filled transformer explosions and fires can be prevented in some cases by the installation of a passive mechanical system designed to depressurize the transformer a few milliseconds after the occurrence of an electrical fault. An example is provided in D.2.14. This fast depressurization can be achieved by a quick oil evacuation triggered by the transient pressure peak generated by the short circuit. The protection technology activates within milliseconds before static pressure increases, therefore preventing transformer explosion and subsequent fire. However, because these devices do not eliminate a fire potential resulting from all forms of transformer failure (e.g., transformer bushing failure), they should be considered as a possible supplement to passive protection features such as physical barriers or spatial separation, not as an alternative to these features. The systems can include outflow devices that are located directly on the high-risk areas of the bushing turrets and oil-bushing cable boxes.

A.6.1.4.3 As a minimum, the firewall should extend at least 1 ft (0.31 m) above the top of the transformer casing and oil conservator tank and at least the width of the transformer oil containment. If columns supporting the turbine building roof at the exterior wall have a 2-hour fire-resistive rating above the operating floor, the firewall need not be higher than required to obtain line-of-sight protection to the height of the operating floor.

A.6.1.4.5 A higher noncombustible shield can be permitted to be provided to protect against the effects of an exploding transformer bushing.

A.6.1.5.2 Where multiple transformers of less than 100 gal (379 L) capacity each are located within close proximity, additional fire protection can be required based on the Fire Protection Design Basis Document.

For wind turbines, transformers are used to step-up the electrical power generated by the generator in the nacelle. These transformers can be located in the nacelle, in the tower, or on pads near the base of the tower. The plant design should include features that address the exposures posed by such transformers and, if the transformers are not dry type or filled with a listed less flammable fluid insulating oil, should take into account transformer location; containment of oil; spacing from other objects, including the tower; and the use of barriers and fixed protection. The same principles should be applied to the step-up transformers used to connect a wind farm to the grid.

The step-up transformer installations should reflect a proper evaluation of the exposure created with respect to other transformers as well as wind farm support structures. Appropriate physical separation should be observed, or barrier walls should be erected, where necessary, to control such exposures.

N **A.6.1.6** The following objectives should be considered during new site selection or existing site analysis. Decisions made should be documented in the Fire Protection Design Basis Document.

(1) External exposure
(2) Site grading
(3) Prevailing winds
(4) Availability of water supplies for fire-fighting
(5) Emergency access to the substation
(6) Fire emergency response capability
(7) Environmental considerations
(8) Equipment separation
(9) Oil containment

Δ **A.6.2.2** It generally is recognized that boiler and turbine buildings, protected in accordance with this document, meet the intent of NFPA *101* for additional travel distances for fully sprinklered facilities.

NFPA *101* 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)*. Examples of these spaces include catwalks, floor areas, or elevated platforms that are provided for maintenance and inspection of in-place equipment.

Spaces internal to equipment and machinery are excluded from the requirements of NFPA *101.* Examples of these spaces include, but are not limited to, the internals of the following:

(1) Boilers
(2) Scrubbers
(3) Pulverizers
(4) Combustion turbine enclosures
(5) Cooling towers
(6) Bunkers, silos, and hoppers
(7) Conveyor pulley take-up areas
(8) Electrostatic precipitators

Examples of these spaces within hydroelectric plants include the following:

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

N **A.6.4.1** Smoke or heat vents should be considered in accordance with 6.4.1 in areas such as the tipping/receiving floor, or in fuel storage areas.

A.6.4.1.1.4 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.6.4.1.3.2 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.6.5.1 For hydroelectric plants, 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.6.5.1.1 Design discharge for the turbine building should be based on the expected time necessary to take the turbine off line and put it on turning gear, but not less than 10 minutes. The provisions are 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.

A.7.2.1 While the use of fire protection systems can be an effective way of cleaning, it is strongly discouraged. The water supply for this non–fire protection activity should be supplied from a separate service water system. Where this separate supply is not available, special considerations should be made prior to using fire protection water for this non–fire demand, including separate pumps.

Operational procedures should be in place to prevent depletion of the dedicated fire protection water supply by incidental water usage for non–fire protection purposes. Procedures should terminate all incidental water usage for non–fire protection purposes upon receipt of a fire alarm.

A.7.2.2 A single water source could be designed to provide an acceptable level of reliability for the fire protection system(s). As an example, a single reliable water source could supply the fire pump(s). The need for multiple or a secondary water source is dependent on several factors and a detailed analysis of the facility, and the level of reliability needed should be part of the Fire Protection Design Basis Document.

The detailed analysis of the water supply reliability needed should include, but not be limited to, the following:

(1) Reliability of source — under normal circumstances, not including a regional event, the water source is expected to operate as designed.
(2) Capacity of source — meets all requirements pertinent to the applicable codes and standards for fixed fire protection and manual fire-fighting.
(3) Reliance on water-based fire protection systems — if the facility relies completely on water-based fixed protection systems, then the water supply reliability is paramount to the success of the overall fire protection system design. A single, credible impairment should not eliminate the water supply from the fire protection system.
(4) Availability of alternate and back-up sources — additional water sources such as connections to the public water supply, cooling tower basins, service water tanks, on-site reservoirs or ponds available for fire department pumper suction — should be available.
(5) Consequences of a loss, in terms of property and generation — this can include the size of a facility from a values standpoint (values at risk) or amount of generation at risk in an owner's generation scheme.

A.7.2.2.1 Hydroelectric, wind, and solar generating plants are commonly located in remote areas and require special consideration with respect to water supplies and their usefulness as follows:

(1) Hydroelectric plants are typically located 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.
(2) Upstream water is frequently the fire protection water supply for hydroelectric facilities. Water for fire suppression should not be taken downstream from any closure device in a penstock, flume, or forebay.

A.7.6.2 Proper gaseous extinguishing system design dictates that the design concentration be held in the compartment for the cooling time necessary to ensure that all exposed surfaces are below the AIT of combustibles within the protected space. Aeroderivative units have a rapid cooldown time due to their lightweight casings. Conversely, the soak time for larger turbines, which can have rundown times exceeding 20 minutes, requires an appropriately selected concentration hold time to ensure that risk of re-igniting is mitigated. It also has been shown that the initial gas discharge will not hold for the cooldown time period in most turbine or engine compartments. Therefore, the designer should determine the extended discharge rate needed to maintain agent concentration. This usually requires discharge testing to determine if design concentrations can be maintained. Where gas concentrations cannot be effectively maintained, an alternative system, such as a high-expansion foam or water extinguishing system, can be desirable.

N **A.7.6.3(6)** If an automatic foam system is provided for the fuel storage tanks, the system should automatically shut down when the foam concentrate supply is exhausted. If automatic water-based fire suppression systems are utilized, a cycling deluge valve should be considered.

A.7.6.5.1(2) Emergency power generation for facilities such as hospitals is provided for life safety of persons who might be nonambulatory. In such situations, the need to provide an uninterrupted power supply for essential services outweighs the desire to minimize damage to the unit and immediately adjacent facilities.

A.7.6.6 Fires involving only surface burning materials can often be extinguished during the gas discharge period. However, where surface temperatures of exposed equipment or installed components remain above the ignition temperature of combustibles present beyond the end of the gas discharge period, and/or where the protected enclosure is not tightly sealed, it is necessary to consider this in the design of the protection system. The common solution is by the addition of an extended gas discharge system to supplement the initial gas flooding system.

The system designer requires, for each type of installation, information on length of time required for "hot" components to cool after shutdown, plus information on gas loss rate from the enclosure.

This information is often obtained by testing prototype units. The information is the start of the proposed gas system design but does not guarantee that a particular system of that type does not have greater gas loss potential. *(See 4.4.3.3.1.4 of NFPA 12, which requires an inspection of each unit that could reveal gas loss points not originally considered.)*

Recognizing this, NFPA 12 requires a full discharge test for each CO_2 system *(see 4.3.3.4.1)* before being placed in service.

Prudent gas system designs anticipate that over a span of time, an enclosure is likely to develop more leakage points, thus making a system designed without any factor of safety potentially prone to failure in the event of a system discharge years after the original installation. Some systems require inspection of storage and components after a number of years. These often require depressurization of the CO_2 supply. This can be an excellent opportunity to discharge the system as a "test," checking that the system still performs as originally designed.

Additionally, during major outages (such as when the casing is removed) both the enclosure and the suppression piping system will typically undergo some degree of disassembly. After reassembly, functional testing is essential to ensure the system will operate as designed.

Only a full discharge test will ensure that adequate concentration is achieved and maintained after maintenance. Alternatively, "door fan" testing of an enclosure can be used to verify the tightness of a protected enclosure following enclosure maintenance if a baseline door fan test was conducted when the original concentration test was performed. A door fan test does not verify the suppression system integrity; a functional test is needed for that verification. However, most turbine and engine enclosures are not set up for functional testing. In addition, the amount of potential loss openings can be identified in this way, but not necessarily the location of the openings. Location of gas loss points as important as their size in enclosures protected with gas flooding systems.

It is important that documentation of the amount of gas loss that has been designed into the system and how that has become a part of the design be retained so there is a basis for determining the adequacy of the system after years of service.

