UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

October 13, 2011

The Honorable Gregory B. Jaczko
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: INITIAL ACRS REVIEW OF: (1) THE NRC NEAR-TERM TASK FORCE REPORT ON FUKUSHIMA AND (2) STAFF'S RECOMMENDED ACTIONS TO BE TAKEN WITHOUT DELAY

Dear Chairman Jaczko:

During the 587th meeting of the Advisory Committee on Reactor Safeguards (ACRS), October 6-8, 2011, we continued our review of the NRC Near-Term Task Force (NTTF) Report on the Fukushima event [1], "Recommendations for Enhancing Reactor Safety in the 21st Century," along with the staff's recommended actions to be taken without delay from the NTTF Report [2], and the staff's report on prioritization of the NTTF recommendations [3]. We were also briefed on the NTTF Report during our 586th meeting, September 8-10, 2011. We also reviewed information related to the Fukushima event on April 7, May 26, June 23, July 12, and August 16, 2011. During these reviews, we had the benefit of discussions with representatives of the NRC staff, the Nuclear Energy Institute (NEI), the Institute for Nuclear Power Operations (INPO), the Department of Energy (DOE), and members of the public. We also had the benefit of the documents referenced.

While complete understanding of the Fukushima Dai-ichi accident will take many years, the NTTF Report and the staff's recommended actions to be taken without delay are appropriately focused on lessons learned from what is currently known. We believe that none of the recommendations enumerated herein will be negated, or rendered inappropriate, by the acquisition of new information. Hence, timely initiation of the staff's recommended actions to be taken without delay, along with corresponding additions or modifications included herein, is appropriate.

CONCLUSIONS AND RECOMMENDATIONS

1. The staff's report [2] on recommended actions to be taken without delay from the NTTF Report identifies immediate actions to be taken. The following additional immediate actions are recommended:

a. Actions related to NTTF Recommendation 2.1 should be expanded to include an expedited update of the applicable regulatory guidance, methods, and data for external flooding to ensure that outdated guidance and acceptance criteria are not used in the reevaluations.

b. Actions related to NTTF Recommendation 2.3 should be expanded to assure that the walkdowns address the integrated effects of severe storms as well as seismic and flooding events.

c. Actions related to NTTF Recommendation 4.1 should be expanded to include issuance of an advanced notice of proposed rulemaking and requiring licensees to provide an assessment of capabilities to cope with an extended station blackout (SBO).

d. Actions related to NTTF Recommendation 5.1 should also be applied to boiling water reactor (BWR) plants with Mark II containments.

e. Discussions with stakeholders should be initiated regarding near-term actions for additional hydrogen control and mitigation measures in reactor buildings for plants with Mark I and Mark II containments.

f. Information should be requested from licensees regarding current plant-specific spent fuel pool instrumentation, power supplies, and sources of makeup and cooling water.

g. Actions related to NTTF Recommendation 8 should be expanded to include fire response procedures.

2. The NTTF Report [1] provides detailed near-term and long-term recommendations for enhancing nuclear reactor safety based on initial lessons learned from the Fukushima event. The following additional actions are recommended:

a. Performance-based criteria to mitigate and manage an extended SBO should be considered as an alternative to the specific coping times proposed in Recommendation 4.1.

b. Recommendation 6 should be expanded to include a requirement for BWR plants with Mark I and Mark II containments to implement combustible gas control measures in reactor buildings as a near-term defense-in-depth measure.

c. Recommendation 6 should be expanded to include an assessment of the vulnerabilities introduced by shared ventilation systems or shared stacks in multi-unit sites.

d. Integration of onsite emergency response capabilities envisioned by Recommendation 8 should be expanded to include fire response procedures.

e. Selected reactor and containment instrumentation should be enhanced to withstand beyond-design-basis accident conditions.

f. The NRC should proactively engage in efforts to define and participate in programs to capture and analyze data from the Fukushima event to enhance understanding of severe accident phenomena, including BWR melt progression, seawater addition effects, hydrogen transport and combustion, and safety systems operability.

