February 10, 2001

MEMORANDUM TO: Gary M. Holahan, Director
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SUBJECT: REPORT ON RESULTS OF STAFF AUDIT CONDUCTED ON MARCH 29-31, 1999, OF DRESDEN NUCLEAR POWER STATION'S RESOLUTION OF ISSUES IDENTIFIED IN NRC BULLETIN 96-03

On March 29-31,1999, the staff conducted an audit of Commonwealth Edison's (CECo, the licensee) resolution for NRC Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris" (NRCB 96-03), for Dresden Nuclear Power Station, Units 2 and 3. The purpose of the audit was to verify the implementation of NRCB 96-03. Specifically, the staff:

1) assessed the adequacy of the licensee's resolution, and
2) evaluated the need for additional review on a generic basis of licensee's resolutions through the NRC inspection program.

On basis of our review of the strainer documentation onsite at Dresden and our confirmatory calculations, we concluded that:

1) Dresden has adequately designed their ECCS strainers to withstand the high debris loads anticipated during a LOCA.
2) Dresden has implemented an appropriate inspection program to ensure the operability of the ECCS (strainer and suppression pool cleanliness).
3) Dresden has implemented a suppression pool cleanliness program and foreign material control procedures to limit the potential for clogging the ECCS by foreign material.
4) The strainer structural design is robust, and the strainer hydrodynamic loads were calculated using conservative assumptions.

We did identify some concerns that Dresden needs to address. Since the Dresden strainers are adequately sized to perform their safety function, there is no safety concern related to the Dresden strainer design. However, we did conclude that some of the analysis methods used by Dresden's contractor to size their strainers are inadequate. These methods are not consistent with the NRC approved methodologies, and lack sufficient supporting data or analysis to support their use. Our assessment of Dresden's analysis methods is that these analysis methods could lead to erroneous conclusions in any future operability assessments, design modifications or procedure changes (e.g., suppression pool cleaning). This is particularly important at Dresden because they have a low NPSH margin, and configuration control is, as a result, important to ensuring that they do not exceed the design basis of the strainers. In addition, the audit team concluded that Dresden has inadequately defined their licensing basis. They have performed a number of parametric analyses demonstrating the performance capability of their strainer under different conditions, but have not defined which parametric case constitutes their licensing basis. This concern affects their bases for such things as configuration control and foreign material issues. We have concluded that these concerns need to be resolved by Dresden. These issues were discussed with Dresden staff at the audit exit meeting and in subsequent phone conversations. It is our expectation that these concerns will be addressed via the Dresden corrective action program. A copy of this report will also be forwarded to Dresden.

Our specific concerns are described in greater detail in Appendix B to this audit report. We note that we have not identified these problems at any of the other sites where we have conducted our audits, or in plant-specific submittals. As a result, we believe that the problem is specific to Dresden, and we conclude that there is no reason at this time to address these concerns on a more generic basis.

The following sections of this audit report describe in greater detail the review performed onsite by the audit team.

1.0 Background

Title 10, Section 50.46 of the *Code of Federal Regulations* (10 CFR 50.46, the ECCS rule) requires that nuclear power plant utilities design their ECCS systems to meet five criteria. Criterion 5 of this rule requires the ECCS to provide long-term cooling capability following a loss-of-coolant accident (LOCA). To meet this criterion, the system should be designed to provide sufficient cooling to maintain the reactor core temperature at an acceptably low value. In addition, the ECCS should continue to remove decay heat for the extended period of time required by the long-lived radioactivity in the core. The ECCS is designed to meet this criterion, assuming the worst case single failure of any piece of equipment or system. However, experience gained from operational events and detailed analyses of BWR designs has demonstrated that excessive buildup of debris from thermal insulation, corrosion products, and other particulates on ECCS pump strainers is likely to occur during a LOCA. This creates the potential for a common-cause failure of the ECCS, which could prevent the ECCS from providing long-term cooling following a LOCA. Based on this information, the NRC decided that BWR licensees should take adequate steps to prevent strainer clogging in order to ensure that the ECCS can perform its safety function during a LOCA.

On May 6, 1996, NRCB 96-03 was issued requesting BWR licensees to implement appropriate procedural measures and plant modifications to minimize the potential for clogging of ECCS suppression pool suction strainers by debris generated during a LOCA. Regulatory Guide 1.82, Revision 2, (RG 1.82) was issued in May 1996 to provide guidance on evaluating plants for compliance with the ECCS rule. On November 20, 1996, the Boiling Water Reactor Owners Group (BWROG) submitted NEDO-32686, "Utility Resolution Guidance for ECCS Suction Strainer Blockage" (also known as the URG) to the NRC for review. The purpose of the URG is to give BWR licensees detailed guidance for complying with the requested actions of NRCB 96-03. The staff approved the URG in an safety evaluation report (SER) dated August 20, 1998. In response to NRCB 96-03, all affected BWR licensees have installed new large-capacity passive strainers to resolve the issue. Licensees have typically concluded that installation of the new strainer designs does not create an unreviewed safety question as defined in 10 CFR 50.59. This means that NRC approval of the new strainers is not required. As a result, we have not performed a comprehensive formal review of licensee resolutions for this issue. Therefore, we decided to conduct 4-6 plant audits to verify adequate implementation prior to closing out this generic issue for BWRs. Dresden Nuclear Power Station, Units 2 and 3, is the second of these audits. Appendix A to this report provides the staff's plan for the conduct of these audits. The audit plan also provides a more detailed description of the background on this issue.

