OFFICE OF THE INSPECTOR GENERAL

U.S. NUCLEAR REGULATORY COMMISSION
DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Audit of NRC's Oversight of Spent Fuel Pools

OIG-15-A-06
February 10, 2015

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

OFFICE OF THE
INSPECTOR GENERAL

February 10, 2015

MEMORANDUM TO: Mark A. Satorius
Executive Director for Operations

FROM: Stephen D. Dingbaum ***/RA/***
Assistant Inspector General for Audits

SUBJECT: AUDIT OF NRC'S OVERSIGHT OF SPENT FUEL POOLS (OIG-15-A-06)

Attached is the Office of the Inspector General's (OIG) audit report titled *Audit of NRC's Oversight of Spent Fuel Pools*.

The report presents the results of the subject audit. Following the January 22, 2015, exit conference, agency staff indicated that they had no formal comments for inclusion in this report.

Please provide information on actions taken or planned on each of the recommendations within 30 days of the date of this memorandum. Actions taken or planned are subject to OIG followup as stated in Management Directive 6.1.

We appreciate the cooperation extended to us by members of your staff during the audit. If you have any questions or comments about our report, please contact me at (301) 415-5915 or Sherri Miotla, Team Leader, at (301) 415-5914.

Attachment: As stated

Office of the Inspector General

U.S. Nuclear Regulatory Commission
Defense Nuclear Facilities Safety Board

Results in Brief

OIG-15-A-06

February 10, 2015

Why We Did This Review

The Nuclear Regulatory Commission (NRC) is responsible for developing the regulatory framework, analytical tools, and data needed to ensure safe and secure storage, transportation, and disposal of spent nuclear fuel. For both operating and permanently shutdown nuclear power plants in the United States, there are a total of 93 spent fuel pools that currently store spent fuel.

Recent NRC staff studies demonstrating the safety of spent fuel pools and the safety of continued storage of spent fuel at reactor sites highlight the need to ensure the safety of pool operations for longer periods than originally envisioned.

The audit objective was to determine whether NRC's oversight of spent fuel pools and the nuclear fuel they contain provides adequate protection for public health and safety, and the environment.

Audit of NRC's Oversight of Spent Fuel Pools

What We Found

NRC provides adequate oversight of spent fuel pools and the fuel they contain to protect public health and safety and the environment; however, opportunities exist for improvement. Specifically, we found that regulatory uncertainty exists in NRC's evaluation of spent fuel pool criticality safety analyses. In addition, there are gaps in NRC's spent fuel pool inspection program as inspections of spent fuel pools greatly vary between licensee sites and are limited in scope.

To fulfill its responsibility to protect public health and safety, NRC must inspect and assess licensee operations and facilities to ensure compliance with its regulatory requirements. NRC should also regulate in a manner that clearly communicates requirements and ensures that regulations are consistently applied and are practical. An absence of effective spent fuel pool criticality analyses guidance for both licensees and NRC staff may lead to a reduction in program efficiency and effectiveness. As a result of spent fuel pools not being inspected with regularity, they could potentially be overlooked.

What We Recommend

To improve the agency's oversight of spent fuel pools, we make recommendations to provide a generic regulatory solution for spent fuel pool criticality analysis by developing and issuing detailed licensee guidance along with NRC internal procedures; develop and implement spent fuel pool inspection guidance at operating reactors; develop an enforceable neutron-absorbing material aging management program; update Inspection Manual Chapter 2561 and Inspection Procedure 60801.

Management stated their general agreement with the findings and recommendations in this report.

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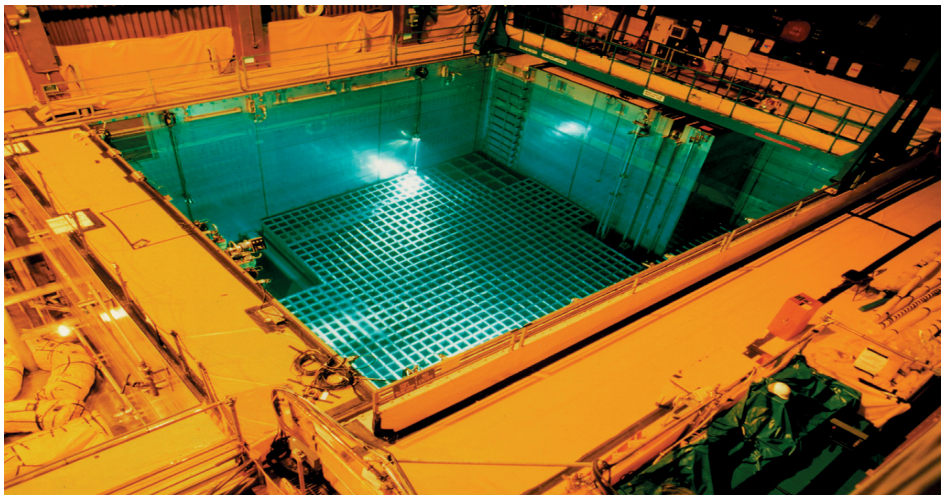
ABBREVIATIONS AND ACRONYMS

10 CFR	Title 10 of the *Code of Federal Regulations*
EA	Enforcement Action
NRC	U.S. Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation
OIG	Office of the Inspector General
RAI	Request for Additional Information
ROP	Reactor Oversight Process

I. BACKGROUND

Spent fuel pools are deep pools of water that hold thermally hot and intensely radioactive spent (used) nuclear fuel after its removal from a nuclear reactor. The water in the spent fuel pools acts as a shield to reduce the radiation levels that people working outside the pool may be exposed to, and it also cools the spent fuel that continues to produce heat for several years after removal from the reactor. See Figure 1 for a photo of a spent fuel pool.