3. Licensing actions requiring the granting of containment accident pressure (CAP) credit should be suspended until the implications of post-Fukushima containment pressure control measures are understood.

BACKGROUND

The Great East Japan Earthquake of 2011 caused massive destruction and tragic loss of lives in Japan. We join the world community in expressing our condolences to those who have been affected by this disaster. We also recognize the heroic efforts of the staff of the Fukushima Dai-ichi Nuclear Power Plant, who have worked tirelessly to stabilize the damaged units.

The NTTF was established in response to the NRC Chairman's tasking memorandum of March 23, 2011 [4]. The NTTF Report [1] was published on July 12, 2011. The SRM to SECY-11-0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," dated August 19, 2011 [5], directed the staff to: (1) within 21 days of its issuance, identify and make recommendations regarding NTTF recommendations that can, and in the staff's judgment, should be implemented, in part or in whole, without unnecessary delay and (2) by October 3, 2011, provide a prioritization of the NTTF recommendations reflecting all regulatory actions to be taken by the staff in response to the Fukushima lessons learned identifying implementation challenges, including the technical and regulatory basis for the prioritization; identifying any additional recommendations; and including a schedule and milestones for appropriate stakeholder engagement and involvement of the ACRS.

The SRM to SECY-11-0093 directed the ACRS to "formally review all Task Force recommendations and the staff's evaluation and recommended prioritization of the Task Force recommendations, and document its review in letter reports to the Commission." To that end, the objectives of this report are: (1) to identify additional recommendations beyond those recommended by the NTTF [1] and (2) to identify additional immediate actions to be taken without delay beyond those identified in the staff's September 9, 2011, report [2]. Consistent with the Commission's instructions, we did not address the first NTTF recommendation regarding the overall regulatory framework. Our review addressed the appropriateness of the regulatory "vehicles" (orders, rulemakings, 10 CFR 50.54(f) requests, etc.) by which the staff intends to implement the immediate actions specified in the September 9, 2011, report [2], rather than those specified by the NTTF for the entire set of recommendations.

Our review of the staff's report on prioritization of all NTTF recommendations [3], including appropriateness of the regulatory vehicles by which the staff intends to implement such recommendations, will be documented in a future letter report prior to the due date of December 3, 2011, established by the Commission. Additional ACRS reports will be provided as we engage with the staff in the formulation of action plans to address each of the NTTF recommendations.

We were briefed by the NRC staff on April 7, 2011, to provide an early overview of the event from the perspective of staff who had served as part of the NRC emergency response in the operations center. On May 26, 2011, we heard perspectives on Fukushima from both DOE and NEI. On June 23, 2011, the NRC Deputy Executive Director for Reactor and Preparedness Programs provided the status of the NTTF activities at that time. On July 12, 2011, INPO provided their perspectives and action plans for our consideration. Following publication of the Task Force Report, we held initial discussions on the report findings on July 15, 2011. Representatives of the NTTF briefed our Fukushima Subcommittee on August 16, 2011, and the Full Committee on September 8, 2011. On October 7, 2011, the staff briefed us on their October 3, 2011, response to the Commission regarding prioritization of the NTTF recommendations (SECY-11-0137).

DISCUSSION

Our reviews of the NTTF recommendations [1] and the staff's list of actions to be implemented without delay [2] have focused on "completeness," i.e., whether additional recommendations should be included, and "appropriateness," i.e., whether the recommendations included in the reports should be modified. Based on these reviews, several findings of both categories within both reports have been noted. These are discussed below.

Protection from External Events

An important reminder from the Fukushima event is that site-specific external hazards, vulnerabilities, and consequences need to be evaluated in an integrated context. For example, tornadoes and hurricanes may cause extended loss of offsite power with coincident physical damage to non-safety structures or equipment at multiple units that has not been fully evaluated. Damage from severe storms or other site-specific hazards may also disable external essential cooling water supplies. Vulnerabilities to those hazards and subsequent damage may not be identified from assessments that focus only on design-basis seismic and flooding events.