2.0 DISCUSSION

The audit team was a five person team including Robert Elliott from the Plant Systems Branch, John Kudrick from the Probabilistic Safety Assessment Branch, Anthony D'Angelo from the Inspection Program Branch of the NRC's Office of Nuclear Reactor Regulation, and D.V. Rao and Bruce Letellier from the Los Alamos National Laboratory (LANL). The audit covered two areas involving the Dresden's resolution of issues identified in NRCB 96-03. In addition, the audit covered issues identified in NRCB 95-02, “Unexpected Clogging of Residual Heat Removal (RHR) Pump Strainer While Operating in Suppression Pool Cooling Mode," dated October 17, 1995. These three areas are:

1. Dresden's strainer modification documentation and associated 50.59 safety evaluation,

2. Dresden's analyses performed in response to NRCB 96-03, including
   a. strainer performance and design calculations
   b. hydrodynamic load calculations

3. Dresden's suppression pool cleanliness program (NRCB 95-02). While not specifically addressed in the audit plan objectives, suppression pool cleanliness and NRCB 95-02 were included in the audit scope because of the potential adverse impact that foreign debris could have on ECCS strainer operability.

As noted above, Appendix A to this trip report provides our plan for conducting plant audits of NRC Bulletins 96-03 and 95-02. For conciseness, the blank plant data spreadsheets normally attached to the audit plan have been left out of this appendix. Detailed descriptions of LANL's review related to strainer performance and associated confirmatory calculations are provided in Appendix B. LANL's report also includes the audit plan plant data spreadsheets filled in with the details of Dresden's strainer designs.

At the time of the audit, Dresden had completed the strainer hardware installation as well as almost all of their planned insulation replacement. They installed new strainers designed by Duke Engineering and Services (DE&S) and Performance Contracting, Incorporated (PCI). The strainers are of a stacked disk design. However, some of Dresden's licensing basis calculations were still being finished (e.g., net positive suction head (NPSH) calculations based on the new strainer characteristics and Dresden's estimated debris loadings and head loss). The following sections describe the review performed at the site and our findings for each area audited.

2.1 The Licensee's Strainer Modification Documentation and Associated Safety Evaluation (10 CFR 50.59)

In order to ensure that the implementation of the strainer resolution did not adversely impact other plant systems in such a way as to create a new or previously unidentified safety concern, we reviewed the licensee's strainer modification package and safety evaluation. The documents reviewed included the Design Input Requirements Document for Modification M12-2(3)-96-006 for Design Change Packages 9600317 and 9600318. We performed a technical review to ensure that Dresden adequately considered the potential impacts of the strainer modification on plant safety. In addition, we evaluated Dresden's safety evaluation to ensure that the potential impacts of the new strainers on the licensee's accident analyses were adequately considered.

The following provides a brief overview of the main design and operational considerations addressed by Dresden in the implementation of the strainer modification:

- The ECCS pumps all take suction off a common ring header through four strainers. This arrangement was maintained with the new strainers. The licensee ensured that the basic ECCS functions remained unchanged by the strainer replacement. For instance, the strainers are designed to screen out objects larger than 1/8 inch in size. This requirement is the same as the old strainers. In addition, the new strainers were designed to have a head loss equal to or less than 5.8 feet of water (ft H_2O) when loaded with debris. The requirement allows Dresden to retain their original net positive suction head (NPSH) margin for the ECCS pumps. The new strainers have a clean strainer head loss of about 1.2 ft H_2O.

- In order to accommodate the weight of the new larger strainers, the torus penetrations were modified to provide external structural reinforcement. The torus attached piping (TAP) is designed to meet the requirements of the American Society of Mechanical Engineers (ASME) Code, Section III (1977 through Summer 1997 Addenda) per NUREG-0661, "Mark I Containment Long Term Program," dated July 1980. Specifically, the piping is designed to meet Subsection NC, the containment penetrations are designed to meet Subsection NE, and the pipe supports are designed to meet

Subsection NF. For testing and non-destructive examination (NDE) of piping and supports, the strainer modification package stated that NDE procedures were in conformance with the ASME Code, Section V. All welds were visually examined, as well as examined by the magnetic particle method in accordance with ASME, Section V, Article 7, and ASME section III, Division I, Article NE-5000. Acceptance standards were in accordance with Article NE-5340 as applicable.

- Dresden conducted an environmental qualification (EQ) screening and concluded that there was no effect on the EQ of the ECCS system or strainers due to the modification.

- Dresden conducted a fire protection screening concluding that the strainer modification did not add combustible material to the containment or wetwell.

- Dresden also performed an ALARA review to ensure that worker exposure from the modification would be minimized.

- The licensee performed two safety evaluations for the strainer modification. These safety evaluations were performed in accordance with the requirements of 10 CFR 50.59. The first safety evaluation was for the nozzle penetration strengthening. The safety evaluation concludes:

    1) The modification does not affect plant operation. The stiffener plates are not welded to any pressure boundary; therefore, the welding process did not effect the function of any structure, system, or component. The materials used for the modification are consistent with ASME requirements, and ECCS suction flow paths are not affected.
    2) The modification does not affect any potential equipment failures. The change is only to the existing penetration support outside the torus. Flow from the torus to the ring header is unaffected. The penetration reinforcement is designed for applicable pool hydrodynamic and seismic loads and meets the Dresden Updated Final Safety Analysis Report (UFSAR) acceptance criteria. No new failure modes are created by the modification.
    3) The modification also has no affect on Dresden’s accident analysis. The modification ensures that the penetration can support the weight of the new strainers as well as any other loads that may be imposed during the most limiting accidents that are described in the UFSAR, Section 15.6.5.
    4) No safety limits, Technical Specification (TS) or safety system settings are affected. Accordingly, no TS or license amendments are needed.
    5) Dresden also concluded that they did not need a license amendment because the modification does not constitute an unreviewed safety question (USQ) as defined in 10 CFR 50.59. This conclusion was based on the following evaluation made by the utility:
        A- The modification does not increase the probability of an accident because reinforcing the penetration does not create an accident initiator for the accidents analyzed in the safety analysis report. The torus penetrations will function as designed within applicable UFSAR acceptance limits.
        B- The modification does not increase the consequences of an accident because the ECCS, torus, ring header will still operate as designed.

C- The modification does not increase the probability of a malfunction of equipment important to safety because the modification does not affect the failure modes of any active component. No new welds were made to any process pipe, torus shell, or torus nozzle penetration. The small amount of heat from welding the new support was dissipated by the existing penetration supports. The small amount of heat that may have been transferred to the pipe, nozzle, and torus will not adversely affect the inner torus coating. The existing penetration supports will not experience any adverse effects of the welding from the reinforcements.