A.7.7.3(2) Special consideration should be given to alerting personnel in remote spaces, such as in scroll/spiral cases or draft tubes.

A.8.7.3 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.8.8.1 Mobile fire-fighting equipment can be utilized to provide necessary first aid fire-fighting equipment.

A.9.2.1 The size and complexity of the power-generating facility site will determine what, if any, control enclosures are provided. Control enclosures are typically used for power conditioning and grid stability equipment and are designed to be unattended. This type of enclosure contains control panels, switchgear, batteries, relays, rectifiers, and electronic switching circuits. Auxiliary electrical equipment enclosures, where provided, might contain excitation equipment, switchgear, current transformers, potential transformers, grounding transformers, and other electrical equipment.

NFPA 54 provides guidance for the design, installation, and testing of applications operating at pressures less than gauge pressure of 125 psi and should be considered a good reference for these types of applications in power generating facilities (for example: hot water heaters, space heaters, cooking applications, auxiliary boilers, and emergency generators). NFPA 54 specifically excludes piping in electric utility power plants that supplies gas utilized directly as the fuel to generate electricity. These systems typically operate at pressures greater than gauge pressure of 125 psi, which are covered by NFPA 56.

N **A.9.2.4** For gas piping less than or equal to 125 psi refer to NFPA 54.

A.9.2.5 It is recommended that oxidants such as air within a flammable gas system be diluted by a nonreactive (inert) gas such as nitrogen, carbon dioxide, or argon to low concentrations so that when a flammable gas is introduced, an ignitable mixture is not created within the system. This is known as *purging into service*. The reverse is also true: dilute the fuel before adding air, which is known as *purging out of service*.

Flammability ranges for various fuels are noted as part of Table 4.4.2 of NFPA 497. While this table addresses fire hazards, if the nonreactive gas is an asphyxiant, proper cautions are to be followed. Chapters 7 and 8 of NFPA 56 outline best practices for purging into service and purging out of service, respectively, to include the best practice for discharging the contents of the system during the purging operations.

Other considerations such as activity planning and fire protection DBD are provided in Chapter 4 of NFPA 56. Additionally, consideration must be given to any toxic hazards associated with the flammable gas (e.g., flammable gas mixtures that contain toxic constituents such as carbon monoxide or hydrogen sulfide). NFPA 55 contains guidance for how to handle these situations.

A.9.2.6 Maintenance, modification, and repair of fuel gas piping should be performed using written procedures developed with full recognition of the hazards involved in the intended operation. Chapter 4 of NFPA 56 provides an outline of considerations to include in assessing the risks associated with flammable gas piping when planning for maintenance modification or repair. Chapters 7 and 8 of NFPA 56 provide specific guidance for the actual removal or induction of flammable gas. NFPA 55 provides additional guidance for gases that have toxic constituents.

A.9.5.1.2 The fuels most susceptible to self-heating are those with high pyritic content and high intrinsic moisture and oxygen content, such as municipal solid waste (MSW), wood chips, and low-rank coals. The mixing of high pyritic coals with high moisture and oxygen coals increases self-heating.

The Powder River Basin (PRB) of Montana and Wyoming has the largest reserves of low-sulfur coal in the United States (76 percent). Coal from PRB is sub-bituminous coal, which has gained popularity as an alternative to expensive scrubbers required to meet emissions standards when burning high-sulfur coal. Sub-bituminous coal has one-half to one-sixth the sulfur content of most other coals.

Sub-bituminous coal presents fire protection challenges due to spontaneous heating characteristics. Also, sub-bituminous coal is extremely friable, which contributes to higher levels of dusting and spillage. Housekeeping, preplanning, coal handling equipment design, and fire protection system design are integral components to minimizing the risks associated with a sub-bituminous coal fire. Table A.9.5.1.2 is a representative, proximate analysis of sub-bituminous coals.

A.9.5.1.5 For additional guidance on cranes and storage pits, refer to 14.4.3.

•

A.9.5.2.1 *Spontaneous Heating.* The chemical properties of coals that effect spontaneous combustion are oxygen content, moisture, impurities (especially sulfur in the form of pyrites), and volatiles. The physical properties are particle size and friability.

Δ **Table A.9.5.1.2 Proximate Analysis of Sub-Bituminous Coals**

Fixed carbon	32.0%–40.00%
Volatile matter	27.70%–32.66%
Moisture	23.80%–31.80%
Ash	3.80%–8.45%
Sodium as a percentage of ash	0.32%–7.50%
Sulfur	0.20%–0.80%
Btu/lb	8050–9500
Size	Nominal 2 in. × 0 in.
Ash fusion temperature/reducing atmosphere:	
Initial,°F	2050°F–2268°F
Initial,°C	1121°C–1242°C
Fluid,°F	2142°F–2348°F
Fluid,°C	1172°C–1287°C

Source: Guide to Coal Mines, Burlington Northern and Santa Fe Railway, courtesy PRB Coal Users' Group.

Spontaneous heating occurs due to oxidation of freshly exposed coal surfaces. For spontaneous heating to lead to ignition, sufficient air must be present and in contact with fresh (unoxidized) surfaces, yet without sufficient air movement to dissipate heat generated by oxidation. The oxidation rate of coal at ambient temperatures is determined by its rank, its exposed surface area, and the percentage of free oxygen in the atmosphere permeating the coal. Coal of low rank (soft coal) will have a higher oxidation rate than harder coal under the same conditions. Likewise, if coal is crushed to a finer particle size, more surface area will be exposed and the oxidation rate will increase. A reduction in free oxygen content in the atmosphere permeating the coal reduces the rate of oxidation (almost proportionately). Oxidation will continue at a reduced rate until the free oxygen is exhausted. Heat produced by spontaneous combustion will be absorbed by the coal, resulting in an increase in coal temperature. Due to the chimney effect, air infiltration leakage might be expected around the discharge valve or other bottom leaks of silos and bunkers or in the top 5 ft to 6 ft (1.5 m to 1.8 m) of the coal in the bunker. Therefore "hot spots" will tend to develop in the lower and upper portions of the coal in the silo and near any seams or openings that allow air infiltration. Inerting the coal with carbon dioxide or nitrogen and covering the top of the bunker to prevent air to cause spontaneous ignition is a common practice for forced and extended outage with coal in the bunker. As the coal temperature increases, the rate of oxidation will also increase. Due to the range and number of variables it is difficult to define the time to ignition of coal in storage.

Spontaneous heating can be mitigated by minimizing wetting of the coal, the duration of storage of the coal, and air movement in the silo.

Various designs can be used for piercing rod access ports for delivery of fire-fighting agents with water. A minimum 4 in. (10.16 cm) diameter access port is recommended to facilitate insertion of the piercing rod. One such design is a 4 in. (10.16 cm) flanged connection with a blind flange. The interior of the access port should be filled with expanded foam (flush with the interior silo surface) to prevent coal from collecting in the access port. When use of a given access port is required, the foam is removed from the outside to allow insertion of the piercing rod. Platform space should be provided at access port locations as required to assemble the piercing rod in 5 ft (1.5 m) sections and to operate the hand line and eductor equipment.

A.9.5.2.2 *Silo Construction.* If the plant is designed to burn a type of coal that is considered prone to spontaneous combustion or one that has a high percentage of "volatiles," silos should be cylindrical with conical hoppers. The coal's angle of repose should be considered when designing the internal slope of the silo and hopper so that coal will flow freely (normally 60 degrees from the horizontal will be sufficient) to avoid arching and voiding. Air cannons located at the throat of the silo can be used to ensure that coal continues to flow. However, caution is necessary to ensure that air cannons are not utilized during a fire or where low coal levels could result in suspended coal dust entering the explosive range.

Experience indicates that low-sulfur Powder River Basin (PRB) coal is highly susceptible to spontaneous heating. For other coal types, experience indicates that coal volatility content above 38 percent might be conducive to spontaneous heating. The designer might consider inerting the silo if the volatiles content of the coal exceeds 38 percent or if PRB coal is used. Where the coal used has known spontaneous heating problems, special conveyors and chutes or pans can be provided to unload silos during forced outages.

A.9.5.2.3 *Silo Operations and Maintenance.* Where possible, coal silos should be operated at full capacity and coal should flow continuously. When silos are not operated at or near full volume, spontaneous combustion can occur at an increased rate.

Dependent on bin, bunker, or silo construction, the internal space might allow the buildup of coal on its walls. Removing the coal from the bin, bunker, or silo wall can be employed to minimize the risk of spontaneous combustion of the trapped coal.

During planned maintenance outages, silos should be emptied and thoroughly cleaned of coal deposits. Operating procedures should ensure that magnetic separators are in service when coal is being conveyed into the silo, to avoid introducing tramp metals. Movement of tramp metal within the silo can result in an ignition source by striking metal parts, causing sparks that might ignite coal dust.

Three fires involving coal silos at one operating electric generating station occurred at or near cracks in the bottom cone of the silo. During maintenance outages the cones should be thoroughly inspected for cracks.

A.9.5.2.4 These conditions should be monitored periodically. Monitoring can be performed at the top of the silo to monitor methane gas and carbon monoxide concentrations.

