July 8, 2009

MEMORANDUM TO: Harold K. Chernoff, Chief
Plant Licensing Branch I-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

FROM: Peter Bamford, Project Manager ***/ra/***
Plant Licensing Branch I-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

SUBJECT: THREE MILE ISLAND, UNIT NO. 1 - ELECTRONIC TRANSMISSION, DRAFT REMAINING ISSUE LIST, REVISION 1, CONCERNING EXELON'S RESPONSE TO A REQUEST FOR ADDITIONAL INFORMATION REGARDING GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS."

The attached remaining issue list was transmitted by electronic transmission on July 8, 2009 to Ms. Wendi Croft, at Exelon Generation Company, LLC (Exelon, the licensee, formerly AmerGen Energy Company, LLC). This draft issue list was transmitted to facilitate the technical review being conducted by the Nuclear Regulatory Commission (NRC) staff and to support a future public meeting conference call with Exelon. The issue list relates to the Exelon response to an NRC staff request for additional information (RAI) regarding the supplemental Generic Letter 2004-02 response for Three Mile Island, Unit 1. The Exelon RAI response was dated November 10, 2008 (Agencywide Documents Access and Management system Accession No. ML083170346). The draft issue list was sent to allow Exelon to prepare to discuss the path forward for resolving the identified issues in an upcoming public meeting conference call. This memorandum and the attachment do not represent an NRC staff position.

Docket No. 50-289

Enclosure: As stated

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Remaining Issues Identified During Staff Review of
TMI-1 Generic Letter 2004-02 Supplemental Responses (sorted by previous RAI)
Revision 1

Attachment 1 – Issues Specific to TMI-1

Debris Characteristics

RAI 2 The NRC staff (the staff) requested that the licensee justify the 60% small fines/40% large pieces size distribution assumed for jacketed low-density fiberglass debris (e.g., Nukon) generated within a 7-diameter (7D) zone of influence (ZOI). This assumption made by the licensee is stated on page 10 of the supplemental response dated December 28, 2007. However, on page 8 of the same response, debris size distribution information presented in Table 2 appears inconsistent with the information on page 10. Specifically, Table 2 indicates that 100% small fines was used within 5D of a break for all Nukon insulation systems, and that a 60%/40% distribution was used between 5D and 7D. In light of the cited information, please clarify the size distribution assumed for jacketed low-density fiberglass debris generated within a 7D ZOI.

Additionally, as shown in Figure II-2 in Appendix II to the [generic safety issue] GSI-191 Safety Evaluation Report "Confirmatory Debris Generation Analysis," dated December 6, 2004 (ADAMS Accession No. ML043280010), for ZOIs smaller than 17D (e.g., 7D or a spherical shell from 5D to 7D), a percentage of up to 100% small fines, higher than the 60/40 distribution assumed by the licensee, may be conservatively expected. Thus, the licensee's assumption of a 60%/40% distribution at distances less than 7D from the break location does not appear consistent with the data in Figure II-2 in Appendix II to the SE, and the staff requested further justification for this assumption in RAI 2. In response to the staff's information request, the licensee stated that results from Westinghouse debris generation testing described in WCAP-16710-P were used to justify the assumed size distribution. The staff is reviewing the methodology used for this testing, and the Pressurized-Water Reactors Owners Group (PWROG) is currently in the process of generically responding to the staff's questions on this testing. After the PWROG generically responds to the staff's questions on the Westinghouse ZOI testing, the staff expects the licensee to provide plant-specific justification to resolve this item for Three Mile Island, Unit 1 (TMI-1).

Debris Transport

RAI 4 The Staff requested that the licensee provide the post-transport size distributions for the reflective metal insulation (RMI), and jacketed and unjacketed Nukon insulation debris with justifications for the transport fractions (e.g., erosion effects). The GSI-191 Safety Evaluation Report (ADAMS Accession No. ML043280007), states that erosion may be neglected if the licensee follows the baseline methodology and considers transport fractions for large debris pieces. The staff noted one apparent inconsistency in the information that was provided regarding the transport of large pieces of fiberglass. Specifically, the information provided in Table 2 of the RAI response indicates that a transport percentage of 15% for large pieces was assumed; however, a note to Table 2 indicates that large pieces are not transported to the sump, and that erosion is also not considered. Further, the licensee has not provided adequate justification (e.g., computational fluid dynamics and experimental debris transport metrics, test results, etc.) for the 15% assumption. The staff requests that the licensee clarify the transport fraction assumed for large pieces of fiberglass debris, state whether it transports as intact large pieces or eroded fines, and provide the technical basis used to derive this transport fraction. Please also clarify whether the transported large debris was modeled in the head loss testing conducted for TMI-1 and identify its prepared size distribution.