Figure 1: Spent Fuel Pool



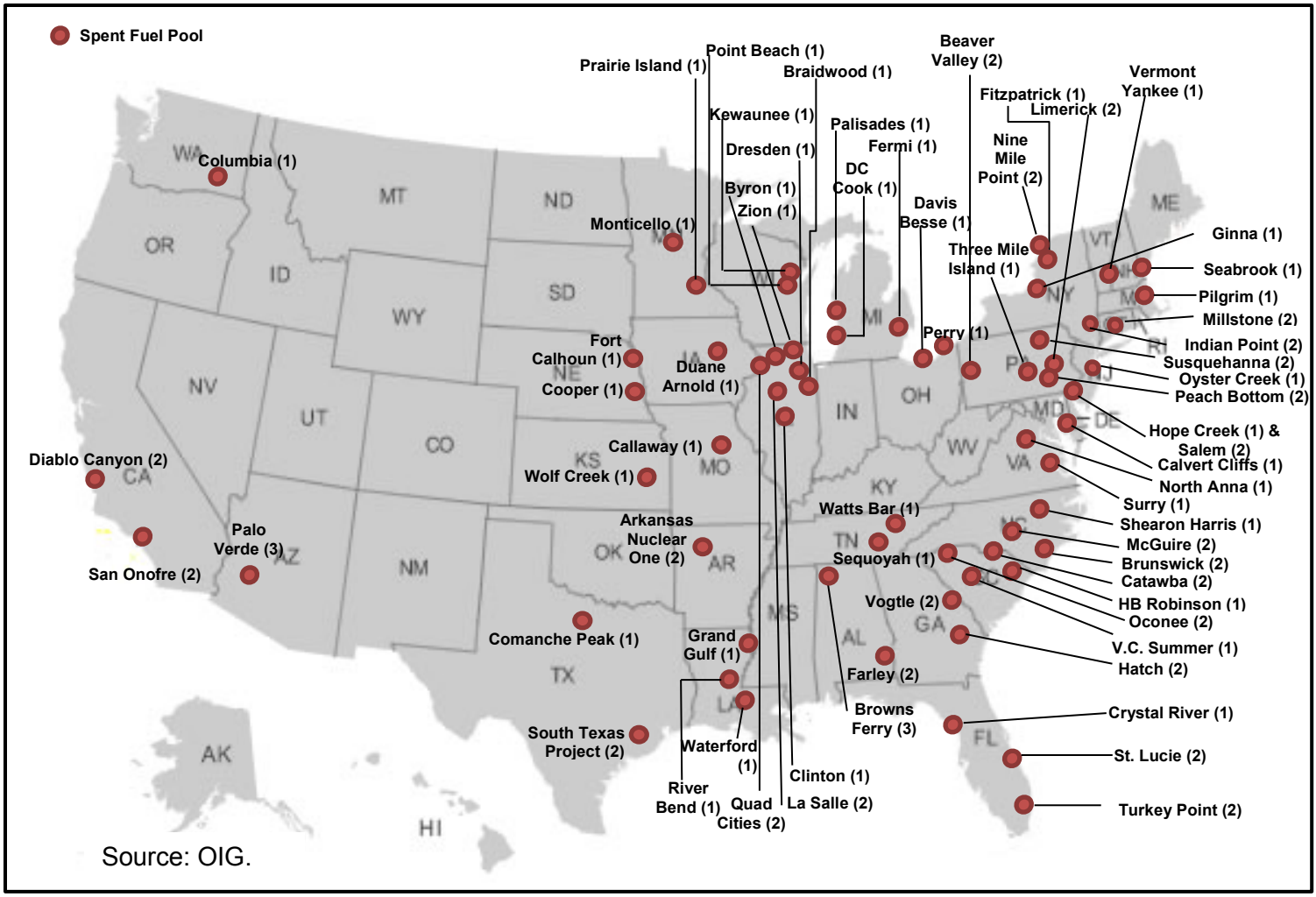
Source: Nuclear Regulatory Commission (NRC).

Spent fuel pools are typically 40 or more feet deep, with at least 20 feet of water covering the spent fuel, to provide safety and allow fuel assemblies[1] to be moved while submerged. The walls of the pools are typically 4- to 6-feet thick with steel-reinforced concrete and a steel liner. The pools must be located inside what is known as the vital area of a nuclear power reactor, protected by armed guards, physical barriers, and limited access.

[1] Spent fuel comes in the form of small pellets that are fitted into 12- to 15-foot hollow metal rods made of a zirconium alloy. These rods are then bound together into a larger "fuel assembly." Typical fuel assemblies for boiling water reactors hold 49 to 63 fuel rods, and for pressurized water reactors hold 164 to 264 fuel rods.

For both operating and permanently shutdown nuclear power plants in the United States, there are a total of 93 spent fuel pools[2] that currently store spent fuel. See Figure 2.

Figure 2: Total Number of Spent Fuel Pools Containing Fuel (Including Those at Shutdown Power Plants[3])



Source: OIG.

[2] There is also a spent fuel pool at GE Morris in Illinois. While it contains spent fuel, it is not associated with any nuclear power plant and is licensed under 10 CFR Part 72.

[3] The number of spent fuel pools at each power plant is represented by the parenthetical number following the name of the plant.