Flammable gas monitors should be arranged to alert plant operators if methane concentrations are detected or exceed 25 percent of the LEL.

Increased carbon monoxide levels can give an early indication of a hot spot or silo fire. Some experience in this area indicates that the carbon monoxide levels could rise days before fires are detected by other means. Acceptable carbon monoxide levels should be determined by plant personnel based on trends for various normal operating modes. Daily carbon monoxide samples should be taken at the top of each silo to establish a benchmark carbon monoxide level. Silos should be run empty and inspected if the carbon monoxide levels exceed twice the benchmark concentration.

Portable infrared heat detection or thermography has proven useful in locating hot spots. Typical hot spots are easily detected when they are in the size range of 2 ft (0.6 m) in diameter. Hot spots in the center and higher up might not be found until the hot spot enters the cone area as the coal level drops. Thermocouples can also be inserted to detect temperature increase due to spontaneous combustion. A long thermocouple [i.e., 10 ft (3 m)] connected to a portable instantaneous readout monitor can be employed. Pushing the thermocouple into the coal storage can detect developing hot areas or strata at different depths. Periodic monitoring of temperature change in these areas will help predict spontaneous combustion development and aid in response preplanning.

A.9.5.2.6 All signs of spontaneous combustion and fire must be eliminated prior to the movement of coal.

Manual Fire Suppression. Fire fighting in coal silos is a long and difficult activity. Some fire-fighting operations have taken several days to completely extinguish a fire.

Smoldering coal in a coal bin, bunker, or silo is a potentially dangerous situation that depends on the location of the smoldering coal. There is a risk of a flash fire or explosion if the smoldering coal is disturbed. This risk should be considered in preplanning. Personnel responding to a coal fire should have proper personal protective equipment, including SCBA and turnout gear, and training in this hazard.

The area surrounding the smoldering coal should also be considered. The potential of developing an immediately dangerous to life and health (IDLH) atmosphere is possible. This should also be considered in preplanning.

Depending on the strategy selected, resource demands will be varied but challenging. Prefire planning is an important element in successful silo fire control and should be included in the Fire Protection Design Basis Document *(see Chapter 4)* and the fire emergency plan *(see 5.4.4)*. Control room operators should be involved with the preplanning.

Use of Water Additives. Use of water additives has been successful in recent years, especially for sub-bituminous coal fires. Application of water additives is the preferred fire suppression method of the PRB Coal Users' Group for bunker, hopper, and silo fire protection *(see the PRB Coal Users' Group Recommended Practice, Coal Bunker, Hopper & Silo Fire Protection Guidelines)*.

Baseline guides and procedures for preplanning and applying water additives to these fires are included in the PRB Coal Users' Group document. These guides and procedures can be used as a starting point by the owner's structural fire brigade and local fire department to customize the approach for the specific facility. These fire-fighting activities are inherently dangerous and should not be performed by incipient fire brigades or other personnel. The document is available to members of the PRB Coal Users' Group online at www.prbcoals.com.

The application of water additives can be enhanced by using an infrared camera to search for hot spots, either on the sides or top of the silo, to facilitate injection as close as possible to the fire area. The infrared imagery can be used to evaluate performance and monitor progress of the attack. The solution must penetrate to the seat of combustion to be effective. This penetration can be affected by the degree of compaction, voids, rate of application, evaporation rate, and so forth. Runoff must be drained through feeder pipe and will require collection, cleanup, and disposal.

Use of Class A Foams and Penetrants. Use of Class A foams and penetrants has had some success, but it has been difficult to predict the resources required for successful fire control. The agents generally require mixing with water prior to application, usually in the range of 1 percent by volume, mixed in a manner similar to Class B agents. While the typical application of Class A foam is to fight wildland fires at 1 percent, many plants have reported success with using Class A foams at 0.1 percent. This causes the agent to act as a surfactant. Higher proportions have caused excessive bubble accumulation that impedes penetration into the coal.

The application of foams and penetrants can be enhanced by using an infrared camera to search for hot spots, either on the sides or top of the silo, to facilitate injection of the agent as close as possible to the fire area. The infrared imagery can be used to evaluate performance and monitor progress of the attack. The water/agent solution must penetrate to the seat of combustion to be effective. This penetration can be affected by the degree of compaction, voids, rate of application, evaporation rate, and so forth. Runoff must be drained through feeder pipe and will require collection, cleanup, and disposal.

Use of Inerting Gas. Carbon dioxide and nitrogen have been used successfully as gaseous inerting systems. Carbon dioxide vapor, with a density of 1.5 times that of air, has proven to be effective in quickly establishing an inert atmosphere in the space above the coal, which prevents the creation of an explosive atmosphere in that space.

At the same time the CO_2 vapor can be injected into the stored coal from the lower part of the silo, where fires are most likely to originate. This CO_2 inerts the voids between the coal pieces while filling the silo from the bottom up with CO_2 vapor. The CO_2 vapor injection rate is that needed to exceed any losses at the bottom of the silo while pushing the inert gas up through the coal at a reasonable rate. (Very tall silos require intermediate injection points for the CO_2 vapor between the top and bottom of the silo.)

Since carbon dioxide is stored as a compressed liquefied gas, it must be vaporized before injection into the silo. External vaporizers are used and sized to handle the maximum anticipated CO_2 vapor flow rates.

It is common practice to monitor the carbon monoxide (CO) level while inerting with CO_2. If the CO level does not decrease, the controls on the CO_2 system are designed to allow for increasing the inerting rate. The flow can also be reduced to conserve the CO_2 supply once fire control has been established.

A large imbedded coal fire provides a heated mass that will be extremely difficult to extinguish with CO_2 alone. It is, however, important that supplemental fire fighting be done in an inert environment. The CO_2 system's primary mission is to prevent the large fire from occurring by detecting the fire early by the CO detectors while it is still small and then inerting to contain and extinguish.

Bulk liquid CO_2 units are generally used, but cylinders can be used for inerting smaller silos. (The bulk CO_2 supply is frequently used for other applications such as pulverizer inerting, generator hydrogen purge, and some fire suppression system applications in the turbine building.) The bulk CO_2 units have the capability of being refilled while they are being used. For the smaller silos, CO_2 vapor is withdrawn from manifolded cylinders without siphon tubes.

Carbon dioxide inerting has a beneficial effect as soon as it reaches the oxidizing coal. As the supporting oxygen level drops, less heat is generated, helping to limit fire spread. But to totally extinguish any large burning coal mass can require a very high CO_2 concentration held for a long time since the cooling capacity of the CO_2 is relatively small and the coal itself tends to retain heat.

The CO_2 system should be considered as a fire prevention/fire containment system. The system can be operated from a dedicated manual release station or by the plant programmable logic controller (PLC) from the control room. Plant personnel need not be involved except to adjust the CO_2 flow rates as needed to manage the inerting or fire suppression.

When carbon dioxide is used, there is a risk of oxygen depletion in the area above, around, or below a silo, bin, or bunker. Areas where gas could collect and deplete oxygen, which might include the tripper room and areas below the discharge feeder gate, should be identified with appropriate barriers and warning signs.

Nitrogen has been used successfully to inert silo fires. It is applied in a manner very similar to carbon dioxide. A notable difference is that nitrogen has about the same density as air (whereas carbon dioxide is significantly more dense). Therefore, it must be applied at numerous injection points around the silo to ensure that it displaces available oxygen, which results in the need for more injection equipment and a larger quantity of agent.

Emptying the Silo. The silo can be unloaded through the feeder pipe, but it is a dirty, messy operation. It is necessary to bypass the feeder belt and to dump the coal onto the floor of the power house at the feeder elevation. A hose crew should be available to extinguish burning coal as it is discharged from the silo. There is a risk that dust raised during this activity can ignite explosively. High-expansion foam can be applied.

Carbon monoxide produced during the combustion process will also tend to settle in the lower elevation and can be a hazard to the hose crew. Once spilled and extinguished, it is usually necessary to shovel the coal into a dump truck for transport back to the coal pile.

Manual Fire-Fighting. Regardless of the type of suppression approach selected, prefire planning is an important element of successful fire control and extinguishment. All necessary resources should be identified and in place prior to beginning fire suppression activities. If necessary materials are not stockpiled on-site, suppliers should be contacted in advance to ensure that equipment and supplies are available on relatively short notice.

The personnel requirements for this fire-fighting activity should be identified in advance. Personnel should be trained and qualified for fire-fighting in the hot, smoky environment that might accompany a silo fire. This training includes the use of self-contained breathing apparatus and personal protective equipment. Personnel engaged in this activity should be minimally trained and equipped to the structural fire brigade level as defined in NFPA 600. If station personnel are not trained in use of self-contained breathing apparatus, it will be necessary for the public fire department to perform fire-fighting in these areas. Station personnel are still needed to assist with operational advice and guidance. The public fire-fighting agency that responds to a fire at the facility should be involved in preplanning fire-fighting activities for silo fires. The public fire service might need specific instruction concerning operation and potential hazards associated with coal silo fires as well as operation in the power plant environment. It is important that the responding fire service be supplied information and guidance at every opportunity.

