Department of Energy
Washington, DC 20585

February 5, 2009

MEMORANDUM FOR ANDREW LAWRENCE
RESPONSIBLE MANAGER
DEFENSE NUCLEAR FACILITIES SAFETY BOARD
RECOMMENDATION 2008-1

FROM: JAMES O'BRIEN
CORE TEAM LEAD
DEFENSE NUCLEAR FACILITIES SAFETY BOARD
RECOMMENDATION 2008-1

SUBJECT: Products for Defense Nuclear Facilities Safety Board Recommendation 2008-1 Milestones 5.1.1 and 5.2.1 and Deliverable for Milestone 5.4.1.

Please find for your approval to transmit to the Defense Nuclear Facilities Safety Board (DNFSB) the attached Products for Milestones 5.1.1 and 5.2.1 identified in the Department of Energy (DOE) Implementation Plan (IP) for DNFSB Recommendation 2008-1, *Safety Classification of Fire Protection Systems.*

As specified in Milestone 5.1.1, the National Nuclear Security Administration (NNSA) and Office of Environmental Management (EM) conducted surveys of fire protection systems used in safety class and safety significant applications in their existing and planned facilities. The attached report (Attachment 1) provides a summary of the data collected and serves as the Product for Milestone 5.1.1.

As specified in Milestone 5.2.1, members of the Core Team for the DNFSB 2008-1 IP performed an analysis of requirements for fire protection systems used in high-risk applications. Attachment 2 provides details of the analysis and serves as the Product for Milestone 5.2.1.

Milestone 5.4.1 of DNFSB Recommendation 2008-1 requires DOE to identify fire protection systems (in addition to sprinkler systems) for which DOE would develop specific design and operational criteria based upon the results of efforts performed in support of Milestones 5.1.1 and 5.2.1. The DNFSB Recommendation 2008-1 Core Team, in conjunction with the DNFSB Recommendation 2008-1 Working Group, concluded that DOE should develop guidance on the design and operation of fire barriers because of the number of these being utilized in safety class and safety significant applications in current and planned nuclear facilities and the benefits of addressing the issue of redundancy and reliability for fire barriers.

Please indicate your approval/disapproval to transmit the attached documents and contact me at 301-903-1408 if you have any questions or comments on the subject reports.

Attachments

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DATE: ______________________

Attachment 1

U. S. Department of Energy

Fire Protection Systems Survey Report

Defense Nuclear Facilities Safety Board
Recommendation 2008-1
Milestone 5.1.1

Washington, DC 20585

January 2009

1.0 INTRODUCTION

The Department of Energy (DOE) Implementation Plan (IP) for the Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 2008-1 identified several Products[1] and Deliverables which were to be initiated to support development of guidance on design and operational criteria for fire protection systems used as safety systems.

Milestone 5.1.1 requires a survey of existing and planned DOE facilities to identify safety class and safety significant fire protection systems. This report documents the survey results and serves as the Milestone 5.1.1 Product.

2.0 BACKGROUND/METHOD OF COLLECTING DATA

To support development of this report, the National Nuclear Security Administration (NNSA) and the Office of Environment (EM) solicited input from their Field Offices on the types and numbers of fire protection systems used in safety class and/or safety significant applications. The primary data of interest was that for planned facilities as these indicate where DOE might apply resources to develop further specific guidance on design of fire protection systems. The data for existing facilities was collected to provide additional insights as to what types of fire protection systems might be utilized in safety class or safety significant applications in the future.

The data collected was forwarded to the Office of Nuclear Safety Policy and Assistance within the Office of Health, Safety and Security for collating and processing into this report.

3.0 RESULTS

The survey results are captured in the following tables, Table 1 covers planned facilities and Table 2 covers existing facilities. Table 1 shows that eight facility projects expect to utilize closed-head automatic sprinkler systems in safety class or safety significant applications and two projects expect to utilize fire barriers in these applications. Closed-head automatic sprinkler systems are further classified into wet pipe, dry pipe, and pre-action systems whose installation is in accordance with National Fire Protection Association (NFPA) Standard No. 13, *Standard for the Installation of Sprinkler Systems.*

Table 2 shows that fire sprinkler systems are the most commonly used fire protection systems in existing safety class and safety significant applications. The most prevalent systems used are: 198 closed-head automatic sprinkler systems, 95 fire barriers, 54 deluge spray systems, and 15 dry chemical systems.

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[1] Products are reports or analysis the DNFSB 2008-1 working group develops to support development of more critical items (Deliverables). The products are not formally transmitted to the DNFSB, but are formally documented and made available to the DNFSB. Deliverables are formally transmitted to the DNFSB.

A description of each of the following types of systems is provided in Appendix 1:

Table 1 - Fire Protection Systems Used in Safety Class (SC) and Safety Significant (SS) Applications in Planned Facilities

System	SC	SS
Closed-head Sprinkler (Wet Pipe)	2	2
Closed-head Sprinkler (Pre-action)		3
Closed-head Sprinkler (type to be determined)		1
Fire Barriers	2	

Table 2 - Fire Protection Systems Used in Safety Class (SC) and Safety Significant (SS) Applications in Existing Facilities

System	SC	SS
Closed-head Sprinkler (Wet Pipe)	116	45
Closed-head Sprinkler (Dry Pipe)	1	34
Closed-head Sprinkler (Pre-action)		2
Fire Barriers	85	10
Deluge Spray	53	1
Dry Chemical		15
Fire Alarm		7
Clean Agent/Halon		2

APPENDIX 1
Description of Fire Protection Systems Used in Safety Class and Safety Significant Applications

1. Wet Pipe Sprinkler System: A closed-head sprinkler system employing automatic sprinklers attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers which are actuated by heat. For additional details refer to NFPA Standard 13 section. 3.4.10.