NRC Oversight

10 CFR 50

The governing NRC regulation for spent fuel pools is Title 10 of the *Code of Federal Regulations (10 CFR)*, Part 50. This regulation provides for the domestic licensing of production and utilization facilities. Some of the sections within the regulation that specify spent fuel include conditions of licenses, requirements for monitoring maintenance effectiveness at nuclear power plants, and criticality[4] accident requirements. The regulation also contains general design criteria that establish the requirements for fuel storage and handling, monitoring fuel and waste storage, and prevention of criticality in fuel storage.

Post-Fukushima Orders[5]

In response to the events at Fukushima,[6] NRC determined that additional requirements must be imposed to mitigate beyond-design-basis[7] external events. Therefore, the agency created two new orders related to spent fuel pools: EA-12-049 and EA-12-051.

The requirements in EA-12-049 provide for mitigation strategies to be available in the event of a power loss. This order requires using installed equipment and resources to maintain or restore core cooling, containment, and spent fuel pool cooling; providing sufficient, portable, onsite

[4] Criticality is the condition in which each fission event releases a sufficient number of neutrons to sustain an ongoing series of reactions (i.e., a self-sustaining nuclear chain reaction). NRC's goal is to prevent any inadvertent criticalities in spent fuel pools.

[5] Safety orders, typically imposing new requirements beyond the current existing regulatory framework, may be imposed in unusual circumstances to provide reasonable assurance of public health and safety.

[6] On March 11, 2011, a 9.0-magnitude earthquake and an estimated 45-foot-high tsunami struck Japan off the Honshu Island coast at the Fukushima Dai-ichi nuclear power plant, causing a hydrogen explosion and release of radioactive material. Radioactive contamination spread over a large area of Japan, requiring the relocation of tens of thousands of people.

[7] "Beyond-design-basis" accidents is a term used as a technical way to discuss accident sequences that are possible but were not fully considered in the design process because they were judged to be too unlikely. As the regulatory process strives to be as thorough as possible, beyond-design-basis accident sequences are analyzed to fully understand the capability of a design.

equipment and consumables to maintain or restore these functions; and obtaining sufficient offsite resources to sustain those functions indefinitely.

The requirements in EA-12-051 mandate that all power reactor licensees and construction permit holders have a reliable means of remotely monitoring spent fuel pool levels.

The intent of these additional requirements is to provide a substantial increase in the protection of public health and safety. NRC is to begin inspecting licensee implementation in 2015.

NRC Program Offices

Several NRC headquarters program offices (as well as the regional offices) have involvement with spent fuel pools, but the primary office responsible for spent fuel pool oversight is the Office of Nuclear Reactor Regulation (NRR). NRR is responsible for the licensing and regulation of nuclear power reactors. This program office is also responsible for overseeing licensee activities that protect the health and safety of workers and the general public from radiation hazards, including those from high level waste such as spent fuel. Within NRR, the Division of Safety Systems is responsible for 10 CFR Part 50 licensing of existing reactors. The Division of Operating Reactor Licensing implements the policy, programs, and activities, including coordinating licensing and technical reviews, associated with the overall safety for operating power reactors. Finally, the Division of Inspection and Regional Support provides inspection support for the regions and performance assessment related to the Reactor Oversight Process.

Recent NRC Initiatives Regarding Spent Fuel Pools

Spent Fuel Pool Study

Although the spent fuel pools and the spent fuel assemblies stored in the pools remained intact after the disaster at the Fukushima Dai-ichi nuclear power plant, the event led to questions about the safe storage of spent

fuel and whether NRC should require expedited transfer of spent fuel from pools to dry cask storage at U.S. nuclear power plants. This prompted NRC to conduct a study to help determine if accelerated transfer of spent fuel from the spent fuel pool to dry cask storage significantly reduces risks to public health and safety.

In October 2013, NRC published the results of its study. The study stated that the analysis was consistent with earlier research conclusions that spent fuel pools are robust structures that are likely to withstand severe earthquakes without leaking. The study estimated that the likelihood of a radiological release from the spent fuel pool resulting from the selected severe seismic event analyzed was on the order of one time in 10 million years or lower. Therefore, NRC concluded that expediting movement of spent fuel from the pool to dry casks does not provide a substantial safety enhancement, and that spent fuel pools provide adequate protection of public health and safety.

Other Initiatives

In addition to the spent fuel pool study, NRC has taken on other recent initiatives to address spent fuel pools. For example, NRC has been working closely with the nuclear industry over the past 2 years to develop improved criticality safety guidance. The guidance is currently in draft mode. NRC is also in the process of updating guidance documents for shutdown nuclear power plants. Additionally, NRC is currently preparing a Generic Letter on neutron-absorbing materials.[8] The intent of the Generic Letter is to seek more information from licensees about their neutron absorbers and determine whether further regulatory action is required to ensure compliance with NRC regulations.

[8] Neutron-absorbing materials, such as Boraflex, Boral, and Carborundum, are placed between fuel assemblies allowing for the safe storage of fuel in close proximity to one another. The purpose of the neutron absorber materials is to ensure criticality does not occur in any spent fuel pool fuel assemblies. Some of the neutron absorber materials have experienced various levels of degradation in the form of blisters as well as general corrosion which, in some instances, has had an impact on criticality safety.

II. OBJECTIVE

The audit objective was to determine whether NRC's oversight of spent fuel pools and the nuclear fuel they contain provides adequate protection for public health and safety, and the environment. Appendix A of this report contains information on the audit's scope and methodology.

III. FINDINGS

NRC provides adequate oversight of spent fuel pools and the nuclear fuel they contain to protect public health and safety and the environment; however, opportunities exist for improvement. Recent NRC staff studies demonstrating the safety of spent fuel pools and the safety of continued storage of spent fuel at reactor sites highlight the need to ensure the safety of pool operations for longer periods than originally envisioned. To accomplish this, NRC's spent fuel pool oversight would be more effective for the long term with additional guidance for NRC staff and licensees in the following areas:

- Improved criticality analyses guidance and reviews to enhance the clarity and predictability of NRC's licensing process related to spent fuel pools.

