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

May 19, 2010

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

SUBJECT: DRAFT GUIDANCE ON CREDITING CONTAINMENT ACCIDENT PRESSURE IN MEETING THE NET POSITIVE SUCTION HEAD REQUIRED TO DEMONSTRATE THAT SAFETY SYSTEMS CAN MITIGATE ACCIDENTS AS DESIGNED

Dear Mr. Borchardt:

In a January 8, 2009, Staff Requirements Memorandum, the Commission directed the staff, in part, to continue working to resolve the differences of opinion between the Advisory Committee on Reactor Safeguards and the staff on the containment accident pressure (CAP) credit issue. At the April 23, 2010, meeting of our Subcommittee on Power Uprates and our 572nd meeting on May 6-8, 2010, we discussed the draft guidance the staff is developing to determine the acceptability of CAP credit for extended power uprates (EPUs) and other applications. The Subcommittee also discussed the Boiling Water Reactor Owners Group (BWROG), Licensing Topical Report NEDC-33347P, "Containment Overpressure Credit for Net Positive Suction Head (NPSH)," that is intended to provide a more standardized and predictable approach for use by applicants to request credit for CAP in computing available NPSH. In addition to the discussions with NRC staff and industry representatives, we also had the benefit of the documents referenced.

CONCLUSIONS AND RECOMMENDATIONS

1. We agree with the staff that, before considering analyses to justify credit for containment accident pressure to maintain available NPSH for emergency core cooling system (ECCS) and containment heat removal pumps, licensees must first demonstrate that it is impractical to make plant modifications that eliminate this need. However, we disagree with the staff's position that a generic waiver of this requirement is appropriate for BWRs with Mark I containments. Any waiver should be evaluated on a plant-specific basis.

2. The draft guidance developed by the staff provides an improved framework for a more comprehensive assessment of the acceptability of crediting containment accident pressure in meeting NPSH requirements. However, the guidance is primarily focused on the deterministic analysis of licensing-basis events. These analyses should be complemented by plant-specific Probabilistic Risk Assessment (PRA) analyses of the impact of CAP credit.

3. We support the staff's reassessment of the potential problems associated with the operation of pumps with available NPSH near or below the required NPSH for the pump.

4. For calculations involving design basis loss-of-coolant accidents (LOCAs), we agree with the position of the BWROG that statistical calculations should be performed to better understand margins and more accurately characterize the potential for pump damage. In most cases, the licensing decision should be based on the conservative, deterministic calculation of available NPSH. In all cases, the comparison of available NPSH with required NPSH should include consideration of the uncertainty in the required NPSH as proposed by the staff in the draft guidance.

5. If no CAP credit is needed for the special events licensing-basis analyses, and the 95/95 lower tolerance bound for LOCAs calculated using an acceptable methodology shows that no CAP credit is needed, then the CAP credit can be deemed small enough that it is acceptable without the need for hardware modifications or additional risk studies.

6. The PRA studies by the staff are helpful in assessing the importance of pre-initiator and post-initiator leak probability and leakage test interval on the changes in risk associated with CAP credit. The seismic studies provide useful order-of-magnitude estimates. Seismic events, fires, and operator actions are potentially significant risk contributors. It is not possible to adequately assess these risks except on a plant-specific basis.

BACKGROUND

For most U.S. nuclear plants, NPSH for ECCS pumps in licensing-basis analyses is calculated assuming that the pressure in containment is atmospheric. In reality, accidents such as a LOCA would lead to an increase in the containment pressure. The assumption of atmospheric pressure in the containment assures that in design-basis accidents, the loss, for any reason, of the capability of the containment to maintain pressure would not affect the ability of the ECCS to maintain core cooling. This assumption maintains the defense-in-depth philosophy for accident prevention and mitigation and the independence of barriers. In addition, in most operating plants, all of the pressure generated during an accident is part of the safety margin against loss of NPSH in the ECCS pumps.

