UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
WASHINGTON, DC 20555-0001

February 21, 2018

NRC INFORMATION NOTICE 2018-01: NOBLE FISSION GAS RELEASES DURING SPENT FUEL CASK LOADING OPERATIONS

ADDRESSEES

All holders of or applicants for 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," including those that have permanently ceased operations and have spent fuel stored in spent fuel pools.

All holders of or applicants for a combined license issued under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

All holders of or applicants for a certificate of compliance (CoC) for a spent fuel transportation package design under 10 CFR Part 71, "Packaging and Transportation of Radioactive Material."

All holders of or applicants for a general or specific license for the storage of spent fuel, or for a CoC of a dry storage system (DSS) under 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste."

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform addressees of operating experience related to noble fission gas releases during spent fuel loading operations, and of the importance of adequate fuel selection and maintaining fuel qualification test records to demonstrate that either the spent fuel cladding continues to serve its design function or that follow-up actions are needed. The addressees may review the information within this IN for applicability to their facilities or DSS designs and consider actions, as appropriate. This IN requires no action or written response on the part of an addressee.

DESCRIPTION OF CIRCUMSTANCES

Several licensees under 10 CFR Part 72 have experienced noble fission gas releases during spent fuel loading operations. In all but one case, the licensees were able to rely on a combination of fuel selection records, qualification tests, and root-cause analyses to demonstrate that, despite the release, the spent fuel conditions were maintained within the bounds of its design-bases safety analyses.

The following events provide a sampling of the operating experience associated with noble fission gas releases during spent fuel loading operations.

ML17234A705

Millstone Power Station, Unit 2

On May 12, 2015, Dominion Resources, the licensee, commenced helium blowdown operations on a NUHOMS®-32PT dry shielded canister (DSC) being loaded with Unit 2 spent fuel. During the blowdown evolution, the licensee received local radiation alarms and observed a spike in activity with the spent fuel pool (SFP) ventilation radiation monitor. In response to the alarms, the licensee suspended additional drying activities and placed the DSC in a safe condition, including maintaining the spent fuel in an inert environment with the required helium overpressure. The licensee obtained detectable krypton (Kr)-85 results from a sample taken directly from the DSC and completed a fuel cladding integrity assessment that involved confirming that the fuel was adequately selected in accordance with the technical specifications for CoC 72-1004 (i.e., undamaged fuel, cladding may contain only hairline cracks or pinholes) and evaluated the potential of fission gas release through hairline cracks or pinholes.

The licensee reviewed pertinent fuel selection records, which included visual inspection of all four sides of each assembly, reactor operating records to confirm loaded assemblies originated from a cycle without known fuel failures, or other fuel qualification test data (ultrasonic testing (UT), vacuum can sipping (VCS), and in-mast sipping). In addition, the licensee completed a review of known cladding failure mechanisms in the reactor, in wet storage, and during dry storage to determine potential causes for the release. From this review, the licensee determined that 15 of the loaded assemblies originated from cycles that experienced grid-to-rod fretting (GTRF), which is known to cause cladding thinning during operations. The licensee concluded that an existing nearly through-wall cladding breach would be exposed to an increased differential pressure during draining and vacuum drying (because of the increasing fuel temperature and reduced external pressure), which could lead to a non-gross failure. However, a failure resulting from gradual changes in pressure during blowdown and drying operations is expected to be non-gross with limited propagation, as the pressure differential is relieved after failure. As additional follow-up, the licensee characterized water samples collected from the vacuum drying condensate and the vacuum pump casing, which did not identify the presence of heavy metals. The licensee also confirmed that the fuel had remained in an inert environment without experiencing oxidizing effects, and that the fuel cladding temperature was maintained below the approved design-bases limit.

On completion of this review, the licensee concluded that the fuel was adequately selected and the cladding was adequately protected against gross ruptures. The licensee resumed loading operations on May 28, 2015, and the DSC was subsequently transferred to the storage pad. Additional information is available in NRC Inspection Report, “Millstone Power Station - Integrated Inspection Report 0500336/2015002 and 05000423/2015002 and Independent Spent Fuel Storage Installation Report 07200047/2015001, August 10, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15222A834).