D- The modification does not affect the consequences of any equipment malfunction that is important to safety. Any equipment malfunction will have the same consequences as previously evaluated. The penetration is designed to withstand the loads associated with equipment failures as well as the extra strainer weight. Therefore, Dresden concluded that the modification ensures that the penetration will retain its ability to perform its function during an equipment malfunction.

E- The modification does not create the possibility of an accident or malfunction of a type different from those evaluated in the SAR. The reinforcing is required for new loads that are a consequence of installing the new strainers. The reinforcing of the piping penetration has no affect on the function or purpose of the supported piping or penetration (i.e., to deliver water from the torus to the ring header for the ECCS suction).

F- No parameters upon which TS are based have been changed by the modification; therefore, the margin of safety is not reduced.

7) Based on the above evaluation, Dresden concluded that no change to UFSAR was required and that the modification to the ECCS containment penetrations does not constitute a USQ.

- The second safety evaluation addressed the installation of new ECCS suction strainers. Dresden installed new ECCS strainers increasing the surface area from 4.5 ft^2 to 118 ft^2 per strainer. The purpose of the modification is to minimize the potential for ECCS suction clogging during a LOCA by increasing the surface area of the strainers (and flow area). The strainer replacement also included several miscellaneous modifications as a result of piping reanalyses including inspecting and resetting several snubbers and a spring can, temporary removal of torus manway ladder and catwalk railings to facilitate installation, and contouring of several small bore socket welds to lower the stress intensification factor. The main conclusions from Dresden's safety evaluation for the new strainers includes:

1) The strainer modification constitutes a change to the facility as described in the SAR. The function of the ECCS is to provide core cooling for the entire spectrum of primary system line breaks, up to and including the maximum break size. The ECCS is designed to provide two automatically actuated, independent cooling methods with no reliance on external sources of power.

2) The modification does not affect plant operation because the new strainers do not change interactions with other structures, systems, and components (SSCs) from a functional perspective. For instance, the head loss across the new strainers is less than the old strainer head loss in all operating modes. This means that the modification improves the NPSH margin for the ECCS system.

The new strainers reduce the clean head loss from 5.8 feet to 1.2 feet. The improvement in NPSH available (NPSHA) means that the new strainers are less likely to cavitate at any operating pressure and temperature. There is also no difference in hole size (0.125 inch diameter) between the new and the old strainers. Therefore, the conclusions from Dresden's analysis of the potential for debris to cause internal damage in the ECCS remain unchanged. In addition, the affects of the structural loads induced on the strainers and associated piping by bulk fluid flow during an accident or transient (hydrodynamic loads) are addressed in Dresden calculation DRE97-0015. Dresden also evaluated the impact of the change in volume of water displaced by the new strainers (versus the old). They concluded that the affect is very small with a negligible effect on suppression pool heat capacity.

3) The new strainers have no affect on equipment failures. The holes are sized to prevent system blockages. The effects of postulated strainer failures are unchanged by the installation of the new strainers. The tops of the new strainers are well below the minimum suppression pool level. Vortexing has been demonstrated not to occur due to low approach velocity and height of water level above strainers (approx 2.4 feet). Additionally, vortexing was demonstrated to not occur in EPRI tests conducted on the prototype strainer in October 1995. No cavitation occurred even with the water level halfway below the top of the strainer. The strainer hardware and fastening devices are designed to applicable standards and therefore, no new failure modes are introduced.

4) The new strainers improve NPSHA, and so do not change the affect of any SSC on an accident analysis. Therefore, the new strainers will improve the NPSH conditions imposed by a DBA LOCA.

5) Heavy loads during the installation phase were considered in Temporary Rigging Permit 97-024 and did not have an impact on the safety of the plant. The installation work package and station procedures were considered adequate to control the safe movement of the heavy loads and the protection of station equipment.

6) Dresden also concluded that they did not need a license amendment because the modification does not constitute an unreviewed safety question (USQ) as defined in 10 CFR 50.59. This conclusion was based on the following evaluation made by the utility:

   A- The probability of an accident is not increased because the strainers perform the same function as the existing strainers and serve their safety function only after an accident initiation. The probability of a line break is not increased by installation of larger strainers. Strainers are not accident initiators.

   B- The new strainers do not affect the consequences of an accident since the strainers are used for accident mitigation and the enlarging of the strainers enhances the ability of the strainers to perform their safety function.

   C- The probability of a malfunction of equipment (important to safety) will not be increased because the probability of strainer failure is not affected by the modification. The new strainers are designed and fabricated to handle the same loads and flows as the previous strainers. The new strainers have larger flow area, smaller head loss, and the same size holes resulting in an improvement in NPSHA while maintaining the equivalent protection against debris entering the ECCS system. The strainers are fabricated of stainless steel to ensure compatibility with existing materials and performance in the harsh environment of the torus. The strainers are also qualified for seismic and suppression pool hydrodynamic loads. However, because installation of the larger strainers results in a significant increase in size and weight, the ECCS ring header piping, supports and penetration were all re-analyzed for the increase. The analyses were all performed using the Plant Unique Analysis Report (PUAR) approved analysis methodology. In cases where insufficient guidance was provided for modeling the new strainers, testing was conducted to determine the appropriate coefficients. As noted above, Dresden performed a separate 10 CFR 50.59 safety evaluation for the penetration modification.

D- The consequences of a malfunction important to safety remain unchanged. The new strainers perform the same function as the old strainers and the failure of a new strainer will have the same consequences as a failure of an old strainer.

E- The modification does not create the possibility of an accident or malfunction different than previously evaluated in the SAR. No new failure possibilities are created by this modification. The strainer function remains unchanged.

