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

March 7, 2013

NRC INFORMATION NOTICE 2013-04: SHIELD BUILDING CONCRETE SUBSURFACE LAMINAR CRACKING CAUSED BY MOISTURE INTRUSION AND FREEZING

ADDRESSEES

All holders of an operating license or construction permit for a nuclear power reactor under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

All holders of an operating license for a non-power reactor (research, test reactor, or critical assembly) under 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," except those who have permanently ceased operations.

All holders of and applicants for a power reactor early site permit, combined license, standard design certification, standard design approval, or manufacturing license under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform addressees of the occurrence of laminar subsurface cracks in the reinforced concrete shield building (SB) of the containment system at the Davis-Besse Nuclear Power Station caused by moisture intrusion and freezing. The NRC expects that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

On October, 10 2011, the shield building (SB) of Davis-Besse's containment was cut open to permit removal of the old reactor vessel head and installation of the replacement vessel head. At that time, the licensee discovered subsurface cracking located near the outer rebar mat, which extended to adjacent areas of the SB that have not been modified since original construction. A manual chipping process was applied to the cracked area in an initial attempt to determine the extent of the cracks. Using this method, crack indications along the vertical edge of the containment access opening essentially disappeared, but a crack at the top horizontal cut for the opening did not disappear. The licensee investigated and confirmed, through the use of impulse response (IR) mapping and core boring samples (CBS), that subsurface laminar cracking had occurred along the outer rebar mat in the SB flute shoulder areas and at the top of the SB near the junction with the

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roof and at specific SB penetration openings. Specifically, CBS results confirmed that the SB walls contained a concrete crack that had a laminar orientation located near the outer rebar mat and passed through the coarse concrete aggregate.

The crack widths were found to be generally tight, less than or equal to 0.03 centimeters (0.012 inches), with one crack measuring 0.033 centimeters (0.013 inches).

Additional flute shoulders were inspected using IR mapping, and the results showed that all shoulders inspected had indications of laminar cracking between the ends of the horizontal reinforcing steel. It was determined that the southern and western portions of the SB wall, had the most extensive cracking.

Based on the licensee's initial condition assessment of the subsurface laminar cracking, it was determined that the SB could not meet technical specifications, operability requirements. After performing additional engineering analysis, the licensee concluded that the SB remained structurally adequate for the controlling design-basis load cases (i.e. was operable). However, the SB areas with the laminar subsurface cracking were nonconforming with respect to the SB design and licensing bases.

The licensee subsequently chartered a Root Cause Team (RCT) supported by vendor subject matter experts knowledgeable in concrete construction, design, examination, and modeling to review evidence associated with the discovery of subsurface laminar cracking. The licensee's RCT evaluated IR results, concrete tests of CBS (including petrographic examinations), and results of computer modeling to identify the causes of the SB laminar cracking. The RCT determined that the direct cause for the SB concrete laminar cracking was the integrated effect of moisture content, wind speed, temperature, and the duration of these conditions created during the blizzard of 1978. The environmental conditions created by the blizzard of 1978 enabled moisture to penetrate the SB concrete, freeze, and expand, which created radial stresses that exceeded the tensile strength of the concrete and initiated the subsurface laminar cracking. The root cause for the SB concrete laminar cracking was due to the design specification for construction of the SB, which did not require application of an exterior moisture barrier. Additionally, the RCT identified three contributing causes for the SB concrete laminar cracking:

- the stress concentration behind the thicker section of the architectural flute shoulder added to the radial stress caused by freezing and expansion of the moisture inside the SB wall creating a radial stress that exceeded the tensile strength of the concrete and initiated a crack.

- the design that did not include radial reinforcing steel ties or stirrups at intermediate spacing, which enabled the laminar crack created by freezing moisture to propagate.

- the density of the structural reinforcing steel that was less than or equal to 15.24-centimeter (6-inch spacing). Once a crack originated in the shoulder region, it continued to propagate into adjacent areas if a higher density of reinforcing steel was present, such as at the top 610 centimeters (20 feet) of the SB and the mainsteam line penetration blockouts. The greater density of structural reinforcing steel enabled the laminar crack created by freezing moisture to propagate into these areas.