The NTTF recommendations and the staff's recommended immediate actions focus on reevaluations and walkdowns that address only seismic and flooding hazards. The NTTF Report states that "In evaluating protection from design-basis natural phenomena, the Task Force considered earthquakes, floods, high winds (due to hurricanes or tornadoes), and external fires. The Task Force concluded that earthquakes and flooding hazards warranted further Task Force consideration due, in part, to significant advancements in the state of knowledge and the state of analysis in these areas in the time period since the operating plants were sited and licensed."

Near-term actions related to NTTF Recommendation 2.3 should be expanded to assure that the walkdowns address the integrated effects of severe storms as well as seismic and flooding events. The walkdowns and associated assessments should confirm that the identified hazards and vulnerabilities remain bounded by the current plant licensing basis.

The staff's recommended actions to be taken without delay regarding NTTF Recommendation 2.1 include initiation of "stakeholder interaction to discuss application of the **present-day regulatory guidance and methodologies**" [emphasis added]. The guidance for external flooding (Regulatory Guide 1.59 Revision 2) has not been revised since the late 1970s. The revision of the regulatory guide for external flooding is currently underway. Therefore, the staff's recommendations for near-term actions should explicitly include an expedited update of applicable regulatory guidance, methods, and data for external flooding to ensure that outdated guidance and acceptance criteria are not used for the current reevaluations.

Mitigation of Extended Station Blackout Events

In its essence, the Fukushima event was an extended SBO event caused by natural forces beyond the plant's design basis. The event resulted in a prolonged loss of AC power from the normal offsite and emergency onsite sources, along with loss of vital AC distribution systems within the plant. It appears that selection of the design-basis tsunami at Fukushima may not have been adequate as judged by accepted practice in the U.S. Nevertheless, consistent with a defense-in-depth philosophy, it is prudent for nuclear power plants to demonstrate that adequate cooling of the core and spent fuel pools, and integrity of the reactor coolant system (RCS) and the containment can be maintained during SBO for a range of external events that go beyond those considered in the design basis.

Current U.S. NRC requirements (10 CFR 50.63) provide assurance that adequate core cooling and containment integrity are maintained for a site-specific coping period following an SBO. Current guidance for SBO coping times focuses on the impact of severe weather (snowfall, tornadoes, hurricanes, etc.). However, it does not explicitly require consideration of seismic events and external flooding. The Fukushima event has demonstrated the need to expand the functional requirements to include cooling of the spent fuel pools and maintaining RCS integrity, and the need to assure that all functions are maintained for an extended period, well beyond the current SBO coping period for operating plants (typically 4 or 8 hours).

NTTF Recommendation 4.1 states that rulemaking should be initiated to revise 10 CFR 50.63 to require each operating and new reactor licensee to: *"(1) establish a minimum coping time of 8 hours for a total loss of AC power; (2) establish the equipment, procedures, and training necessary to implement an 'extended loss of all AC coping time of 72 hours for core and spent fuel pool cooling and for reactor coolant system and containment integrity as needed; and (3) preplan and pre-stage offsite resources to support uninterrupted core and spent fuel pool cooling, and reactor coolant system and containment integrity as needed, including the ability to deliver the equipment to the site in the time period allowed for extended coping under conditions involving significant degradation of offsite transportation infrastructure associated with significant natural disasters."*

There is general agreement that rulemaking should be initiated to strengthen SBO mitigation capability at all operating and new reactors for design-basis and beyond-design-basis external events by extending the coping period and expanding the functional requirements to include cooling of the spent fuel pools and maintaining RCS integrity. At issue, however, is whether this objective can be best achieved through requirement of specific coping times for each stage of the event (8 hours, 72 hours, and beyond), or through a performance-based rule that accounts for site-specific considerations.

The bases for the 8-hour and 72-hour periods are not specified in the NTTF Report. The ability to deliver offsite support during an emergency, and the timeliness of such delivery, will be highly site-specific, inasmuch as they depend on regional features and resources, as well as the nature of the emergency and its impact on the surrounding infrastructure. Clearly, considerable discussion between the staff and stakeholders, including the ACRS, is needed to determine the best approach to be taken in developing an effective rule.