Calvert Cliffs Nuclear Power Plant, Unit 1

On September 17, 2015 and October 8, 2015, the Unit 1 wide range noble fission gas monitor detected Kr-85 releases during vacuum drying of DSC-77 and DSC-78, respectively. Exelon Generation Company, the licensee, performed an apparent cause analysis to define potential cladding failure initiators and release mechanisms. The investigation concluded the probable cause to be latent near-through-wall failure sites which fully opened when subjected to the vacuum environment.

The licensee performed technical evaluations in response to each event, using release magnitude and rate in order to characterize the nature of any new cladding breach. For both DSCs, the licensee demonstrated that the loaded fuel remained undamaged.

As corrective actions, the licensee developed procedural guidance providing immediate response to any future area alarms that might occur, including field worker actions and technical evaluations. Additionally, the licensee will perform VCS several months prior to each loading campaign in the interest of potentially identifying any legacy fuel that would be vulnerable to failures during drying.

Arkansas Nuclear One, Units 1 and 2

September 2014

On September 12, 2014, the control room emergency ventilation system at Arkansas Nuclear One (ANO) was unexpectedly triggered, placing both Unit 1 and 2 control rooms on emergency recirculation because of increased radiation levels. The event occurred during the process of decreasing the helium pressure from Phase 1 to Phase 2 operations during forced helium dehydration (FHD) drying of a Multipurpose Canister (MPC)-24, which was being loaded under the requirements of Amendment 5 of CoC 72-1014. In accordance with loading procedures, Entergy Operations, Inc., the licensee, stabilized the pressure of the MPC and suspended additional pressure changes.

Certificate of Compliance 72-1014 defines allowable contents as intact fuel assemblies without known or suspected cladding breaches greater than pinhole leaks or hairline cracks. The licensee characterized a sample of the helium vented from the MPC, which identified Kr-85 levels representative of a cladding breach in one or more fuel rods within the MPC. A review of records of individual sipping traces and ultrasonic testing inspection of the assemblies did not reveal the presence of a fuel rod breach. All fuel had been visually examined before loading for indications of rod or assembly damage, or other potential issues. None of the subject assemblies contained visible rod or assembly anomalies. As a result, all of the assemblies loaded into the MPC were originally classified as intact, consistent with the certificate of compliance technical specifications.

The CoC holder recommended that the licensee finish the FHD drying process and backfill to the CoC technical specification requirements while monitoring for increasing Kr-85 levels. The licensee agreed with the CoC holder’s assessment and completed the drying and backfill process, electing to complete the closure welding of the MPC (i.e., closure welding and nondestructive examination of the port cap covers and closure ring), placing the MPC in a fully contained and passive cooling condition.

The licensee performed an apparent cause evaluation that determined two potential causes for the release (ADAMS Accession No. ML14286A037). The licensee cited both the prevalence of GTRF in the operating cycles of the subject assemblies, which may produce breaches larger than a pinhole, and the limitations of ultrasonic testing in accurately identifying leaking fuel. The licensee further cited the potential for fuel failure caused by depressurization of the MPC. However, it determined the latter apparent cause to be unlikely because of the small pressure change during the relevant FHD operation.

As a corrective action, the licensee elected to conservatively reclassify the fuel loaded into the MPC as damaged and submitted an exemption request from the requirements in

10 CFR 72.212(a)(2) and 10 CFR 72.212(b)(11), as the loaded MPC had not been approved for damaged fuel. The licensee identified additional corrective actions that included precluding the loading of fuel not tested through in-mast sipping or not originating from a failure-free cycle as identified by reactor core chemistry records, and adding the subject MPC to an internal record of DSSs with potentially leaking fuel pins (in recognition of potential future transport).

Additional information is available in NRC Inspection Report, “Arkansas Nuclear One, Units 1, 2, and Independent Spent Fuel Storage Installation (ISFSI) - NRC Inspection Report 05000313/2015011, 05000368/2015011, and 07200013/2015001, dated January 21, 2016 (ADAMS Accession No. ML16021A485).

August 2015

On August 21, 2015, the licensee’s process radiation monitor for Unit 2 spent fuel area alarm was activated, which tripped the exhaust system. The alarm activated during the process of decreasing the helium pressure from Phase 1 to Phase 2 operations during FHD drying of a MPC-32 canister being loaded under CoC 72-1014. The licensee obtained a gas sample from the condensate discharge line to the SFP, which the licensee stated was representative of the MPC atmosphere. The licensee characterized the sample and identified fission product gas Kr-85.