Head Loss and Vortexing

RAI 7 The staff requested additional information on the size distribution of fibrous debris used during testing and requested that the licensee provide information that justified the fibrous debris used during testing. The licensee stated that small fines were used. However, the staff guidance requests that the fibrous debris sizing be further broken down into small and fine debris categories. Current staff guidance states that thin bed testing should be conducted with only fine (easily suspendable) fiber (until all predicted fine fibers have been added to the test). The licensee response to the RAI did not address the referenced guidance. It is possible, but unlikely, that a thin bed test conducted in accordance with the latest guidance could result in higher head losses than were attained during the TMI-1 testing. It is more likely that the full load test, if conducted with prototypically sized fiber could have resulted in higher head losses. The licensee should provide information that justifies that the head losses attained during testing were not influenced non-conservatively by the sizing of the fibrous debris used during testing.

RAI 9 The staff requested additional information on how the extrapolation of head loss results to the strainer mission time would affect the head loss evaluation. The licensee provided additional information that clarified some aspects of the need to perform an extrapolation of the data to the pump mission time. The licensee response to the RAI is reasonable. In addition, the rate of increase of head loss over the last 12 hours was very small such that less than one foot additional head loss would likely occur over the strainer mission time. However, the TMI-1 supplemental response states that the limiting net positive suction head (NPSH) margin for the low pressure injection (LPI) pump single operation is 0.1 ft. This is a relatively small margin. The variance of margin related to time was not provided. Because of the low margin available, the licensee should verify that the evaluation of the head loss test data did not include a non-conservative assumption regarding extrapolation that could affect the available pump margin throughout the mission time.

RAI 11 The staff requested additional information on whether containment overpressure was credited for the strainer flashing evaluation. The licensee provided additional information in this area, but it seemed that the question was not understood. The licensee evaluated flashing at the pump suction, but did not address potential flashing in the debris bed or within the strainer. Flashing within the strainer or debris bed can result in additional head losses. The licensee should verify that the potential for flashing at the strainer has been evaluated or provide the parameters such that the staff can verify that flashing will not occur. The minimum margin to flashing at the strainer should be provided. For example, provide strainer submergence, sump temperature, and strainer head loss as a function of time. If required, provide the minimum available containment pressure at the evaluated times.

RAI 13 The staff requested justification for why the settlement that occurred during integrated chemical effects testing did not result in non-conservative head loss values. The licensee stated that multiple attempts were made to re-entrain settled debris into the test flume. The staff was present at a test of the TMI-1 strainers. During the test the staff noted non-prototypical settlement of both chemical and non-chemical debris in the test tank. The trip report reference may be found at ADAMS Accession No. ML071230203. As noted in the trip report, the test tank geometry was significantly less conducive to transport than actual plant conditions. The trip report noted that the effects of debris settling should be addressed during the evaluation of the testing. The licensee should evaluate the effects of the settling on the test results.

Net Positive Suction Head

RAI 16 The staff requested that the licensee provide a more detailed description of the NPSH margin calculation methodology, including a description of the time-dependent analysis specifying selected values for NPSHa (NPSH available) and NPSHr (NPSH required) throughout the mission time. Although some information was provided in response to this request, the staff did not consider the response complete because sufficient information was not provided for the dependence of NPSHa on the sump pool water temperature as well as the time-dependence of the NPSH margin. While it is clear that the available margins are very small at the worst point in the limiting accident sequence (i.e., the minimum NPSH margin is 0.1 ft), it is unclear to the staff when this minimum margin occurs, how long it persists, and how much margin exists at other times during the accident. Therefore, to fully resolve this RAI, the Staff is requesting that the licensee provide plots of NPSH margin versus time (or sump temperature if this parameter was used in lieu of time) for the limiting case (or cases) for both the LPI and BS pumps that demonstrate the periods of minimum NPSH margin and the behavior of the NPSH margin as a function of time (or sump temperature).