2. Dry Pipe Sprinkler System: A closed-head sprinkler system employing automatic sprinklers attached to a piping system containing air or nitrogen under pressure, the release of which permits the water pressure to open a valve known as a dry pipe valve. The water then flows into the piping system and out the opened sprinklers. Note that the opening of a sprinkler under most cases occurs by heat from a fire and may involve a larger number of sprinklers operating when compared to a Wet Pipe Sprinkler system. For additional details refer to NFPA Standard 13 section 3.4.5.

3. Pre-action Sprinkler System: A closed-head sprinkler system employing automatic sprinklers that are attached to a piping system that contains air that might or might not be under pressure, with a supplemental detection system installed in the same areas as the sprinklers. Note that the detection system can exist in a number of different types and arrangements from pneumatic to air-sampling whose installation is in accordance with NFPA Standard 72. Actuation of this detection system leads to the tripping of a sprinkler system deluge valve allowing water to flow into the piping system and, if a sprinkler head is opened by the heat from a fire, then water will flow from the sprinkler opening. If a sprinkler is opened from some other event that does not actuate the detection system, then a signal may or may not be transmitted to a central location and the deluge valve will remain closed. This type of system is specified in environments where water damage is problematic, particularly in a non-fire situation. For additional details, refer to NFPA Standard 13 section 3.4.9.

4. Deluge Sprinkler System: A sprinkler system employing open sprinklers that are attached to a piping system that is connected to a water supply through a valve (e.g., deluge valve) that is opened by the operation of a detection system installed in the same areas as the sprinklers. When this valve opens, water flows into the piping system and discharges from all sprinklers attached thereto. Note that some DOE facilities employ the ultra-fast type of deluge system in which the piping system is primed with water and the actuation of the deluge valve is achieved through a faster (e.g., ballistic) actuating mechanism. For additional details refer to NFPA Standard 13 section 3.4.4.

5. Dry Chemical System: A dry chemical system is a non-water based suppression system arranged according to the requirements of NFPA Standard 17, *Standard for Dry Chemical Extinguishing Systems.*

6. Fire Barriers: A wall other than a Fire Wall[2] having a fire resistance rating which may or may not include opening protection such as fire rated doors, windows, and dampers. Note that the fire resistance rating is 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 221, *Standard for High Challenge Fire Walls, Fire Walls and Fire Barrier Walls.*

7. Fire Alarm System: A system or portion of a combination system that consists of components and circuits arranged to monitor and communicate the status of fire alarm or supervisory signal-initiating devices and to initiate the appropriate response to those signals. For additional details, refer to section 3.3.67 of NFPA 72, *National Fire Alarm Code.*

8. Clean Agent: An electrically non-conducting, volatile, or gaseous fire extinguishant that does not leave a residue upon evaporation. Such systems employing clean agents are installed as prescribed in NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems.*

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[2] NFPA 221 defines a Fire Wall as one that separates buildings or subdivides a building to prevent the spread of fire and having a fire resistance rating and structural stability. This standard also defines a High Challenge Fire Wall as one that separates buildings or subdivides a building with high fire challenge occupancies, having enhanced fire resistance ratings and enhanced appurtenance protection to prevent the spread, and having structural stability. NOTE: NFPA 221 also contains descriptions of other wall types such as an angle, bearing and end wall.

The 2006 edition of the International Building Code (IBC) defines a Fire Barrier as a fire-resistance-rated wall assembly of materials designed to resist the spread of fire in which continuity is maintained. This is different from the IBC's "Fire Wall" term which is a fire-resistance-rated wall having protected openings, which resists the spread of fire and extends continuously from the foundation to or through the roof, with sufficient structural stability under fire conditions to allow collapse of construction on either side without collapse of the wall.

Attachment 2

U.S. Department of Energy

Analysis of Requirements for Fire Protection Systems Used in High Risk Applications

Milestone 5.2.1 Identified in the Implementation Plan for Defense Nuclear Facilities Safety Board Recommendation 2008-1

Safety Classification of Fire Protection Systems

Washington, DC 20585

January 2009

Executive Summary

The Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 2008-1, *Safety Classification of Fire Protection Systems,* identified the need for standards applicable to design and operation of fire protection safety systems. The Department of Energy (DOE) Implementation Plan for DNFSB Recommendation 2008-1 documents the milestones and associated deliverables required to develop and implement these standards. Milestone 5.2.1 requires the review of current DOE design practices for safety systems and industrial design and operational criteria used for fire protection systems in critical applications. This report documents the required review and serves as the product deliverable for Milestone 5.2.1.

The current practices for designing DOE safety class and safety significant systems at nuclear facilities were reviewed, including the applicable design requirements. In addition, comparable industry and government codes and standards for high-risk facilities were identified and reviewed. These reviews included the Nuclear Regulatory Commission (NRC), Factory Mutual (FM) Global, Department of Defense (DOD) Uniform Facilities Criteria, General Service Administration (GSA) supplemental criteria, and the International Building Code (IBC). The identified codes and standards were documented and then compared to the current DOE requirements.

Current DOE design practices rely on safety analysis to determine the type and functional requirements for safety systems. DOE-developed general design criteria reference industry codes and standards, which are utilized to support the design of systems to meet the functional requirements. For fire protection systems, the applicable codes and standards are those developed by the National Fire Protection Association (NFPA) and the IBC. In addition, DOE Order 420.1B, *Facility Safety,* requires that fire protection design, systems, and management controls fulfill requirements for the best-protected class of industrial risks (e.g., by implementing supplemental criteria contained in the FM Global Data Sheets). DOE Standard 1066, *Fire Protection Design Criteria*, also provides design criteria for fire protection systems in areas such as water supply and distribution and seismic supports.

The NRC fire protection requirements for nuclear facilities are similar to the DOE requirements; safety analyses are used to determine the need for fire protection safety systems and industry codes and standards are applied for system design.

Non-nuclear industry and government fire protection requirements for high risk facilities rely largely on NFPA and IBC codes and standards but also utilize supplementary requirements to meet facility-specific needs and/or improve system reliability.