The licensee's corrective actions included establishing a test program to investigate the steel reinforcement capacity adjacent to structural discontinuities (e.g., cracking), development of an engineering plan to reestablish design and licensing bases for the SB, development of a procedure for long-term monitoring of the SB laminar cracking, and installation of an exterior sealant system on the SB. Additional information appears in the FirstEnergy Nuclear Operating Company

(FENOC) root cause analysis report, "Concrete Crack within Shield Building Temporary Access Opening," Condition Report (CR) No. 2011-03346, Revision 1, dated May 8, 2012, an extent of condition review. The report is located on the NRC's public Web site in the Agencywide Documents Access and Management System (ADAMS) under Accession No. ML12142A053. The NRC dispatched an inspection team to evaluate the root cause and corrective actions for this event as documented in the Davis-Besse Inspection Report 05000346-46-12-009, dated June 21, 2012, (ADAMS Accession No. ML12173A023).

BACKGROUND

General Design Criterion 2, "Design Bases for Protection against Natural Phenomena," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, states, in part, that structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena, including, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components (SSCs) shall reflect: (1) appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated; (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena; and (3) the importance of the safety functions to be performed.

In the 10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants" (the maintenance rule), the NRC requires that licensees monitor the performance or condition of SSCs against licensee-established goals in a manner sufficient to provide reasonable assurance that such SSCs are capable of fulfilling their intended function. The regulations in 10 CFR 50.65 require that these goals be established commensurate with safety and, where practical, take into account industrywide operating experience.

In Section C of Regulatory Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," the NRC provides guidance for monitoring structures. Specifically, in accordance with10 CFR 50.65, the structural monitoring programs must provide reasonable assurance that in-scope structures are capable of fulfilling their intended functions. An acceptable structural monitoring program for the purposes of the maintenance rule should have the attributes discussed in Section 9.4.1.4, "Structure Level," of NUMARC 93-01, "Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants." Structures monitored in accordance with 10 CFR 50.65(a)(1) would continue to be monitored until the degradation and its cause have been corrected. For these structures, there would be additional degradation-specific condition monitoring and increased frequency of assessments until the licensee's corrective actions are completed and the licensee is assured that the structure can fulfill its intended functions and will not degrade to the point that it cannot fulfill its design basis.

DISCUSSION

For the Davis-Besse SB, the applicable construction and design standards were American Concrete Institute (ACI)-307-69, "Design and Construction of Reinforced Concrete Chimneys," and ACI-318-63, "Building Code Requirements for Reinforced Concrete." For the Davis-Besse SB, an external moisture barrier was not required by the applicable construction/design standards. The SB design also was consistent with recommendations identified in ACI-201.2R-01, "Guide to Durable Concrete," but these measures were not effective at preventing the moisture intrusion associated with the 1978 blizzard event.

In practice, for concrete structures, application of 10 CFR 50.65 requirements usually translates into periodic visual inspection, which would not be effective in identification of subsurface laminar cracking developed by conditions of moisture intrusion and freezing. Site technical specifications contain requirements for maintaining the containment systems operable and the site Corrective Action Program, Criterion XVI of Appendix B 10 CFR Part 50, would require identification of and correction of deficiencies adverse to quality, as noted in this IN. Therefore, if a licensee identifies environmental and design vulnerabilities that could produce subsurface cracking (e.g., a lack of adequate waterproof barrier or a design configuration that creates inherent stress concentrations), nondestructive examination such as IR mapping with confirmatory CBS are techniques that have identified subsurface laminar cracking.

The environmental effects on nuclear power plant concrete structures and related operating experience are discussed in NUREG/CR-6927, “Primer on Durability of Nuclear Power Plant Reinforced Concrete Structures.” Recommendations in this NUREG include radial reinforcement of concrete structures to enhance concrete durability and this design element should prevent or limit concrete problems similar to those discussed in this IN. Further, some of the causes for concrete degradation identified included improper design specifications or violations of construction specifications. Thus, for new reactors, preventative measures can be taken in the design and construction phase to ensure the effect of moisture intrusion in concrete will be mitigated. For example, the application of waterproofing material (e.g., sealant or coating) on the outer surface of the containment combined with an effective maintenance program for the waterproofing material should preclude moisture induced subsurface laminar cracking.

CONTACTS

This IN requires no specific action or written response. Please direct any questions about this matter to the technical contact listed below or to the appropriate Office of Nuclear Reactor Regulation project manager.

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Note: NRC Generic Communications may be found on the NRC public Web site, http://www.nrc.gov, under Electronic Reading Room/Document Collections

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