The resources of the station and the local fire service need to work in concert, including working with control room operators and keeping them apprised of fire control operations. Preplanning should include administrative details such as chain of command, access, and so forth. Operations should be coordinated by an established incident command system in conformance with NFPA 1561. All personnel should be familiar with and practice this system prior to the event.

A.9.5.3 *Coal Dust Hazards.* The hazard of any given coal dust is related to the ease of ignition and the severity of the ensuing explosion. The Bureau of Mines of the U.S. Department of Interior has developed an arbitrary scale, based on small scale tests, that is quite useful for measuring the potential explosion hazard of various coal dusts. The ignition sensitivity is a function of the ignition temperature and the minimum energy of ignition, whereas the explosivity is based on data developed at the Bureau of Mines. The test results are based on a standard Pittsburgh coal dust taken at a concentration of 0.5 oz/ft^3 (0.5 kg/m^3). The explosibility index is the product of ignition sensitivity and explosion severity. This method permits evaluation of relative hazards of various coal dusts.

When coal silos are operated with low inventory there is potential for suspended coal dust to enter the explosive range. As in spontaneous heating, the explosive range and potential for explosion are based on the above variables.

A.9.5.3.1 Constructing enclosure hoods at transfer points can minimize the amount of dust released to surrounding areas, which can reduce the need for dust collection.

A.9.5.3.3 At times when wet coal is being handled, additional dust suppression might not be desired. In these cases, the interlock between the suppression system and the conveyor should be capable of an override to allow moving coal without suppression. Overriding the dust suppression interlock should be considered to be an impairment of the overall fire protection system and should be handled per 5.4.2.

A.9.5.6.2 In many cases, coal conveyors within structures are equipped with dust collection hoods or "skirting," which makes the protection of the top conveyor belt(s) difficult by conventional placement of sprinklers and nozzles. In plants where high pyritic coals are being used, it is recommended that protection be provided inside these hoods as well as all drive pulley enclosures. Care should be taken when installing the sprinklers or nozzles to allow for easy access to these devices for inspection purposes.

Where conveyors are located in enclosed gallery structures, protection for the top belt commonly takes the form of sprinklers or nozzles at the ceiling of the gallery with a second level of protection for the return belt. In this instance, the entire width of the gallery should be included in the design area for the upper level of protection.

If a water spray system is selected for conveyor fire protection, consideration should be given to designing the conveyor structure to support the weight of wetted coal for the entire length of the conveyor.

All conveyors that present an exposure to critical facilities or processes should be considered as "critical to power generation." Fire due to an unprotected conveyor transporting materials into the powerhouse can result in fire that creates unacceptable loss of power generation.

A.9.5.6.5 Water has been successfully used to control dust collector fires. However, the amount of water delivered to a dust collector can create structural support problems for the equipment itself and for the supporting structure or building. The use of fire-fighting additives with water can be highly effective for coal fires, especially sub-bituminous coal fires. This use of fire-fighting additives can typically result in less water being delivered into the dust collector due to the enhanced fire suppression properties of the agent, subsequently shortening the delivery period. A reduction in water can assist in minimizing the potential weight issues.

N **A.9.5.6.5.3(3)** An example of limited access would be collectors that have catwalks for access.

N **A.9.6.1.1** Lubrication and hydraulic oil systems should minimize the amount of oil and the amount of piping and associated components needed.

N **A.9.7.2.1** The size and complexity of the power-generating facility site will determine what, if any, control enclosures are provided. Control enclosures are typically used for power conditioning and grid stability equipment and are designed to be unattended. This type of enclosure contains control panels, switchgear, batteries, relays, rectifiers, and electronic switching circuits. Auxiliary electrical equipment enclosures, where provided, might contain excitation equipment, switchgear, current transformers, potential transformers, grounding transformers, and other electrical equipment.

Δ **A.9.7.8** IEEE 484, *Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*, recommends a minimum ventilation rate of 2 percent for battery rooms. However, NFPA 497 indicates that such areas should be classified if the ventilation rate is not at least 1 percent (25 percent of the lower flammable limit for hydrogen).

A.9.7.9 In recent years some transformers have been designed with relatively high design temperatures. Operation of the cooling fans can release large amounts of heat that can inadvertently trip deluge systems using rate-of-rise or rate-compensated heat detection equipment. To avoid these inadvertent trips, fixed temperature heat detection systems should be used to activate transformer deluge water spray systems.

Δ **A.9.7.10** For information pertaining to fire protection guidelines for substations, see IEEE 979, *Guide for Substation Fire Protection.*

A.10.1.4 Although it is intended that these recommendations are to be applied to fixed, nonresidential ICEs only, larger portable units (often trailer mounted) can include fire detection and suppression systems to limit damage from fire. The recommendations of this chapter can be used as guidance for these units as well.

A.10.3.1.3 In the event of a pipe failure, large amounts of oil or fuel could be released and ignite on contact with hot metal parts. In addition to external fire hazards, CTs are subject to explosions if flameout occurs and the fuel is not shut off immediately, or if fuel is admitted to a hot engine and ignition does not occur. Crankcase explosions in ICEs have caused large external fires.

A.10.3.1.4.1 On some turbine-generators employing the guard pipe principle, the guard piping arrangement terminates under the machine housing where feed and return piping run to pairs of bearings. Such locations are vulnerable to breakage with attendant release of oil in the event of excessive machine vibration and should be protected.

Lubricating oil system designs should reflect a design objective to minimize the amount of oil needed and the amount of piping and associated components necessary.

A.10.3.1.4.2 To avoid water application to hot parts or other water sensitive areas and to provide adequate coverage, designs that incorporate items such as fusible element operated directional spray nozzles can be necessary.

A.10.3.1.4.4 Above the operating floor, ceiling level sprinkler systems might not be effective to protect floor level equipment and components from oil fires because of the high ceilings [typically in excess of 40 ft (12 m)].

A spray fire can blow past conventional automatic sprinkler protection without operating the system and can expose structural steel or critical components of the turbine generator. The concern is that fire exposure to the roof for the rundown time of the turbine could bring down building steel and result in damage to long lead time equipment critical to operation of the turbine or that the fire could directly expose critical equipment such as the generator. Where possible, one of the following protection measures should be used:

(1) *Enclosure of the hazard.* An example would be location within a room of noncombustible construction protected with automatic sprinkler protection.
(2) *Use of a barrier.* A metal barrier could be installed between the hazard and critical equipment or the roof of the building with automatic sprinklers installed under the barrier.
(3) *Water spray protection.* Tests have shown that deluge sprinklers over the hazard can reduce the size of an oil spray fire. The tests were conducted with pendant sprinklers spaced 5 ft × 5 ft (1.5 m × 1.5 m) apart, with an orifice coefficient of K-8.0 (115) and an end head pressure of 50 psi (3.9 bar) located 6 ft (1.8 m) over the hazard. The system should be automatically activated by a listed line type heat detection or flame detection system.

A.10.3.1.4.5 Protein and aqueous film-forming foams (AFFF) are effective in control of flammable liquid pool fires in high bay buildings. FM Global conducted tests for the Air Force at the Test Campus in 1975. Flammable liquid pool fires 900 ft^2 (83.6 m^2) in area were used. Foam was applied from nozzles at ceiling level 60 ft (18.3 m) above the floor. Foam reduced the fire area by 90 percent less than 5 minutes after application started. It is effective on high flashpoint liquid fires such as mineral oil. Tests have also been conducted using foam for the protection of chemical process structures. The tests involved a three-dimensional spill of flammable liquid from a process vessel 20 ft (6.1 m) above the floor onto grade level. The process structure was 40 ft (12.2 m) high. Foam protection was provided at each floor elevation. Foam limited the size of the pool fire but had no effect on the three-dimensional spill fire.

Micelle-encapsulating agents can enhance open head water spray systems for pool fires. Research has been conducted for use of this agent on some hydrocarbon pool fires, although turbine lubricating oil has not been tested. In addition, testing has not been performed for three-dimensional fire scenarios that can occur during a turbine lubricating oil spray fire. See A.9.5.2.6 for additional information on micelle-encapsulating agents.

A.10.3.1.4.7 Internal combustion engines do not normally have any hydraulic systems.

A.10.3.1.5.1 There is limited information available detailing industry experience with fire-resistant fluids as turbine lubrication oils or in seal oil systems. The use of fire-resistant fluids in hydraulic systems is common in the utility industry. Literature is available documenting use of these fluids in Europe. Information detailing operational experience using fire-resistant fluids on lubrication oil systems on turbine-generators in North America is limited.

Utilizing a listed fire-resistant turbine lubricating oil potentially reduces the hazard associated with the lubricating oil system, but the remaining hazards still need to be addressed in determining the appropriate suppression systems and design densities needed in these areas (i.e., grouped cables and other mineral oil–based lubricating systems).

Given the fact that fire-resistant fluid still has the ability to burn, care should be exercised in selecting the fluid. When selecting the fluid, consideration should be given to the fluid's heat release rate, fire point, and ability to sustain a spray or cascading fire once the ignition source is removed. The autoignition temperature of the fluid used should be sufficient to minimize the potential for a fire based on common ignition and heat sources located in the turbine generator area.

•

A.10.3.1.5.8.1 If the lubricating oil reservoir is elevated, sprinkler protection should be extended to protect the area beneath the reservoir.