F- All changes to the parameters or conditions used to establish the TS requirements are in a conservative direction. Therefore, the actual acceptance limit need not be identified to determine that the margin to safety is not reduced. No limiting condition of operation, safety limit, or limiting safety settings were affected by this change, so no TS amendment was needed (Containment overpressure was already addressed by a previous license amendment).

- Dresden proceeded with the installation of the new strainers after concluding that the modification did not constitute an unreviewed question. Dresden also indicated that the UFSAR will be updated.

Staff Evaluation: We reviewed Dresden’s engineering packages described above to determine if Dresden had fully considered the systems potentially affected by the strainer modification. In addition, we evaluated these packages to ensure that Dresden made appropriate engineering, procedural, or documentation changes to ensure that plant safety is adequately maintained during the installation of the new strainers and in normal operation with the new strainers. Based on our review, we concluded that Dresden’s engineering package and associated safety evaluation were adequate in scope and appropriately evaluated the impact of the strainer replacement. We did not identify any systems or components that would be impacted by the strainer replacement that were not considered by the utility. As a result, we conclude that appropriate steps were taken by Dresden to safely install the new strainers and to ensure that the installation improved overall plant safety.

2.2 Plant-specific Analyses, Strainer Performance and Design Calculations, and Hydrodynamic Loads

Strainer Performance and Design Calculations: We evaluated Dresden's strainer analyses and design calculations through a series of confirmatory calculations. These calculations were performed by our contractor, LANL. LANL's confirmatory analyses focused on two objectives:

1) Confirm Dresden's estimated debris loadings for the new strainers.
2) Confirm the performance of the strainer design based on the strainer design criteria and Dresden's calculated accident conditions.

These calculations are designed to confirm that the strainers will function as intended during a LOCA. LANL conducted three sets of calculations to achieve these objectives. First, they independently estimated the debris loadings for the strainers using the methods approved by the NRC. Second, they calculated the head loss across the clean strainer and determined the NPSH margin available to accommodate debris as a function of suppression pool temperature. And finally, they estimated the head loss across the strainers using (a) the debris loadings calculated by Dresden in their analyses, and (b) the debris loadings independently estimated by LANL. LANL's report is included in Appendix B of this report. Their report includes a description of their analyses, their analyses results, and calculation summary tables. LANL's overall conclusion in their report is that the Dresden strainers are "adequately sized to handle the debris loading expected to reach the strainer following a LOCA. This conclusion was reached based on independent analyses performed by the LANL staff..." These analyses were performed both on-site and in the ensuing months following the Dresden site visit. However, LANL noted deficiencies in the Dresden analyses which were not consistent with the NRC approved URG methodologies. Specific deficiencies identified include the following:

- Dresden does not have a clearly defined licensing basis for the new strainers. While they have performed many calculations for several different debris loadings, it is not clear which calculation forms the basis for licensing basis analysis. Specifically, Dresden's has not defined a clear licensing basis that:
  1- defines the licensing basis debris loading on the strainer
  2- establishes the resultant head loss across the strainer due to the debris loading, and
  3- demonstrates the overall effect of debris on their NPSH margin.

- Dresden's rationale for debris transport in the suppression pool was inconsistent with the approved URG. Dresden's analyses simply assumed a turbulence factor of 0.5 without any supporting justification. This factor allowed them to assume considerable debris settling in the suppression pool. Dresden's analyses also assume that considerable debris would pass through the strainer and be caught up in the primary system where it would be unavailable to clog the strainers. LANL does not agree with these assumptions because they are unsupported by either experimental evidence or analyses.

- The ECCS operating parameters used in Dresden's analyses were identified as being inconsistent. Two specific examples were noted by LANL in their report. First, in some portions of their analyses, Dresden assumes that one strainer has failed. This assumption is consistent with their original licensing basis. However, in other portions of their analyses, the calculations are run assuming all strainers are working. While the licensee could perform the analyses either way, it should be done in a consistent manner. The second inconsistency noted by LANL is in Dresden's head loss calculations. Some of their calculations are based on a ECCS flowrate of 29,000 gpm. This flowrate is inconsistent with their licensing basis flowrate of 19,000 gpm. Dresden operators are expected to throttle the ECCS flowrate to 19,000 gpm within 10 minutes of the start of the accident because their ECCS system does not have sufficient NPSH margin to support a 29,000 gpm flowrate for the long term.

- Dresden used a different method for calculating head loss caused by particulate and miscellaneous debris than was approved by the NRC in the URG. We have not reviewed their methodology, and they did not present test data or analytical evidence to support their method for determining the contribution to strainer head loss from these debris types.

- Dresden's calculation of head loss across mixed fiber and reflective metallic insulation debris beds is not consistent with the NRC approved methodology. This appears to be a misinterpretation of the position defined by the NRC staff in our safety evaluation of the URG.

- Dresden did not address asbestos or calcium silicate debris in their analyses due to the lack of available data. However, they did not provide an adequate technical basis to support neglecting these debris sources.

- At the time of the audit, Dresden's NSPH calculations did not reflect their new licensing basis for their strainers and their associated debris loadings. This contributed to our confusion about what their new strainer licensing basis is. Dresden's NPSH calculations still show 29,000 gpm flow and one strainer assumed failed.

Hydrodynamic Load Calculations: We also evaluated the submerged structure loads (forces) on the strainers and their associated piping. The detailed methodology of how the submerged structure loads were calculated along with the supporting test data to justify the conservatism of the method was available at the time of the audit, and were reviewed. Some of this information has since been docketed by the licensee following the audit. Therefore, our review of the hydrodynamic forces acting on the Dresden strainers focused on understanding the methodology used to develop the submerged structure loads on the new strainer and the associated margins.

In preparation for the audit, we reviewed a letter from Commonwealth Edison Company (ComEd) dated February 26, 1999, entitled, "Submittal of Technical Information Concerning Emergency Core Cooling System Suction Strainers." The purpose of the letter was to inform the NRC about the use of revised hydrodynamic loads by ComEd in conjunction with the installation of new ECCS suction strainers at Dresden and Quad Cities Station. The letter included a report that discusses the hydrodynamic testing that was done to determine the hydrodynamic mass coefficient, C_m, for the new strainers. The testing was jointly performed by Duke Engineering (Duke) and Performance Contracting, Inc. (PCI). The report also provides a correction factor that can be used to apply the results of Duke/PCI testing to strainers of similar design, such as those at Dresden. The staff notes that the Dresden strainer was not tested. Determination of the C_m for the Dresden strainer relied on test data from the Quad Cities strainer and appropriate correction factors.

