EM-5.22 Lessons Learned Bulletin

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Lessons Learned from Experience with Fire Safety at Nuclear Facilities

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Fire safety is important to all operating facilities, but it is especially critical to operational nuclear facilities. Fire safety programs have been developed through various documents by the Department of Energy (DOE), the Nuclear Regulatory Commission (NRC) and for international nuclear power plants, by the International Atomic Energy Agency (IAEA).

Two major incidents are discussed in this lessons learned bulletin including a significant fire at the Tennessee Valley Authority's Brown's Ferry nuclear power plant in Alabama and at the DOE Office of Environmental Management (EM) operation at the Waste Isolation Pilot Plant (WIPP) outside Carlsbad, New Mexico. Lessons learned based on these incidents and from an International Atomic Energy Agency (IAEA) study of fire incidents at nuclear power plants around the world are discussed below.

Discussion:

Background

Fire safety is important throughout the lifetime of a nuclear facility, from design to construction and commissioning, throughout facility operations and in decommissioning. Requirements for fire safety in the operation of nuclear power plants and nuclear facilities are established in various documents by the Department of Energy (DOE), the Nuclear Regulatory Commission (NRC) and for international nuclear power plants, by the International Atomic Energy Agency (IAEA). The DOE Fire Protection Program is multi-faceted, which includes published fire safety directives (Orders, standards, and guidance documents), a range of oversight activities, and an annual fire protection program summary. The NRC program requires robust fire protection at every commercial nuclear facility in the United States with plants being able to choose between two approaches for managing their fire safety: deterministic fire protection or risk-informed, performance-based fire protection. These approaches apply the concept of defense-in-depth to meet fire protection objectives. The IAEA uses a Safety Guide for fire protection that provides guidance on how to meet these requirements by making recommendations on the elements of plant management and operation that are necessary to achieve and maintain satisfactory fire safety.

The concept of defense-in-depth incorporates multiple levels of protection, which are subject to layers of overlapping provisions and should be extended to all safety activities, whether organizational, behavioral or equipment related. These levels of protection are intended to compensate for human errors or plant failures and should encompass radiation protection and the prevention and mitigation of accidents. Fire is a hazard that has the potential to create a common cause failure mode for which prevention and mitigation measures should be provided.

Discussion

Two major incidents are discussed below: One dealing with a significant fire at a nuclear power plant, Brown's Ferry, and one dealing with a fire at an operational DOE EM waste disposal facility, Waste Isolation Pilot Plant (WIPP).

In 1975, a fire at the Brown's Ferry nuclear power plant near Athens, Alabama, damaged critical control cables and hampered operators' ability to monitor the status of the plant's reactor. The fire began in the cable spreading room directly below the combined control room for the Unit 1 and Unit 2 reactors. As the fire progressed, it damaged power and control cables for safety systems and their backups. All of the emergency core cooling systems for the Unit 1 reactor and most of those systems for the Unit 2 reactor were disabled during the fire. The fire defeated many of the defense-in-depth barriers erected to guard against reactor core damage. Fortunately, workers were able to use non-emergency

components and restore enough emergency components to service in time to prevent the significant damage to Unit 1 and Unit 2 cores.

As a result of this accident, NRC subsequently issued deterministic fire safety regulations for plants to follow, but differences in plant design, coupled with changes in NRC guidance, made it difficult for most plants to meet the regulations without seeking numerous exemptions. In 2004, NRC issued a regulation permitting plants to voluntarily transition to risk-informed fire protection requirements. This new approach mirrors NRC's efforts to adopt a more risk-informed regulatory approach to nuclear safety in general.

In February 2014, an underground mine fire involving a salt haul truck occurred at the DOE WIPP near Carlsbad, New Mexico. There were 86 workers in the mine (underground) when the fire occurred. All workers were safely evacuated. Six workers were transported to the Carlsbad Medical Center (CMC) for treatment for smoke inhalation and an additional seven workers were treated on-site. The fire is believed to have originated in the truck's engine compartment and involved hydraulic fluid and/or diesel fuel that contacted hot surfaces on the truck, possibly the catalytic converter, and then ignited. The fire burned the engine compartment and consumed the front tires, which contributed significantly to the amount of smoke and soot in the underground.

Following this incident, the DOE established an Accident Investigation Board (AIB) to assess the WIPP safety systems programs and processes at the federal and contractor levels. These investigations include analysis of training and qualifications, maintenance, and emergency management response to the events. AIBs use a rigorous process to investigate events that had, or potentially could have had, a negative impact on employees, the public or the environment. The following were conclusions drawn by the AIB for the truck fire event:

