INTERIM STAFF GUIDANCE
Compliance with Order EA-12-051
Reliable Spent Fuel Pool Instrumentation
NRR ISG XXX
[NRO ISG-XXX]

Purpose

This interim staff guidance (ISG) provides review criteria to enable staff to identify acceptable means for licensees to implement Order EA-12-051, issued March 12, 2012. In this order, holders of operating licenses (OLs), construction permits (CPs), and combined licenses (COLs) were required to implement a reliable means of remotely monitoring wide-range spent fuel pool levels to support effective prioritization of event mitigation and recovery actions in the event of a beyond-design-basis external event. Licensees and CP holders may use other methods for satisfying these requirements. The U.S. Nuclear Regulatory Commission (NRC) staff will review such methods and determine their acceptability on a case by case basis.

Background

On March 11, 2011, a magnitude 9.0 earthquake struck off the coast of the Japanese island of Honshu. The earthquake resulted in a large tsunami, estimated to have exceeded 14 meters (45 feet) in height, that inundated the Fukushima Dai-ichi nuclear power plant site. The earthquake and tsunami produced widespread devastation across northeastern Japan and significantly affected the infrastructure and industry in the northeastern coastal areas of Japan.

Approximately 40 minutes following the earthquake and shutdown of the operating units, the first large tsunami wave inundated the site, followed by additional waves. The tsunami caused extensive damage to site facilities and resulted in a complete loss of all AC electrical power at Units 1 through 5, a condition known as station blackout. In addition, all direct current electrical power was lost early in the event on Units 1 and 2 and after some period of time at the other units. Unit 6 retained the function of one air-cooled EDG. Despite their actions, the operators lost the ability to cool the fuel in the Unit 1 reactor after several hours, in the Unit 2 reactor after about 70 hours, and in the Unit 3 reactor after about 36 hours, resulting in damage to the nuclear fuel shortly after the loss of cooling capabilities.

The Unit 4 spent fuel pool contained the highest heat load of the six units with the full core present in the spent fuel pool and the refueling gates installed. However, because Unit 4 had been shut down for more than 3 months, the heat load was low relative to that present in spent fuel pools immediately following shutdown for reactor refueling. Following the earthquake and tsunami, the operators in the Units 3 and 4 control room focused their efforts on stabilizing the Unit 3 reactor. During the event, concern grew that the spent fuel was overheating, potentially causing a high-temperature reaction of steam and zirconium fuel cladding generating hydrogen gas. This concern persisted primarily due to a lack of readily available and reliable information on water levels in the spent fuel pools. Helicopter water drops, water cannons, and cement delivery vehicles with articulating booms were used to refill the pools, which diverted resources and attention from other efforts. Subsequent analysis determined that the water level in the Unit 4 spent fuel pool did not drop below the top of the stored fuel and no significant fuel damage occurred. The lack of information on the condition of the spent fuel pools contributed to a poor understanding of possible radiation releases and adversely impacted effective prioritization of emergency response actions by decision makers.

Following the events at the Fukushima Dai-ichi nuclear power plant, the NRC established a senior-level agency task force referred to as the Near-Term Task Force (NTTF). The NTTF was tasked with conducting a systematic and methodical review of the NRC regulations and processes and determining if the agency should make additional improvements to these programs in light of the events at Fukushima Dai-ichi. As a result of this review, the NTTF developed a comprehensive set of recommendations, documented in SECY 11 0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," dated July 12, 2011. These recommendations were modified by the NRC staff following interactions with stakeholders. Documentation of the NRC staff's efforts is contained in SECY 11 0124, "Recommended Actions to Be Taken without Delay from the Near Term Task Force Report," dated September 9, 2011, and SECY 11 0137, "Prioritization of Recommended Actions to Be Taken in Response to Fukushima Lessons Learned," dated October 3, 2011.