Specifically, ComEd used tests of strainers and correction factors to obtain realistic and bounding results for the hydrodynamic mass and standard drag coefficients for the Dresden ECCS strainers. Tests were performed on the Quad Cities stacked disk strainer and were applied to the Dresden stacked disk strainer. Both strainers were manufactured by PCI. The Quad Cities strainer has 11 stacked disks made with perforated plate. The strainer perforated plate has 0.125 inch diameter holes and 40 percent open area. In overall dimensions, the Quad Cities strainer is 45 inches in diameter and 42 inches long while the Dresden strainer is 32.5 inches in diameter (24.3 inches inner diameter) and 54 inches long. The Dresden strainers has 16 disks made of perforated plate. Similar to the Quad Cities strainers, the Dresden strainers have 0.125 inch diameter holes and 40% open area.

For the hydrodynamic mass coefficient, C_m, a value of 0.44 was determined from the Quad Cities strainer tests. IEEE-323 recommends the application of 10 percent margin to test data when it is compared to actual application requirements. The resulting value for C_m with the added 10 percent margin was 0.48. This value was then rounded up to 0.50. This 10 percent was a specific concern to us. It is important that the margin selected for this application be adequate to account for the uncertainty in the analysis methodology.

Although the audit was not focused on the structural aspects of the new strainer design, we obtained a brief summary of the criteria used in the design. We reviewed the torus attached piping (TAP) stress analysis. It was noted that none of the external piping loads outside the containment had changed as a result of the addition of the new strainer. The torus attached external piping stress analysis, which includes thermal, deadweight, seismic and suppression pool hydrodynamic events, was not changed as a result of the new strainer. Additionally, no design bases were changed with regard to torus attached external piping. However, the loads associated with the new strainer design did increase the penetration loads. The increased penetration loads required the addition of external gussets between the existing stiffening plates. The addition of the gussets was such that it did not require any direct welding on the torus body. With this modification and the supporting re-analysis, the design was able to meet all ASME code requirements.

Staff Evaluation: We have reviewed LANL's findings relative to the performance of the Dresden strainer design and agree with their results. While the audit's confirmatory analyses demonstrate that the Dresden strainers are adequately sized, they also identified weaknesses in Dresden's analyses and documentation that we believe need to be addressed. Due to compensating errors, Dresden's strainer sizing calculations provided them with adequately sized strainers through an incorrect analysis. Therefore, we conclude that these assumptions need to be corrected in order to prevent compounding of errors in the future. For instance, Dresden's assumptions regarding the settling characteristics of corrosion products (sludge) is clearly in error. There is abundant experimental evidence which clearly shows that sludge does not settle very rapidly even in a quiescent pool. Therefore, assuming 50% settling of sludge is highly unrealistic. In reality, the only sludge that's not likely to accumulate on the strainers is that which passes through the strainer without being filtered by the fibrous debris on the strainer surface. Experiments have shown that the filtration efficiency of a fiberglass insulation bed on the strainer surface is about 75% on average for sludge, which means that only about 25% would successfully pass through the strainer. Our concern with this type of error is that it could lead the utility to erroneously evaluate the impacts of debris in the future. For instance, if the utility were to discover that more sludge had accumulated in the suppression pool than they had previously assumed, the erroneous concept of sludge settling could lead to incorrect evaluation of the safety impact of their finding. This is particularly important for Dresden because LANL's report clearly shows that Dresden has low NPSH margin. Configuration control is, as a result, very important for Dresden. As a result, we conclude that Dresden should revise their analysis to a more acceptable technical approach, such as the approved URG methodologies. The assumptions and methods of concern are identified in the LANL report in Appendix B to this audit report.

LANL's review also identified a second concern dealing with inadequate documentation of Dresden's licensing basis. While several calculations were performed to evaluate varying conditions and debris loadings on the strainers, there is no document which clearly defines what Dresden has decided to use as their licensing basis. This was confusing to the audit team because it made it challenging to evaluate Dresden's licensing basis. Additionally, it makes it unclear as to how they would handle future design issues or operability assessments. Therefore, we conclude that Dresden needs to clearly define their licensing basis for the new ECCS suction strainers.

In our review of Dresden's hydrodynamic loads, we were concerned about the 10% margin utilized in the determination of the strainer C_m. The determination of adequate margin must consider whether conservatism has been added into other aspects of the methodology. Specifically, the purpose of adding margin is to specifically account for uncertainty in the analysis method. In addition, margin is also added to account for the accuracy of the measurement equipment, errors in manufacturing, and the fact that the test or experiment may not completely model all parameters of the physical event simulated by the test. Based on our review of the Dresden strainer, we concluded that sufficient testing and analysis was performed by Duke/PCI, and that sufficient manufacturing expertise has been developed by Duke/PCI. In addition, we conclude that sufficient data has been obtained from testing various of the Duke/PCI strainer sizes that the 10% margin used in the Dresden C_m is sufficient to account for uncertainties in the analysis and assure that confidence is maintained in the design methodology.

While the staff's main concern was centered on the methodology used to calculate C_m, the staff was also interested in the value of the standard drag coefficient, C_d. Standard drag is generally considered to be small in comparison with C_m but it can represent about 10 percent of the combined load, C_m and C_d. During the audit, a ComEd staff member indicated that a value of 1.2 was used for the calculation of the standard drag load. This is consistent with the original acceptance criteria as approved in NUREG-0661. Therefore, the staff indicated that this is an acceptable value for use in calculating standard drag loads. However, we noted that this information was strictly verbal and not docketed in any form.