- Enhanced reactor oversight process inspection guidance to call attention to spent fuel pools and their related systems.

A. Regulatory Uncertainty Exists Over Spent Fuel Pool Criticality Analyses

Regulatory uncertainty exists in NRC's evaluation of spent fuel pool criticality safety analyses. NRC should regulate in a manner that clearly communicates requirements and ensures that regulations are consistently applied and are practical. However, there is an absence of effective spent fuel pool criticality analyses guidance for both licensees and NRC staff. This could lead to a reduction in program efficiency and effectiveness.

What Is Required

NRC Should Clearly Communicate Requirements

According to NRC's Strategic Plan, Fiscal Years 2014-2018,[9] the agency should maintain stable and predictable regulatory programs and policies. NRC should apply regulatory tools consistently across and within agency program areas, and regulate in a manner that clearly communicates requirements and ensures that regulations are practical and consistently applied. In addition, NRC should conduct quality reviews of licensing requests and issue timely decisions consistent with agency performance indicators. The Strategic Plan also highlights that NRC's vision is to be a transparent and effective nuclear regulator.

NRC's Principles of Good Regulation states that regulations should be coherent, logical, and practical. There should be a clear nexus between regulations and agency goals and objectives. Agency positions should be readily understood and easily applied. Moreover, regulatory decisions should be made without undue delay.

[9] NUREG-1614, Vol. 6, published August 2014.

What We Found

Regulatory Uncertainty Over Spent Fuel Pool Criticality Analyses

Whenever licensees make a major change to their plant that could affect the spent fuel pool, such as a high density rerack[10] or a change to their nuclear fuel design, they must go through NRC's license amendment process before the change can be implemented. As part of this license amendment process, licensees must conduct new criticality safety analyses[11] to ensure that the changes made to the pool do not affect the pool's existing subcritical status.[12] NRC then must review and approve these criticality analyses prior to the license amendment's final approval.

There is regulatory uncertainty over the spent fuel pool criticality safety analyses. Licensees submit their criticality analyses to NRC for review but often the analyses are inadequate or insufficient according to NRC. NRC typically responds to criticality analysis submissions by sending licensees large numbers of requests for additional information (RAI). A licensee likened the RAI process to a "fishing expedition," noting that it required a lot of resources and research with little instruction on how to address the questions.

According to an industry representative, licensees do not always know what to expect when they submit a criticality analysis for review as part of a license amendment application as there is no consistency in NRC's reviews. Another industry representative stated that the success of a license amendment application was a "crapshoot" depending on which NRC reviewer was assigned to the application. Yet another

[10] Nuclear power plants rerack their spent fuel pools to allow for the storage of larger numbers of fuel assemblies. To remedy the situation of limited storage capacity, "high density" spent fuel storage racks were introduced. As the inventory of spent fuel has grown, reactor operators have increased the number of assemblies stored in the pools by replacing existing storage racks with newer racks holding denser arrangements of fuel assemblies.

[11] Criticality analyses are complex analytical methods and calculations performed to determine that proper margin exists to maintain spent fuel pool subcriticality.

[12] Subcriticality is the condition of a nuclear reactor system in which nuclear fuel no longer sustains a fission chain reaction. Subcriticality is the desired state of all spent fuel pools.

representative said that licensees did not have confidence that NRC could do the necessary analyses and that licensees did not want to submit license amendment requests.

Compounding the issue is the amount of time it might take NRC to do the criticality reviews. One licensee explained the process and said it generally took his utility approximately 6 months to complete the initial criticality analysis. NRC would then take anywhere from 6 to 12 months to respond with its initial RAIs. The licensee said it would take about 1 month to answer the RAIs, and then he would wait to hear from NRC again. This process would continue until the licensee sufficiently answered all the RAIs, possibly taking up to 3 years before the criticality analysis was approved and the license amendment granted.

NRR staff provided data on all license amendment requests related to spent fuel pool criticality analyses covering the past 5 years through October 2014. See Table 1 for NRR timeliness statistics on license amendment requests involving spent fuel pool criticality reviews.

Table 1: License Amendment Request Timeliness Table

NRC Review Time	License Amendment Requests Completed	License Amendment Requests Withdrawn	License Amendment Requests Currently Under Review
≤ 1 year	6	4	5
> 1 year & ≤ 2 years	20	10	3
> 2 years & ≤ 3 years	6	0	0

Source: Table generated by OIG from NRR data.

Out of 54 eligible submitted applications, NRC completed only 6 reviews within 1 year. According to NRC's Fiscal Year 2015 Congressional Budget Justification,[13] the agency's timeliness metrics for license amendment requests should be at a 95-percent completion rate within 1 year and a 100-percent completion rate within 2 years. An NRC senior manager acknowledged that these license amendment reviews "take a long time."

While the specific reasons for each of the 14 withdrawn license amendment requests above are not known, one licensee said his utility withdrew a couple of license amendment requests because of how long NRC's reviews were taking. An industry representative also claimed that NRC review times averaged nearly 2 years and that license amendment withdrawals had increased roughly 50 percent since the mid-2000s.

