Appendix 9 Potential Fire Protection Methods for Mitigating a Fire

A major concern regarding a SFP draindown is recovering the coolant inventory to prevent or mitigate a zirconium fire. In any case, taking mitigative actions which could potentially increase the rate of spent fuel heat is to be avoided. At decommissioning plants, fire protection equipment could be the only water source available to provide a large enough flow rate to mitigate a zirconium fire in the SFP. Draft Regulatory Guide 1069 [Ref. 1] contains specific guidance on the level of fire protection to be provided for structures, systems and components (SSCs) that are necessary to provide protection of the spent fuel. Specifically, with respect to fire protection procedures, it recommends the following:

- Coordination with offsite responders and fire brigade leadership for both onsite fire brigade and offsite responders should be explained.
- Procedures should be provided that describe emergency response actions that are necessary to mitigate the consequences of fires.
- Responding offsite emergency services should receive training on facility layout, fire hazards, fire pre-plans, fire fighting equipment, radiation hazards, and health physics as it pertains to fire fighting operations.
- Routine drills should be conducted to determine the readiness and capability of fire brigade personnel and offsite responders.

To assist with the delivery of water to the SFP, offsite responders such as a local fire department may be required. Therefore, we reviewed commonly practiced fire protection mitigation methods to determine their applicability to a zirconium SFP fire.

For decommissioning plants, the optimal solution is to remove the fuel from the SFP and into a permanent depository as soon as possible. Since permanent depositories are not available for spent fuel storage, we reviewed the applicability of commonly practiced fire protection mitigation methods to a spent fuel zirconium fire after a catastrophic failure resulting in loss of SFP water.

Two initiating events could create cracks in the SFP, resulting in a rapid pool draindown: A beyond-design-basis seismic event could result in rapid leakage rates and render onsite water storage tanks, fire protection pumps, piping, and water based suppression systems inoperable. For a heavy load drop or other slow-developing scenarios, fire protection equipment may remain available; however, a load drop through the SFP could create large cracks, resulting in rapid leakage rates.

Fire Department Response for A Spent Fuel Pool Draindown Event

On a conceptual level, the Nuclear Energy Institute (NEI) has submitted potential industry commitments to mitigate a zirconium fire, transmitted in a November 12, 1999, NEI letter [Ref. 2]. Several commitments pertain to offsite response or SFP reflooding:

- procedures and personnel training to ensure that onsite and offsite resources are available during an event
- offsite resource plan to identify organizations or suppliers where offsite resources (portable pumps and emergency power) can be obtained in a timely manner

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- onsite restoration plan to repair the SFP cooling systems or provide access for makeup water to the SFP through remote alignment of the makeup source to the SFP, without requiring entry to the refuel floor.

The specific guidelines needed to implement offsite fire department response have not been discussed in any detail and could vary from plant to plant according to site location. The basic fire apparatus is a diesel or gasoline engine-driven vehicle that carries an extensive assortment of tools and equipment for fighting fires. One type of fire apparatus, typically referred to as a pumper, includes a pump, hose, and a water tank mounted on a truck. The size of the pump, the amount of the water, and the hose will vary with the type of service (urban, suburban, or rural) the fire department provides to the public. The fire pump flow rates range anywhere from 250 gallons per minute (gpm) to 2,000 gpm. To permit variable use of the hose apparatus, many fire departments carry 2,000 feet of 2½ inch diameter hose, and 800-1000 feet of 1½ inch diameter hose. The minimum recommended hose they should carry is 1,200 feet of 2½ inch diameter hose [Ref. 3]. Most fire apparatus equipped with pumps are also equipped with water tanks. Pumpers typically carry a minimum of 500 gallons of water. Some fire departments also have mobile water-supply vehicles designed to transport water to the scene of an emergency to be applied there by other vehicles or pumping equipment. National Fire Protection Association Code 1901, "Standard for Fire Pump Apparatus," requires a water tank of at least 1,000 gallons per minute (gpm) for new mobile vehicles.

Successful implementation of offsite response using fire department apparatus may be influenced by several factors:

- the amount of water available to supply the fire apparatus
- whether enough hose is available to reach a SFP, or a remote hookup
- fire apparatus access to the site after a BDB event could hinder efforts to reflood the pool
- whether fire apparatus within the vicinity of the site could be destroyed or unable to arrive onsite in a timely manner since fire stations are not seismically qualified to nuclear standards
- whether remote alignment of the makeup source to the SFP is dependent on access to a large volume of available water supply
- whether estimated radiation levels within 50' - 100' of the pool could pose personnel radiation hazards
- how far the site is from a river or lake, if no available water supply is on site

In the event that no water source is available due to onsite equipment and piping failures related to a beyond-design-basis earthquake, a fire apparatus supplying the minimal flow of 250 gpm per minute will deplete a minimum 500 gallon fire tank water supply in 2 minutes. At this point the fire department could hook hoses to a mobile unit, which, if new, is required to contain a minimum water supply of 1,000 gpm. However, this may only guarantee 4 minutes of flow at 250 gpm. Again, fire departments vary based on their locations and the type of services they provide for the public. In all cases, the limiting factors are the type of fire apparatus available to the site and a large, available water supply. Therefore, it is important to identify available resources surrounding the site and to determine, based on the volume of the SFP, the total time and amount of water required to reflood the SFP at a specific flow rate.

