TOWARDS A UNIFIED APPROACH TO FIRE SAFETY IN NUCLEAR POWER PLANTS

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Abstract

North American standards in nuclear fire safety have been developed for specific reactor types. NFPA standards 804 and 805 were specific to light water reactors while CSA N293, prior to 2012, was explicit to CANDU reactors. Recent trends have seen some movement towards technology neutral standards in North America. With the advent of several power reactor technologies emerging in the market, a need may be realized towards a common approach to fire safety. This paper will attempt to provide an overview of the current approaches to fire safety, and distill the common methodologies and factors for fire safety that can be utilized in a unified standard.

1. Introduction

North American standards in nuclear fire safety have been developed for specific reactor types. A new exception was realized through the development of the CSA N293 standard which has recently adopted a technology-neutral approach. However, certain elements of the standard still contain a CANDU inference, and the structural configuration of the Canadian building codes that are referenced within the standard may limit the use of the standard in the international market.

In contrast to CSA N293, NFPA nuclear fire standards rely on a library of NFPA standards that is already integrated and can be more readily utilized in the international market. Yet NFPA nuclear power fire standards, such as NFPA 804 and NFPA 805 are limited to light water reactors.

Since current standards have limitations, a need may be realized towards establishing a generalized standard that can be utilized for future generations of nuclear power reactors in the international market.

2. Standards Utilized for Principle Derivation

To facilitate development of a guiding fire standard for future generations of nuclear power reactors, the common principles within the current standards must be derived, conceptualized, and presented in a framework that can be common to several future technologies.

Three standards are utilized as a base case for derivation of principles:

2.1 CSA N293-12 *"Fire Protection for Nuclear Power Plants"*

This standard is published by the Canadian Standards Association (CSA) and is the updated and revised version of the previous CSA N293-07 *"Fire protection for CANDU nuclear power plants"*. This standard is intended to be a technology-neutral standard that is applicable to new, existing facilities, and facilities under decommissioning. The standard provides the minimum fire requirements for the design, construction, maintenance and operations of these facilities.

Although the CANDU terminology has been removed from the body of the standard, references and aspects related to CANDU power reactors, are still evident in the standard such as pressure retaining and electrical power requirements,

Some differences in structure, design and analysis approaches between CSA N293-12 and NFPA 805/804 do exist, such as the approach to the fire analysis.

2.2 NFPA 804 (2015) *"Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants"*

This standard is published by the National Fire Protection Association (NFPA). The standard is specific to advanced light water reactors and provides the minimum fire protection requirements to ensure safe shutdown of the reactor, provide life safety to on-site personnel, and minimize any release of radioactive materials. While the standard is not specific to new facilities, the main construction requirements are mostly related to new builds.

The standard, as typical to the majority of NFPA standards, relies on the extensive NFPA library which is already correlated with the standard. This allows any user of an NFPA standard to easily equivalence ambiguous or alternative requirements through applying other NFPA standards. A very simplified example includes the use of NFPA 805 for existing facilities in the event NFPA 804 requirements are impractical.

2.3 NFPA 805 (2015) *"Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants"*

This is another standard published by the National Fire Protection Association (NFPA) and is also specific to light water reactors. The standard is significantly different from both NFPA 804 and CSA N293 as it is limited in scope to specifying the minimum fire protection requirements for existing light water nuclear power plants.

A noted feature in NFPA 805 is an ordered approach to utilizing performance-based methods for operations of existing power plants, an approach that is not as readily outlined in CSA N293 and NFPA 804.

3. Derivation of Principles

Although the three standards are scoped and structured differently, common principles do exist as commensurate with any fire safety application. In general terms, a nuclear power plant would require the following activities over its life time:

a) Constructing the facility;

b) Operating the facility;

c) Decommissioning the facility.

These three activities will be common among all nuclear power plants irrespective of the technology and the governing body. One can easily conclude that a fire standard for a future technology will have to incorporate these three activities.