The licensee reviewed fuel selection records and verified that the MPC contained only fuel assemblies that were either discharged after operating in a failure-free cycle or were in-mast sipped to confirm them as intact. The sipping trace data confirmed no anomalies that would contradict the licensee’s conclusions that the selected fuel assemblies were intact. All assemblies had been visually examined prior to MPC loading for evidence of cladding damage. The licensee confirmed that the MPC had remained under a helium atmosphere, which would limit the potential for the fuel cladding to undergo unanticipated oxidation. The licensee’s description of temperatures measured from drying inlet and outlet readouts gave no evidence that peak cladding temperatures exceeded those defined in the design bases, consistent with the guidance in NUREG-1536, Revision 1, “Standard Review Plan for Dry Cask Storage Systems,” dated July 2010 (ADAMS Accession No. ML101040620).

The licensee identified that there was still a potential that radiochemical analyses would not have identified a very tight (pinhole) fuel failure, even if the assembly originated from a cycle declared failure-free. Gross failures, which would classify the fuel as damaged, would be much more easily detectable by in-mast sipping. Therefore, the licensee concluded that any failure from a declared failure-free cycle or missed by in-mast sipping would be expected to be a pinhole leak and that the MPC met the certificate of compliance technical specifications definition for intact fuel.

Additional information is available in NRC Inspection Report, “Arkansas Nuclear One, Units 1, 2, and Independent Spent Fuel Storage Installation (ISFSI) - NRC Inspection Report 05000313/2015011, 05000368/2015011, 07200013/2015001, dated January 21, 2016 (ADAMS Accession No. ML16021A485).

BACKGROUND

As required by 10 CFR 72.122(h)(1), the spent fuel cladding is to be protected against degradation that leads to gross ruptures or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. In addition, per 10 CFR 72.122(l), the DSS must be designed to allow ready retrieval of the spent fuel, which may be on an assembly basis in accordance with the approved design bases (see NUREG-1536, Revision 1). In transportation, the chemical and physical form of the spent fuel must be accurately specified (10 CFR 71.33(b)(3)), the geometric form of the package contents must not be substantially altered during normal conditions of transport (10 CFR 71.55(d)(2)), and the package is to be proper for the contents to be shipped (10 CFR 71.87(a)). Therefore, for undamaged and intact assemblies, the fuel cladding serves a design function in both DSSs and transportation packages for assuring that the spent fuel configuration remains within the bounds of the reviewed safety analyses. If the fuel is classified as damaged, a separate canister (e.g. can for damaged fuel) that confines the assembly to a known volume may be used to provide this assurance. NUREG-1536, Revision 1, provides NRC staff guidance on fuel classification and definitions of breached spent fuel rods, pinhole leaks, hairline cracks, and gross cladding breaches.

The technical specifications of the license or CoC generally define the allowable cladding condition for the spent fuel contents, and the nomenclature may vary from system to system. For example, the terms “intact” and “undamaged” have both been used historically to describe cladding without any known gross cladding breaches. Per 10 CFR 72.212(b)(3), 10 CFR 72.212(b)(11), and 10 CFR 71.17(c)(2), users of DSSs and transportation packages are required to comply with the license or CoC by selecting and loading the appropriate fuel, and they must maintain records that reasonably demonstrate that loaded fuel was adequately selected, in accordance with their approved site procedures and quality assurance (QA) program.

Licensees may consider several methods, either singular or in combination, to demonstrate that fuel cladding does not contain gross breaches.

<u>Reactor Operating Records</u>

The guidance in NUREG-1536, Revision 1, states that evidence of only gaseous or volatile decay products (no heavy metals) in the reactor coolant system may provide evidence that a cladding breach is no larger than a pinhole leak or hairline crack. Records showing the presence of heavy metal isotopes that are characteristic of fuel release in the reactor coolant system may indicate gross breaches in the cladding.

Licensees may assess whether any missing records from early reactor operation, such as those lost because of changes in plant ownership, may impact conclusions made about fuel discharged from a given cycle. They may determine whether additional fuel qualification is necessary to provide reasonable assurance that the fuel was properly classified.