The staff's recommended actions to be taken without delay [2] regarding NTTF Recommendation 4.1 should be expanded to include issuance of an advanced notice of proposed rulemaking. Staff should also require licensees to provide an assessment of capabilities to cope with an extended SBO, including system vulnerabilities (e.g., reactor coolant pump seal qualifications) and capabilities to mobilize and deliver offsite resources (e.g., portable generators, fuel supplies, water pumping equipment). This information will inform staff interactions with the industry during the rulemaking process and help develop guidance that can be applied in the near term for enhanced confidence that each site has identified their available options.

Containment Overpressure Protection

Available plant data indicate that the primary containment pressures in Fukushima Dai-ichi Units 1, 2, and 3 substantially exceeded the design pressure for the containments. Although these plants had hardened wetwell vents, operators had great difficulty in trying to use the venting systems to reduce pressure in the containments. All U.S. BWRs with Mark I containments and three of the eight U.S. BWRs with Mark II containments have installed hardened vents [1]. Current NRC regulations do not require hardened vents or specify their functional capabilities. Installation of the vents was done on a voluntary basis under the provisions of 10 CFR 50.59 subsequent to staff's issuance of Generic Letter 89-16, "Installation of a Hardened Wetwell Vent," on September 1, 1989. The designs of these vents vary from plant to plant, and many are dependent on AC power. The Fukushima event has demonstrated the need for reliable hardened vents with valves that can be readily accessed and operated under extended SBO conditions.

NTTF Recommendation 5.1 states that licensees should be ordered to include a reliable hardened vent in BWR Mark I and Mark II containments. However, the staff's recommended actions to be taken without delay regarding NTTF Recommendation 5.1 are limited only to licensees with BWR Mark I containments. As noted in the NTTF Report, *"because Mark II containment designs are only slightly larger in volume than Mark I containment designs, it can reasonably be concluded that a Mark II under similar circumstances would have suffered similar consequences."* We concur. Therefore, we recommend that the staff's recommended actions to be taken without delay regarding NTTF Recommendation 5.1 also be applied to BWR Mark II containments.

The events at Fukushima demonstrated the difficulties encountered by operators in controlling containment pressure during a severe accident. Post-Fukushima actions will, in all likelihood, impact the manner, timing, and procedural guidance for containment pressure control (e.g., venting) during an accident. These actions may affect the transient containment pressure history during an accident, and therefore affect the available net positive suction head for the emergency core cooling pumps. Therefore, it would be prudent for the agency to suspend the granting of CAP credit in licensing actions until the implications of such measures are understood.

Combustible Gas Control

10 CFR 50.44, "Combustible Gas Control for Nuclear Power Reactors," requires BWRs with Mark I and Mark II containments to have an inerted atmosphere. BWRs with Mark III containments and PWRs with ice condenser containments must be able to control combustible gas generated from a metal-water reaction involving 75% of the fuel cladding surrounding the active fuel region so that there is no loss of containment integrity. This is accomplished through the use of hydrogen igniters to control the buildup of hydrogen.

When 10 CFR 50.44 was promulgated, it was thought that inerting the containment atmosphere in BWRs with Mark I and Mark II containments was sufficient to eliminate any concerns regarding combustible gas control. The events at Fukushima Dai-ichi have shown this to be incorrect. Units 1, 3, and 4 experienced explosions causing severe damage to the reactor buildings for those units. The NTTF and the staff have elected to wait to find out more details on how the hydrogen was released into the reactor building before recommending specific actions for additional or immediate combustible gas control measures in BWRs with Mark I and Mark II containments. However, we believe that there are enough possible mechanisms for hydrogen release to the building to raise concerns regarding this issue for all aging BWRs with Mark I and Mark II containments, and that the issue is not merely a peculiarity of the Fukushima reactors. Speculations on possible paths for hydrogen release into the reactor buildings at the Fukushima plant include degradation of drywell head seals, leakage through damaged valves and couplings in vent lines, and damage to downcomers venting into the suppression pools.

