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

September 19, 2011

Mr. R. W. Borchardt
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: DRAFT FINAL REGULATORY GUIDE 1.115, REVISION 2, "PROTECTION AGAINST TURBINE MISSILES"

Dear Mr. Borchardt:

During the 586th meeting of the Advisory Committee on Reactor Safeguards, September 8-10, 2011, we completed our review of draft final Regulatory Guide (RG) 1.115, Revision 2, "Protection against Turbine Missiles." Our Regulatory Policies and Practices Subcommittee also reviewed an earlier version of this draft RG during its meeting on October 4, 2010. During these reviews, we had the benefit of discussions with representatives of the NRC staff. We also had the benefit of the documents referenced.

RECOMMENDATIONS

1. Revision 2 of RG 1.115 should be issued after adequate justification is provided for excluding an evaluation of high-trajectory missiles under Regulatory Position 2.b.

2. The staff should supplement its review of domestic nuclear operating experience by including operating experience at large U.S. conventional power plants and international nuclear facilities for the last ~20 years to confirm that the nominal frequency of 1×10^{-4} turbine missile ejection event per year from all causes is justified. This review should not delay the issuance of RG 1.115, Revision 2. A substantial update to RG 1.115 would be necessary if the expanded operating experience does not support the nominal turbine missile frequency.

BACKGROUND

Regulatory Guide 1.115, "Protection against Low-Trajectory Turbine Missiles," Revision 1, was issued in July 1977. In July 1986, the NRC revised its guidance on turbine missiles in Appendix U to NUREG-1048, "Safety Evaluation Report Related to the Operation of Hope Creek Generating Station." The guidance in NUREG-1048 has since been used by the industry in generic and plant-specific applications related to turbine missiles and by the NRC staff in its safety evaluations of those applications.

Key elements of Revision 2 to RG 1.115 include:

- Consolidation of NRC guidance on turbine missiles into one document.
- Expansion of the guidance to include high-trajectory missiles.
- Clarification of the analysis scope to include all structures, systems, and components (SSCs) that are important to safety, rather than only designated safety-related SSCs.
- Clarification of the scope to include the effects from other units at multi-unit sites.
- Inclusion of the option for a risk-informed evaluation of turbine missile damage.

The guidance in RG 1.115 states that an acceptable level of risk is achieved if the frequency of turbine missile damage to SSCs that are important to safety is less than 1×10^{-7} event per year. The damage frequency is quantified according to the following general formula.

$$P_4 = P_1 \times P_2 \times P_3$$

Where

P_4 = Frequency of turbine missile damage to an essential SSC (event per year)
P_1 = Frequency of turbine missile ejection (event per year)
P_2 = Conditional probability that the missile will strike an essential SSC (strike per event)
P_3 = Conditional probability that the SSC will be damaged by the missile (damage per strike)

For favorably oriented turbines, the staff endorses the use of a generic conditional probability of damage ($P_2 \times P_3$) of 1×10^{-3}. For unfavorably oriented turbines, the endorsed conditional probability of damage is increased to 1×10^{-2}. This formulation provides the rationale for evaluating an acceptable level of turbine missile risk that is derived primarily from the frequency of turbine missile ejection events, P_1. For favorably oriented turbines, an acceptable missile ejection frequency is less than 1×10^{-4} event per year; for unfavorably oriented turbines, an acceptable frequency is less than 1×10^{-5} event per year.

DISCUSSION

Regulatory Position 2.b in RG 1.115, Revision 2, states that the frequency of low-trajectory missiles should be limited to less than 1×10^{-5} event per year for an unfavorably oriented turbine. It also states that an evaluation of the frequency of high-trajectory missiles is not needed because "the turbine missile generation frequency for low-trajectory missiles is bounding." It is not evident why the frequency of turbine missiles that are ejected on high trajectories is necessarily bounded by the frequency of missiles that are ejected on low trajectories. The potential strike areas and damage footprints from high trajectory missiles and low trajectory missiles differ substantially. The guidance should better explain and justify why an evaluation of the frequency of high-trajectory missiles is not needed for unfavorably oriented turbines.

Regulatory Position 2.c in RG 1.115, Revision 2, states that an acceptable option for demonstrating adequate protection against low-trajectory and high-trajectory turbine missiles for unfavorably oriented turbines may include a more detailed evaluation of the conditional probability of essential SSC damage, $P_2 \times P_3$. That evaluation should show that the frequency of turbine missile ejection (P_1) is less than 1×10^{-4} event per year, and the total frequency of essential SSC damage ($P_1 \times P_2 \times P_3$) is less than 1×10^{-7} event per year. In effect, this new guidance allows relaxation of the acceptable turbine missile frequency for unfavorably oriented turbines by a factor of 10, supported by a more detailed evaluation of the conditional SSC damage probability. In the absence of a fully integrated risk-informed evaluation of P_1, P_2, and P_3, we concur that these combined acceptance criteria maintain adequate assurance of defense in depth against essential SSC damage by catastrophic turbine failures.