If the lubricating oil reservoirs and handling equipment are located on the turbine operating floor and not enclosed in a separate fire area, then all areas subject to oil flow or oil accumulation should be protected by an automatic sprinkler or deluge system.

A.10.3.1.6.1 The use of less flammable filter or media in the CT air inlet is recommended where not constrained by other engineering needs (such as pressure loss across the elements) and cost considerations associated with UL 900 Class I (do not contribute fuel) versus Class II fire-resistant elements.

A.10.3.2.3.1 When a flameout occurs, fuel valves should close as rapidly as possible to preclude the accumulation of unburned fuel in the combustion chamber. Loss experience documents that fires or explosions have occurred in systems where the fuel isolation was not achieved within 3 seconds.

A.10.3.3.1 Additional information concerning turbine-generator fire protection can be found in EPRI Research Project 1843-2 report, *Turbine Generator Fire Protection by Sprinkler System.*

In February 1997 the National Institute of Standards and Technology published NIST Report Technical Note 1423, "Analysis of High Bay Hangar Facilities for Fire Detector Sensitivity and Placement." This report provides design recommendations for sprinkler and detection systems (protecting fuel pool fires) at those facilities, which can provide some design guidance if sprinkler systems are installed at the ceiling level of the turbine building.

However, turbine building hazards include pool fires and three-dimensional and spray fires. Without further testing, such systems should not be considered to provide equivalent protection to the turbine building systems recommended in the body of NFPA 850. If used in addition to those recommended systems, a properly designed ceiling level sprinkler system can provide additional protection for the turbine building roof if exposure to a large fire on the operating floor is a concern.

A.10.3.3.1.1 Automatically actuated systems have proven to actuate properly under fire conditions and are not prone to spurious actuation. If a manually operated water system is installed, consideration should be given to a supplemental automatic gaseous fire extinguishing system.

A.10.3.3.1.3 The 2000 edition of NFPA 850 allowed manual operation of bearing protection systems. In most incidents involving bearing oil releases this would be adequate. In some types of release, such as seal oil failures, that might not allow the operator time to activate the system. There are some turbine buildings where the control room is not located in the turbine building, which would also delay response.

If turbine-generator bearings are protected with a manually operated sprinkler system, the following should be provided:

(1) Manual activation should be from the control room or a readily accessible location not exposing the operator to the fire condition. Staffing of plant should be sufficient to promptly handle this function as well as other responsibilities during an emergency of this nature.
(2) Automatic fire detection should be provided over the area of each bearing and within the skirting of the turbine where a potential for oil to pool can alert operators to a fire condition.
(3) Documented procedures should be in place with authorized approval given to operators to activate the system if necessary in a fire condition.
(4) Periodic training should be given to operators regarding the need for prompt operation of the system.

N **A.10.3.5.1** For hydrogen storage systems, see NFPA 2.

A.10.3.5.10 ICE-powered generators are normally provided with an open drip-proof enclosure. Shielding might be needed when a water-based fire protection system is used.

N **A.11.1** Examples of alternative fuels include, but are not limited to, refuse derived fuel (RDF), municipal solid waste (MSW), and biomass.

N **A.11.1.2** Based on plant geometry, combustible loading, and staff size, a 250 gpm (946 L/min) monitor nozzle could be needed in lieu of or in conjunction with hose.

N **A.11.4.2.1** The requirements are based on storage heights not exceeding 20 ft (6.1 m).

The specified density was based on a composition of 34 percent paper, 17 percent food waste, 8 percent plastic and rubber, 10 percent glass, 11 percent metal, 14 percent leaves and grass. Solid pile storage to 20 ft (6.1 m) was used. This resulted in selecting a Class III commodity (.22/3000) for 20 ft. The decision was made to increase the density to .25/3000.

If the mix is different from above, consult NFPA 13.

N **A.11.4.2.2** See NIST Report Technical Note 1423, "Analysis of High Bay Hangar Facilities for Fire Detector Sensitivity and Placement."

N **A.11.5.2.3** An example of the postulated worst-credible-case explosion might be an acetylene tank. Explosions involving detonable material are beyond the scope of this document.

N **A.11.5.3.2** The radiation imaging equipment is superior to methods relying on operators standing beside the conveyor using rakes to identify tanks or other containers of flammable materials. The following factors make this method less than effective:

(1) Speed of conveyor — the faster the conveyor is moving, the less chance operators have to detect tank-shaped objects
(2) Depth of trash on the conveyor
(3) Concealment of tanks in other waste (e.g., a propane tank inside a mattress)

N **A.11.5.4.1** Where a facility has a rigidly enforced operating sequence and satisfies itself and the authority having jurisdiction that the operating practices and the judgment of the plant operators provide acceptable protection, this interlock with the fire protection system could be permitted to be provided through operator action in accordance with operating procedures.

N **A.11.5.4.3** The recommendations in 11.5.4.3 are based on storage heights not exceeding 20 ft (6.1 m).

N **A.11.5.4.4** Due to the large quantity of platforms, equipment, and walkways, care should be taken to include coverage under all obstructions greater than 4 ft (1.2 m) wide.

N **A.11.5.5.3** Automatic cleaning systems have not been practical. Manual cleaning of at least once per work shift has been found necessary in several facilities to be effective. Manual cleaning could also not be practical because the shredder could be in continuous operation for several days. Manufacturers have attempted to locate pressure sensors in areas where they will not be plugged. If there is a delay in operation of the suppression system, there could be an increase in pressure above what would be expected in an unsuppressed explosion.

N **A.11.6.4** Biomass fuels exhibit a wide range of burning characteristics and upon evaluation can require increased levels of protection.

N **A.11.7.1.1** In general, rubber tires have a Btu content of 15,000 Btu/lb (7180 J/kg), roughly two to three times that of wood or RDF.

N **A.12.1** Examples of alternative fuel include, but are not limited to, refuse derived fuel (RDF), municipal solid waste (MSW), and biomass.

A.12.1.2 Duct systems could be used for odor control by exhausting air from processing to the boiler. A fire in an unprotected plastic duct system could result in a number of fires in different areas of the processing buildings overtaxing the sprinkler system.

•

A.12.1.4 Conveyors can be considered protected by overhead building protection if not enclosed or hooded.

A.12.3.2.2 For personnel safety considerations, see NFPA 85 for further guidance.

•

A.12.3.5.3 Special detection systems currently used are the following:

(1) Infrared detection systems to monitor rotor or stator surfaces
(2) Line-type detectors between intermediate and cold-end basket layers

There has been limited fire experience with both systems to date. Low light television cameras mounted outside the air heater have a possible application in air heater fire detection.

A.12.3.7.2 Temperature sensors alone might not be adequate to provide early warning of a fire in an electrostatic precipitator.

•

A.13.3.1 The wind turbine generators are supplied typically as a packaged unit with blades and hub mounted to a shaft that turns a gearbox and generator, all of which are installed within a nacelle that is, in turn, placed at the top of the wind turbine tower. The nacelle and a tubular tower form an all-weather housing. In addition to weather protection, the nacelles are designed to provide thermal and acoustical insulation. More recent designs employ a torque converter that allows the variable speed of the rotor and drive shaft to be converted to a constant speed for rotor rotation within the generator. Other designs feature direct-drive, permanent magnet type machines in which the rotor rotation is translated directly to the generator field so that a gearbox, with its weight and oil hazards, is not required.

Control cabinetry can be mounted in the nacelle or tower, or within a pad-mounted enclosure located adjacent to the tower, or in a combination of these. Power developed by the generator is routed through cabling down the tower and then onward to join in parallel the outputs of other units before power conditioning is applied and the facility's power output voltage is stepped up for use on the grid. For large wind farms, power conditioning (i.e., harmonics, reactive and real power controls) is done in the power electronic module located at each individual wind turbine. Large wind farms have a significant effect on the stability of the power grid, so the wind turbine generator is required to exhibit voltage, power, and frequency stability at the generator terminal in a way that is similar to conventional generators.

The wind turbine tower foundation might include a concrete or steel vault through which power and control cabling is routed. Power conditioning needs and voltage step-up requirements will dictate what other structures or enclosures might be needed.

Major fire hazards associated with wind farms are as follows:

(1) Flammable and combustible liquids
(2) Electrical components and wiring
(3) Combustible materials of construction

In the event of a pipe or fitting failure within the nacelle, significant amounts of oil could be released and ignite. In addition, faults in electrical cabinetry, cabling, and transformers in the nacelle or tower could result in fires.

Figure A.13.3.1(a) shows a typical wind turbine, which has the following components:

(1) *Anemometer.* Measures the wind speed and transmits wind speed data to the controller.
(2) *Blades.* Most turbines have either two or three blades. Wind blowing over the blades causes the blades to "lift" and rotate.
(3) *Brake.* A disc brake, which can be applied mechanically, electrically, or hydraulically to stop the rotor in emergencies.