The comparison of industry and other government fire protection requirements to current DOE requirements identified that, although most requirements were the same and relied on industry standards, some additional requirements were identified. For example, the DOD supplemental criteria for sprinkler systems design and installation includes requirements for: (1) contractor qualification and licensing, (2) preparation of drawings and calculations, and (3) limitations on use of Schedule 10 piping, that are not included in DOE or industry requirements. In addition, the review found that some of DOE requirements and guidance related to the application of redundancy criteria, seismic criteria, and quality assurance requirements to support design of fire protection systems used in safety class and safety significant applications could be clarified.

DOE will consider this information in its development of new guidance for the design and operation of fire protection systems as identified its implementation plan for DNFSB Recommendation 2008-1.

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1.0 INTRODUCTION

The Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 2008-1, *Safety Classification of Fire Protection Systems,* identified the need for standards applicable to design and operation of fire protection safety systems. The Department of Energy (DOE) Implementation Plan for DNFSB Recommendation 2008-1 documents the milestones and associated deliverables and products required to develop and implement these standards. Milestone 5.2.1 requires the review of current DOE design practices for safety systems and industrial design and operational criteria used for fire protection systems in critical applications. This report documents the required review and serves as the product for Milestone 5.2.1.

This report documents reviews conducted in the following areas: (1) DOE general design practices for safety class and safety significant systems, (2) DOE design practices for fire protection systems, (3) Nuclear Regulatory Commission (NRC) and industry, including other government agencies, fire protection practices. The gathered information was then compared to and evaluated against the current DOE design practices. The resulting variation is documented in this report and intended to support development of additional design and operational criteria for fire protection sprinkler systems. Development of the additional criteria is discussed in Section 5.3 of the DNFSB Recommendation 2008-1 Implementation Plan.

This report was developed by a team of three fire protection engineers and a safety basis expert with the review and support from the DNFSB Recommendation 2008-1 working group. Team members were:

James Bisker: Fire Protection Engineer, Office of Health, Safety and Security
William Boyce: Fire Protection Engineer, Office of Environmental Management
Sharon Steele: Fire Protection Engineer, National Nuclear Security Administration
James O'Brien: Safety Basis Expert, Office of Health, Safety and Security

2.0 DOE DESIGN CRITERIA FOR SAFETY CLASS AND SAFETY SIGNIFICANT SYSTEMS

2.1 Summary of Design Criteria

General design criteria specified in Chapter I of DOE Order (O) 420.1B, *Facility Safety,* and DOE Guide (G) 420.1-1, *Nonreactor Nuclear Safety Design Criteria*, are applicable to fire protection systems utilized in safety significant and safety class applications. The following is a synopsis of DOE requirements for safety class and safety significant systems and a discussion of their impact on the design of fire protection systems. Excerpts from these documents are included in Appendix B. A list of references used throughout this report are also provided in Appendix A.

Per 10 CFR 830, *Nuclear Safety Management,* safety class systems are systems whose preventive or mitigative functions are necessary to limit radioactive hazardous material exposure to the public, as determined from safety analyses. Safety significant systems are systems which are not designated as safety class, but whose preventive or mitigative function is a major contributor to defense in depth and/or worker safety as determined from safety analyses.

DOE O 420.1B states that safety analyses must be used to establish the identity and functions of safety class and safety significant structures, systems, and components (SSCs) and provides nuclear facility design objectives that include applying conservative design margins and quality assurance (QA) requirements.

DOE Guide 420.1-1, *Nonreactor Nuclear Safety Design Criteria and Explosive Safety Design Criteria Guide for use with DOE Order 420.1,* provides guidance for implementing DOE Order 420.1B. Section 5 of DOE Guide 420.1-1 provides the following supplementary guidance for the design and construction of safety significant and safety class SSCs to ensure reliable performance of their safety function under those conditions and events for which they are intended:

- **Conservative Design Features**: Safety Systems must[1] be designed to withstand all design basis loadings with conservative design margins.

- **Quality Assurance**: The QA requirements for the design, fabrication, construction, and modification of safety SSCs are developed using the facility safety analysis.

  In most cases, components used in DOE nonreactor nuclear facilities will be "off the shelf"; that is, they will not be subjected to the rigorous Nuclear Quality Assurance (NQA)-1-based requirements for "nuclear-grade" components. Therefore, safety SSC quality standards can either be design based or achieved through testing, vendor control, and inspection. However, the requirements of 10 CFR 830 Subpart A, *Quality Assurance Requirements,* also apply to safety SSCs.

- **Reliability/Redundancy**: Systems must be designed to reliably perform their safety function under those conditions and events for which their safety function is intended (e.g., must be designed to perform all safety functions with the reliability indicated by the safety analysis).

[1] Note: DOE Guide 420.1-1 is a guide and does not establish requirements. However, the Guide does state that "must" statements are utilized to denote actions that are required to comply with the Guide and that "should" statements indicate recommended practices. Furthermore, DOE Order 420.1B states that "DOE implementation guidance and technical standards referenced in this Order are not mandatory; however they must be considered in conjunction with the specific requirements. Such guidance, along with both DOE and industry standards referenced therein, represent acceptable methods to satisfy the provisions of this Order. Alternate methods that satisfy the requirements of this Order are also acceptable. <u>Any implementation method selected must be justified to ensure that an adequate level of safety commensurate with the identified hazards is achieved</u>." (Emphasis Added)

The single-point failure criterion, requirements, and design analysis identified in ANSI/IEEE 379 must be applied during the design process as the primary method of achieving reliability.[2]

For mechanical systems, Section 5.2.2 of DOE Guide 420.1-1 states that the redundancy criteria must be applied to the design of safety class SSCs that provide an active safety function. The redundancy criteria should be considered in the design of safety significant SSCs that provide an active safety function. Redundancy criteria are generally not applied to the design of safety SSCs that provide a passive safety function.

Safety class electrical power must be designed against single-point failure. Redundancy requirements for electrical systems pertain to normal and alternative power sources and should be analyzed on a case-by-case basis. For safety significant systems, redundancy is not required if it can be shown that there is sufficient response time to provide an alternative source of electrical power. (Note: For fire protection systems, mandatory codes and standards normally require back-up power, regardless of the nuclear safety classification of the system.)