The summary criteria in RG 1.115, Revision 2, Table 1, indicate that an evaluation of the frequency of low-trajectory missiles is not required if the turbine is oriented favorably. This exclusion is based on the staff's conclusion that the generic conditional probability of damage ($P_2 \times P_3$) is on the order of 1×10^{-3} for favorably oriented turbines, and historical evidence that the overall turbine missile ejection frequency (P_1) is generally less than 1×10^{-4} event per year. This generic value is based on very limited data. It was derived from a 1973 compilation of failure data from nuclear and conventional power plant turbines and was originally cited as a basis for the analyses in NUREG-1048. The initial data have been supplemented by the 1995 summary of operating experience in NUREG-1275, “Operating Experience Feedback Report-Turbine-Generator Overspeed Protection Systems,” Volume 11, April 1995, which includes the 1991 Salem turbine overspeed event. Data after 1995 are from Licensee Event Reports (LERs) and other nuclear event reports. The staff concludes that these data support the assertion that the generic frequency of turbine missile ejection events remains less than 1×10^{-4} event per year.

We did not review the data or the analyses that were performed to derive the 1973 turbine missile frequency estimate. However, after publication of NUREG-1048, supplemental data to support the estimated frequency have been derived primarily from U.S. nuclear power plant operating experience. The discussion in RG 1.115, Revision 2, acknowledges this limitation and notes that:

> The staff’s review of the operating experience is limited to the turbines at nuclear power plants because it is unlikely that non-nuclear plants, that are not required to meet NRC regulations, have the same level of uniformity in operating practices, maintenance, testing, and inspections as have been implemented at nuclear plants after the Salem 2 event.

The U.S. nuclear power plant fleet currently contains 104 operating units. Each unit typically has two or three low pressure turbines, depending on the plant power rating and turbine design. Thus, the U.S. nuclear power plant fleet accumulates approximately 200 to 300 turbine-years of operating experience each calendar year. At that rate, approximately 35 to 50 calendar years are required to accumulate 10,000 turbine-years of operating experience.

Protection against catastrophic turbine failures is a vital safety and investment consideration for every nuclear and conventional power plant. Therefore, the turbine operating experience from a broader spectrum of nuclear and conventional power plants should provide relevant data to support the assertion that the generic frequency of turbine missiles is less than 1×10^{-4} event per year. An expanded data sample may also capture operating experience from advanced turbine control systems, protection systems, and valve designs which may not be installed at currently operating U.S. nuclear plants, but may be installed in new reactors. The staff should include data from the most recent 20 years of operating experience from international nuclear power plants and large U.S. conventional power plants to confirm that the nominal frequency of 1×10^{-4} turbine missile ejection event per year from all causes remains justified.

Sincerely,

/RA/

Said Abdel-Khalik
Chairman

REFERENCES

1. Draft Final Regulatory Guide 1.115, "Protection against Turbine Missiles," Revision 2, September 2010 (ML101650671).

2. Draft Final Regulatory Guide 1.115, "Protection against Turbine Missiles," Revision 2, June 2011 (ML101650671)

3. NRC Responses to Public Comments on DG-1217 (Draft RG 1.115 Rev. 2) (ML092250316 and ML103350136).

4. NUREG-1048, “Safety Evaluation Report Related to the Operation of Hope Creek Generating Station,” U.S. Nuclear Regulatory Commission, Washington, DC, October 1984 (ML091310373)

5. NUREG-1048, “Safety Evaluation Report Related to the Operation of Hope Creek Generating Station,” Supplement 5, U.S. Nuclear Regulatory Commission, Washington, DC, April 1986 (ML091310370)

6. NUREG-1275, “Operating Experience Feedback Report-Turbine-Generator Overspeed Protection Systems,” Volume 11, U.S. Nuclear Regulatory Commission, Washington, DC, April 1995, (ML063560418)

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7. Draft final Regulatory Guide 1.115, "Protection against Turbine Missiles," Revision 2, September 2010 (ML101650671).

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12. NUREG-1275, “Operating Experience Feedback Report-Turbine-Generator Overspeed Protection Systems,” Volume 11, U.S. Nuclear Regulatory Commission, Washington, DC, April 1995, (ML063560418)

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Letter to R.W. Borchardt, EDO, from Said Abdel-Khalik, ACRS Chairman, dated September 19, 2011

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