- The preventative and corrective maintenance program did not prevent or correct the buildup of combustible fluids on the salt truck. There is a distinct difference between the way waste-handling and non-waste-handling vehicles are maintained.
- The fire protection program was less than adequate in regard to flowing down upper tier requirements relative to vehicle fire suppression system actuation from the Baseline Needs Assessment into implementing procedures. There was also an accumulation of combustible materials in the underground in quantities that exceeded the limits specified in the Fire Hazard Analysis (FHA) and implementing procedures. Additionally, the FHA does not provide a comprehensive analysis that addresses all credible underground fire scenarios including a fire located near the Air Intake Shaft.
- The training and qualification of the operator was inadequate to ensure proper response to a vehicle fire. He did not initially notify the Central Monitoring Room (CMR) that there was a fire or describe the fire's location.
- The CMR Operations response to the fire, including evaluation and protective actions, was less than adequate.
- Elements of the emergency/preparedness and response program were ineffective.
- A nuclear versus mine culture exists where there are significant differences in the maintenance of waste-handling versus non-waste-handling equipment.
- The Nuclear Waste Partnership (NWP) Contractor Assurance System (CAS) was ineffective in identifying the conditions and maintenance program inadequacies associated with the root cause of this event.
- The DOE Carlsbad Field Office (CBFO) was ineffective in implementing line management oversight programs and processes that would have identified the NWP CAS weaknesses and the conditions associated with the root cause of this event.
- Repeat deficiencies were identified in DOE and external agencies' assessments prior to the event, e.g., Defense Nuclear Facility Safety Board (DNFSB) emergency management, fire protection, maintenance, CBFO oversight, and work planning and control, but were allowed to remain unresolved for extended periods of time without ensuring effective site response.
- There are elements of the Conduct of Operations (CONOPS) program that demonstrate a lack of rigor and discipline commensurate with the operation of a Hazard Category 2 Facility.

The International Atomic Energy Agency (IAEA) undertook a systematic look at operational experience on fire and explosions at nuclear power plants around the world. The intent was to gain necessary information for a thorough

safety analysis, generate lessons learned and apply this information in current plants to avoid or minimize the recurrence of events. The IAEA analysis has determined the principal causes of the events. As for causes of the events, items such as deficiencies in design, operation (rules and procedures for plant operation), construction, quality assurance, and in lack of emergency procedures were chosen. The following observations were derived from the data that was generated:

- Many of the events had multiple causal factors
- Design and human factors were major contributors
- Only a few external hazards, e.g., storm, flooding, forest fire etc. caused some internal fire events
- In some cases, sometimes significant ones, the same type of event recurs in the same nuclear power plant
- In several cases, plant modifications contributed to fire events because these modifications had not been checked against fire safety needs before their implementation; this underlines the need to do careful planning of modifications including taking into account fire safety aspects
- More fires were reported during operation than during shutdown states, although practical experiences in the nuclear facilities show a high amount of fires occurred during shutdown states, especially during outage phases.
- The emergency response teams (in particular, fire-fighting brigades) were generally effective when available, however there was one case that the team staff made matters worse
- The lack of emergency response teams was sometimes a contributor to the fire
- The lack of, or failure of, detection and suppression systems and equipment appeared significant and were contributors to some fires
- Human factors, besides control room operator actions, featured general failure to perform required maintenance, surveillance and verification reflecting the lack of operational procedures or rules
- Lack of, or deficiencies in, fire barriers were significant contributors
- In some cases, the non-safety related equipment was the main event contributor to affect the safety related equipment

Conclusion

Inclusion of fire safety is important through all phases of an operational nuclear facility. This includes the full lifecycle of a plant from design to construction and commissioning, through plant operation and in decommissioning. Fire Safety Programs that include policies and procedures have been developed for commercial nuclear power plants by the NRC and for EM facilities by the DOE. In addition, the IAEA has developed programs and guidelines for fire safety at all nuclear power plants worldwide. Investigations into numerous fire incidents have been made and many causal effects and lessons learned have been developed.

Recommended Actions:

Lessons Learned:

The following lessons learned are derived from the IAEA study, which includes the Brown's Ferry fire and the WIPP truck fire:

- Design deficiencies and human factors are large contributors to the events. Thus initiators, propagators and mitigators need to be considered.
- A fire event contains multiple causal factors. This recalls the importance of the implementation of the defense-in-depth concept in the design and operation of a nuclear facilities.
- Emergency response teams should be organized and adequately trained since their efficient reaction is important to containing accidents.
- Improved emergency procedures, including emergency communications, should be in place to reduce the causes relevant to human factors.
- Adequate and reliable detection and extinguishing features (both manual and automatic) should be provided since a lack of these features was a significant contributor to fires.
- Failure or deterioration of fire barriers led to undesired consequences to the nuclear safety. Fire barriers should be adequately provided and maintained.

- Fire and explosion events will at times cause plant operators to take special actions to modify the plant status (e.g., reactor shutdown). Practical training of plant operators is needed for emergency cases together with the document preparation of emergency procedures.
- Fire safety assessment of the plant should be reviewed before the plant modifications are implemented so that negative impacts on the plant fire safety can be avoided.
- Preventative and Corrective Maintenance Programs should be designed and conducted with a fire safety perspective included.
- Analyses of fire hazards should include all credible fire scenarios.
- Adequate training and qualification of operating staff and emergency response personnel regarding fire safety should be provided, and drills should be designed and conducted on a periodic basis.

Critical Decision(s):	CD-1 to CD-4 and Operations
Facility Type(s):	All
Work Function(s):	Project/Program Management, Engineering, ES&H, Operations
Technical Discipline(s):	All

References:

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5. "Fire Safety in the Operation of Nuclear Power Plants", Safety Guide, Safety Standards Series No. NS-G-2.1, International Atomic Energy Agency, July 2000.
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