<u>Visual Inspection</u>

Visual examination of selected fuel has a two-fold purpose: (1) to identify any mechanical damage to the assembly that may preclude its ability to be retrieved, and (2) to assess the extent and size of any cladding failure or failures. The guidance in NUREG-1536, Revision 1, states that a visual examination of a breached rod can be used to determine if a breach is gross (i.e., cladding breaches greater than 1 mm). The extent of visual inspection is generally limited in assessing flaws behind the spacer grids (e.g., pellet-clad interaction flaws, debris fret) and in rods in the inner matrix. Therefore, most licensees use a tape-recorded visual inspection of the exterior of the fuel assembly only as a supplement to other fuel qualification test data (e.g., sipping, UT). In addition, accessibility in boiling-water reactor (BWR) assemblies may also be limited by the flow channel. Because of these limitations, unless a licensee can reasonably demonstrate sufficient resolution and inspection coverage, visual inspection may not provide, on its own, reasonable assurance that the fuel cladding does not contain gross cladding breaches.

Fuel Qualification Testing

Sipping

Sipping techniques are widely used to identify failed fuel assemblies by detection of radioactive fission gases (Kr-85, xenon (Xe)-133) released through cladding breaches. The techniques are not considered adequate for breach sizing; therefore, licensees generally conservatively classify fuel with detected fission gases as damaged.

Mast sipping is generally performed during refueling operations, as the first lift from the core generally yields the highest release of fission gases (because of the decreasing water head pressure). Three primary techniques are used depending on the reactor type: (1) in-mast sipping (pressurized-water reactor (PWR)), (2) telescope sipping (PWR/BWR), and (3) mast sipping (PWR). The operations vary. For example, in-mast sipping generally employs air injection at the bottom of the mast to help entrain released fission gases; telescope sipping generally includes processing a gas sample from a liquid extraction; and mast sipping allows for sampling at different locations. The NRC staff considers mast sipping records to be adequate for fuel selection as long as testing is performed at the time of discharge under conditions not known to result in missed calls. For example, inner core assemblies from cycles with significant GTRF may increase the background counts and mask small-release leakers, particularly for sipping methods that do not use gas entrainment. Therefore, when determining whether the fuel is intact or undamaged, the licensee can review mast sipping data considering the limitations of the respective technique.

Telescope sipping has been used historically for fuel qualification of wet stored fuel (e.g., during SFP transfers). However, the use of telescope sipping for fuel that has been in wet storage for a significant period may consider the sensitivity of the technique relative to the fuel's decreasing fission gas inventory. International Atomic Energy Agency Nuclear Energy Series No. NF-T-3.6, "Management of Damaged Spent Nuclear Fuel," issued June 2009,[1] recommends that Xe-133 measurements be performed up to 2 months after discharge and Kr-85 measurements be performed up to 10 years after discharge.

The industry generally regards VCS as one of the most sensitive fuel qualification techniques currently available, particularly for low-power and low-fission-yield assemblies. In this technique, each assembly is individually placed inside an isolation chamber (sealed can) and a negative pressure is drawn to drive noble fission gas releases (if the cladding is breached), which are collected at the top of the can.

Ultrasonic Testing

In-bundle UT is generally performed by placing multiple UT wands at a pre-established axial elevation on the probed assembly. Pressurized water reactor assemblies do not require dismantling for accessibility; however, de-channeling is generally required for BWR assemblies. Ultrasonic testing relies on the measurement of the reflected amplitude of a shear wave signal

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[1] http://www-pub.iaea.org/books/IAEAbooks/8023/Management-of-Damaged-Spent-Nuclear-Fuel

as it transverses the cladding tube. Water ingress to the rod leads to UT signal attenuation (amplitude reduction) and identification of a cladding breach.

The guidance in NUREG-1536, Revision 1, states that ultrasonic testing may be used to classify rods as unbreached or breached. The licensee's review of UT data may be performed while considering potential technique limitations. More specifically, the licensee's review may consider (1) whether the lack of water inside the fuel rod at the elevation of the UT inspection can reasonably ensure no water ingress at other axial elevations (particularly for high burnup fuel, where the interspace between the cladding and the fuel pellet may be closed), (2) the effects of pellet-to-clad interactions, which may produce multiple echo signals that are difficult to assess, and (3) any potential misalignment of the transducers caused by the presence of Chalk River Unidentified Deposit or oxide flaking, or any fuel rod bowing or geometry changes caused by irradiation (e.g., bowing caused by larger diameter guide tubes). Failures missed due to these limitations could potentially result in fission gas releases during drying operations if the cladding condition had not been adequately assessed.