The Fukushima accident clearly demonstrates that hydrogen combustion events can cause significant structural damage. Such damage can also cause debris to fall into the spent fuel pools with subsequent potential ramifications not heretofore considered. NTTF Recommendation 6 defers action on combustible gas control until additional information becomes available through further study of the Fukushima Dai-ichi accident and longer term reviews are completed. As a defense-in-depth measure, NTTF Recommendation 6 should be expanded to include a requirement for BWR plants with Mark I and Mark II containments to implement combustible gas control measures in the reactor buildings functionally akin to those provided in the Mark III reactor buildings. This might include passive hydrogen recombiners or getters. Additionally, the staff's recommended actions to be taken without delay should be expanded to include initiation of discussions with stakeholders regarding near-term actions for additional hydrogen control and mitigation measures in plants with Mark I and Mark II containments consistent with the above recommendation.

Another aspect of combustible gas control demonstrated by the observed hydrogen explosion in the defueled Unit 4 of the Fukushima Dai-ichi plant is the potential vulnerabilities introduced by shared stacks in multi-unit sites. There is evidence [6, 7] that suggests that the observed explosion in Unit 4 was caused by hydrogen transport from Unit 3 through exhaust systems connected to a common stack. Staff should engage licensees of multi-unit sites with shared stacks, ventilation systems, or pathways to collect information on the design of such systems to aid in the long-term evaluation of hydrogen control and mitigation measures.

Emergency Response Capabilities

The Fukushima event highlights the importance of having plant operators who are well prepared and well supported by technically sound and practical procedures, guidelines, and strategies. The NTTF has clearly articulated the need to strengthen and integrate the onsite emergency response capabilities. The discussion in the NTTF Report appropriately focuses on the need to clarify the transition points, command and control, decision making, and training requirements for the various emergency response capabilities.

NTTF Recommendation 8 and the corresponding staff recommended actions to be taken without delay include integration of the Emergency Operating Procedures (EOPs), the Severe Accident Management Guidelines (SAMGs), and the Extensive Damage Mitigation Guidelines (EDMGs). In our view, these efforts to integrate the onsite emergency response capabilities should be expanded to include the plant fire response procedures. These procedures provide operator guidance for coping with fires that are beyond a plant's original design basis. Some plant-specific fire response procedures instruct operators to manually de-energize major electrical buses and realign fluid systems in configurations that may not be consistent with the guidance or expectations in the EOPs. Experience from actual fire events has shown that parallel execution of fire procedures, Abnormal Operating Procedures (AOPs), and EOPs can be difficult and can introduce operational complexity. Therefore, these procedures should also be included in the comprehensive efforts to better coordinate and integrate operator responses during challenging plant conditions.

Enhancement and integration of the various onsite emergency response capabilities (EOPs, SAMGs, EDMGs, and fire response procedures) and the development of command and control and decision-making structures (as identified in NTTF Recommendations 8 and 10.2) will be a complex effort requiring substantial interactions among licensees' operations, engineering and management personnel; industry Owners Groups; vendor experts; and regulators. Use and integration of the guidance will also require extensive testing. This work should begin immediately, but should be viewed as a long-term endeavor.

Reactor and Containment Instrumentation

Immediately after the tsunami flooded the Fukushima Dai-ichi plant, key instrumentation for the reactor vessel, drywell, and wetwell were unavailable for Units 1 and 2 due to loss of AC and DC power sources; the instruments at Unit 3 lost power nearly 30 hours later [6]. When power was restored, the validity of data from available sensors was questionable. Pressure transients

and seawater addition adversely affected water level accuracy. Thermocouples attached on exterior vessel surfaces were exposed to temperatures above their operating range. Subsequent evaluations indicate that some pressure gauges gave erroneous readings. The Japanese government has included the need for enhanced reactor and containment instrumentation in their list of key actions that will be implemented in response to the accident at Fukushima [6].

As noted in Section 4.2 of the NTTF Report, the Fukushima Dai-ichi operators faced significant challenges in understanding the condition of the reactors, containments, and spent fuel pools because instrumentation was either lacking or giving erroneous readings. However, the recommendations for enhancement of instrumentation in the NTTF Report are limited to sensors monitoring the spent fuel pools. In our view, identification and development of enhanced reactor and containment instrumentation should be included in the list of recommendations for long-term review. Robust and diverse instrumentation that can withstand anticipated accident conditions should be available to provide information needed to diagnose, select, and implement accident mitigation strategies and monitor their effectiveness.