As directed by the Commission's Staff Requirements Memorandum (SRM) for SECY 11 0093, the NRC staff reviewed the NTTF recommendations within the context of the NRC's existing regulatory framework and considered the various regulatory vehicles available to the NRC to implement the recommendations. SECY 11 0124 and SECY 11 0137 established the NRC staff's prioritization of the recommendations based upon the potential safety enhancements.

Order EA-12-051

On March 12, 2012, the NRC issued Order EA-12-051, "Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation (Effective Immediately)." The Order requires all power reactor licensees and CP holders must have a reliable means of remotely monitoring wide-range spent fuel pool levels to support effective prioritization of event mitigation and recovery actions in the event of a beyond-design-basis external event.

Basis

Basis for Order
The NRC's assessment of the unprecedented events at Fukushima Dai-ichi led the Commission to conclude that additional requirements must be imposed on licensees and CP holders to increase the capability of nuclear power plants to mitigate beyond-design-basis external events. The additional requirements imposed by Order EA-12-051 represent a significant enhancement to the protection of public health and safety. For these reasons, as well as the broad stakeholder endorsement of these actions, the Commission administratively exempted this Order from applicable provisions of the Backfit Rule, 10 CFR 50.109, and the issue finality requirements in 10 CFR 52.63 and 10 CFR Part 52, Appendix D, Paragraph VIII.

Regulatory Bases
While the Commission determined to administratively exempt the spent fuel pool Order from the requirements of the Backfit Rule, there are bases for reliable spent fuel pool instrumentation in existing regulations. Nuclear Regulatory Commission regulations in Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, "Domestic Licensing of Production and Utilization Facilities," Section 50.34, "Contents of Applications; Technical Information," specifies that the application for an operating license must include the principle design criteria for the facility and the relationship of the design bases of the new structures, systems, and components (SSCs) to the design criteria. Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," establishes minimum requirements for the principal design criteria for later applications for water-cooled nuclear power plants. Earlier applications included design criteria with a similar

intent. The following general design criteria (GDC) from Appendix A to 10 CFR Part 50 are applicable to a spent fuel storage system:

- GDC 2, "Design Bases for Protection against Natural Phenomena," specifies, in part, that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes and tornados without loss of capability to perform their safety functions.

- GDC 4, "Environmental and Dynamic Effects Design Bases," specifies, in part, that SSCs important to safety shall be appropriately protected against dynamic effects, including the effects of missiles that may result from equipment failures.

- GDC 61, "Fuel Storage and Handling and Radioactivity Control, " specifies, in part, that fuel storage and handling systems shall be designed (1) with a capability to permit appropriate periodic inspection and testing of components important to safety, (2) with suitable shielding for radiation protection, (3) with appropriate containment, confinement, and filtering systems, (4) with a residual heat removal capability having reliability and testability that reflects the importance to safety of decay heat and other residual heat removal, and (5) to prevent significant reduction in fuel storage coolant inventory under accident conditions.

- GDC 62, "Prevention of Criticality in Fuel Storage and Handling," specifies that criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations.

- GDC 63, "Monitoring Fuel and Waste Storage," specifies that appropriate systems shall be provided in fuel storage and radioactive waste systems and associated handling areas (1) to detect conditions that may result in loss of residual heat removal capability and excessive radiation levels and (2) to initiate appropriate safety actions.

In addition, 10 CFR 50.34 specifies that the safety analysis report include an analysis of the performance of SSCs with the objective of assessing the risk to public health and safety resulting from operation of the facility. This analysis shall include determination of the margins of safety during normal operations and transient conditions anticipated during the life of the facility. The analysis shall assess the adequacy of SSCs provided for the prevention of accidents and the mitigation of the consequences of accidents.

Finally, 10 CFR 50.34(i) specifies that the safety analysis report include a description and plans for implementation of the guidance and strategies intended to maintain or restore spent fuel pool cooling capabilities under the circumstances associated with the loss of large areas of the plant due to explosions or fire as required by 10 CFR 50.54(hh)(2).