(4) *Controller.* The controller starts up the machine at wind speeds of about 8 to 16 mph (13 to 26 kph) and shuts off the machine at about 55 mph (89 kph). Turbines do not operate at wind speeds above about 55 mph (89 kph) because they might be damaged by the high winds.
(5) *Gear box/torque converter.* Gears/torque converters connect the low-speed shaft to the high-speed shaft and increase the rotational speeds from typically less than 60 rotations per minute (rpm) to about 1000 to 1800 rpm, the rotational speed required by most generators to produce electricity. The gear box is a costly (and heavy) part of the wind turbine, and wind turbine manufacturers have developed “direct-drive” generators that operate at lower rotational speeds and do not need gear boxes.
(6) *Generator.* Usually an off-the-shelf induction generator that produces 60-cycle ac electricity.
(7) *High-speed shaft.* Drives the generator.
(8) *Low-speed shaft.* The rotor turns the low-speed shaft at typically less than 60 rotations per minute.
(9) *Nacelle.* The nacelle sits atop the tower and contains the gear box, low- and high-speed shafts, generator, controller, and brake. Some nacelles are large enough for a helicopter to land on.
(10) *Pitch.* Blades are turned, or pitched, out of the wind to control the rotor speed and keep the rotor from turning in winds that are too high or too low to produce electricity.
(11) *Rotor.* The blades and the hub together are called the rotor.
(12) *Tower.* Towers are made from tubular steel [as shown in Figure A.13.3.1(a)], concrete, steel lattice, or a combination thereof. Because wind speed increases with height, tall towers enable turbines to capture more energy and generate more electricity.
(13) *Wind direction.* The turbine in Figure A.13.3.1(a) is an “upwind” turbine, so-called because it operates facing into the wind. Other turbines are designed to run “downwind,” facing away from the wind.
(14) *Wind vane.* Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind.
(15) *Yaw drive.* Upwind turbines face into the wind; the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. Downwind turbines do not require a yaw drive; the wind blows the rotor downwind.
(16) *Yaw motor.* Powers the yaw drive.

See Figure A.13.3.1(b) for wind farm facility components.

• **A.13.5.3.2.2** The duration that fire suppression is maintained should be sufficient to span the particular wind turbine shutdown and cooldown times as determined by the manufacturer.

• **A.14.1** Solar plants use the energy of the sun to produce electrical power. The process used in current commercial utility–scale applications typically involves one of two basic technologies:

(1) Photovoltaic (PV) solar power that is associated with the use of PV panels in various arrays in which energy from the sun is converted to dc electrical energy in each of the panels that is subsequently converted to ac power for delivery to the grid.

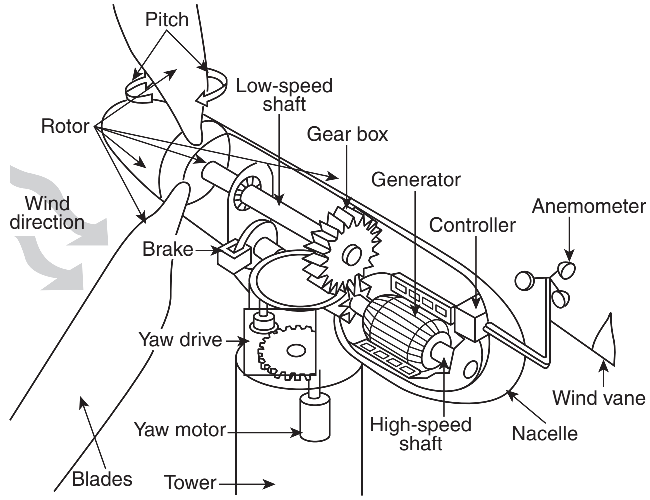


FIGURE A.13.3.1(a) Typical Wind Turbine Components. ***[Courtesy of U.S. DOE Energy Efficiency and Renewable Energy (EERE).]***

(2) Concentrated solar power (CSP) that involves the production of steam via a heat transfer mechanism and then using the steam to drive a steam turbine generator.

A.14.3.1.1 Pressurized leaks can ignite and spray burning HTF with thermal and nonthermal damage to other equipment. In one incident a valve stem failure resulted in HTF mist being carried over a large area, causing contaminate damage to a number of mirrors. A pressurized leak, even if distant from mirrors, could carry a long way due to high ambient temperature in solar plant locations.

A.14.4 The flammable HTF constitutes a significant fire hazard. Adequate protection in the form of hydrants and monitor nozzles, in addition to appropriate HTF piping isolation capability, is needed in the solar fields. Water-spray sprinkler protection should be provided for the HTF pumps, the ullage system, and the steam generator heat exchanger areas.

A.14.4.1 Photovoltaic (PV) technology involves the conversion of solar radiation into dc electricity using semiconductors that exhibit the photovoltaic effect. This conversion takes place in a PV solar cell that is made of various materials demonstrating photovoltaic properties and employing various technologies (e.g., crystalline silicon, thin film, etc.). Solar cells are assembled to form a solar panel, and multiple panels are put together to form a solar module. PV modules are installed on steel support structures arranged in long rows called strings that are adequately spaced to avoid “shading” of one from another. In the northern hemisphere, PV modules typically face south and are tilted according to the latitude of the PV site to maximize the solar radiation energy available to the module. Frequently, computer-controlled tracking systems are used to rotate the PV strings on a single axis as necessary to follow the movement of the sun throughout the day.

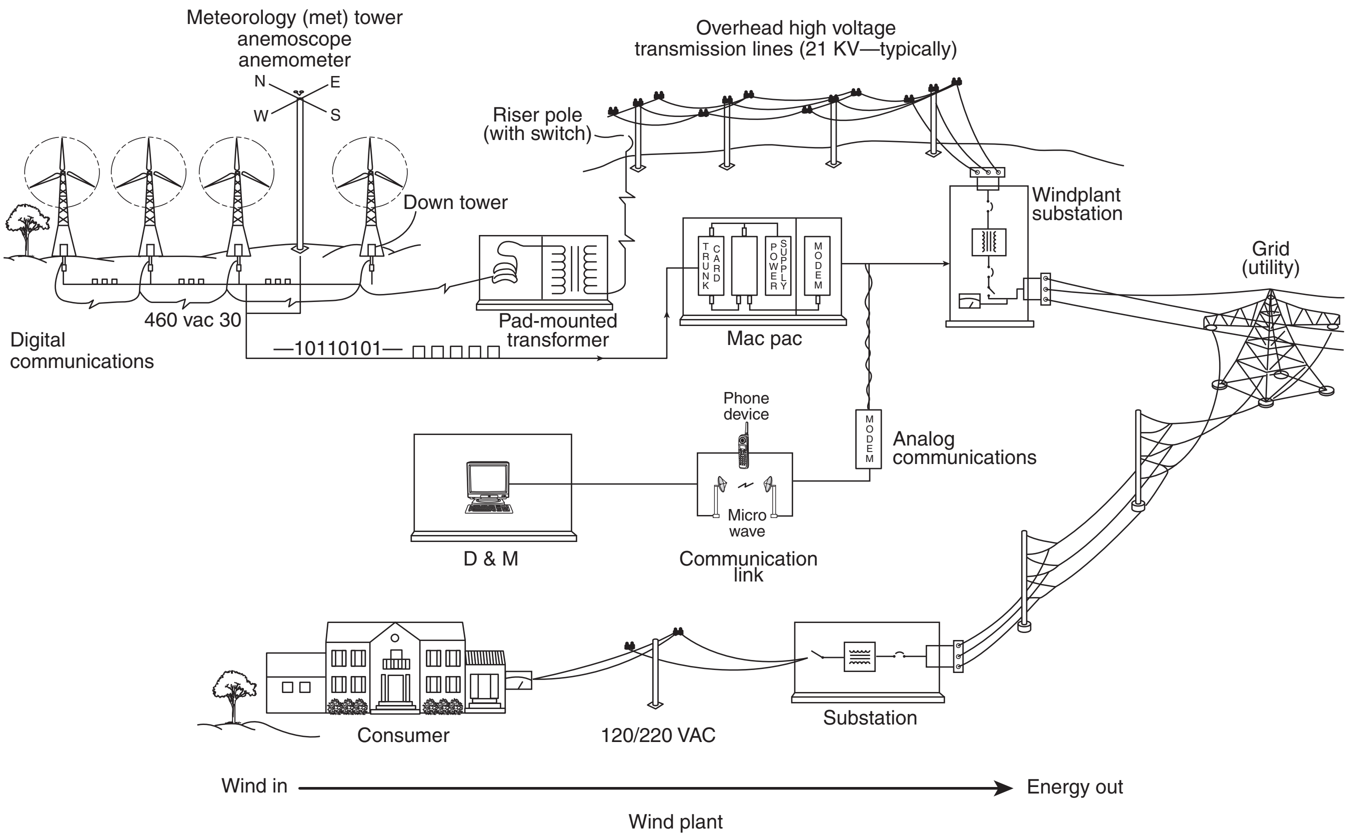


FIGURE A.13.3.1(b) Typical Wind Farm Facility Components.

PV modules/strings are connected electrically in series and parallel and then connected by dc cabling to inverters that convert dc power into ac power. The number of inverters will depend on the size and layout of the PV site. The ac power produced in the inverters is then directed through a step-up transformer to a medium-voltage (e.g., 24 KV) ac cabling and delivered to a local substation where a plant step-up transformer raises the voltage to match that of the grid being served.