2.3 Suppression Pool/Strainer Cleanliness

Consistent with the requested actions of NRCB 95-02, Dresden has established a suppression pool cleaning program to ensure operability of the ECCS and to prevent the design basis for the new strainers from being exceeded. The program consists of a combination of inspection and cleaning activities. We reviewed Dresden's suppression pool/strainer cleanliness program to ensure that the program is adequate to maintain ECCS operability during normal operation.

Specifically, we interviewed the station personnel regarding the suppression pool cleanliness and reviewed selected procedures and work requests from the program including:

- Dresden's strainer inspection procedure (Dresden Procedure DTS 1600-36).
- Dresden's torus structure and coating inspection procedure (Dresden Procedure DTS 1600-11)
- Dresden's torus program for desludging of the torus.
- The suppression pool cleanliness program.

Our review of the Dresden suppression pool/ECCS strainer cleanliness program noted the following:

- Maintenance Rule: Dresden considers the strainers to be a part of the ECCS. Accordingly, this places the strainers within the scope of the Maintenance Rule (10CFR50.65). The licensee has taken a monitoring approach to the strainers and a preventative maintenance approach to the suppression pool. Specifically, Dresden conducts regular cleanings of the suppression pool and inspections of the ECCS suction strainers. Maintenance Rule goals have not been established for the strainers or the suppression pool because both of these components have been performing satisfactorily. The Maintenance Rule only requires that goals be established for structures, systems and components which do not perform satisfactorily.
- Surveillances: The ECCS pumps are tested quarterly to demonstrate operability. The suppression pool structure and coatings are inspected each refueling outage under Dresden procedure DTS 1600-11. The strainers are inspected every refueling outage under Dresden procedure DTS 1600-36.
- Suppression Pool Cleaning: The suppression pool is cleaned every refueling outage. Cleaning (desludging) of torus is accomplished via the preventative maintenance (PM) program.
- Preventative Maintenance Program: PM identification (ID) numbers 0000122840 for Dresden, Unit 3 (D3) and 0000122841 for Dresden, Unit 2 (D2) identify the requirements for conducting strainer inspections. Similarly, PM ID numbers 0000134165 (D2) and 0000134367 (D3) identify the requirements for desludging the torus, 0000093212 (D2) and 0000097774 (D3) for Coatings Inspections, and 0000137627 (D2) and 0000147256 (D3) for vent tube/centipede inspections. The PMs automatically generate work requests associated with these inspections and cleanings. We reviewed the following work requests from previous outages as examples of those generated by the PM system: work request (WR) 970075561-01 for desludging the torus, WR 970076164-01 for performing coating inspections of the drywell head and inside the torus, WR 970076164-02 for performing coating inspection of the drywell internals, WR 970080132-03 for ensuring the correct torque on the ECCS strainer bolts, WR 970083626-01 for foreign material inspections of the vent tubes and centipede, and WR 970114154-01 for inspecting the ECCS suction strainer cleanliness.
- Shutdown Risk: Dresden reviews the above maintenance activities prior to their performance to determine the effect on core damage frequency or shutdown risk.
- Configuration Control: Because of the tightness of their design (i.e., low NPSH margin, see Appendix B to this report), configuration control is critical for Dresden. They have changed the general work package specification K-4080, "Maintenance/Modification Work" to prevent replacement of RMI with fibrous insulation without going through the

engineering change process. This would require engineering to approve a change in the fibrous material inventory.

Staff Evaluation: Based on our review and interviews with Dresden's staff, we conclude that Dresden has a good focus on maintaining adequate cleanliness in the suppression pool, the drywell, and on the strainer surfaces. We also conclude that they have implemented appropriate programs and procedures to ensure operability of the ECCS strainers and availability of suppression pool water for ECCS injection during a LOCA. As noted above, Dresden also accounts for the impact of surveillances and maintenance activities on shutdown risk. We, therefore, conclude that Dresden has adequately addressed the issues raised in NRCB 95-02.

3.0 CONCLUSIONS

As shown by the audit team's confirmatory calculations, we believe that Dresden has adequately designed their ECCS strainers to withstand the high debris loads anticipated during a LOCA. In addition, they have implemented an appropriate inspection program to ensure the operability of the ECCS (relative to strainer and suppression pool cleanliness), and they have also implemented a suppression pool cleanliness program and foreign material control procedures to limit the potential for clogging the ECCS with materials brought into the drywell or wetwell during outage operations.

Their structural design is robust, and the strainer hydrodynamic loads were calculated using conservative assumptions. Dresden performed appropriate analyses to ensure the adequacy of the strainer structure and the support structure for the strainer and associated suction piping. Their analyses led to additional external gussets being added to support the piping penetrations.

We did, however, note some concerns which need to be addressed. As noted above, our confirmatory calculations have demonstrated that the Dresden strainers are adequately sized to perform their safety function. As such, we do not believe we have a safety concern with the design of the Dresden strainers. However, we have concluded that some of the analysis methods used by Dresden's contractor to size their strainers are inadequate. These methods are not consistent with the URG or the URG SER, and lack sufficient supporting data and or analysis to support their use. Based on our assessment of Dresden's analysis methods, we concluded that the results of these analyses could lead to erroneous conclusions in any future operability assessments which are based on these strainer sizing analyses. This is particularly important at Dresden because they have a low NPSH margin, and configuration control is, as a result, important to ensuring that they do not exceed the design basis of the strainers. Similarly, any future design modifications could also be jeopardized if the same analysis methods were used. Accordingly, we conclude that these concerns need to be resolved by Dresden.

A second concern noted by the audit team is that Dresden has inadequately defined their licensing basis. They have performed a number of parametric analyses demonstrating the performance capability of their strainer under different conditions, but have not defined which parametric case will be used as their licensing basis. This concern affects their bases for such things as configuration control and foreign material issues, and should be corrected. These issues were discussed with Dresden staff at the audit exit meeting and in subsequent phone conversations. It is our expectation that these concerns will be addressed via the Dresden corrective action program. A copy of this report will also be forwarded to Dresden.