<u>Licensing Basis</u>
The spent fuel pool structure at all facilities is a robust reinforced concrete structure with a low leakage welded stainless steel liner. Connected piping systems are configured to minimize the loss of coolant resulting from connected system pressure-boundary failures or improper operation. However, the fuel transfer system, which is fully connected to the spent fuel pool during refueling, may present greater potential for loss of inventory because the system typically connects many potential paths for water loss to the pool at an elevation just above the top of stored fuel.

Through licensing reviews and design surveys associated with generic issue related activities, the staff has determined that the design of spent fuel pool cooling and coolant makeup systems can be classified in the following groups:

1. Both the forced cooling and the makeup systems are non-safety-related
2. The forced cooling system is non-safety-related and safety-related makeup is available with operator action outside the control room
3. The normally operating forced cooling system is non-safety-related and both safety-related forced cooling and safety-related makeup are available with operator action outside the control room
4. Both the forced cooling and the makeup systems are safety-related, but safety-related makeup requires operator action outside the control room.

The first two groups include the earliest licensed facilities and consider spent fuel pool boiling as the safety-related means of spent fuel cooling. In addition, some facilities in the third group have spent fuel pool boiling included within the facility licensing basis. For all facilities, the time to reach boiling following a loss of forced cooling was considered in evaluating operator actions outside the control room. For many facilities, effective provision of makeup water, and, thus, long-term cooling, requires access to the spent fuel pool operating floor.

Existing spent fuel pool instrumentation typically consists of temperature, level, and area radiation monitors. The temperature and level instruments often provide only local indication at the SFP and remote alarms in the control room for high temperature and both high and low water level. The alarm set-points typically correspond to an off-normal condition. Therefore, currently installed instrumentation typically provides insufficient information to evaluate event progression in the SFP without direct observation of spent fuel pool conditions locally at the SFP.

<u>Technical Basis</u>
The spent fuel pool design criteria provide protection against a substantial release of radioactive material by maintaining adequate cooling for stored fuel. Maintaining adequate spent fuel pool water level provides this essential cooling function, in addition to providing appropriate confinement and shielding for the radioactive material within the stored spent fuel. Maintenance of an adequate water level alone satisfies the essential safety functions for the spent fuel pool, thus, instrumentation monitoring of the water level in the spent fuel pool provides sufficient information to promptly initiate appropriate actions to maintain safe storage conditions for spent fuel.

Applicability

All power reactor licensees and holders of CPs in active or deferred status as specified in Attachment 1 to Order EA-12-051 issued March 12, 2012 (ADAMS Accession No. ML12056A044).

Licensees that have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel are outside the scope of this Order. For these facilities, the enhanced instrumentation is not required because the decay heat rate of the fuel within the spent fuel pools is very low. Since the heat load in the pool is low, extended recovery times are available to responders in the event of coolant loss. Further, the heat load is insufficient to generate temperatures that could lead to a large radioactive material release.

Guidance

Italicized portions of this guidance are taken directly from Order EA-12-051.

1. Spent Fuel Pool Instrumentation Design Criteria

All licensees identified in Attachment 1 to this Order shall have a reliable indication of the water level in associated spent fuel storage pools capable of supporting identification of the following pool water level conditions by trained personnel: (1) level that is adequate to support operation of the normal fuel pool cooling system, (2) level that is adequate to provide substantial radiation shielding for a person standing on the spent fuel pool operating deck, and (3) level where fuel remains covered and actions to implement make-up water addition should no longer be deferred.

Definitions:

- Reliable – a spent fuel pool level instrument channel is reliable when the instrument channel satisfies the design elements listed in Section 1 of this ISG (below) and personnel training and channel operation, maintenance, and testing/calibration have been implemented consistent with the programs listed in Section 2 of this ISG. Appropriate quality assurance measures, such as those specified in Appendix A, "Quality Assurance Guidance for Non-Safety Systems and Equipment," of Regulatory Guide 1.155, "Station Blackout," or Section C.1.7, "Quality Assurance," of Regulatory Guide 1.189, "Fire Protection for Nuclear Power Plants," should be applied to processes important to the reliability of instrument channels, such as procurement, design, qualification of components, installation, testing, procedures, and corrective actions.