- **Environmental Qualification:** Environmental qualification must be used to ensure that safety class SSCs can perform all safety functions, as determined by the safety analysis, with no failure mechanism that could lead to common cause failures under postulated service conditions.

  A main concern in the area of environmental qualification is the qualification of safety systems to withstand seismic events. DOE guidance related to seismic qualification is contained in DOE G 420.1-2, *Guide for the Mitigation of Natural Phenomena Hazards,* and supporting DOE Standards (See Appendix A for References) including the recently issued DOE Standard 1189, *Integrating Safety into the Design Process.* Seismic qualification of sprinkler systems is addressed in DOE-STD-1066-99.

DOE directives identify national codes and standards that can be utilized to provide the basic design criteria for most safety class or safety significant systems but do not require blanket application of any individual codes and standards. The exception is for fire protection systems for which DOE O 420.1B requires use of NFPA codes and standards (for all fire protection systems in DOE facilities whether the systems are used in safety class or safety significant applications or not). This is discussed further in Section 3 below. For other types of safety systems, designers tailor selections of codes and standards for each specific application based on the required safety function. DOE Guide 420.1-1 lists national codes and standards that should be considered for structural systems, mechanical systems, and electrical and instrument and control systems.

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[2] Note: DOE Order 420.1B requires application of single point failure criteria only to electrical systems. DOE Guide 420.1-1 does not limit the application of single point failure to only electrical systems, but as discussed in Note 1 this is provided as guidance and not a requirement.

Additional design criteria may be applied as necessary to ensure the system can perform its safety function.

A challenge with the use of fire protection systems in safety class and safety significant applications is the translation of some of the general design criteria into specific design details that apply for the fire protection systems. For some general design criteria, the NFPA codes and standards can in the most part be directly used. In other cases, additional criteria may be needed for some types of systems. This report is not intended to completely resolve this issue but rather to provide some insights based upon what is done in other nuclear and non-nuclear high risk applications.

2.2 Analysis of Design Criteria

DOE Order 420.1B and Guide 420.1-1 provide appropriate criteria to support design of any safety class and safety significant system and can be effectively utilized for the design of fire protection systems utilized in safety class and safety significant applications. However, one area where additional specific guidance for the implementation of general criteria would be beneficial for fire protection systems is the application of redundancy (or single failure proof) criteria and use of ANSI/IEEE 379.

3.0 DOE DESIGN CRITERIA/GUIDANCE FOR FIRE PROTECTION SYSTEMS

3.1 Summary of Design Criteria

For fire protection systems, design criteria specified in Chapter II of Attachment 2 of DOE O 420.1B, must be followed. DOE O 420.1B requires DOE facility fire protection designs to include the following elements:

- A reliable and adequate supply of water for fire suppression.
- Noncombustible construction materials for facilities exceeding the size limitations established by DOE (See DOE-STD-1066-99, *Fire Protection Design Criteria*, for information on size limitations).
- Complete fire-rated construction and barriers, commensurate with the applicable codes and fire hazards, to isolate hazardous areas and minimize fire spread and loss potential consistent with limits as defined by DOE (See DOE-STD-1066-99).
- Automatic fire extinguishing systems throughout all significant facilities and in all facilities and areas with potential for loss of safety class systems (other then fire protection systems), significant life safety hazards, unacceptable program interruption, or fire loss potential in excess of limits defined by DOE (See DOE-STD-1066-99).

- Redundant fire protection systems in areas where—
  - safety class systems are vulnerable to fire damage, and no redundant safety capability exists outside of the fire area of interest, or
  - the maximum possible fire loss (MPFL) exceeds limits established by DOE.
  - In new facilities, redundant safety class systems (other than fire protection systems) are located in separate fire areas bounded by fire rated enclosures.

In addition, DOE Standard 1066 discusses the seismic design of fire protection systems, i.e., "where required by a Documented Safety Analysis (DSA) or a Fire Hazards Assessment (FHA), the design of fire protection systems to withstand seismic events should be in accordance with the criteria developed by the National Fire Protection Association ..." In developing DOE Standard 1066, DOE performed a detailed evaluation of the NFPA seismic criteria against DOE seismic criteria and determined that, in most respects, the NFPA criteria met the DOE criteria but did identify some additional requirements related to sway bracing for safety class/significant systems. This analysis is now out-of-date because of revisions to seismic criteria as identified in DOE Standard 1189.

3.2 Analysis of Design Criteria

The fire protection design criteria provided in Chapter II of DOE Order 420.1B and Standard 1066 apply to all fire protection systems. These documents do not provide additional criteria for fire protection systems used in safety class or safety significant applications. In most respect, the criteria are sufficient to meet the requirements for safety class and safety significant systems as delineated in Chapter I of DOE Order 420.1B. However, addition analysis is needed to evaluate some of the details, in particular quality assurance requirements and seismic requirements.

4.0 FIRE PROTECTION DESIGN CRITERIA PRACTICES IN OTHER HIGH RISK INDUSTRIES

4.1 Nuclear Regulatory Commission Fire Protection Design Criteria

The U.S. Nuclear Regulatory Commission (NRC) established fire protection requirements for commercial nuclear power plants in 10 CFR Part 50 and for other nuclear fuel cycle facilities in 10 CFR Part 70. Both are discussed below followed by a discussion on how they relate to DOE facilities and requirements.

4.1.1 Commercial Nuclear Power Plants

After a significant fire occurred at a commercial nuclear power plant in 1975 (the Browns Ferry fire), the NRC revised its fire protection regulations to reduce the likelihood and the consequences of a fire. To meet these objectives, the fire protection programs for operating nuclear power plants are designed to provide reasonable assurance, through defense in depth, that a fire will not prevent the performance of necessary safe shutdown functions and that radioactive releases to the environment in the event of a fire will be minimized.