Concentrated photovoltaic (CPV) technology uses optic lenses/receptors to concentrate sunlight onto high-performance solar cells, thus increasing the electricity generated. The high-performance cells are then arranged on panels that are mounted to steel support structures that can be moved by dual-axis tracking systems to maximize the benefit of each ray of sunlight. Modules typically have their own inverter and are, otherwise, electrically connected in a manner similar to that employed in a flat-panel PV plant. The routing of electrical power out of a CPV plant is similar to that of a PV plant.

A.14.4.3 In concentrating solar plants, the heat energy of the sun is used to generate steam that will, in turn, be used in a steam turbine generator as part of a Rankine cycle similar to that employed in fossil fuel–fired steam plants.

Linear concentrating systems collect the sun's energy using long rectangular, curved (U-shaped) mirrors/reflectors referred to as solar collection assemblies that focus sunlight on tubes (or receivers) that run the length of the mirrors. The reflected sunlight heats a fluid flowing through the tubes. The hot fluid then is used to produce steam in a conventional steam generator, which is then used to turn a steam turbine generator to produce electricity. There are two major types of linear concentrator systems: 1) parabolic trough systems, where receiver tubes are positioned along the focal line of each parabolic mirror; 2) and linear Fresnel reflector systems, where one receiver tube is positioned above several strip-like mirrors to allow the mirrors greater mobility in tracking the sun. Such systems permit the use of more reflective surface in the same amount of space as a parabolic trough system.

A power tower system uses a large field of flat mirrors known as heliostats to focus and concentrate sunlight onto a receiver on the top of a tower. The heliostats are positioned by a dual-axis, sun-tracking system. A heat transfer fluid heated in the receiver is used to generate steam, which, in turn, is used in a conventional turbine generator to produce electricity. Some power towers use water/steam as the heat transfer fluid.

Each such system will differ from the other in thermodynamic efficiencies and the associated peak temperatures involved.

A parabolic trough system uses solar collection assemblies in which a tube-type receiver is positioned along the focus line in the middle of a trough-like parabolic mirror reflector that rotates around the receiver on a single axis as the sun moves from east to west. The tube-like receiver is filled with a working fluid that picks up heat as it flows through the receiver. The heated fluid is then used as a heat source in a steam generator that provides steam to a steam turbine generator.

Fresnel reflectors work in a similar manner in terms of focusing the sun's energy on a receiver through which a working fluid moves. Fresnel reflector technology employs many thin, flat mirror strips to concentrate sunlight onto the receiver tubes.

In concentrating solar power plants that use a "power tower," a vast array of computer-controlled mirrors/reflectors surrounds the tower. The reflectors are referred to as heliostats and use a dual-axis tracking system to focus the sun's energy on a specially designed thermal receiver at the top of a tower. The working fluid in the receiver can be water, and the water is sufficiently heated in the tower to make steam, thus eliminating the need for a separate steam generator.

With respect to the working fluid discussed above, the working fluid is frequently a specially formulated heat transfer fluid (HTF) that is heated in the solar fields to temperatures above 700°F (371°C). That heat is subsequently transferred from the HTF to water in a steam generator to produce steam. In a given solar field, there can be several hundred solar collection assemblies (SCAs) typically arranged in quadrants, with aisles between them. The HTF is moved through a given field by HTF pumps that bring the heated fluid to the power plant where, in steam generators (heat exchangers with the HTF on the primary side and water/steam on the secondary side) the hot fluid then flashes water to steam. The steam is then used to drive one or more steam turbine generators. Other than the aforementioned heat exchangers, the steam side is similar to most traditional steam turbine generator installations.

To augment the heating of the HTF, each solar generating unit is typically provided with auxiliary natural gas–fired HTF heaters. As the amount of available sunlight decreases, or during cloudy days, the heaters are operated as needed to maintain adequate HTF temperatures. Solar plants also typically have an ullage system that is used for removing impurities and water from the HTF to a separate ullage vessel. This vessel is then emptied into a truck-mounted tank for later disposal.

In some systems, the working fluid is molten salt. Such a fluid retains heat for some time and is therefore amenable to a plant design that incorporates energy storage with the ability to produce steam when the sun is over the horizon.

A.15.2 Additional guidance for geothermal plants includes the following:

Geothermal Plants. Geothermal applications use heated fluids obtained by drilling wells in areas where there is a hydrothermal source. Most geothermal resources have temperatures from 300 to 700°F (149 to 371°C, but geothermal reservoirs can reach temperatures of nearly 1000°F (538°C). Steam or water from geothermal wells usually contains carbon dioxide, hydrogen sulfide, ammonia, and low concentrations of other constituents such as methane, ethane, propane, nitrogen, and antimony.

The energy conversion technologies are direct steam, flash steam, and binary systems. The type of conversion used depends on the state of the fluid (whether steam or water) and its temperature.

Direct Steam Systems. Direct steam systems are also called dry steam systems and direct brine steam systems. Steam taken from the ground is the working fluid. In this case, the plant is typically served by a number of production wells and injection wells.

The steam system typically comes to the turbine building directly from the production wells to supply the steam turbine. The turbine typically exhausts into a condenser. The low-energy steam is condensed back into low-pressure condensate in a contact- or surface- type condenser and is then typically redirected to the cooling tower. The overall system water balance is typically maintained by condensate injection pumps discharging the excess condensate back into the geothermal reservoir.

Because of the sulfur content (hydrogen sulfide) of the steam, this type of plant might have equipment for removal and for recovery of sulfur. Sulfur is typically converted to elemental form. Stainless steel piping is common, and titanium can be used in the turbine and condenser construction.

Special hazards include hydrogen sulfide abatement systems. Hydrogen sulfide is extracted from the condenser and can be burned in a gas-fired incinerator, depending on the constituents present in the noncondensable gas stream and the overall design characteristics of the abatement system. In addition, there could be arsenic present in the steam that precipitates on equipment components, which needs to be considered during maintenance activities. *[See Figure A.15.2(a).]*

Flash Steam Systems. In flash steam plants, the fluid either is pumped or flows under its own high pressure to generation equipment at the surface. The fluid enters a separator as a two-phase mixture of liquid and steam. The mixture is separated, with the vapor being directed to a steam turbine generator. Unflashed brine is typically piped to a second-stage separator, where a drop in pressure allows a second flashing of the brine. The two streams of steam (one high pressure and one lower pressure) drive the turbine generator. The spent steam from the turbine is condensed by circulating water from the cooling tower, and excess fluid from the cooling tower is either injected into the "cold" injection into system or combined with the brine and injected into the "hot" injection system. The unflashed brine from the second-stage separator is pumped into the "hot" injection pipeline. This pipeline returns the brine to the geothermal reservoir at the outer limits of the reservoir. The injected brine provides both fluid makeup and pressure support to the reservoir. *[See Figure A.15.2(b).]*

Binary Cycle Systems. Binary cycle plants are plants in which moderate-temperature water from a geothermal field is used to flash a working fluid to vapor, which then drives a turbine. The working fluid is condensed and cycled back to the heat exchanger for renewal of the process. This is a closed-loop system.

The working fluid used is a low flash point flammable liquid (e.g., isobutane, isopentane, and n-pentane). Fluid selection is largely based on water temperature from the field and subsequent efficiency of the process. There could be several thousand gallons of fluid in enclosed systems depending on the size of the plant. The fluid is condensed in either a water-cooled condenser or an air-cooled condenser. The fluid is recycled to the vaporizer by a fluid cycle pump. Pressure relief valves are installed on the closed-loop piping and set to operate to prevent overpressure in case of process upset or fire exposure. In early designs, multiple small generating units (energy converters) were used to make up a typical binary plant. For modern facilities, power is produced by a limited number of turbine generator sets.

Individual power units typically comprise the following:

(1) Pumps and piping for transfer of flammable organic fluid
(2) Expander turbine(s)/converter(s) and generator(s)
(3) Heat exchangers, cooling towers, or air-cooled condenser for providing the cycle heat sink

Special hazards include the accidental release of flammable liquid above its boiling point and the formation of a vapor cloud with the potential for a vapor cloud explosion and/or fire with damage to the following:

(1) Process equipment such as turbines/energy converters, heat exchangers, and other nearby process equipment such as motor control centers
(2) Storage tanks and piping for working fluids

[See Figure A.15.2(c).]