- Associated spent fuel pool – an associated spent fuel pool is a water-filled structure housing storage racks that contain irradiated fuel discharged from the reactor vessel and used for power generation within the last five years. Two or more spent fuel pools connected by normally open gates designed for under-water transfer of irradiated fuel may be treated as a single spent fuel pool. Spent fuel pools that contain no fuel used in a reactor vessel for power generation within the past five years are not associated spent fuel pools. Water-filled structures within primary containments that contain temporary fuel storage locations are not considered to be associated spent fuel pools, provided that strategies for maintaining the containment function have been established for the refueling mode of operation.

The reliable indication of spent fuel pool water level is expected to allow trained personnel to differentiate among the following spent fuel pool conditions:

- Level adequate to support operation of the normal fuel pool cooling system - The range of water level where forced cooling of the spent fuel pool can be established using installed equipment regardless of the status of fuel transfer gates. In boiling water reactors (BWRs), this range of level is the normal operating level range. For pressurized water reactors (PWRs), this is the level range where adequate net positive suction head would be available to the installed spent fuel pool cooling pumps with the pool at saturation conditions, which typically extends several feet below the normal operating level range.

- Level adequate to provide substantial radiation shielding for a person standing on the spent fuel pool operating deck - The range of water level where any necessary operations in the vicinity of the spent fuel pool can be completed without significant dose consequences from direct gamma radiation from the stored spent fuel. The bottom of the level range may be selected at 10 feet (3 meters) above the top of fuel assemblies seated in the storage racks based on guidance in Regulatory Guide 1.13, "Spent Fuel Storage Facility Design Basis." Lower water levels may be specified for the bottom of the level range based on plant-specific analyses of necessary actions to confirm dose consequences to individuals would be within applicable limits at that water level.

- Level where fuel remains covered - The range of water level above the top of the fuel when it is properly seated in the storage racks, but distinct from and below the range of water level adequate to provide substantial radiation protection. The lowest indication in this range should be below the bottom of any opening in the storage pool wall used for fuel transfer, but above the top of the stored fuel. At this level, recovery actions for the spent fuel pool would have priority comparable to actions to provide reactor core cooling, and the actions should not be deferred.

1.1 Instruments: The instrumentation shall consist of a permanent, fixed primary instrument channel and a backup instrument channel. The backup instrument channel may be fixed or portable. Portable instruments shall have capabilities that enhance the ability of trained personnel to monitor spent fuel pool water level under conditions that restrict direct personnel access to the pool, such as partial structural damage, high radiation levels, or heat and humidity from a boiling pool.

At least one primary and one backup instrument channel shall be provided for each associated spent fuel pool. Each channel may monitor level over a continuous range, at discrete levels, or a combination of continuous and discrete level sensing elements.

Portable instrument channels may rely on fixed components for functions such as level sensing or data transmission or a combination thereof. Capabilities that enhance the ability of trained personnel to monitor spent fuel pool water level under conditions that restrict access include capabilities to place the instrument in a position to monitor pool level using remotely-controlled devices or pre-staged sensing capabilities that can be connected to the portable remainder of the instrument channel. Specific examples of these two methods include (1) delivery of an ultra-sonic or guided wave radar level instrument to the pool using a robot, and (2) pre-installed stainless steel tubing for sensing the static pressure at the top of the stored fuel, which can be filled, flushed, and connected to a portable pressure instrument from a remote location.

For portable instruments, the resources required for deployment and the timing of deployment should be verified to be within the capabilities of the on-site staff and early-responders expected on-site by the time of deployment. Deployment within 4 hours is acceptable under all conditions, and longer deployment times may be justified based on the ability to readily identify rapid spent fuel pool coolant loss from structural failure and estimates of the time for evaporative coolant losses to become significant (e.g., level no longer adequate to support operation of the normal fuel pool cooling system). Evaluation of resources should consider the potential for concurrent resource requirements to implement strategies required by Order EA-12-049.