At a nuclear power conference, a licensee claimed that one of its power plants had lost full core offload capability because it was behind schedule to rerack its spent fuel pool due to NRC's license amendment request process. The utility submitted a license amendment request, which was necessary for its spent fuel pool rerack. The representative said there were a significant number of NRC RAIs during the course of the next 13 months that were issued a few at a time. He said the license amendment request was finally approved nearly 2 years after the initial submission, thereby delaying the fuel rerack by a year. He commented that, going forward, there would be no additional spent fuel pool criticality license amendment requests from his utility until NRC fixed its license amendment request timeliness issues. Conversely, regarding this specific incident, an NRC manager countered that the delays were caused by the utility doing a poor job with its criticality analysis.

Why This Occurred

Lack of Effective Guidance for Licensees and NRC

There is an absence of effective spent fuel pool criticality guidance for both licensees and NRC staff.

[13] NUREG-1100, Volume 30, "FY2015 Congressional Budget Justification."

Licensee Guidance

The primary spent fuel pool criticality guidance document available to licensees is the NRR Division of Safety Systems' Interim Staff Guidance 2010-01, which was issued in 2010. This guidance document serves as a reference point for other criticality safety guidance documents. It was created to reiterate the existing guidance documents, clarify some of the ambiguity in the existing guidance documents, and identify lessons learned based on recent criticality submittals. However, licensee questions still remain as the guidance documents referenced by the interim staff guidance address only certain aspects of criticality safety and are not viewed by licensees as being descriptive enough.

For example, one licensee claimed that spent fuel pool criticality guidance contains a lot of open-ended statements and is subject to interpretation. Another licensee opined that it would be great as an industry to reach a consensus on what a proper spent fuel pool criticality submittal should be. Finally, an NRC senior manager stated that NRC could improve on how the agency interprets spent fuel pool criticality guidance into its policy — "NRC should tell licensees what it accepts."

Interim Staff Guidance and Regulatory Guides

Interim staff guidance may not be an appropriate form of licensee guidance. As the definition states,

> Interim staff guidance documents are issued by an NRC office to clarify an aspect of the Standard Review Plan or to address issues not discussed in a Standard Review Plan.[14] As suggested by its name, an interim staff guidance document serves as a placeholder guidance document until it is incorporated into the next revision of the applicable (permanent) guidance document.

[14] A standard review plan contains guidance for NRC staff reviewers for performing safety reviews for applications to construct or operate nuclear power plants, or to obtain operating license amendments. It helps to ensure consistency of NRC staff reviews.

By contrast, NRC has a regulatory guide when it comes to nuclear criticality safety for fuel and material facilities.[15] Per the definition,

> Regulatory guides provide guidance for preparing a license application. They also describe acceptable methods for implementing NRC regulations, techniques used by the NRC staff in evaluating specific problems or postulated accidents, and data needed by NRC staff in its review of license applications and amendments. Regulatory guides are typically issued to define approaches acceptable to the NRC that licensees may take to comply with regulatory requirements. Regulatory guides may also provide sufficient information to help NRC staff perform its function.

Based on the definitions of the two guidance documents above,[16] it appears that a regulatory guide would be a more appropriate form of licensee guidance than interim staff guidance.

NRC Staff Guidance

Like licensees, NRC employees have insufficient criticality guidance. Currently, Interim Staff Guidance 2010-01 also serves as one of the primary guidance documents for NRC staff. In an OIG review of public meetings on spent fuel pool criticality safety between NRC and industry over the past 5 years, NRC stated on two separate occasions, "The [NRC] staff has found that a need exists to establish a consistent technical basis for validation of commercial spent nuclear fuel criticality safety evaluations." An NRC senior manager said that the Standard Review Plan and other guidance that NRC had been reliant upon are outdated, and this is part of the reason why reviews have taken longer than expected.

A lack of effective internal guidance has created a dependency on individual or tribal[17] knowledge because the spent fuel pool criticality team

[15] Regulatory Guide 3.71, "Nuclear Criticality Safety Standards for Fuels and Material Facilities."

[16] From NEI 07-06, "The Nuclear Regulatory Process."

in NRR is a very small group. According to an NRC manager, the group has often been understaffed over the years due to reassignments, staff departures, and extended absences. As a licensee said, "There is one reviewer who is very experienced, but the other reviewers seem to get switched out quite often, so there is a lot of educating in some cases."

Criticality analyses are very specialized and highly technical. There are only a small number of NRC staff who are trained and qualified to conduct this type of work. Likewise, licensees often lack the expertise to perform these analyses internally and must hire contractors to do the work. In addition to lack of sufficient guidance, NRR management stated that the ever-increasing complexity of criticality reviews,[18] the large workload, and the lack of resources have contributed to the delays in approving license amendment requests.

Why This Is Important

Decrease in Program Efficiency and Effectiveness

A lack of effective guidance could reduce program efficiency and effectiveness. An NRC senior manager claimed that licensees have expressed their desire to increase their use of NRC's 50.59 change process[19] to avoid what licensees perceive as NRC's unpredictable review times and overly detailed RAIs concerning spent fuel pool criticality analyses. OIG performed a search on all 50.59 violations within the past 5 fiscal years and found 4 instances where 50.59 violations occurred related to spent fuel pool criticality safety. While these particular violations do not necessarily indicate an intentional workaround by licensees, they do

[17] Tribal knowledge refers to a set of unwritten rules or information that is known by a group of individuals within an organization but is not commonly known by others. This term is used most when referencing information that may need to be known by others in order to produce a quality product or service.

[18] NRR management stated that criticality analyses are becoming more complex due to the increasing density of spent fuel stored in pools. This has led to licensee submissions that routinely challenge safety limits. Thus, more NRC review time and effort are needed to ensure licensees' pools remain subcritical.