Our specific concerns are described in greater detail in Appendix B to this audit report. We note that we have not identified these problems at any of the other sites where we have conducted our audits. The other audited plants all use different strainer designs than Dresden. In addition, we have reviewed NRCB 96-03 related submittals from other plants with PCI strainers which were submitted to the NRC to support the installations of new strainers (e.g., license amendments for suppression pool water inventory technical specification changes, or containment pressure credit in NPSH analyses). We did not identify the analysis methodology concerns cited above in our reviews of these other plants. As a result, we believe that the problem is plant-specific. It appears the analysis problems directly stem from the fact that Dresden completed the design and installation of their strainers before we completed our review of the URG. As a result, we conclude that there is no reason at this time to address these concerns on a more generic basis (e.g., additional audits or a temporary instruction for the NRC regional or resident inspectors).

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*See previous concurrences

DOCUMENT NAME: DRESDEN AUDIT REPORT FINAL.WPD

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APPENDIX A

AUDIT PLAN

Implementation of NRC Bulletin 96-03 Resolutions

Applicability: The staff plans to audit the following sites:

1- Duane Arnold (Mark I, GE Bolt-on, NUKON Fibrous Insulation)
2- Dresden (Mark I, PCI Bolt-on, RMI Insulation)
3- Limerick (Mark II, ABB, NUKON Fibrous Insulation)
4- Grand Gulf (Mark III, Enercon, Calcium Silicate and Kaowool Insulation)

After performing the above audits, the staff will evaluate the need for additional audits. If additional audits are needed, the staff would most likely select from the following plants:

- Susquehanna (Mark II, GE Bolt-on, RMI)
- Fitzpatrick (Mark I, PCI Ring Girder, Various Fibrous Insulations)
- Peach Bottom (Mark I, ABB, NUKON Fibrous Insulation)
- Perry (Mark III, Enercon, NUKON Fibrous Insulations)

The choice of any additional plants to be audited will be assessed by the staff based on findings from the initial four audits. If the initial audits identify any safety issues, then additional sites may be selected to determine if the issues are vendor-specific, plant-specific, or generic in nature.

Objective: To verify the implementation of NRC Bulletin 96-03 (NRCB 96-03), "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris." Specifically, the staff will:

1) assess the adequacy of licensee resolutions,
2) identify if additional evaluation of licensee resolutions through the NRC inspection program is necessary, and
3) if additional inspection effort is needed, identify areas to be inspected and guidance needed to support inspection effort (i.e., a Temporary Instruction).

Background: On July 28, 1992, an event occurred at Barsebäck Unit 2, a Swedish boiling-water reactor (BWR), which involved the plugging of two containment vessel spray system (CVSS) suction strainers. The strainers were plugged by mineral wool insulation that had been dislodged by steam from a pilot-operated relief valve that spuriously opened while the reactor was at 435 psig. Two of the three strainers on the suction side of the CVSS pumps that were in service became partially plugged with mineral wool. Following an indication of high differential pressure across both suction strainers 70 minutes into the event, the operators shut down the CVSS pumps and backflushed the strainers. The Barsebäck event demonstrated that the potential exists for a pipe break to generate insulation debris and transport a sufficient amount of the debris to the suppression pool to clog the ECCS strainers.

Similarly, on January 16 and April 14, 1993, two events involving the clogging of emergency core cooling system (ECCS) strainers occurred at the Perry Nuclear Power Plant, a domestic BWR. In the first Perry event, the suction strainers for the residual heat removal (RHR) pumps became clogged by debris in the suppression pool. The second Perry event involved the deposition of filter fibers on these strainers. The debris consisted of glass fibers from temporary drywell cooling unit filters that had been inadvertently dropped into the suppression pool, and corrosion products that had been filtered from the pool by the glass fibers which accumulated on the surfaces of the strainers. The Perry events demonstrated the deleterious effects on strainer pressure drop caused by the filtering of suppression pool particulates (corrosion products or “sludge") by fibrous materials adhering to the ECCS strainer surfaces. This sludge is typically present in varying quantities in domestic BWRs, since it is generated during normal operation. The amount of sludge present in the pool depends on the frequency of pool cleaning/desludging conducted by the licensee.

On September 11, 1995, Limerick Unit 1 was being operated at 100-percent power when control room personnel observed alarms and other indications that one safety relief valve (SRV) was open. The licensee implemented emergency procedures. Attempts by the reactor operators to close the valve were unsuccessful, and a manual reactor scram was initiated. Prior to the opening of the SRV, the licensee had been running the "A" loop of suppression pool cooling to remove heat being released into the pool by leaking SRVs. Shortly after the manual scram, and with the SRV still open, the "B" loop of suppression pool cooling was started. The reactor operators continued their attempts to close the SRV and reduce the cooldown rate of the reactor vessel. Approximately 30 minutes later, operators observed fluctuating motor current and flow on the "A" loop of suppression pool cooling. Cavitation was believed to be the cause, and the loop was secured. After it was checked, the "A" pump was successfully restarted and no further problems were observed. After the cooldown following the blowdown event, the licensee sent a diver into the Unit 1 suppression pool to inspect the condition of the strainers and the general cleanliness of the pool. The diver found that both suction strainers in the "A" loop of suppression pool cooling were found to be almost entirely covered with a thin "mat" of material, consisting mostly of fibers and sludge. The "B" loop suction strainers had a similar covering, but less of it. Analysis showed that the sludge primarily consisted of iron oxides and the fibers were polymeric in nature. The source of the fibers was not positively identified, but the licensee has determined that the fibers did not originate within the suppression pool, and contained no trace of either fiberglass or asbestos. This event at Limerick demonstrated the need to ensure adequate suppression pool cleanliness. In addition, it re-emphasized that materials other than fibrous insulation could clog strainers.