A common feature among these standards is the presence of a **Fire Protection Program.** This program is generally intended to address facility operations and operational programs, but in due course, has become the main driver of fire safety in nuclear applications.

Since the fire protection program is theoretically activated at the start of plant operations and continues over the life time of the plant, two of the three activities indicated above can be incorporated in the fire protection program. This will result in the above three activities being revised as follows:

a) Constructing the facility, i.e. Design and Construction;

b) Implementation of the Fire Protection Program

To further assist in formulating this framework, it can also be concluded that, in general terms, the Design and Construction will contain the majority of technology-specific requirements while the Fire Protection Program can be easily made technology-neutral.

Thus, the main features of the three standards are outlined in Table 1

Table 1: Comparison of Fire Standards

Activity	CSA N293	NFPA 804	NFPA 805
Design and Construction	**Fire Protection Assessments** - Fire Safe shutdown analysis - Code compliance review - Fire hazard analysis	**Fire Safe Shutdown Assessment** - Safe shutdown analysis - Analysis of external fire events - Fire hazard analysis	**Deterministic vs Performance-Based approaches**
	General Plant Design - Separation - Protection of fire safe shutdown - Reducing spread of fire - Life safety - Maintaining plant operation - Fire prevention	**General Plant Design** - Plant arrangement - Life safety - Building construction and material - Ventilation - Drainage - Emergency lighting - Lightning protection - Electrical cabling	**Prescriptive Upgrades** -Water supply -Standpipe and hose stations -Fire extinguishers -Fire alarm and detection systems - Automatic and manual water-based fire suppression systems

Activity	CSA N293	NFPA 804	NFPA 805
		- Exposure protection - Electrical systems -Communications	-Gaseous fire suppression systems -Passive fire protection features
	Design and Installation of Fire Protection Systems - Fire alarm systems - Fire suppression - Seismic qualification		
		Fire Protection Systems and Equipment	
		Identification and Protection against Hazards	
Fire Protection Program	**Management Policy** - Roles and responsibilities - Establishing the fire protection program	**Management Policy Direction and Responsibility** - Roles and responsibilities - Interfaces - Authority for conflict resolution	**Fire Protection Plan** - Intent - Management policy, direction and responsibility - Procedures
	Program elements - Organization - Procedures - Staffing - FHA - Plant documentation -Change management - Hazard mitigation -Fire prevention -Inspection and testing - Fire emergency plans - Quality control - Prefire plans - Fire brigade training **Fire Safety Plans** **Fire Reporting**	**Fire Prevention Program** - Fire safety information - Inspections - Fire hazard control procedures (operations) -Surveillance -Reporting	**Prevention** -Fire prevention for operations. -Specific material and operational requirements
		Fire Hazard Analysis	
		Fire Procedures Inspection, testing and maintenance - Operation of fire safety equipment - Trend analysis - Controlled access - Training	
		Quality Assurance	
		Fire Emergency Plan Fire notification, response, and evacuation -Fire extinguishment, coordination, and recovery -Prefire plans - Interface and mutual aid	
		Fire Brigade - Fire fighting capability - Qualifications - Training and drills - Fire-fighting equipment - Off site interface - Fire fighting access - Water drainage and smoke/heat removal -Radiation shielding	**Industrial Fire Brigade** -On site Fire fighting capability -Pre-fire plans -Training and drills -Fire-fighting equipment -Off-site fire department interface

Activity	CSA N293	NFPA 804	NFPA 805
	Fire Protection requirements for decommissioning		**Fire protection during decommissioning and permanent shutdown**

As per Table 1, the common feature among the three standards is the presence of a Fire Protection Program. If this feature of the standard is utilized as the main common driver for fire safety, the principles in the three standards can be integrated under this common driver which will form a new approach to future standards.

Figure 1 provides an illustration to this approach.