[19] 10 CFR 50.59 allows licensees to make certain procedure or facility changes without a license amendment provided that licensees meet specific requirements.

illustrate that some licensees inappropriately used the 50.59 process related to criticality safety. With better guidance, these violations may be preventable as licensees should be able to submit higher quality criticality analyses and NRC should be able to decrease review times.

Program efficiency and effectiveness are also reduced when timeliness metrics are not achieved and licensees are unable to implement important changes to their spent fuel pools via the license amendment process. An industry representative stated that the regulatory uncertainty has been detrimental to safety as licensees have been "afraid" to apply for a license amendment; thus, licensees were afraid to make a change when the change may have improved spent fuel pool safety.

Improved guidance could provide better support for NRC's succession planning and knowledge management efforts.[20] According to a senior NRC manager, if the current lead of the spent fuel pool criticality group were to leave NRC, there may not be a viable replacement readily available. This puts the agency in a very vulnerable position without proper effective guidance. NRR's internal Web page states the importance of knowledge management – a loss of knowledge could challenge NRR in accomplishing its mission. Effective internal guidance addresses knowledge loss by reducing the reliance on any specific individual.

Recommendation

OIG recommends that the Executive Director for Operations

1. Provide a generic regulatory solution for spent fuel pool criticality analysis by developing and issuing detailed licensee guidance along with NRC internal procedures.

[20] Knowledge management entails capturing critical information and making the right information available to the right people at the right time.

B. NRC's Spent Fuel Pool Inspection Program Could Be Enhanced

There are gaps in NRC's spent fuel pool inspection program as inspections of spent fuel pools greatly vary between licensee sites and are limited in scope. To fulfill its responsibility to protect public health and safety, NRC must inspect and assess licensee operations and facilities to ensure compliance with its regulatory requirements. However, variations in spent fuel pool inspections result from guidance that is either outdated or virtually silent on spent fuel pools. Without improved guidance, spent fuel pools could potentially be overlooked.

What Is Required

NRC Must Inspect and Assess Licensee Operations and Facilities

NRC's responsibility and authority to inspect licensee facilities are both derived from the Atomic Energy Act of 1954, as amended, which provides the basis for the Commission to set standards and establish the rules for licensed activities and to inspect those activities. Inspections are intended to ensure that licensees meet NRC's regulatory requirements, demonstrating that they are most likely conducting safe operations that protect the public and the environment from any undue nuclear risk.

As stated in NRC's Strategic Plan, Fiscal Years 2014-2018, to fulfill its responsibility to protect public health and safety, NRC must inspect and assess licensee operations and facilities to ensure compliance with its requirements. NRC should evaluate domestic operational experience associated with licensed facilities and activities. The agency must develop the regulatory framework, analytical tools, and data needed to ensure safe and secure storage, transportation, and disposal of spent nuclear fuel. NRC also must maintain effective and consistent oversight of licensee performance to drive continued licensee compliance with NRC safety requirements and license conditions.

What We Found

Spent Fuel Pool Inspection Oversight Varies Greatly Among Licensed Facilities

There are gaps in NRC's spent fuel pool inspection oversight as inspections of spent fuel pools greatly vary among licensee sites and are limited in scope.

Spent Fuel Pool Inspections Based on Inspector Discretion

The Reactor Oversight Process (ROP) is the agency's program to inspect, measure, and assess the safety and security performance of operating commercial nuclear power plants, including spent fuel pools. The ROP monitors plant performance in three key areas – reactor safety, radiation safety, and safeguards.

However, within the ROP baseline program, there is no targeted safety inspection procedure for spent fuel pools.[21] According to NRC guidance,[22] a separate spent fuel pool inspection procedure was not developed because the baseline inspection program is primarily based on the risk associated with reactor core damage when the reactor fuel is in the reactor vessel. Full-time resident inspectors and regional inspectors must complete baseline inspections and choose inspection areas using a risk-informed approach based on potential risk and past operational experience, as well as on regulatory requirements. Thus, inspections of spent fuel pools at operating reactors depend on the experience of the resident inspectors and the history of the plant. At their

Resident inspector. Source: NRC.

[21] There is a required safety inspection that involves spent fuel pools, Inspection Procedure 71111.20, "Refueling and Other Outage Activities," and a required security inspection involving spent fuel pools, Inspection Procedure 71130.11, "Material Control and Accounting."

[22] Inspection Manual Chapter 0308, Attachment 2, *Technical Basis for Inspection Program.*

discretion, residents may include the spent fuel pools in samples selected for any of a number of procedures. Resident inspectors provided examples of inspection procedures with samples that could electively include an aspect of the spent fuel pool. These procedures are listed in Table 2.[23]

Table 2: Suggested Inspection Procedures for Spent Fuel Pools

Inspection Procedure Number	Inspection Procedure Title
71111.04	Equipment Alignment
71111.12	Maintenance Effectiveness
71111.13	Maintenance Risk Assessments and Emergent Work Control
71111.15	Operability Determinations and Functionality Assessments
71111.18	Plant Modifications
71111.19	Post Maintenance Testing
71111.21	Component Design Bases Inspection
71111.22	Surveillance Testing
71152	Problem Identification and Resolution

Source: OIG generated based on resident inspector interviews.

Inspection Numbers Vary

Inspections of spent fuel pools vary in number among reactor facilities. OIG reviewed inspection reports issued over a 5-year period at a sample of reactor licensees.[24] The sample included 18 operating nuclear power plants with 25 spent fuel pools. For fiscal years 2010 through 2014,

[23] This list of inspection procedures is not a comprehensive list within the ROP. Rather, it is a list of inspection procedures where, according to resident inspectors, spent fuel pools could be inspected even though the pools are not specifically mentioned.
[24] The sample of facilities is discussed in Appendix A, Objective, Scope, and Methodology, of this report.