If the SFP is cracked and the leak cannot be isolated, the use of fire apparatus tanks to reflood the pool is only a temporary measure since fire apparatus have a limited water supply.

Furthermore, if the rate at which the fire apparatus can reflood the pool is considerably less then the rate at which the pool is leaking, a more permanent solution for SFP recovery should be identified.

For heavy load accidents and slow-developing events, onsite fire protection equipment may be available so the fire department can hook hoses to existing standpipes or draft water using a pumper, from a river, a lake, or the source of the nuclear power plant's ultimate heat sink. This approach is more realistic then trying to reflood only from a fire apparatus tank supply. However, problems associated with laying long lengths of hose from a water supply would prevent prompt delivery of water to the SFP. NFPA 1410, "Training for Initial Attack," provides guidance on the process of laying hose correctly. Based on the length of hose required to reach an available water supply, more then one fire engine may be needed. Laying hose correctly and efficiently involves making adequate connections to utilize the available water supply, using the correct size and number of hoses to carry the needed flows at the necessary pressures, and teamwork between different fire companies. Factors such as volunteer response and delays due to the distance of the fire department from the site can affect the ability to provide effective streams of water in a prompt manner. Furthermore, if fire personnel have to run hoses through the plant to flow water into the SFP, there could be delays due to unfamiliarity with the plant, if pre-plans are not developed and periodically practiced. This type of evolution is complex and typically requires rehearsed drills with trained fire personnel on the actions to establish and maintain effective streams at the required flows.

Review of Commonly Practiced Mitigation Methods

As mentioned, we examined commonly practiced fire protection mitigation methods to determine their applicability to a spent fuel zirconium fire and SFP recovery. In the following paragraphs we discuss the limitations of each method and factors to consider before implementation. The methods reviewed include the use of fire hoses, portable monitor nozzles, dry chemicals, and inert gases; the use of existing Class 1E equipment to reflood the SFP; water spray systems; high expansion foam; and development of a generic contingency plan. Some of these methods require successful coordination with an offsite fire department. The effects of these mitigation methods on the heatup of spent fuel or criticality event during efforts to recover the pool, have not been analyzed in this Appendix. Therefore, caution is recommended in using these methods to mitigate a spent fuel pool zirconium fire. No research was conducted, or is planned for the future, to support any of the mitigation methods discussed within this Appendix.

Fire Hoses

Assuming that an initiating event causes the draindown of the spent fuel pool, and that after the event, the fire protection water supply is operable, Sandia National Laboratory (SNL) recommends the use of fire hoses to provide an emergency water spray to maintain fuel cooling on a temporary basis until the pool leak can be repaired. A limitation of this method, noted by SNL, is that the required spray rates would be approximately 100 gpm and that the exposure to an individual 50 feet from the pool would be approximately 200 rem per hour. Excessive radiation levels to workers should be considered before implementing this method.

Portable Monitor Nozzle

If a large water supply is available and the SFP is not cracked, connection of a portable monitor nozzle may successfully reflood the pool. This is a common piece of fire-fighting equipment, which plant personnel can set up at a much greater distance from the spent fuel pool than they can a manual hose line. It does not require continuous manning, reducing the potential for personnel radiation exposure. However, if the SFP water level has drained significantly, workers may be exposed to levels of radiation in excess of 10 CFR Part 20 limits while setting up the portable monitor nozzle. A portable monitor nozzle can discharge a minimum of approximately 500 gpm (depending on the water supply) with an effective range of more than 100 feet, but, the spray pattern from the portable nozzle may not provide effective cooling if the SFP cannot hold any water and the pattern of the stream would only wet some of the fuel. These factors should be considered prior to implementation of this method.

Total Flooding Dry Chemical Agent for Metal Fires

Dry chemical agents, which are known as Class D extinguishing agents, do not involve the use of water and are suitable for fires involving combustible metals such as magnesium, titanium, zirconium, sodium, and lithium. Dry powder agents suitable for zirconium, like Met-L-X or Pyromet, inhibit or break the combustion chain process by smothering the flame when uniformly applied. We did not assess the effectiveness of dry chemical agents as a suitable mitigation method for massive amounts of irradiated zirconium. Also, large amounts of dry chemical to fill a SFP would be costly, difficult to store on site, and difficult to uniformly apply throughout the SFP. The application of Met-L-X or Pyromet have been known to obscure vision, create temporary breathing difficulty, and force personnel to evacuate the area [Ref. 4]. Furthermore, Met-L-X or Pyromet are approved by Underwriter's Laboratory for use with manually operated hose lines. Therefore, difficulties associated with implementation and worker safety should be considered before using this method.