The inclusion of the pressure developed in the containment during an accident in the calculation of the available NPSH is referred to as CAP credit. We have consistently expressed concern with the use of this margin for voluntary licensing actions because it represents a decrease in the safety margin available to deal with a phenomenon that is subject to large uncertainties, namely, maintenance of adequate NPSH for ECCS pumps during accidents. Such margin protects against unanticipated accident phenomena, such as sump strainer blockage or an inadvertent loss of containment isolation. In some requests for CAP credit, operator actions are required to establish or maintain elevated containment pressure in order to attain adequate pump NPSH. Of particular concern are actions that stop or reduce operation of systems whose normal design function is to remove heat from the reactor core or containment.

The staff has also recognized that use of CAP credit compromises the independence of barriers. The first Regulatory Guide published in 1970 as Safety Guide 1.1 addressed this issue and stated:

> *It is important that the proper performance of emergency core cooling and containment heat removal systems be independent of calculated increases in containment pressure*

> *caused by postulated loss of coolant accidents in order to assure reliable operation under a variety of possible accident conditions. For example, if proper operation of the emergency core cooling system depends upon maintaining the containment pressure above a specified minimum amount, then too low an internal pressure (resulting from impaired containment integrity or operation of the containment heat removal systems at too high a rate) could significantly affect the ability of this system to accomplish its safety functions by causing pump cavitation. In addition, the deliberate continuation of a high containment pressure to maintain an adequate pump NPSH would result in greater leakage of fission products from the containment and higher potential offsite doses under accident conditions than would otherwise result.*

Additionally, the regulatory position established in this guide is:

> *Emergency core cooling and containment heat removal systems should be designed so that adequate NPSH is provided to system pumps assuming maximum expected temperatures of pumped fluids and no increase in containment pressure from that present prior to postulated loss of coolant accidents.*

This position has essentially remained unchanged in the current guidance, Regulatory Guide 1.82, Revision 3.

Since 1997, we have expressed concerns over the crediting of CAP in NPSH calculations in a series of reports. In a June 17, 1997, report, we stated that CAP should not be granted. In a December 12, 1997, report, we concluded that granting CAP credit of small magnitude may be acceptable in some cases. In our last report on this topic on March 18, 2009, we again stated that hardware changes or requalification of equipment to eliminate the need for CAP should be demonstrated to be impractical, before consideration is given to CAP credit.

The current guidance in Regulatory Guide 1.82, Revision 3, is focused on the conservative calculation of containment pressure for design-basis accidents. The staff contends that the significant conservatism included in the LOCA analyses provides adequate margin. Also, they argue that for special events, which are analyzed with less conservative thermal-hydraulic assumptions, a reasonable level of safety is maintained because of the other conservatisms in the analyses. Although it is true that the licensing-basis analyses currently submitted by licensees to justify CAP credit are based on conservative input assumptions, it is difficult to assess the degree of conservatism and hence the impact on margin against loss of NPSH associated with these analyses.

DISCUSSION

The current guidance in Regulatory Guide 1.82, Revision 3, includes a staff regulatory position that ECCS and containment heat removal systems be designed so that adequate available NPSH is provided to the system pumps, assuming the maximum expected temperature of the pumped fluid and no increase in containment pressure from that present prior to the postulated LOCAs. However, Regulatory Guide 1.82 permits exceptions to this position for operating reactors for which the design cannot be altered in a practical way to achieve conformance with this regulatory position. It appears that the impracticality of such alterations has been essentially presumed in applications for CAP credit. The draft CAP credit guidance now includes an explicit expectation that licensees demonstrate that it is impractical to avoid use of CAP in determining the available NPSH of ECCS and containment heat removal pumps. We

strongly support this position. This demonstration should be performed on a plant-specific basis. The staff does not have detailed knowledge of each plant nor are the risks associated with CAP credit sufficiently well characterized for generic waivers to be granted.

If hardware changes are not practical, then analyses to justify the use of CAP credit should be provided. Two types of analyses and justification are needed. First are deterministic licensing-basis analyses, such as design-basis LOCAs, Appendix R fires, Anticipated Transient Without Scram, and station blackout analyses. These are basically the currently required analyses. They are based on the usual licensing-basis assumptions, e.g., for LOCAs, a large break, conservative boundary and thermal-hydraulic inputs, and the most limiting single failure. They are intended to provide conservative estimates of available NPSH under the assumption that containment integrity is maintained. The second type of analyses addresses non-design-basis conditions, i.e., scenarios including failure of containment integrity prior to core damage. Typically these would be based on PRA and would seek to show that the risk associated with CAP credit is acceptably small.

