UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, DC 20555-0001

December 17, 2020

NRC INFORMATION NOTICE 2020-04: OPERATING EXPERIENCE RELATED TO FAILURE OF BURIED FIRE PROTECTION MAIN YARD PIPING

ADDRESSEES

All holders of, or applicants for, a fuel facility license under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 40, "Domestic licensing of source material."

All holders of and applicants for an operating license or construction permit for a nuclear power reactor issued under 10 CFR Part 50, "Domestic licensing of production and utilization facilities," including those that have permanently ceased operations and certified that fuel has been permanently removed from the reactor vessel.

All holders of and applicants for a power reactor combined license, standard design approval, or manufacturing license under 10 CFR Part 52, "Licenses, certifications, and approvals for nuclear power plants." All applicants for a standard design certification, including such applicants after initial issuance of a design certification rule.

All holders of, or applicants for, a fuel cycle facility license under 10 CFR Part 70, "Domestic licensing of special nuclear material."

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform the addressees of operating experience involving the loss of function of buried cast iron fire water main yard piping due to multiple factors, including graphitic corrosion[1], overpressuration, low-cycle fatigue, and surface loads. Some of the operating experience has not been captured in industry-wide operating experience reports. The NRC expects that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. INs may not impose new requirements, and nothing in this IN should be interpreted to require specific action.

BACKGROUND

Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 establishes the minimum criteria for materials, design, fabrication, testing, inspection, and certification of all structures, systems, and components important to safety. In 10 CFR 50.48, "Fire protection," the NRC requires that each operating nuclear power plant has a fire protection plan that satisfies 10 CFR Part 50, Appendix A, General Design Criterion 3, "Fire protection." General Design Criterion 3 states that fire detection and fighting systems of appropriate capacity and capability be provided and designed to minimize the adverse effect of fires on structures, systems, and components that

[1] Graphitic corrosion is a form of galvanic corrosion that occurs in wet or moist environments; it is also known as selective leaching.

are important to safety, and that firefighting systems be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components. Subpart H of 10 CFR Part 70 establishes the NRC's fire protection program requirements for fuel cycle facilities. Some specific source material licensees have similar commitments in their NRC license. In 10 CFR 70.61 of Subpart H, the NRC requires each applicant or licensee to limit the risk of each credible high-consequence event. Several fuel cycle facilities, including some specific source material facilities, have fire suppression systems credited as mitigative controls needed to meet these performance requirements. The purpose of these programs is to safeguard any nuclear material on site and protect the public from radioactive releases due to a fire event.

The fire protection main yard piping is typically maintained at required operating pressures using pressure maintenance components, such as a jockey pump. The smaller pump accommodates nominal system leakage from either non-pressure-boundary sources (e.g., packing, gaskets) or pressure boundary sources (e.g., through-wall defect). The jockey pump prevents cycling of the larger main fire pumps, which start on decreasing header pressure or another anticipatory signal. As pipes leak, over time, the water pressure inside becomes more difficult to maintain within the set points of the jockey pump.

The water supply of any fire protection system is often considered the most critical component of the system. The function of underground or buried fire water main yard piping is to move the water from its source to its final point of use. This piping must be extremely reliable, capable, and able automatically to distribute enough water directly to a fire to extinguish it or to hold it in check until the fire brigade arrives.

Internal corrosion of ferrous piping materials (cast iron, ductile iron, and carbon steel) can be a problem for fire water supply systems. Microbiological action is the most common mechanism causing the internal corrosion process to occur. Living microorganisms such as sulfate-, iron-, and manganese-reducing bacteria cause this form of corrosion. These bacteria can develop in the piping environment with or without oxygen. They can be concentrated and accelerate internal corrosion, causing either pitting (creating pinhole leaks) or mineral deposits that introduce increased pressure loss due to the turbulence of the water flow. This is referred to as microbiologically induced corrosion. External corrosion of buried fire water main yard piping has no adverse effect on the flow of water through the piping system, up to the point of pipe failure. Factors influencing external corrosion of buried cast iron piping include piping material, soil corrosivity, and stray electric ground currents.