The objectives of NRC's fire protection regulations in 10 CFR 50.48 and Appendix R to 10 CFR Part 50 are to:

1. Prevent fires from starting;
2. Rapidly detect, control, and extinguish fires that do occur; and
3. Provide protection for structures, systems, and components important to safety so that a fire that is not promptly extinguished by fire suppression activities will not prevent the safe shutdown of the plant.

Fire protection for nuclear power plants uses the concept of defense in depth to achieve the required degree of reactor safety by using administrative controls, fire protection systems and features, and safe shutdown capability.

Commercial nuclear power plant licensees have two alternative regulatory approaches to manage their fire risk:

- **Deterministic fire protection requirements.** Deterministic fire protection requirements seek to establish safety margins through the post-fire survival of the systems needed to shut down the reactor. These requirements, based on a set of postulated severe fires, were developed before the staff or the industry had the benefit of probabilistic risk assessments (PRAs) for fires and other recent technical advances.

- **Risk-informed fire protection requirements.** Risk-informed fire protection requirements consider risk insights as well as other factors to establish requirements that better focus attention on design and operational issues according to their importance to public health and safety. Performance-based regulations rely on a required outcome rather than requiring a specific process or technique to achieve the outcome. The NRC lists these requirements in 10 CFR 50.48(c). They require the implementation of NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants.*

4.1.2 Non-reactor Nuclear Fuel Cycle Facilities

Fuel cycle facilities containing a critical mass or more of Special Nuclear Material are licensed under Subpart H of 10 CFR 70. 10 CFR 70.61 contains performance requirements which limit the risk from individual events including those initiated by fire.

In addition, 10 CFR 70.64 contains Baseline Design Criteria which requires protection from fire and explosions to be explicitly considered in the design of new facilities or new processes added to existing facilities.

The gaseous diffusion plants which were formerly DOE controlled facilities are now NRC certified under 10 CFR 76. UF_6 Conversion facilities are licensed under 10 CFR 40, which governs source material (i.e., unenriched uranium or thorium). Research reactors such as those at research institutes or universities are licensed under 10 CFR 70 but not under Subpart H.

Guidance for fire protection of fuel cycle facilities licensed under Subpart H of 10 CFR 70 is provided in NUREG-1718, *Standard Review Plan for a Mixed Oxide Fuel Fabrication Facility*, and NUREG-1520, *Standard Review Plan for Fuel Cycle Facilities*. In addition to these two NUREGS, NFPA 801, *Standards for Facilities Handling Radioactive Materials,* contains general guidance for fuel cycle and other nuclear material sites. Regulatory Guide 3.55, *Standard Format and Content for the Health and Safety Sections of License Renewal Applications for Uranium Hexafluoride Production*, provides guidance for uranium hexafluoride conversion facilities.

The objectives of NRC's fire protection regulations and guidance with respect to 10 CFR 70, Subpart H, licensed facilities are to assure that risk to both workers and the public is acceptably low, to assure the use of good engineering practice in the fire protection engineering design of new facilities and processes, and to promote defense-in-depth principles which incorporate independent layers of protection, diversity, and redundancy. The demonstration of compliance with the 10 CFR 70, Subpart H, performance requirements is provided in the Integrated Safety Analysis (ISA) Summary, which is submitted by the applicant along with the License Application for a new facility. Existing facilities were required to perform an ISA and submit an ISA Summary by October 18, 2004.

4.1.3 Summary of NRC Requirements and Comparison to DOE Requirements

The NRC has fire protection requirements for both commercial nuclear power reactors and non-reactors. For reactors, the requirement is in essence that fire barriers or automatic suppression systems or both shall be installed as necessary to protect redundant systems or components necessary for safe shutdown. For nuclear fuel cycle facilities (which have more in common with DOE facilities) the requirements are simply that the design must provide for adequate protection against fires. Facility safety analysis is utilized to determine what systems are needed and then national consensus codes are applied to the systems. The licensee must identify Items Relied On for Safety (IROFS), which, along with management measures are required to minimize the likelihood and consequence of a fire.

This is similar to DOE practices for design of safety class and safety significant systems where a facility safety analysis is relied on to identify what types of systems are needed for nuclear safety purposes and the functional requirement of the systems. Similar to the

NRC, DOE relies on national consensus codes and standards for design criteria. However, DOE also provides additional general criteria related to conservative design features and redundancy that are not provided in the NRC requirements and differentiates between safety class and safety significant systems (the NRC does not provide this type of a breakdown of its safety controls. For example, reactor fire protection systems are regarded as defense-in-depth, and can be denoted as safety-related; and non-reactor significant safety systems are called, "items relied on for safety."

4.2 Non-nuclear Fire Protection System Design Criteria for High Risk Facilities

4.2.1 Overview

Non-nuclear commercial industry and government agencies (e.g., Federal, State and local) rely on NFPA standards and the International Building Code (IBC) to establish design requirements for fire protection systems used in high risk facilities. The NFPA and IBC requirements are, in some instances, supplemented by requirements that are identified in State or local administrative codes, insurance industry criteria, or specific agency criteria. The following sections describe some of the additional requirements (beyond the NFPA and IBC) that have been identified. Since there are huge variations and most State and local administrative codes do not apply on Federal reservations, this paper does not discuss the State and local government codes. However, the Department of Defense criteria discussed below closely parallel the best of the State and local requirements.

4.2.2 Department of Defense (DOD) Uniform Facilities Criteria

The DOD Uniform Facilities Criteria contains the following guidance for fire suppression systems and for essential facilities:

- Specifications must contain provisions regarding sprinkler contractor qualifications.
- Drawings and calculations for all fire suppression systems must be prepared by National Institute for Certification in Engineering Technologies (NICET) Level III or IV individuals.
- Sprinkler shop drawings must be stamped by a Professional Engineer.
- Shop drawings are reviewed by a Federal fire protection engineer.
- Current water flow test results must be accepted before a project can be advertised.
- Pipe schedule systems are limited to 1500 square feet.
- Design densities are similar to NFPA 13, *Standard for the Installation of Sprinkler Systems*, but design areas are doubled for most systems.
- Hose stream allowances are approximately double the NFPA 13 minimum.
- Schedule 10 pipe is permitted for wet systems only with acceptable water quality tests for micro-biological and galvanic corrosion.