At the present time, requests for CAP credit are associated with licensee requests for power uprates. These license amendment requests are not risk-informed, and, therefore, are not generally supported by a risk analysis. The staff is constrained from seeking risk information for non-risk-informed applications by the policy expressed in Standard Review Plan Section 19.2, Appendix D, and can do so only if “Special Circumstances” are suspected to exist, i.e., if the licensing request creates conditions or situations that would raise questions about whether there is adequate protection and that could rebut the normal presumption of adequate protection from compliance with existing requirements.

We concluded that the long history of questions concerning defense in depth and independence of barriers associated with CAP credit qualify as a sufficient “Special Circumstance” so that licensees can be requested to provide additional analyses or provide additional justification to demonstrate that the risks are acceptably small.

The draft guidance from the staff provides an improved framework for the licensing-basis analyses. In previous reports on the CAP credit issue, we recognized that the deliberate conservatism in the deterministic calculations could make it difficult to assess the actual available margins and the true impact on defense in depth. We recommended that more realistic assessments be performed. Such assessments must consider both the aleatory variability in such parameters as the service water temperature, which can vary significantly through the course of the year, and the epistemic uncertainty in many of the thermal-hydraulic parameters used in the analyses. For this reason, such calculations could be done using a Monte Carlo approach, such as that proposed by the BWROG. It is difficult to define a single representative accident sequence, as suggested in the staff guidance. While the approach suggested by the BWROG is adequate to give an understanding of the range of responses that could occur in an accident and for assessing the potential for damage to the pumps, we agree with the staff and the BWROG that the licensing decision should be based on a conservative, deterministic calculation. Licensees should submit upper bound and mean estimates as well as the 95/95 estimate to provide a more complete assessment of the available margins and impact on defense in depth.

The staff has also reassessed the potential problems associated with operation of pumps near the required NPSH. They have engaged two pump experts and have developed some preliminary criteria to ensure adequate performance of pumps. In addition, for cases in which

the available NPSH is less than the required NPSH, even if all the calculated containment accident pressure is credited, they have developed additional guidance to ensure meaningful testing of pumps for operation with NPSH less than the required NPSH. They have also asked that the uncertainty in the required NPSH be addressed in the comparison of available NPSH with required NPSH. The staff recognizes that their current draft guidance in this area is based on relatively limited input and intends to seek further input from industry and pump vendors.

One of the interesting results from this reassessment of pump performance is that the maximum wear rate does not occur at the minimum required NPSH, but rather at a value near 1.4 times the minimum value. The draft guidance addresses this by suggesting that the maximum time of operation with NPSH between 1.1 and 1.6 times the required NPSH be limited. The staff and their consultants believe that 100 hours is a conservative estimate for this limited time of operation, but they are seeking input on additional data and experience to support a higher value. We support the staff's approach and will be interested to see if sufficient data are available to justify the duration of operation.

We disagree with the staff's proposal to use a single "realistic" NPSH time history to determine the period of time the pumps may operate in the region of high wear rate. No single time history can be considered as representative. Instead, the time of operation in the high wear region should be based on the time, during which the range of statistical results intersects the range of NPSH margin ratios, representing the region of high wear rate.

Neither Regulatory Guide 1.82, Revision 3, nor the draft CAP credit guidance explicitly address operator actions, although requests for CAP credit often include the use of operator action. The staff has stated that these operator actions will be reviewed in a manner that is typical of operator actions for design-basis analyses, where the focus is on the feasibility of the action. The staff's review of the operator actions and the associated procedures should include human performance and PRA experts to help assure that the likelihood of undesirable unintended consequences is acceptably small.