Similar observations were made regarding the adequacy and availability of instrumentation after the Three Mile Island, Unit 2, (TMI-2) event. In the 1990s, research sponsored by the NRC [8-10] demonstrated that it is possible to address this issue by implementing a systematic methodology that includes tasks to identify the required plant information, the location and operating range of sensors currently available to provide such information, and the environmental conditions that such sensors must withstand during risk-dominant accident sequences. A similar process can guide implementation of the above recommendation for enhanced reactor and containment instrumentation.

Spent Fuel Pool Enhancements

The integrity of spent fuel pools and the possibilities of radionuclide releases from fuel stored in these pools were the subjects of much speculation in the immediate aftermath of the events at the Fukushima site. Concerns over the integrity of the spent fuel pool could not be relieved because there was no definitive evidence to show adequate coolant levels were being maintained. It emerged, however, that the integrity of the pools had not been compromised by the accident events. Although the pools contained large quantities of water capable of cooling the spent fuel for several days, maintenance of coolant levels by *ad hoc* measures became essential as the station blackout continued. These coolant inventory maintenance activities would have been facilitated by reliable, direct, measures of water level and temperature in the spent fuel pool.

On the other hand, in at least one Fukushima unit, a hydrogen explosion cast large amounts of debris into the spent fuel pool. This debris may have caused some damage to the stored fuel though it did not compromise cooling of the fuel. Leaching of the debris may change the water chemistry in the pools so that aluminum fuel racks may corrode, which could eventually degrade their integrity.

These events at Fukushima have reminded us that spent fuel pools at nuclear power plants can be contributors to the overall risk posed by the plants. The vulnerabilities of spent fuel pools under accident conditions and the need for measures to assure adequate coolant levels are design specific.

The staff's recommended actions to be taken without delay [2] do not address any of the spent fuel pool makeup capability and instrumentation enhancements specified in NTTF Recommendation 7. Staff should initiate a request for information for licensees to document details such as their current plant-specific spent fuel pool instrumentation, sources of spent fuel pool makeup and cooling, power supplies, contingencies and procedures for alternate makeup sources, etc. This information would better inform subsequent staff efforts and would help focus industry communications with respect to these issues. As steps are taken to assure coolant availability to the reactor core, the need to assure reliable spent fuel pool cooling and instrumentation should also be considered.

Collection of Data from Fukushima

The events at Fukushima, particularly Dai-ichi Units 1 through 3, provide a rare opportunity to glean critical data related to severe accident progression and mitigation. It is essential that data from these plants be obtained and evaluated. Full understanding of what occurred during these events can inform whether additional measures should be implemented to ensure that the U.S. fleet continues to operate safely. The NTTF Report acknowledges the need for the staff to "maintain awareness and develop further insights" during the long-term follow up of the Fukushima event. The NRC should proactively engage in efforts to define and participate in programs to capture and analyze data from the Fukushima event to enhance understanding of severe accident phenomena, including BWR melt progression, seawater addition effects, hydrogen transport and combustion, and safety systems operability. Staff should ensure that adequate resources are allocated to support these efforts.

As noted earlier, this report does not address the staff's prioritization of the NTTF recommendations [3]. Our review of such prioritization will be completed prior to the due date of December 3, 2011, established by the Commission. Nevertheless, we note that prioritization of actions in response to all NTTF recommendations, as well as subsequent additional recommendations, should be made with the recognition that the required response will vary widely and will be site specific. The benefits to be derived from many of the recommended actions will be highly plant specific. The plans should anticipate that site-specific considerations may mandate modification to projected schedules.

We look forward to working with the staff on these important matters in the coming months and years. As always, we stand ready to support the Commission and welcome any specific Commission tasking on any aspects of this review.

Sincerely,

/RA/

Said Abdel-Khalik
Chairman

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