Combined
RAI 19
RAI 17 The staff requested that the licensee provide a discussion of how the single failure criterion was used in determining the bounding NPSH margin and why there is confidence that the worst-case single failure was identified and considered. The licensee's response to this item described a single failure of an LPI pump as being the worst-case single failure. Upon considering the NPSH margin results in Table 14 in the supplemental response, as well as the response to RAI 17 that indicates that maximizing reactor building cooling is considered a limiting condition, the staff questioned whether a configuration with one operating LPI pump and two operating building spray (BS) pumps would be bounded by the results presented. For the case of two operating LPI pumps, having two operating BS pumps led to the minimum NPSH margin, but a corresponding case was not analyzed for single-train LPI operation. Please either (1) provide a basis for considering the configuration of one LPI pump and 2 BS pumps operating to be bounded by the cases analyzed or (2) provide a basis for concluding that this operating configuration will not be implemented following a LOCA (e.g., it would not be allowed by emergency procedures).

General

(No Previous
RAI Reference)

Please evaluate the potential for deaeration of the sump fluid to occur as it flows through the debris bed. The guidance in Reg Guide 1.82, Revision 3, Appendix A, states that entrained gas at the pump inlet can result in an increase in required NPSH. Please evaluate whether any adverse effect to pump performance could occur as a result of entrained gas at the pump inlets. If applicable, provide an evaluation of the effects on the pumps.

Remaining Issues Identified During Staff Review of TMI-1 Generic Letter 2004-02 Supplemental Responses (sorted by previous RAI) Revision 1

Attachment 2 – Issues Generic to Westinghouse Debris Generation Testing

Debris Generation/Zone of Influence

Review of the Debris Generation/Zone of Influence area noted the licensee used a 7D zone of influence for its jacketed Nukon insulation, which is based on Westinghouse testing. This testing has not been accepted by the staff and is currently under review. The staff further noted that the jacketing system was not described in the original supplemental response, but it was stated that the application of the testing to TMI-1 was independently reviewed. Additional details of the issues related to the zone of influence are included below.

The issues listed below are a set of RAIs that apply to TMI-1 credited debris generation testing. The PWROG has committed to consider resolving some of the issues generically. The issues to be resolved by the PWROG have not been identified as of this time. TMI-1 should respond to all questions since they credited debris generation reductions based on testing conducted by Westinghouse and documented in WCAP-16710-P for Jacketed Nukon Insulation. TMI-1 may choose to use the responses that the PWROG generates in response to these issues. All questions below are related to the WCAP-16710-P test report that the licensee claims as justification for reducing the jacketed Nukon zone of influence (ZOI) from 17D to 7D. The licensee should reference the WCAP when considering responses to the issues. Alternately, TMI-1 may be able to show that reducing the ZOI for jacketed Nukon from 17D to 7D does not significantly affect postulated LOCA debris loads or their associated head loss. If this is the case the specific questions do not need to be answered separately.

1. Although the ANSI/ANS standard (ANSI/ANS-58.2-1988) predicts higher jet centerline stagnation pressures associated with higher levels of subcooling, it is not intuitive that this would necessarily correspond to a generally conservative debris generation result. Justify the initial debris generation test temperature and pressure with respect to the plant specific reactor coolant system (RCS) conditions, specifically the plant hot and cold leg operating conditions. If ZOI reductions are also being applied to lines connecting to the pressurizer, then please also discuss the temperature and pressure conditions in these lines. Were any tests conducted at alternate temperatures and pressures to assess the variance in the destructiveness of the test jet to the initial test condition specifications? If so, provide that assessment.
2. Describe the jacketing/insulation systems used in the plant for which the testing was conducted and compare those systems to the jacketing/insulation systems tested. Demonstrate that the tested jacketing/insulation system adequately represented the plant jacketing/insulation system. The description should include differences in the jacketing and banding systems used for piping and other components for which the test results are applied, potentially including steam generators, pressurizers, reactor coolant pumps, etc. At a minimum, the following areas should be addressed:
    a. How did the characteristic failure dimensions of the tested jacketing/insulation compare with the effective diameter of the jet at the axial placement of the target? The characteristic failure dimensions are based on the primary failure mechanisms of the jacketing system, e.g., for a stainless steel jacket held in place by three latches where all three latches must fail for the jacket to fail, then all three latches must be

effectively impacted by the pressure for which the ZOI is calculated. Applying test results to a ZOI based on a centerline pressure for relatively low length/diameter (L/D) nozzle to target spacing would be non-conservative with respect to impacting the entire target with the calculated pressure.