To complement the deterministic licensing-basis analyses, which assume containment integrity, realistic analyses that assess the impact of the loss of containment integrity are also needed. These analyses will typically be PRAs. However, if no CAP credit is needed for the special events licensing-basis analyses, and the 95/95 lower tolerance bound for LOCAs calculated using an acceptable methodology shows that no CAP credit is needed, then the CAP credit can be deemed to be small enough that it is acceptable without the need for hardware modifications or additional risk studies. This is consistent with the intent of our previous position that if the CAP associated with the licensing basis analysis is sufficiently "short" and "small," then it can be assumed to be largely due to conservatism in the calculation and does not represent a significant challenge to the independence of barriers and the associated risk is small.

In support of their effort to develop updated guidance, the staff has carried out their own independent risk evaluation of the use of CAP to prevent ECCS pump cavitation. The analysis was performed for an hypothetical BWR with a Mark I containment. In the model, the increase in risk with CAP credit is associated with the occurrence of containment leakage large enough to diminish the pressure in the containment to below that needed for operation of the pumps.

One of the risk insights developed from this study is that the risk is a strong function of the surveillance interval for containment leakage, because it is directly related to the probability of the presence of a pre-initiator containment leak large enough to cause failure of the ECCS

pumps. For leakage test intervals believed to be representative of BWRs with Mark I containments (about once per week), the predicted change in core damage frequency, ΔCDF, is less than $1x10^{-7}$/yr, which is very small.

The model assumes that the failure rate of containment isolation after an accident is the same as that during normal operation, despite the more challenging conditions. The containment tests performed by the NRC over the past two decades do show that the containment and seals have robust margins for beyond design-basis conditions under static, isothermal pressure tests. Based on the results presented by the staff, it would appear that a factor of 100 increase in this failure rate is required to increase the ΔCDF by about $1x10^{-6}$/yr. A very large increase in the failure rate does not seem likely, based on environmental qualification programs for design-basis conditions and the NRC sponsored testing that extended into severe accident conditions. However, the model also does not include the possibility that head loss due to sump strainer and other debris blockage is greater than the predicted value used in the calculation of available NPSH. Risk is very sensitive to head loss. The staff's PRA can be used to show that a probability of only $5x10^{-4}$ that debris blockage head loss was underestimated, would increase the ΔCDF to greater than $1x10^{-6}$/yr.

The staff's initial risk assessment was limited to internal events, with no consideration of fire or seismic events. The staff has recently updated their risk study to include some initial estimates of seismic risk. Fire and seismic events introduce modes for loss of containment integrity that are not addressed by the available testing and probably dominate the risk for the class of reactors of most interest, BWRs with Mark I containments. The staff requires consideration of spurious actuations in the Appendix R scenario, but it is not clear what fraction of the fire risk is addressed by this calculation. Clearly, we will have a much better understanding of this risk in plants that have converted to NFPA 805, but until this is complete, any estimate of fire risk is highly uncertain.

The seismic studies provide useful order-of-magnitude estimates and provide assurance the CAP credit does not threaten adequate protection, but better estimates are needed for comparison with Regulatory Guide 1.174 guidelines. Seismic events, fires, and operator actions are potentially significant risk contributors. It is not possible to adequately assess these risks except on a plant-specific basis. Licensees requesting CAP credit should provide these plant-specific risk estimates.

We look forward to further discussions with the staff on these important matters.

Sincerely,

/RA/

Said Abdel-Khalik
Chairman

Additional Comments by Members Dr. Sam Armijo, Dr. Sanjoy Banerjee, Mr. Charles Brown Jr., and Mr. Harold Ray

We agree with the Committee letter, except for Recommendation 5 and the associated discussion on granting of CAP credit. Recommendation 5 states:

"If no CAP credit is needed for the special events licensing-basis analyses, and the 95/95 lower tolerance bound for LOCAs calculated using an acceptable methodology shows that no CAP credit is needed, then the CAP credit can be deemed small enough that it is acceptable without the need for hardware modifications or additional risk studies."