- Sprinklers must protect 100 percent of a building including electrical and mechanical rooms.
- For buildings four stories and higher, there must be sprinkler risers in at least two stairwells that are interconnected at each floor with a check valve and bypass at each riser.
- For additions or modifications, the entire gross floor area must be used to determine sprinkler protection needs for the project.
- Sprinklers must be provided for smaller (i.e., less than 5000 square feet) facilities containing materials, equipment, and supplies that are mission essential, pose a severe fire hazard, are of high monetary value, pose a safety or environmental health risk, or expose an important structure. Sprinkler protection must include covered loading docks.

4.2.3 Insurance Industry (Factory Mutual) Global Data Sheets

Factory Mutual (FM) Global Data Sheets provide supplemental requirements for highly protected risk properties (HPR). HPR criteria are not limited to critical facilities by FM. HPR criteria already apply to all DOE facilities (per DOE O 420.1B). The following are some examples of FM Data Sheets:

- Data Sheet 2-1 provides detailed criteria for prevention and control of internal corrosion in automatic sprinkler systems.
- Data Sheet 2-2 provides supplemental criteria for suppression mode (early suppression fast response) sprinklers.
- Data Sheet 2-7 provides criteria for sprinkler systems using large drop sprinklers.
- Data Sheet 2-8 provides criteria for earthquake protection for water based fire protection systems. Seismic requirements for acceleration and sway bracing and hangars were enhanced by FM in 2004 but it appears that the 2007 edition of NFPA 13 raised the requirements beyond the FM requirements. Both are consistent with DOE-STD-1066.
- Data Sheet 2-8N, installation of automatic sprinkler systems, is undergoing extensive modifications and is not currently available.

4.2.4 General Service Administration (GSA) Supplemental Criteria

The GSA specifies the following supplemental criteria for essential electronic facilities:

- A wet pipe sprinkler system shall be provided throughout the facility including data storage areas.
- Quick response sprinklers shall be used throughout the facility including data storage areas.
- The sprinkler system shall have a separate isolation valve and a separate water flow switch located outside of each protected area in an accessible location. Each valve shall be provided with a tamper switch that is connected to the building's fire alarm system.

- Activation of the sprinkler water flow switch shall disconnect power to the computers and to the heating ventilation and air conditioning (HVAC) systems with no time delay.
- The activation of two cross-zoned conventional photoelectric smoke detectors or the activation of one intelligent analog/addressable photoelectric smoke detector utilizing early warning smoke detection technology within a single protected area shall disconnect power to the computer equipment and to the HVAC system after a pre-set time delay.

4.2.5 Modification to IBC as a Result of Attacks on the World Trade Center

A modification of the IBC was recently approved to address lessons learned from the September 11th terrorist attacks on the World Trade Center. The National Institute of Standards and Technology submitted the proposal to modify the IBC and International Fire Code to include redundant risers for each sprinkler zone protecting high-rise buildings over 420 feet in height. In addition the following modifications were approved:

- Risers must be widely separated.
- Alternate floors cannot be on the same riser.
- Draw water from at least two water mains on different streets or with suitable isolation valves so that damage can be isolated without interruption of the water supply.

4.2.6 Summary of Non-nuclear Industry and Government Fire Protection Requirements and Comparison to DOE Requirements

Industry relies on the NFPA and IBC Codes and Standards for the design of fire protection systems utilized for the protection of high risk property. A widely used fire protection system, i.e., sprinkler systems, are in essence "safety" systems as they are called on to be used for safety purposes in the nationally applicable IBC and the NFPA Life Safety Code. Sprinkler systems have evolved over the last 150 years and are extremely reliable. Very few government and industry communities consider that additional fire protection requirements (beyond the NFPA and IBC) are warranted for protection of high value or high risk systems or facilities. Governments and businesses do not often apply supplemental design standards even for the most critical fire protection systems. DOE facilities meet the NFPA codes and standards (and the IBC if it is identified as the model building code applicable to the DOE site) and some of these additional requirements, in particular the additional requirements specified by the insurance industry for highly protected risks.

DOE does not require the use of some of the supplemental criteria utilized in other government agencies. In particular, DOE does not require the use of supplemental criteria that DOD requires for sprinkler systems. These supplemental criteria provide for greater assurance that fire protection systems will meet their functional requirements and may be warranted to be applied to fire protection systems at DOE, in particular to a fire protection system utilized in safety significant or safety class applications. Other supplemental criteria, such as the GSA criteria, that were reviewed as part of this effort are very narrowly focused to specific applications and may not be appropriate for DOE facilities.

5.0 SUMMARY/RECOMMENDATIONS

The data and analysis in this report are intended to support the development of additional guidance for design of fire protection systems used in safety class and safety significant applications.

The review of DOE requirements and guidance for safety class and safety significant systems shows that DOE utilizes facility-specific safety analysis to identify the types and functions of safety systems needed to prevent and mitigate accidents. DOE-developed general design criteria reference industry codes and standards, which are utilized to support the design of systems to meet the functional requirements for the safety systems. These general criteria would also apply to fire protection systems utilized in safety class and safety significant applications and the applicable codes and standards would be those from NFPA and the IBC. These are the same codes and standards which are mandatory for all fire protection systems through DOE Order 420.1B and 10 CFR 851 whether or not they are classified as safety class or safety significant. Furthermore, DOE Order 420.1B requires that supplemental criteria in FM Global Data Sheets that are applicable to "Highly Protected Risk" be applied for fire protection, which is consistent with the best commercial industry practice.

The NRC requirements related to fire protection systems are similar to DOE's in that they rely on the safety analysis to identify what types of safety systems are needed for some nuclear safety applications. In general, NRC has performance-based criteria for design, installation, and operation of fire protection systems in nuclear applications. In most cases, NRC requirements and guides are based on industrial codes and standards for the system design criteria and administrative features.