- There were 1,061 total inspection reports published for the 18 reactor facilities, with many of the reports discussing results of several inspection procedures.

- Of the 1,061 reports, there were only 67 spent fuel pool-related inspections using elective procedures.[25]

- Although these 67 total inspection procedures equate to nearly 4 spent fuel pool inspections per facility over the 5-year time period, some facilities had as many as 10 inspections during this timeframe while other facilities had no inspections.

Neutron Absorbers Not Focus of Inspectors

NRC has documented industry operating experience involving the degradation of neutron absorbers such as Boraflex. However, NRC's efforts to learn more about the long-term behavior of other neutron absorbers have been challenged as the tools used to evaluate Boraflex may not be reliable with other neutron absorbers. Numerous NRC staff stated that although not an immediate safety concern, neutron absorber degradation is probably the most important spent fuel pool safety issue and learning more about degradation is a priority for NRR. However, neutron absorbers largely do not fall in the regional or resident inspectors' purview. Inspectors indicated awareness of the issues with neutron absorbing materials. Nevertheless, the extent of a resident inspector's direct experience related to neutron absorbers and how they are monitored or managed by the licensee depends on conditions at the plants.

Shutdown Plant Spent Fuel Pool Inspections Do Not Consistently Reflect Recent Operating Experience

At shutdown power plants, NRC regional inspectors conduct annual inspections using Inspection Procedure 60801, "Spent Fuel Pool Safety at Permanently Shutdown Reactors," issued in 1997.

[25] These inspections do not include the mandatory security or reactor outage activities inspections. Furthermore, other inspections that may have touched spent fuel pools in some capacity, such as radiation protection and license renewal, were not included since their focus is not on spent fuel pools. Finally, one-time inspections such as temporary instructions also were not included.

Permanently shutdown reactors at San Onofre Station. Source: NRC.

Inspection procedures from the ROP baseline program can also be used at decommissioning facilities, thus enhancing inspection effectiveness with operating experience. Also available to enhance inspection effectiveness are five NRC Information Notices based on spent fuel pool operating experience issued since IP 60801 was published.

However, OIG's review of spent fuel pool inspections at shutdown facilities over the past 5 years showed only 3 of 26 cases where operating experience may have informed the inspection. For example, one inspection included the Temporary Instruction for followup to the Fukushima Dai-ichi event, demonstrating use of industrywide operating experience. In the majority of cases, however, inspection reports reflected close adherence to the requirements of Inspection Procedure 60801 without incorporating additional operating experience.

Why This Occurred

Inspection Program Guidance Virtually Silent or Outdated

Inspection program guidance is insufficient because ROP is virtually silent on operating spent fuel pools and shutdown facility inspection guidance is outdated.

Virtual Silence in ROP

For operating reactors, other than the mandatory reactor outage activities and security inspections, only one inspection procedure in the ROP baseline inspection program mentions the spent fuel pool as a system that could be included electively in an inspection sample. The procedures cited by resident inspectors listed in Table 2 do not explicitly call out the spent fuel pool in the discussion of samples. As a result, spent fuel pools were rarely included in samples when these inspection procedures were used by inspectors.

Although some inspectors explained that they maintain awareness of the spent fuel pool condition through their plant status observations, Inspection Manual Chapter 2515 Appendix D, "Plant Status," makes no mention of spent fuel pools and only advises inspectors to "cover all spaces" of a power plant. Overall, explicit inspection guidance is not provided for spent fuel pools at operating reactors, in contrast to the specific guidance to review such areas as drain and siphon protection, instrumentation, and leakage detection during inspections of spent fuel pools at permanently shutdown reactors.

Inspectors also do not have a clear means in the inspection guidance to oversee licensees' monitoring of neutron absorbers. Some inspectors reported being "asked" to look at licensee monitoring efforts, but, as one resident inspector put it, neutron absorbers are largely a "headquarters thing." Another resident observed that he "has never personally looked at this [neutron absorbers]" and his guess is that "the region never has either." Headquarters staff acknowledged that, for many nuclear power plants, there is no NRC-endorsed aging management program for neutron- absorbing material. As such, it is extremely difficult for inspectors to oversee a program for which a standard currently does not exist.

Decommissioning Guidance Outdated

For shutdown plants, Inspection Manual Chapter 2561, "Decommissioning Power Reactor Inspection Program," published in 2003, and Inspection Procedure 60801, published in 1997, have become outdated. These guidance documents do not reflect more recent operating experience, such as higher fuel enrichments, denser and more complex storage patterns, and unexpected (and potentially unknown) deterioration of spent fuel pool neutron absorber material, nor do they reflect current practices in aging management.

Why This Is Important

Spent Fuel Pools Could Potentially Be Overlooked

Spent fuel pools are not being inspected with regularity and could potentially be overlooked. License renewals, decommissioning, and the lack of a long-term solution to spent fuel storage means that some spent fuel pools may store fuel for many years. Although largely viewed as passive or static between refueling outages, spent fuel pool degradation may become more significant due to aging as pools are kept in service for longer periods of time. Given the low number of inspections, other than for reactor outages and security, prudence suggests that the extension of time in service could increase risk of onsite consequences for workers or the local environment.

Further, more plants are going into decommissioning status. The most recently shutdown plants have more high burnup fuel and higher density pools than was foreseen in the existing guidance, possibly reducing the overall effectiveness of the inspections.