Actions to mitigate external corrosion typically include properly designed and applied coatings; appropriately specified and installed backfill; and properly designed, tested, and maintained cathodic protections systems. Coatings, however, have a finite effective life, and coating degradation has been identified in some instances of external corrosion. One method of minimizing both internal and external corrosion of buried fire water main yard piping is to use nonferrous piping materials such as HDPE. Some plants have replaced cast iron piping with HDPE piping because it is immune to service water corrosion and highly resistant to fouling.

Some plants have replaced cast iron piping with HDPE piping because it is immune to service water corrosion and highly resistant to fouling. However, HDPE piping is a relatively new material compared to cast iron piping, and therefore long-term service-life data does not exist in significant quantities. The NRC has approved the replacement of steel piping with HDPE piping in American Society of Mechanical Engineers Class 3 safety-related nuclear service water system piping associated with the essential service water system at Callaway Plant (ADAMS Accession No. ML083100288), the emergency diesel generator jacket water coolers at Catawba Nuclear Station (Catawba) (ADAMS Accession No. ML091240156), and the plant service water at Hatch, Unit 2 (ADAMS Accession No. ML15337A414). In addition, Catawba has installed aboveground HDPE for nonsafety-related applications. Nonsafety-related use is not part of the NRC approval.

Monitoring jockey pump run times and fire water storage tank levels for adverse trends may help to detect leaks that could further degrade piping. Excessive jockey pump cycling or a pump that is continuously running may be indicative of a leak that can erode the supporting soil, resulting in the cast iron piping being unsupported and subject to tensile stress. These conditions can result in catastrophic failure of the fire main.

DISCUSSION

Many probabilistic risk assessments (PRA) have shown that fire is a potentially important risk contributor for U.S. nuclear power plants and may be a significant contributor to a plant's total core damage frequency.[2] This IN gives examples in which failures of the buried fire water system main yard piping involved degradation from selective leaching (graphitic corrosion), overpressure, cyclic fatigue, and surface loads. Degradation of buried fire water main yard piping could impair the operation of the fire water suppression system and thus impact the overall risk at the plant.

Cast iron piping is susceptible to the loss of material caused by selective leaching, and it is prone to sudden ruptures because of its brittle nature. Multiple failures have occurred when pressure transients from main fire pump starts caused significant cracking in the cast iron piping. These ruptures have mostly occurred during periodic pump testing and indicate an increased likelihood of failures during an actual demand on the fire protection system. Taking steps to minimize pressure transients during periodic testing may mask potential piping degradation.

Leakage from the fire protection water system can be assessed by monitoring pressure maintenance during component activity (e.g., jockey pump run times). However, non-pressure-boundary leakage cannot be distinguished readily from through-wall degradation, and the ability to find leakage locations in buried piping will depend on the leak rate and soil drainage characteristics. In addition, long-term non-pressure-boundary leakage may contribute to higher soil corrosivity, resulting in more aggressive degradation of the piping. The examples discussed in this IN illustrate the importance of an effective fire water system aging management program and represent operating experience related to the failure of buried fire water main yard piping at operating nuclear power plant sites.

Buried fire water piping systems are built to withstand high levels of pressure. However, the sudden starting and stopping of flow caused by such components as pumps or hydrants can trigger a sudden and even dangerous increase in pressure that those systems cannot handle. Buried fire water piping is vulnerable to cracking from applied loads, such as pressure surges or other dynamic loading.

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2 These include the NRC technical opinion paper "Fire PRA Maturity and Realism: A Technical Evaluation," issued January 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16022A266), and various detailed plant fire risk analyses related to license amendment requests for the transition to a risk-informed, performance-based fire protection program in accordance with National Fire Protection Association (NFPA) 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants," and Technical Specifications Task Force Traveler TSTF-505, "Provide Risk-Informed Extended Completion Times—RITSTF Initiative 4b."

Nothing in this IN should be interpreted to require specific action; however, enhancements used at other sites include 1) replacing buried piping with high-density polyethylene (HDPE) piping; 2) incorporating current National Fire Protection Association (NFPA) code and standard requirements; and 3) expanding the scope of inspection so that the intended function(s) of structures, systems, and components will be maintained consistent with the current licensing basis through the period of extended operation.