   b. Was the insulation and jacketing system used in the testing of the same general manufacture and manufacturing process as the insulation used in the plant? If not, what steps were taken to ensure that the general strength of the insulation system tested was conservative with respect to the plant insulation? For example, it is known that there were generally two very different processes used to manufacture calcium silicate whereby one type readily dissolved in water but the other type dissolves much more slowly. Such manufacturing differences could also become apparent in debris generation testing, as well.
   c. The information provided should also include an evaluation of scaling the strength of the jacketing or encapsulation systems to the tests. For example, a latching system on a 30 inch pipe within a ZOI could be stressed much more than a latching system on a 10 inch pipe in a scaled ZOI test. If the latches used in the testing and the plants are the same, the latches in the testing could be significantly under-stressed. If a prototypically sized target were impacted by an undersized jet it would similarly be under-stressed. Evaluations of banding, jacketing, rivets, screws, etc., should be made. For example, scaling the strength of the jacketing was discussed in the Ontario Power Generation Report ("Jet Impact Test - Preliminary Results and Their Application," OPGN Engineering Report, File N-REP-34320-10000) on calcium silicate debris generation testing.

3. There are relatively large uncertainties associated with calculating jet stagnation pressures and ZOIs for both the test and the plant conditions based on the models used in the WCAP reports. What steps were taken to ensure that the calculations resulted in conservative estimates of these values? Please provide the inputs for these calculations and the sources of the inputs.

4. Describe the procedure and assumptions for using the ANSI/ANS-58.2-1988 standard to calculate the test jet stagnation pressures at specific locations downrange from the test nozzle.
   a. In WCAP-16710-P, why was the analysis based on the initial condition of 530°F whereas the initial test temperature was specified as 550°F?
   b. Was the water subcooling used in the analysis that of the initial tank temperature or was it the temperature of the water in the pipe next to the rupture disk? Test data indicated that the water in the piping had cooled below that of the test tank.
   c. The break mass flow rate is a key input to the ANSI/ANS-58.2-1988 standard. How was the associated debris generation test mass flow rate determined? If the experimental volumetric flow was used, then explain how the mass flow was calculated from the volumetric flow given the considerations of potential two-phase flow and temperature dependent water and vapor densities? If the mass flow was analytically determined, then describe the analytical method used to calculate the mass flow rate.
   d. Noting the extremely rapid decrease in nozzle pressure and flow rate illustrated in the test plots in the first tenths of a second, how was the transient behavior considered in the application of the ANSI/ANS-58.2-1988 standard? Specifically, did the inputs to the standard represent the initial conditions or the conditions after the first extremely rapid transient, e.g., say at one tenth of a second?

   e. Given the extreme initial transient behavior of the jet, justify the use of the steady state ANSI/ANS-58.2-1988 standard jet expansion model to determine the jet centerline stagnation pressures rather than experimentally measuring the pressures.

5. Describe the procedure used to calculate the isobar volumes used in determining the equivalent spherical ZOI radii using the ANSI/ANS-58.2-1988 standard.
   a. What were the assumed plant-specific RCS temperatures and pressures and break sizes used in the calculation? Note that the isobar volumes would be different for a hot leg break than for a cold leg break since the degrees of subcooling is a direct input to the ANSI/ANS-58.2-1988 standard and which affects the diameter of the jet. Note that an under calculated isobar volume would result in an under calculated ZOI radius.
   b. What was the calculational method used to estimate the plant-specific and break-specific mass flow rate for the postulated plant LOCA, which was used as input to the standard for calculating isobar volumes?
   c. Given that the degree of subcooling is an input parameter to the ANSI/ANS-58.2-1988 standard and that this parameter affects the pressure isobar volumes, what steps were taken to ensure that the isobar volumes conservatively match the plant-specific postulated LOCA degree of subcooling for the plant debris generation break selections? Were multiple break conditions calculated to ensure a conservative specification of the ZOI radii?