Instrument channels may rely on wireless or hard-wired data transmission from the data transmitting device to the indication device, or a combination thereof. Data transmission shall neither degrade performance of safety-related equipment nor interfere with wireless communications expected to be used for on-site emergency communications.

1.2 Arrangement: The spent fuel pool level instrument channels shall be arranged in a manner that provides reasonable protection of the level indication function against missiles that may result from damage to the structure over the spent fuel pool. This protection may be provided by locating the primary instrument channel and fixed portions of the backup instrument channel, if applicable, to maintain instrument channel separation within the spent fuel pool area, and to utilize inherent shielding from missiles provided by existing recesses and corners in the spent fuel pool structure.

Permanently installed portions of instrument channels should be located in a manner that provides limited missile protection without the installation of missile shields. This reasonable protection should be provided by locating the primary instrument channel and fixed portions of the backup instrument channel in a manner that maintains instrument channel separation within the spent fuel pool area and utilizes inherent shielding provided by existing recesses and corners in the spent fuel pool structure. However, moving components (e.g., float switches) should be shielded by guards designed to prevent interference from loose components, such as control rod blade guides or other components commonly stored in and around the spent fuel pool.

Each licensee should specify the specific criteria applied to selecting the location of the instrument channel components. The following criteria are acceptable without justification:

- instrument channel components are mounted such that no portion extends above the top of the pool structure
- sensing components are located near inside corners of the pool structure
- data transmission and power cables are routed within recessed areas in the operating floor or through penetrations in the pool wall below the operating floor (e.g., ventilation ducts).

1.3 Mounting: Installed instrument channel equipment within the spent fuel pool shall be mounted to retain its design configuration during and following the maximum seismic ground motion considered in the design of the spent fuel pool structure.

The permanently installed portions of instrument channels shall be mounted in a manner consistent with Class I or Category I components, as defined in the facility safety analysis report, to ensure the instrument configuration supports reliable monitoring of spent fuel pool level, and does not pose a risk of damage to stored fuel in the pool in the event of a seismic event.

1.4 Qualification: The primary and backup instrument channels shall be reliable at temperature, humidity, and radiation levels consistent with the spent fuel pool water at saturation conditions for an extended period. This reliability shall be established through use of *an augmented quality assurance process (e.g., a process similar to that applied to the site fire protection program).*

The reliability of components used in the instrument channels shall be demonstrated reliable at the temperature, humidity, and radiation levels expected when the spent fuel pool remains at saturation conditions without makeup water addition for an extended period. The extended period of operation should be the time necessary to procure and deploy an effective replacement portable instrument from a distant, off-site location, but no less than 7 days.

Component reliability shall be demonstrated by one or more of the following bases:

1. Component operating history in high temperature, high humidity, or high radiation environments.
2. Commercial testing of components in high temperature, high humidity, or high radiation environments.
3. Specification of components designed and constructed to be inherently resistant to the effects of high temperature, humidity, and radiation.

Appropriate quality assurance measures, such as those specified in Appendix A, "Quality Assurance Guidance for Non-Safety Systems and Equipment, of Regulatory Guide 1.155, "Station Blackout," or Section C.1.7, "Quality Assurance," of Regulatory Guide 1.189, "Fire Protection for Nuclear Power Plants," shall be applied to the qualification of components used in the level instrument channels.

1.5 Independence: The primary instrument channel shall be independent of the backup instrument channel.

The two instrument channels provided shall not share common components or power supplies, and the instrument channels shall be physically separated and electrically isolated from one another to minimize the likelihood for a common cause failure or common event from rendering both channels inoperable.

1.6 Power supplies: Permanently installed instrumentation channels shall each be powered by a separate power supply. Permanently installed and portable instrumentation channels shall provide for power connections from sources independent of the plant ac and dc power distribution systems, such as portable generators or replaceable batteries. Onsite generators used as an alternate power source and replaceable batteries used for instrument channel power shall have sufficient capacity to maintain the level indication function until offsite resource availability is reasonably assured.