Recommendations

OIG recommends that the Executive Director for Operations

2. Develop and implement spent fuel pool inspection guidance at operating reactors.

3. Develop an enforceable neutron-absorbing material aging management program.

4. Update Inspection Manual Chapter 2561 and Inspection Procedure 60801.

Summary and Conclusion

NRC should apply regulatory tools consistently across and within agency program areas, and regulate in a manner that clearly communicates requirements and ensures that regulations are practical and consistently applied. NRC also must maintain effective and consistent oversight of licensee performance to drive continued licensee compliance with NRC safety requirements and license conditions. Effective guidance for submitting and reviewing criticality analyses will help enhance program efficiency and effectiveness. Further, as time in service increases for spent fuel pools, guidance for inspections in the areas most subject to degradation will help ensure continued safe operations.

IV. CONSOLIDATED LIST OF RECOMMENDATIONS

OIG recommends that the Executive Director for Operations

1. Provide a generic regulatory solution for spent fuel pool criticality analysis by developing and issuing detailed licensee guidance along with NRC internal procedures.

2. Develop and implement spent fuel pool inspection guidance at operating reactors.

3. Develop an enforceable neutron-absorbing material aging management program.

4. Update Inspection Manual Chapter 2561 and Inspection Procedure 60801.

V. AGENCY COMMENTS

An exit conference was held with the agency on January 22, 2015. Prior to this meeting, after reviewing a discussion draft, agency management provided supplemental information that has been incorporated into this report, as appropriate. As a result, agency management stated their general agreement with the findings and recommendations in this report and opted not to provide formal comments for inclusion in this report.

Appendix A

OBJECTIVE, SCOPE, AND METHODOLOGY

Objective

The audit objective was to determine if NRC's oversight of spent fuel pools and the nuclear fuel they contain provides adequate protection for public health and safety, and the environment.

Scope

The audit focused on reviewing current NRC oversight processes for wet storage of spent reactor fuel in pools at operating and permanently shutdown reactors. We conducted this performance audit at NRC headquarters (Rockville, MD) from July 2014 through November 2014. We also visited two nuclear power plants in Hancocks Bridge, New Jersey during this time. Internal controls related to the audit objective were reviewed and analyzed. Throughout the audit, auditors were aware of the possibility of fraud, waste, or abuse in the program.

Methodology

OIG reviewed relevant criteria, such as Federal legislation pertaining to NRC's regulatory authorities to oversee spent fuel pools, including the Atomic Energy Act of 1954, as amended; the Energy Reorganization Act of 1974; and the Nuclear Waste Policy Act of 1982. OIG reviewed relevant portions of Title 10 of the Code of Federal Regulations, particularly 10 CFR Part 50 *Domestic Licensing of Production and Utilization Facilities*. OIG reviewed NRC's Strategic Plan, Fiscal Years 2014-2018, and NRC's Principles of Good Regulation. OIG reviewed the Government Accountability Office's "Standards for Internal Control in the Federal Government" and the Office of Management and Budget's "Final Bulletin for Agency Good Guidance Practices."

OIG reviewed NRC guidance documents such as Standard Review Plans, Inspection Manual Chapters, Inspection Procedures, and other guidance pertaining to spent fuel pools. OIG reviewed NRC communications

with licensees, including Information Notices, Generic Letters, Enforcement Actions (Orders), and summaries of public meetings with licensees and industry representatives. OIG reviewed reports of research by NRC, the Electric Power Research Institute, and the National Academy of Sciences addressing aspects of spent fuel pools in the United States.

OIG conducted records reviews during the course of the audit. Specifically, the audit team reviewed safety inspection reports of a judgmentally selected sample of 18 plants covering a 5-year period (Fiscal Years 2010 – 2014) to determine the frequency of spent fuel pool related safety inspections. Additionally, the audit team reviewed inspection reports, issued over a 5-year period, of spent fuel pools at permanently shutdown reactors. OIG also reviewed Operating Experience and the Reactor Oversight Process Plant Information Matrix for information on spent fuel pool performance and inspection findings.

OIG interviewed NRC staff and management at headquarters and the regions to gain an understanding of the roles and responsibilities related to oversight of spent fuel pool safety. Auditors interviewed management and staff from NRR, the Office of New Reactors, the Office of Nuclear Regulatory Research, the Office of Nuclear Material Safety and Safeguards, and the Advisory Committee on Reactor Safeguards. Additionally, OIG interviewed staff from each of the four regions (Region I, King of Prussia, PA; Region II, Atlanta, GA; Region III, Lisle, IL; and Region IV, Arlington, TX) who participate in activities related to spent fuel pools. More specifically, OIG conducted telephone interviews with senior resident inspectors and resident inspectors at 18 operating nuclear power plants. Those plants were selected as a judgmental sample to include both boiling water reactors and pressurized water reactors in all the regions, a range of facility ages, and a range of spent fuel pool capacities. OIG conducted telephone interviews with staff in Regions I, III, and IV responsible for oversight of spent fuel pools at permanently shutdown facilities.

OIG conducted interviews with representatives of the Nuclear Energy Institute and with licensees and other stakeholders interested in spent fuel pool safety. The audit team toured the spent fuel pools at the Hope

Creek Generating Station and Salem Nuclear Generating Station in Hancocks Bridge, New Jersey, to observe a boiling water reactor and a pressurized water reactor spent fuel pool system and to speak with inspectors about their onsite inspection activities.

We conducted this performance audit in accordance with generally accepted Government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

The audit work was conducted by Sherri Miotla, Team Leader; Michael Blair, Audit Manager; Kevin Nietmann, Senior Technical Advisor; Amy Hardin, Senior Auditor; and Regina Revinzon, Auditor.

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COMMENTS AND SUGGESTIONS

If you wish to provide comments on this report, please email OIG using this link.

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