DESCRIPTION OF CIRCUMSTANCES

Operating experience has indicated that multiple failures of the buried cast iron fire water main yard piping have occurred due to aging effects, including graphitic corrosion (i.e., selective leaching), corrosion buildup, low-cyclic fatigue, and general wall thinning or localized loss of material. Degradation can occur internally or externally to the pipe, or both. Degradation may develop due to environmental conditions, or it may be initiated as a result of deficiencies in system design, installation, or maintenance. Licensees can detect only such flow blockage as fouling from silt or sediment, internal coating failures that block flow, or internal tuberculation (i.e., small mounds of corrosion products on the inside of the pipe). Internal degradation due to corrosion, selective leaching, or cracking cannot be detected by NFPA periodic testing. Below are descriptions of recent or recently available operating experience concerning failures of buried fire water main yard piping.

<u>Edwin I. Hatch Nuclear Plant, Units 1 and 2</u>

On January 25, 2019, a buried 12-inch-diameter fire protection cement-lined cast iron main yard pipe ruptured as a result of fire water sectional valve isolation capability testing. The pressure drops from the rupture led to all three fire water pumps starting on a low-pressure signal. After securing the two diesel-driven fire water pumps, the licensee was able to maintain the system header pressure with only the motor-driven and jockey pumps running.

The piping rupture was caused by the start of a fire pump and the subsequent pressure surge. The resulting leak eroded the supporting soil around the pipe, intensifying the bending forces on the pipe, with a catastrophic pipe failure occurring four hours after the initial pressure change. During the four-hour period between the fire water sectional valve isolation capability testing and the pipe rupture, the licensee observed that the jockey fire pump was cycling excessively, indicating a loss of pressure in the fire protection system from the leak. The licensee later identified a preexisting pipe crack that had propagated over time until the remaining piping material could no longer withstand the stresses and ultimately failed.

<u>Surry Power Station, Units 1 and 2</u>

On July 13, 2019, during a periodic test of the electric fire pump, a rupture occurred in a buried section of 12-inch-diameter fire protection main yard piping. The resulting loss of system pressure initiated an automatic start of the diesel-driven fire pump. Operators isolated the leak, restoring the fire protection system function after approximately 18 minutes, but the leak resulted in a loss of an estimated 112,000 gallons from the fire protection water tanks.

The fire protection main yard piping was made of gray cast iron, internally lined with cement mortar and externally protected with a bituminous coating. Initial investigation into the rupture found a 10-foot longitudinal crack along the bottom surface of the pipe, and a second circumferential crack on an adjacent pipe segment that was apparently caused by uplift forces from flow through the initial longitudinal crack. Subsequent evaluations determined that long standing exposure to moist or wet soil had resulted in the external reduction in wall thickness at several locations due to graphitic corrosion. The thin asphalt coating could not protect the pipe from the highly corrosive environment. The piping was approximately 49 years old. The licensee modified its selective leaching aging management program to increase the number of examinations that it performed to identify selective leaching. Additional information can be found in Virginia Electric and Power Co., Supplement to Subsequent License Renewal Application, dated October 31, 2019 (ADAMS Accession No. ML19310E716).

July 2019 Surry Power Station Fire Main Yard Loop Piping Rupture
(ADAMS Accession No. ML20056D677)

North Anna Power Station, Units 1 and 2

In October 2001, a 12-inch buried fire water main yard pipe ruptured during routine fire pump performance testing. Excavation identified a crack more than eight feet long that had progressed mainly in the axial direction down the length of the pipe. The analysis of the gray cast iron piping determined that the failure most likely occurred as a result of a low-cycle fatigue process that originated at a pre-existing manufacturing flaw in the pipe. Periodic pump tests apparently caused pressure surges in the system. Otherwise, the overall condition of the pipe appeared to be good, with no indications of damage to the internal mortar lining or of external corrosion. This information was recently provided as part of the North Anna Power Station, Application for Subsequent License Renewal, August 24, 2020 (ADAMS Accession No. ML20246G696).

CONTACT

Please direct any questions about this matter to the technical contacts listed below or to the appropriate Office of Nuclear Reactor Regulation (NRR) or Office of Nuclear Material Safety and Safeguards (NMSS) project manager.

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Note: NRC generic communications may be found on the NRC public Web site, http://www.nrc.gov, under NRC Library/Document Collections.

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