Some additional fire protection systems requirements that are utilized in the non-nuclear commercial industry and other governmental organizations include:

- The insurance industry offers a significant premium reduction for properties with sprinkler systems without requiring any supplemental design criteria. Factory Mutual Global, which insures only highly protected properties, specifies supplemental criteria only for specialty sprinklers which are not fully addressed in national codes and standards. DOE already requires the supplemental criteria in FM Global Data Sheets.

- The Department of Defense specifies supplemental criteria for all sprinkler systems, whether or not they are vital. These supplemental criteria parallel the licensing and qualification requirements found in some state and municipal administrative codes. Since state and local requirements have significant gaps and do not apply on Federal reservations, it would be prudent for DOE to adopt similar criteria at a national level, including: requirements for contractor licensing; preparation of drawings and calculations by NICET Level III or IV individuals; and drawings being stamped by a registered professional engineer in the state where installed, and reviewed by a qualified Federal fire protection engineer. Limitations on schedule 10 piping, dual risers for buildings over four stories, and certain other DOD criteria would also be prudent for DOE safety systems. The remaining DOD criteria, including higher densities, increased hose stream allowance, and area protection should be evaluated for general fire protection applicability when DOE-STD-1066 is updated.

In addition, the review found that some of DOE requirements and guidance related to the application of redundancy criteria, seismic criteria, and quality assurance requirements to support design of fire protection systems used in safety class and safety significant applications could be clarified.

DOE will consider this information in its development of new guidance for the design and operation of fire protection systems as identified its implementation plan for DNFSB Recommendation 2008-1.

Appendix A
References

DOE Directives

- DOE O 420.1B, *Facility Safety*
- DOE G 420.1-1, *Nonreactor Nuclear Safety Design Criteria and Explosives Safety Criteria Guide for use with DOE O 420.1, Facility Safety*
- DOE G 420.1-2, *Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Nonnuclear Facilities*

DOE Technical Standards (STD)

- DOE-STD-1189-2008, *Integration of Safety into the Design Process*
- DOE-STD-1066-99, *Fire Protection Design Criteria*

Code of Federal Regulations (CFR)

- 10 CFR Part 50, *Domestic Licensing of Production and Utilization Facilities*
- Appendix R to 10 CFR Part 50, *Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979*
- 10 CFR 50.48, *Fire protection*
- 10 CFR Part 70, *Domestic Licensing of Special Nuclear Material*
- 10 CFR Part 830, *Nuclear Safety Management*
- 10 CFR Part 851, *Worker Safety and Health Program*

Nuclear Regulatory Commission

- NUREG-1520, *Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility – Final Report*

Non-Government Standards

- NFPA 13, *Standard for the Installation of Sprinkler Systems*
- NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials*
- NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants*
- ANSI/IEEE 370-2000, *IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Safety Systems*
- IAEA Safety Series No. 50-P-1, *Safety Practices - Application*

Appendix B
DOE Safety Class and Safety Significant System Design Criteria

The following are excerpts from DOE Directives related to the design of safety class and safety significant systems. These were utilized in analysis performed in the main body of the report.

DOE Order 420.1B

- Safety analyses must be used to establish the identity and functions of safety class and safety significant structures, systems, and components (SSCs).

- Nuclear facility design objectives must include multiple layers of protection to prevent or mitigate the unintended release of radioactive materials to the environment, otherwise known as defense in depth. Defense in depth must include applying conservative design margins and quality assurance requirements.

- Hazard Category 1, 2, and 3 nuclear facilities must be designed to facilitate inspections, testing, maintenance, repair, and replacement of safety SSCs as part of a reliability, availability, and maintainability program with the objective that the facility is maintained in a safe state.

- Safety SSCs and safety software must be designed, commensurate with the importance of the safety functions performed, to perform their safety functions when called upon and to meet the quality assurance program requirements of either 10 CFR 830, Subpart A, or DOE O 414.1C, *Quality Assurance*, as applicable.

- Safety class electrical systems must be designed to preclude single point failure.

DOE G 420.1-1 (See footnote 3.)

- Safety SSCs and their associated support systems must be designed, fabricated, erected, and tested to standards and quality requirements commensurate with their importance to safety.

- Safety SSCs must be designed to reliably perform their safety function under those conditions and events for which their safety function is intended.

- Safety SSCs must be designed to withstand all design basis loadings with an appropriate margin of safety.

- The facility and its systems must be designed to perform all safety functions with the reliability indicated by the safety analysis. The single-point failure criterion, requirements, and design analysis identified in ANSI/IEEE 379 must be applied during the design process as the primary method of achieving this reliability.

Appendix C
DOE Fire Protection
Design Criteria

The following are excerpts from DOE Directives and Standards related to the design of fire protection systems. These were utilized in analysis performed in the main body of the report.

DOE Order 420.1B

The fire protection design program must include the following elements:

- A reliable and adequate supply of water for fire suppression.

- Complete fire-rated construction and barriers, commensurate with the applicable codes and fire hazards, to isolate hazardous areas and minimize fire spread and loss potential consistent with limits as defined by DOE.

- Automatic fire extinguishing systems throughout all significant facilities and in all facilities and areas with potential for loss of safety class systems (other then fire protection systems), significant life safety hazards, unacceptable program interruption, or fire loss potential in excess of limits defined by DOE.

- Redundant fire protection systems in areas where:

  - safety class systems are vulnerable to fire damage, and no redundant safety capability exists outside of the fire area of interest, or

  - the maximum possible fire loss (MPFL) exceeds limits established by DOE.

- In new facilities, redundant safety class systems (other than fire protection systems) located in separate fire areas bounded by fire rated enclosures.

- Provide a level of safety sufficient to fulfill requirements for highly protected risk (HPR).

- Prevent loss of safety functions and safety systems as determined by safety analysis and provide defense-in-depth.

- Meet or exceed applicable building codes for the region and NFPA codes and standards.