For instrumentation that requires electrical power, the capability shall be provided to connect the permanent and portable instrument channels to alternate sources of power independent of the plant AC and DC distribution systems. The alternate on-site power supplies (i.e., a generator and associated supplies or a set of replaceable batteries) should have sufficient capacity to support at least 3 days of instrument channel operation.

1.7 Accuracy: The instrument channels shall maintain their designed accuracy following a power interruption or change in power source without recalibration.

Required instrument accuracy should be sufficient to allow trained personnel to determine the actual level exceeds the specified lower level of each indicating range without conflicting or ambiguous indication (e.g., if a series of lights are used to indicate level, the instrument channel accuracy must be adequate to support sequential change in state of the lights as the actual pool level changes). If the capability is provided to monitor level over a continuum of range (i.e., not discrete level points with separation between successive points), the required accuracy of such indication must be specified for meeting the goals in Design Criterion 1 above, and licensees should demonstrate how the accuracy of their proposed installed instrumentation meets that accuracy requirement.

1.8 Testing: The instrument channel design shall provide for routine testing and calibration.

Each instrument channel should be designed with the capabilities for trained personnel to conduct periodic functional testing and periodic calibration over the full range of measurement. The establishment of the required surveillance interval between successive calibrations shall take into account the observed drift performance of the instruments and the need to verify that the instrument channel is still capable of achieving its required performance specification at the conclusion of each surveillance interval. Each type of instrument should be tested and calibrated in a manner consistent with the manufacturer's recommendations, but the maximum surveillance interval should not exceed once per refueling cycle. Ideally such periodic calibration shall be performed in such a manner that very little time has elapsed between the completion of a periodic calibration and the start of the next refueling operation. The development of procedures for and the selection of functional testing and periodic calibration intervals should be consistent with that for other augmented quality instrumentation in the plant licensing basis.

1.9 Display: Trained personnel shall be able to monitor the spent fuel pool water level from the control room, alternate shutdown panel, or other appropriate and accessible location. The display shall provide on-demand or continuous indication of spent fuel pool water level.

Accessible locations are those areas physically remote from the spent fuel pool and protected from natural phenomena. Locations in or near the control room or the technical support center are preferred based on proximity to accident management decision-makers, however, locations in addition to these may be used, provided that the level instrumentation is capable of driving multiple displays.

2. Spent Fuel Pool Instrumentation Program Guidelines

The spent fuel pool instrumentation shall be maintained available and reliable through appropriate development and implementation of the following programs:

2.1 Training: Personnel shall be trained in the use and the provision of alternate power to the primary and backup instrument channels.

Classes of personnel appropriate for this function shall be designated consistent with the emergency response staffing plan. The designated personnel shall be trained in the maintenance of the entire instrument channel, including the power supplies and operation of both the primary and backup instruments used to determine spent fuel pool level.

2.2 Procedures: Procedures shall be established and maintained for the testing, calibration, and use of the primary and backup spent fuel pool instrument channels.

Written procedures for use of the instrument channels shall be developed to be consistent with procedures governing strategies to maintain or restore spent fuel pool cooling capability.

Written procedures for testing and calibration shall be developed to ensure the instrument channel retains its design accuracy over the interval between successive calibrations. Procedures shall identify appropriate corrective actions when instruments cannot be calibrated or fail to satisfy test acceptance criteria.

2.3 Testing and Calibration: Processes shall be established and maintained for scheduling and implementing necessary testing and calibration of the primary and backup spent fuel pool level instrument channels to maintain the instrument channels at the design accuracy.

The process for scheduling testing and calibration of the instrument channels should ensure reliability and availability of the instrument by specifying calibration at necessary intervals to maintain the design accuracy of the instrument, and the performance of such regularly scheduled testing and calibration should be consistent with that performed for other augmented quality instrumentation in the plant.

Testing and calibration failures should be addressed through the corrective action program associated with the quality assurance program for the spent fuel pool level instruments. The priority for resolution of degraded or non-conforming conditions shall be consistent with the overall degradation of the instrument function.

Attachments

References