A.15.3.1.1 NFPA standards containing guidance on spacing are NFPA 30, NFPA 58, NFPA 59, NFPA 59A, NFPA 80A, and API 752, *Management of Hazards Associated with Locations of Process Plant Buildings.*

A.16.1 IGCC plants typically use one of three partial oxidation reaction processes to produce synthesis fuel gas (syngas) for subsequent combustion in gas turbines. The three methods of gasification are moving bed, fluidized bed, and entrained. IGCC technology takes advantages of the efficiencies available via combined-cycle power generation, more readily available

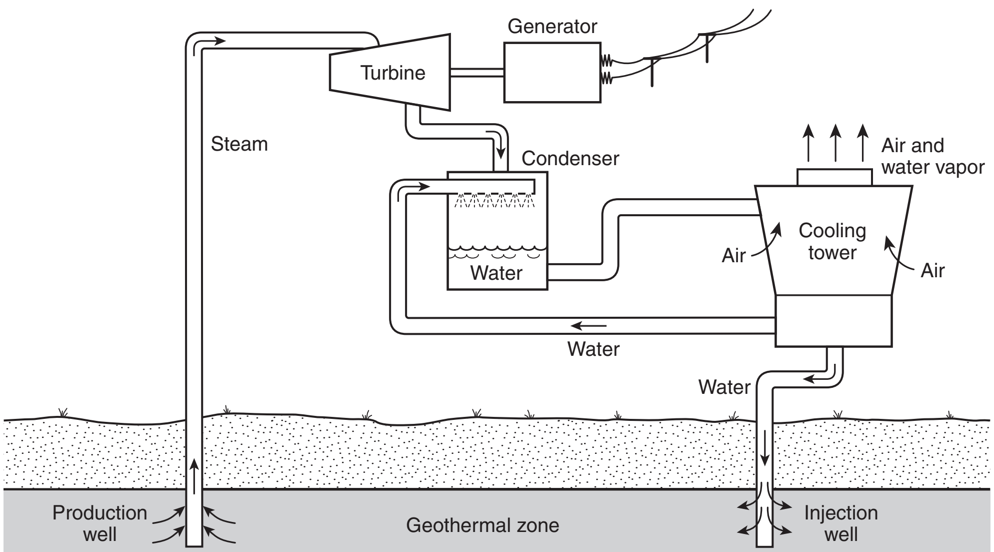


FIGURE A.15.2(a) Direct Brine/Steam (Dry Steam) Geothermal Power Plant. ***(Courtesy Idaho National Laboratory.)***

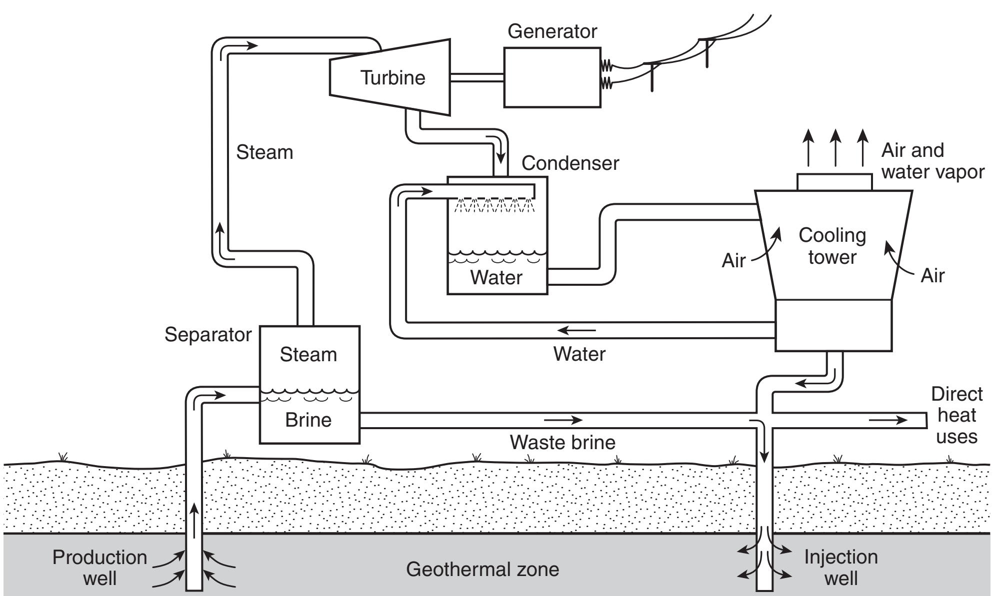


FIGURE A.15.2(b) Flash Steam Geothermal Power Plant. ***(Courtesy Idaho National Laboratory.)***

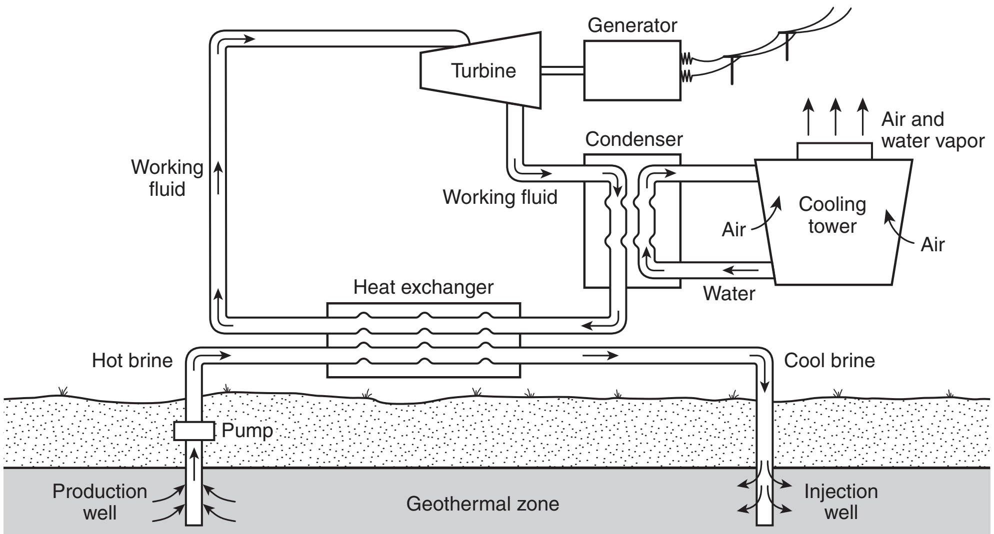


FIGURE A.15.2(c) Binary Cycle Geothermal Power Plant. ***(Courtesy Idaho National Laboratory.)***

carbon-based fuels, and more economical compliance with emission standards. In the simplest of cases, as frequently seen in refineries, derivative gases or oils with adequate heating values are sent directly to a combustion turbine that, in turn, drives an electrical generator while its exhaust gases are sent to a heat recovery steam generator (HRSG) that produces steam to be used in a steam turbine generator. The HRSG design can include reheat and a selective catalytic removal (SCR) system, as are common in many power plants. Carbon-based products such as coal, residual oils, petroleum coke, waste sludge, biomass, and so forth, can be used as feedstock in the IGCC process. The feedstock is converted into a syngas to be used as fuel in the combustion turbine. This occurs in a gasification unit. A gasification unit operates in a manner very similar to a chemical processing plant.

Syngas conversion apparatus includes the following:

(1) *Moving bed gasifier.* Oxidant is introduced at the bottom of a bed of fuel and moves downward as it is consumed by the gasification reactions at the bottom. Coal is introduced through a lockhopper at the top. These gasifiers produce tars and oils, a special hazard for plants with these types of gasifiers, because of both fire and personnel exposure to carcinogens.
(2) *Circulating fluidized bed gasifier.* Circulating fluidized-bed combustors use higher air flows to entrain and move the bed material, and nearly all of the bed material is continuously recirculated with adjacent high-volume hot cyclone separators. This approach simplifies feed design, extends the contact between the sorbent and flue gas, reduces the likelihood of heat exchanger tube erosion, and improves sulfur dioxide capture and combustion efficiency. This is the most appropriate design for use with lower-quality fuels such as biomass, lignite, and subbituminous coal. Some later designs include a topping combustor in which fuel gas is combusted to add energy to the combustor's flue gas. More advanced designs can include a pressurized carbonizer that converts feed coal into fuel gas and char. The char is then burned to produce steam while the fuel gas from the carbonizer is routed through a topping combustor.
(3) *Entrained gasifier.* Another approach to converting a fuel to syngas is the use of a gasifier in which prepared feedstock is reacted with a substoichiometric amount of air or oxygen at high temperature [more than 2300°F (1260°C)] and moderate pressure in a reducing atmosphere. The gasification process produces a syngas product that is mostly carbon monoxide and hydrogen, with smaller quantities of carbon dioxide. For air-fired gasifiers, there is also a significant quantity of nitrogen in the resulting syngas. Entrained gasifiers are typically tall refractory-lined cylindrical vessels into which the prepared fuel is fed along with oxygen or air. Ash runs down the refractory-lined walls to a quench tank. The hot gas produced in the gasifier is then cooled in a syngas cooler. This cooler can be incorporated into the gasifier design, or it can be a stand-alone unit. In many designs, the cooling medium is water/steam that is changed to superheated steam in the cooler and then used in the power plant steam cycle or for other support functions in a refinery.

A.16.3 General Design. Depending on the plant design, a number of different IGCC support systems will be included in addition to the combined-cycle power plant, including the following:

(1) *Fuel Preparation.* In any IGCC facility, the feedstock fuel will have to be readied for use and delivered to the gasifier. Various types of feedstock could require heating, mixing, drying, etc., and will be delivered to the gasifier by various means.
(2) *Air Separation.* If oxygen is used for combustion in the gasifier, an air separation unit will typically be needed unless, in a refinery or air products process environment, the oxygen can be made available from another process. Air separation design choices are based on how many products are desired, required product purities, gaseous product delivery pressures, and whether or not products will be produced in liquid form. In most modern applications, cryogenic processes are used for air separation. In such facilities, air separation will involve large gas compressors, numerous pressure vessels, and specially