To assure adequate core cooling and containment integrity, the margins implicit in the independence of barriers should be maintained whenever practical by making plant modifications to eliminate the need for CAP credit. Using Recommendation 5 as guidance, licensees requesting plant license amendments that increase licensed thermal power would not have to demonstrate that safety system modifications are impractical, or complete detailed PRAs to quantify the risk of unmodified safety systems. In our opinion, the granting of CAP credit for amendments that increase licensed thermal power should require the following analyses to demonstrate that adequate margins are being maintained for all credible accident and special event scenarios. These include:

1. A thorough evaluation of potential safety system modifications, and implementation of practical modifications that eliminate the need for CAP credit. The criteria used in assessing practicality should be explicitly identified and justified and should be commensurate with the magnitude of the increased thermal power.

2. A plant-specific, full-scope PRA that demonstrates that the increase in risk is small in the event that plant modifications are determined to be impractical.

References:

1. Memorandum to Edwin Hackett, Staff Requirements - Meeting with Advisory Committee on Reactor Safeguards (ACRS), 2:00 p.m., Friday, November 7, 2008, Commissioners' Conference Room, One White Flint North, Rockville, Maryland (Open to Public Attendance) SRM M081107, 01/08/2009 (ML090090338)

2. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.82, Revision 3, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," January 2003 (ML023100171)

3. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.174, Revision 1, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," November 2002 (ML023240437)

4. U.S. Nuclear Regulatory Commission, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition," Section 6.2.2, Containment Heat Removal Systems, Revision 5, March 2007 (ML070160661)

5. Letter from R. L. Seale, ACRS Chairman, to L. Joseph Callan, NRC Executive Director for Operations, Subject: Proposed Final Generic Letter, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps," 06/17/1997

6. Letter from R. L. Seale, ACRS Chairman, to S. A. Jackson, NRC Chairman, Subject: "Credit for Containment Overpressure to Provide Assurances of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps," 12/12/1997 (ML091130712)

7. Letter from Joseph Callan, NRC Executive Director for Operations, to R. L. Seale, ACRS Chairman, Subject: Proposed Final Generic Letter, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps," 08/15/1997

8. Letter to Luis A. Reyes, Proposed Revision 4 to Regulatory Guide 1.82, "Water Sources for Long-Term Recirculation Cooling Following A Loss-of-Coolant Accident," 09/20/2005 (ML052630562)

9. Letter to Nils J. Diaz, Vermont Yankee Extended Power Uprate, 01/04/2006 (ML060090125)

10. Letter to Dale Klein, Browns Ferry Nuclear Plant, Unit 1, 5-Percent Power Uprate, 02/16/2007 (ML070470314)

11. U.S. Nuclear Regulatory Commission, Safety Guide 1.1 (Regulatory Guide 1.10), "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal System Pumps," 11/02/1970 (ML003739925)

12. NUREG/CR-6906, "Containment Integrity Research at Sandia National Laboratories, An Overview", 07/31/2006 (ML062440075)

13. Parks, M. B. and Clauss, D. B., “Performance of Containment Penetrations under Severe Accident Loading,” Nuclear Engineering and Design, No. 134, 1992, pp. 177-197

14. GE Hitachi Nuclear Energy, Licensing Topical Report, NEDC-33347P, “Containment Overpressure Credit for Net Positive Suction Head (NPSH),” January 2008 (ML080520263) GEH Proprietary Information

pumps. For leakage test intervals believed to be representative of BWRs with Mark I containments (about once per week), the predicted change in core damage frequency, ΔCDF, is less than $1x10^{-7}$/yr, which is very small. The model assumes that the failure rate of containment isolation after an accident is the same as that during normal operation, despite the more challenging conditions. The containment tests performed by the NRC over the past two decades do show that the containment and seals have robust margins for beyond design-basis conditions under static, isothermal pressure tests. Based on the results presented by the staff, it would appear that a factor of 100 increase in this failure rate is required to increase the ΔCDF by about $1x10^{-6}$/yr. A very large increase in the failure rate does not seem likely, based on environmental qualification programs for design-basis conditions and the NRC sponsored testing that extended into severe accident conditions. However, the model also does not include the possibility that head loss due to sump strainer and other debris blockage is greater than the predicted value used in the calculation of available
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/RA/

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