6. Provide a detailed description of the test apparatus specifically including the piping from the pressurized test tank to the exit nozzle including the rupture disk system.
   a. Based on the temperature traces in the test reports it is apparent that the fluid near the nozzle was colder than the bulk test temperature. How was the fact that the fluid near the nozzle was colder than the bulk fluid accounted for in the evaluations?
   b. How was the hydraulic resistance of the test piping which affected the test flow characteristics evaluated with respect to a postulated plant specific loss of coolant accident (LOCA) break flow where such piping flow resistance would not be present?
   c. What was the specified rupture differential pressure of the rupture disks?

7. WCAP-16710-P discusses the shock wave resulting from the instantaneous rupture of piping.
   a. Was any analysis or parametric testing conducted to get an idea of the sensitivity of the potential to form a shock wave at different thermal-hydraulic conditions? Were temperatures and pressures prototypical of Pressurized Water Reactor (PWR) hot legs considered?
   b. Was the initial lower temperature of the fluid near the test nozzle taken into consideration in the evaluation? Specifically, was the damage potential assessed as a function of the degree of subcooling in the test initial conditions?
   c. What is the basis for scaling a shock wave from the reduced-scale nozzle opening area tested to the break opening area for a limiting rupture in the actual plant piping?
   d. How is the effect of a shock wave scaled with distance for both the test nozzle and plant condition?

8. Please provide the basis for concluding that a jet impact on piping insulation with a 45° seam orientation is a limiting condition for the destruction of insulation installed on steam generators, pressurizers, reactor coolant pumps, and other non-piping components in the containment as applicable to TMI-1. For instance, considering a break near the steam

generator nozzle, once insulation panels on the steam generator directly adjacent to the break are destroyed, the LOCA jet could impact additional insulation panels on the generator from an exposed end, potentially causing damage at significantly larger distances than for the insulation configuration on piping that was tested. Furthermore, it is not clear that the banding and latching mechanisms of the insulation panels on a steam generator or other RCS components provide the same measure of protection against a LOCA jet as those of the piping insulation that was tested. Although WCAP-16710-P asserts that a jet at Wolf Creek or Callaway cannot directly impact the steam generator, but will flow parallel to it, it seems that some damage to the SG insulation could occur near the break, with the parallel flow then jetting under the surviving insulation, perhaps to a much greater extent than predicted by the testing. Similar damage could occur to other component insulation. Please provide a technical basis to demonstrate that the test results for piping insulation are prototypical or conservative of the degree of damage that would occur to insulation on steam generators and other non-piping components in the containment.

9. Some piping oriented axially with respect to the break location (including the ruptured pipe itself) could have insulation stripped off near the break. Once this insulation is stripped away, succeeding segments of insulation will have one open end exposed directly to the LOCA jet, which appears to be a more vulnerable configuration than the configuration tested by Westinghouse. As a result, damage would seemingly be capable of propagating along an axially oriented pipe significantly beyond the distances calculated by Westinghouse. Please provide a technical basis to demonstrate that the reduced ZOIs calculated for the piping configuration tested are prototypical or conservative of the degree of damage that would occur to insulation on piping lines oriented axially with respect to the break location.

10. WCAP-16710-P noted damage to the cloth blankets that cover the fiberglass insulation in some cases resulting in the release of fiberglass. The tears in the cloth covering were attributed to the steel jacket or the test fixture and not the steam jet. It seems that any damage that occurs to the target during the test would be likely to occur in the plant. Was the potential for damage to plant insulation from similar conditions considered? For example, the test fixture could represent a piping component or support, or other nearby structural member. The insulation jacketing is obviously representative of itself. What is the basis for the statement in the WCAP that damage similar to that which occurred to the end pieces in not expected to occur in the plant? It is likely that a break in the plant will result in a much more chaotic condition than that which occurred in testing. Therefore, it would be more likely for the insulation to be damaged by either the jacketing or other objects nearby.