A secondary review of UT data from assemblies loaded during a late 2004 campaign at ANO resulted in the conservative reclassification of five assemblies loaded in four MPCs as damaged fuel (ADAMS Accession No. ML052510724). The licensee concluded that UT data could not reasonably be used to size the identified failures. Therefore, the licensee submitted an exemption request from the requirements of 10 CFR 72.212(a)(2) and 10 CFR 72.214, which included revised safety analyses assuming up to two damaged fuel pins, each in a separate fuel assembly. In a separate event in 2014, ANO conservatively reclassified an assembly as damaged following a noble fission gas release (Kr-85) during FHD drying of a loaded MPC (ADAMS Accession Nos. ML16021A485, ML14286A037). The licensee cited the prevalence of GTRF in the operating cycles for the subject assemblies and the lower reliability of UT relative to other fuel qualification test methods as the most likely cause of the event. As a corrective action, the licensee revised operating procedures to avoid the use of UT for future fuel classification. The licensee for Calvert Cliffs has also chosen to rely on VCS for fuel classification activities in the interest of potentially identifying any legacy fuel that may be vulnerable to releases.

DISCUSSION

Licensees that experience noble fission gas releases during spent fuel cask loading operations may determine follow-up actions based on a review of fuel selection records, results from root-cause or apparent-cause analyses, or other relevant operating experience. A licensee may evaluate whether the design-bases fuel temperature limits were exceeded or whether the fuel was inadvertently exposed to oxidizing species that compromised cladding integrity. The guidance in NUREG-1536, Revision 1, states that if fuel oxidation occurred, it may lead to a configuration not adequately analyzed for radiation dose rates or criticality safety. Additionally, the guidance further states that the release of fuel fines or grain-sized powder into the inner cask environment from ruptured fuel may be a condition outside of the approved design bases.

The NRC staff recognizes that no fuel qualification test method is 100 percent accurate and that quantifying reliability is difficult because of the low failure rate of modern fuel (about 0.001 percent). Nevertheless, a licensee's evaluation of operating experience may identify limitations of a given technique, and appropriate actions consistent with the licensees' approved site procedures and QA program are recommended. Such actions may include revising operating procedures to limit the use of certain techniques, depending on the type of fuel or sensitivity limits of the instrumentation, as well as assessing the need for secondary characterization. The staff discusses fuel qualification testing, inspection method limitations, and staff considerations in the "Background" section of this IN.

Releases of detectable gases, such as Kr-85, may also be an indication of a substantive release of tritium, which is not readily detectable by plant radiation monitoring instruments or routinely used portable survey instruments. The release of this gas could have implications for occupational workers, as well as members of the public. Regulations in 10 CFR 20 Subpart C require summing of internal and external doses. Regulations in 10 CFR 20 Subpart D require monitoring and control of gaseous effluents. Regulations in 10 CFR 20 Subpart F require performance of adequate surveys. Fuel bundles containing burnable boron poison may contain higher quantities of tritium than bundles not containing boron poisons. Since personal dosimetry devices may not respond to gases such as tritium, the need for bioassay of workers involved with these transients may be evaluated by the licensee at the time of the event.

CONTACT

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 or Office of New Reactors 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.

NRC INFORMATION NOTICE 2018-01, "NOBLE FISSION GAS RELEASES DURING SPENT FUEL LOADING OPERATIONS," DATE: February 21, 2018

ADAMS Accession No.: ML17234A705 **CAC No. MG0051**

OFFICE	QTE	NMSS/DFSM/RMB	NRO/DSEA/RPAC/BC	NRR/DSS/D	NMSS/DFSM/RMB/BC
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NAME	TGovan	ELee	HChernoff	TMcGinty	MLayton
DATE	10/18/2017	10/30/2017	02/01/2018	02/06/2018	02/08/2018
OFFICE	NRR/DIRS/D				
NAME	CMiller				
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