Inert Gases

Inert gases act to extinguish a fire primarily by dilution [Ref. 5]. In some cases, argon and helium can control zirconium fires if all air can be excluded from the area of application. However, the dilution of air poses personnel hazards because of the danger of suffocation. Due to leakage paths, a SFP environment could not be maintained which would exclude fresh air from entering the building, unless all leakage paths are sealed. Therefore, difficulties associated with implementation and worker safety concerns should be considered before implementation of this method.

Reflood With Existing Class 1E Equipment

We examined the ability of a decommissioned plant to maintain or modify an existing safety-related train of equipment to remotely reflood the SFP in the event of a draindown. For example, the service water system is typically capable of supplying large quantities of water. Water could be supplied to the SFP by modifying existing piping that supplies the SFP. However, there is no guarantee that the system and its piping would survive a beyond design basis earthquake. If there are existing connections to the piping of a large water supply exists, fire hoses or portable monitor nozzles could be attached, to reflood the SFP. If these connections were used, actions would need to be taken early in the event, to prevent excessive radiation exposure to workers. For all other events which could cause a draindown, the system may reflood the SFP, but only if the rate of reflood exceeds the leakage rate in the SFP. These factors should be considered before implementing this method.

Water Spray Systems

For operating plants, NUREG-1353 [Ref. 6] and NUREG/CR- 5281 [Ref. 7] examined the benefit of installing a post-accident water spray system above the pool to decrease the release of fission products in the pool and pool building. It was assumed that the major benefit of spray systems was a reduction in offsite consequences. Water spray systems were discounted in these NUREGs because they were not considered cost-effective for operating plants. The costs of installing a Category I water storage tank, a spray system with pumps, spray nozzles, and associated hardware, was estimated at $1.2 million per SFP (1988 dollars). This does not include the cost for review or development and approval of a Technical Specification for the control of administration, surveillance, and maintenance of the spray system.

A cost-benefit analysis has not been performed for the costs of a water spray system at decommissioning plants. However, for a beyond-design-basis earthquake, there is a concern that the hardware for a water spray system would not survive due to failure of piping and equipment which supply the water to the nozzles. These factors should be considered before implementing this method.

High Expansion Foam

The June 1999 draft report recommended that the applying of high-expansion foam to the top of the assemblies, could be considered as an alternative to using unborated water since foam has slower leakage rates and the lower water requirements. The premise of foam is that submergence in foam will significantly reduce air movement into the combustion zone and smother the fire. Whether high-expansion foam can prevent the fuel from reaching its critical temperature, and potentially prevent propagation to the other spent fuel assemblies is not known at this time. However, there is concern that if a fire started in some limited section of an assembly, a foam blanket could trap air under the foam and the fire would continue for some time. Successful foam application is depends on several factors:

- providing a sufficient amount of foam to penetrate down the length of the assembly
- preventing the assembly from reaching its critical temperature
- serving as an effective fire suppression agent

To determine the effectiveness of foam on spent fuel based on those factors would require extensive research and time, which we don't have. As with the portable monitor nozzles, if the SFP water level has drained significantly, workers could be exposed radiation in excess of 10 CFR Part 20 limits, while setting up the foam equipment.

Furthermore, the use of foam in some cases may require the installation of a water-foam separator for environmental protection [Ref. 8]. In some areas, local water treatment facilities insisted that power plants or chemical plants that have total flooding foam systems, install water-foam separators to remove foam from any fire water runoff stream before the fire suppression water enters the municipal water treatment facility. During the waste treatment process, the water is usually aerated. This aeration causes residual surfactants to foam, creating and upset in the plant. Furthermore, some fire-fighting foam is toxic to aquatic life and has been placed on the Environment Protection Agency's list of hazardous pollutants. These factors should be considered prior before implementing this method.

Development of A Generic Contingency Plan

We suggested the development of a generic contingency plan, which industry could commit to for covering the SFP with debris (sand, dirt, lead, clay) as a mitigative option for decommissioned plants. Further research revealed that this option was previously discussed for operating plants in NUREG-1353 and NUREG/CR- 5281. The determination made was that this option was not cost-effective for operating plants with emergency procedures in place. There were also technical concerns that debris could not be promptly transported to the site and into the SFP to decrease radiological release or in time to mitigate a zirconium fire. Finally, this method may expose personnel to radiation in excess of 10 CFR Part 20 limits. These factors should be considered before implementing this method.

Recommendations

It is our view that industry should give further consideration to the limitations associated with mitigative actions that may involve the local fire department. Procedures should be established, implemented, and maintained, and drills should be periodically conducted with offsite responders, for spent fuel pool evolutions which may require site interactions with local fire departments. Furthermore, if industry needs to consider alternative mitigation methods for a SFP in decommissioned plants, we recommend that industry take the lead to develop and implement acceptable mitigative methods.

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