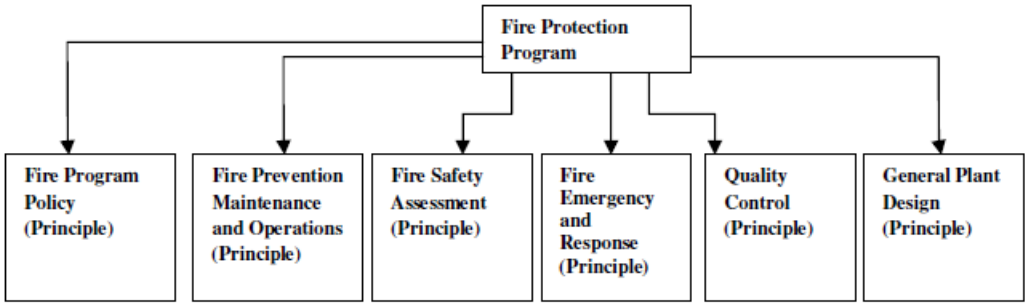

Figure 1: Proposed Nuclear Fire Safety Standard Approach Logic

An important consideration in the proposed approach is the fact that a Fire Protection Program may not exist prior to construction of a new build or a new technology. As such a new standard formulated around the proposed approach may not address a required framework for a new construction. However, in any new standard these construction features can be easily captured under the “General Plant Design” as they both apply to modifications and new construction.

The proposed approach to a future standard framework can now be validated by ensuring that the main concepts in the three standards are already encompassed in the proposed approach. This is outlined in Table 2.

Table 2: Future Fire Standard Proposed Framework

Fire Protection Program	CSA N293	NFPA 804	NFPA 805
Fire Program Policy	Policy document	Management Policy Direction and Responsibility (Quality Assurance)	Fire Protection Plan
Fire Prevention Maintenance and Operations	Program elements Fire protection and assessments (Fire Protection Requirements for Decommissioning)	Fire Prevention Program Fire Procedures	Prevention
Fire Safety Assessment	Program elements Fire protection and assessments	Fire Hazard Analysis Fire Safe Shutdown Analysis	(Deterministic vs Performance-Based approaches)
Fire Emergency and Response	Fire Brigade Fire safety plans Fire reporting	Fire Emergency Plan Fire Brigade	Industrial Fire Brigade
Quality Control	Program elements	(Quality Assurance)	
General Plant Design	General plant design Design and installation of fire protection systems (Fire protection requirements for decommissioning)	General Plant Design Fire Protection Systems and Equipment Identification and Protection against Hazards	(Deterministic vs Performance-Based approaches) Prescriptive Upgrades Fire protection during decommissioning and permanent shutdown

In essence, the majority of principles, with the exception of plant design, can be easily utilized for future technologies in the nuclear reactor field without significantly compromising the approach of a standard. The only principle that may have technology-related features is that of plant design. However, this issue can be addressed by moving towards a less scripted or prescriptive design outline and more towards a performance-based design outline for future technologies.

4. Conclusion

It is evident that nuclear fire standards, while differing in structure, application, and use, have a significant number of common principles. This is a logical conclusion as the main driver for these principles is ensuring fire safety. The revised approach distils these principles and subordinates them to the Fire Protection Program as the main driver for future generic nuclear power fire safety standards.

Most of the principles outlined in the revised approach are technology neutral and as such, are liable to be integrated in future technologies with little modifications. Technology-specific principles in the proposed approach, such as plant design requirements, may be tailored towards performance-based designs, or designs that are purely based on the Fire Safety Assessments to allow them to easily integrate in a generic future standard without compromising the standard logical process.

5. References

[1] Canadian Standards Association, CSA N293-12 “Fire protection for nuclear power plants”.

[2] National Fire Protection Association, NFPA 804 “Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants”, 2015 Edition.

[3] National Fire Protection Association, NFPA 805 “Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants”, 2015 Edition.

[4] Canadian Standards Association, CSA N293-07 “Fire protection for CANDU nuclear power plants”.