DOE Standard 1066

4. DEFINITIONS

Redundant Fire Protection System - A fire protection system that is designed and installed to function in the event of the failure of a primary fire protection system. Where redundant fire protection systems are specified, any two of the following are considered satisfactory:

- Automatic suppression systems, such as fire sprinklers, foam, gaseous, explosion suppression, or other specialized extinguishing systems plus appropriate alarms. An adequate supply, storage, and distribution system is an essential element.
- Automatic fire detection, occupant warning, manual fire alarm, and fire alarm reporting systems (considered together) combined with a sufficiently-staffed, properly-equipped, and adequately-trained fire department or brigade that is able and committed to respond in a timely and effective manner.
- Fire barrier systems or combinations of physical separation and barriers for outdoor locations.
- Other systems, such as alternate process control systems, as approved by the Authority Having Jurisdiction (AHJ).

Redundant fire protection systems may include dual water supplies to sprinkler systems, dual piping risers, or valving systems such that adequate redundancy in water supply to the sprinkler heads is provided to cover maintenance or emergency outages of either of the water supply systems or may include multiple types of automatic fire suppression systems (e.g., water sprinklers and a gaseous fire suppression system).

Portable fire extinguishers, interior fire hose systems, or interior fire detection and alarm systems do not meet the definition of a redundant fire protection system.

5. GENERAL CRITERIA

5.1.1 When the Maximum Possible Fire Loss (MPFL) exceeds $50 million, a redundant fire protection system should be provided that, despite the failure of the primary fire protection system, will limit the loss to acceptable levels as determined by the AHJ.

5.1.2 When the MPFL exceeds $150 million, a redundant fire protection system and a three-hour fire barrier should be provided to limit the MPFL to acceptable levels as determined by the AHJ.

5.1.3 Where a potential fire would represent an unacceptable risk to the health and safety of the public, workers, the environment, DOE programs, or DOE property (as determined by a fire hazard analysis), fire protection should be provided for special structures, commensurate with the risk.

5.3.3 Where required by the Safety Analysis Report (SAR), the design of fire protection systems to withstand seismic events should be in accordance with the criteria developed by the National Fire Protection Association, except as required by other DOE criteria, such as in Section 7 of this standard.

5.3.4 Fire protection systems or portions of them, which must function to control effects of a Design Basis Accident (DBA) event (as determined by safety analysis accident scenarios), should be designed to be functional for all conditions included in the accident scenario. This should include both the event initial cause and its consequences.

6. WATER SUPPLY AND DISTRIBUTION SYSTEM CRITERIA

6.1 Demand

6.1.1 Domestic water distribution systems that also serve fire protection requirements should be designed to satisfy the calculated Fire Hydrant Demand (see Paragraph 6.1.2) and the peak domestic demand. Where no other requirements are applicable, the peak domestic demand should be based on 2.5 times the calculated average daily demand plus any special demands, such as industrial or processes that cannot be reduced during a fire. The distribution system should be capable of meeting this combined demand at a minimum residual pressure of 20 psi at ground elevation (or higher elevation if special conditions apply) for a period of not less than two hours. Municipal supplies having the same capability are acceptable.

6.1.2 Fire Hydrant Demand - Where reliance is placed on fire department response, either for protection of unsprinklered buildings or where the fire department will serve as redundant (e.g., backup) protection, the water supply available from hydrants should be capable of providing the flow rates established in NFPA 1 based on the most severe facility fire risk on site. These values may be reduced by a maximum of 50 percent when the facility is provided with automatic sprinkler protection throughout, in accordance with the applicable NFPA Standards.

6.1.3 Within a building or facility, domestic water should be supplied by a separate service line and not be a combined fire protection and potable water service or a combined process water and potable water system. Where combined fire and domestic-process water systems are used, distribution piping should be routed and provided with valves such that the domestic and process systems can be isolated without shutting off the fire system supply.

6.2 System Arrangement

6.2.1 Facilities having a Maximum Possible Fire Loss (MPFL) in excess of $100 million and significant nuclear facilities (i.e., Category 1 Hazard) should be provided with an additional, independent source of fire protection water.

6.2.2 Listed and/or approved control valves should be installed at maximum intervals of not more than 5,000 feet on long supply lines and at maximum intervals of not more than 1,200 feet on main distribution loops, feeders and all primary branches connected to these lines. Such control valves should also be installed at selected points throughout the distribution system to provide system control over each service area. At intersections of distribution mains, one less control valve than the total number of intersecting mains may be provided. As an aid in determining the minimum number of sectional control valves, the critical nature of the building/facility should be considered as well as the number of fire and domestic systems affected in a potential line failure.

6.2.3 Sprinkler system water supply lead-ins should not run under buildings except for the minimum distance possible. Sprinkler system risers and alarm valves should be located as close as practical to a building entry point. Where a riser would otherwise be located in a potentially contaminated area, consideration should be given to locating the riser exterior to the building in a heated enclosure.

6.2.4 Hydrants should be provided so that hose runs from hydrants to all exterior portions of a protected building are no more than 300 feet. Hydrants should not be closer to than 40 feet to buildings.

6.3 Seismic Criteria

6.3.1 In addition to the applicable seismic requirements delineated in NFPA 13, the following criteria should apply in the design of new sprinkler systems relied upon to prevent or mitigate the adverse nuclear safety consequences of seismically induced: fires, inadvertent actuations, structural failures, and leakage as set forth in the facility Safety Analysis Report (SAR).

6.3.2 In the design of sway bracing, the criteria of Section 4-14.4.3.5.3 (or current equivalent) of NFPA 13 (1996) should be revised as follows. Horizontal force should be determined by the equation $F(p) = K \times W(p)$. A value of K, consistent with the criteria in DOE-STD-1020-94 should be determined by an engineer qualified in seismic analysis. Values for K less than 0.5 should not be used unless specifically justified. Exception 1 or 2 following Section 4-14.4.3.5.3 should be applied. If Exception 1 is applied, use "K" instead of "half." If Exception 2 is applied, divide "K" by 0.5 to determine the multiplier for Table 4-14.4.3.5.3 (or current equivalent).