In response to the Limerick event, the staff issued NRCB 95-02, "Unexpected Clogging of Residual Heat Removal (RHR) Pump Strainer While Operating in Suppression Pool Cooling Mode," on October 17, 1995. The bulletin requested that licensees (1) assess the operability of their ECCS on the basis of the cleanliness of their suppression pool and ECCS strainers, (2) verify the operability of the ECCS through an appropriate pump test and strainer inspection within 120 days from the date of the bulletin, (3) establish a pool cleaning program, (4) review their foreign material exclusion (FME) practices and correct any identified weaknesses, and (5) implement any additional appropriate measures for ensuring the availability of the ECCS.

Title 10, Section 50.46 of the *Code of Federal Regulations* (10 CFR 50.46) requires that licensees design their ECCS systems to meet five criteria, one of which is to provide long-term cooling capability following a successful system initiation for a sufficient duration so that the core temperature is maintained at an acceptably low value and decay heat is removed for the extended period of time required by the long-lived radioactivity remaining in the core. The ECCS is designed to meet this criterion, assuming the worst single failure. However, experience gained from operating events and detailed analyses has demonstrated that excessive buildup of debris from thermal insulation, corrosion products, and other particulates on ECCS pump strainers is highly likely to occur. This creates the potential for a common-cause failure of the ECCS, which could prevent the ECCS from providing long-term cooling following a LOCA. The staff has concluded, therefore, that licensees must take adequate steps to prevent strainer clogging in order to ensure compliance with the regulations.

As a result, NRCB 96-03 was issued on May 6, 1996, requesting BWR licensees to implement appropriate procedural measures and plant modifications to minimize the potential for clogging of ECCS suppression pool suction strainers by debris generated during a LOCA. Regulatory Guide 1.82, Revision 2, (RG 1.82) was issued in May 1996 to provide non-prescriptive guidance on performing plant-specific analyses to evaluate compliance with 10CFR50.46. On November 20, 1996, the Boiling Water Reactor Owners Group (BWROG) submitted NEDO-32686, "Utility Resolution Guidance for ECCS Suction Strainer Blockage" (also known as the URG) to the staff for review. The purpose of the URG is to give boiling-water reactor (BWR) licensees guidance for complying with the requested actions of NRCB 96-03. The staff approved the URG in an safety evaluation report (SER) dated August 20, 1998. In response to NRCB 96-03, all affected BWR licensees have installed (or will install during their next refueling outage) new large-capacity passive strainers to resolve the issue. These installations have typically been conducted under 10CFR50.59 with the licensees concluding that no unreviewed safety question exists due to the installation of the new strainer designs. As a result, no detailed review of licensee resolutions for this issue has been performed by the staff. Therefore, the staff will conduct 4-6 plant audits to verify implementation prior to closing out the generic issue for BWRs.

Audit Requirements: The following analyses and programs will be included in the audit scope:

1) the licensee’s 50.59 safety evaluation,
2) the licensee’s plant-specific analyses performed in response to NRCB 96-03,
3) the licensee’s strainer performance and design calculations, and
4) the licensee’s ongoing suppression pool cleanliness program (NRCB 95-02).

Audit Guidance

1) Licensee’s 50.59 safety evaluation

Purpose: to perform a technical review to ensure that implementation of the strainer resolution did not create new safety concerns (e.g., hydrodynamic loads), as well as to ensure that the licensee’s safety evaluation is sufficiently comprehensive to ensure that no additional safety concerns were caused by the strainer resolution.

Specifically, the auditor will review the licensee’s 10CFR50.59 safety evaluation performed in response to its NRCB 96-03 resolution to assess the:

- affect of any changes to strainer hydrodynamic load calculations on plant safety
- affect of the increased strainer size (and associated supporting structure) on suppression pool inventory/accident analyses
- adequacy of scope of resolution (e.g., is change only required to low pressure ECCS pumps)
- potential for new failures not previously evaluated being created by the resolution
- potential for an increase in the probability of a failure previously evaluated

The staff will perform a technical review of the 10CFR50.59 safety evaluation to confirm that the licensee’s resolution adequately addressed the potential impacts of the new strainer design on plant safety.

2) Plant-specific analyses performed in response to NRCB 96-03

Purpose: Evaluate plant-specific application of the URG in plant analyses to determine if the calculated strainer debris loadings are appropriate.

Specifically, the auditor will review the licensee’s plant-specific strainer analyses:

- to assess the overall application of the URG to the plant
- to confirm consistent interpretation of the URG and the staff’s SER
- to evaluate licensee analyses of areas where the URG did not provide detailed guidance (e.g., evaluation of debris generation and transport inside the bio-shield wall)

Limited confirmatory calculations will be performed, as necessary, to confirm consistency in the application of the URG methodologies.

3) Strainer performance and design calculations

Purpose: To confirm that the strainer has been adequately designed and constructed to meet its safety function.

Specifically, the auditor will review the licensee’s strainer design calculations to confirm:

- the adequacy of the licensee’s basis for determining their strainer head loss
- the adequacy of the licensee’s basis for calculation of their NPSH margin
- the adequacy of the strainer structural design and construction (e.g., ASME code requirements)

In addition, the auditor will compare calculated clean strainer head losses with results of post-implementation testing performed by the licensee.

4) Ongoing suppression pool cleanliness program (NRCB 95-02)

Purpose: To confirm that the licensee's program to ensure appropriate levels of suppression pool and ECCS suction strainer cleanliness is adequate to ensure operability of the ECCS.

Specifically, the auditor will review the licensee's suppression pool cleanliness program to confirm:

- the licensee has established an adequate suppression pool cleaning program including:
  1) procedures to evaluate pool cleanliness
  2) criteria for cleaning pool/strainers
  3) frequency of pool evaluation and cleaning
  4) basis for cleaning frequency and criteria
- the licensee has established adequate administrative controls on the program (e.g., included in the plant maintenance program)

The appendices to this audit plan (not included herein) provide spreadsheets detailing the specific information which will be evaluated by the auditors. The auditors will review plant drawings, calculations, strainer specification and other design documentation, as appropriate. The licensee's documentation will be used to fill in the attached spreadsheets. Confirmatory calculations will be performed by the team as shown on the spreadsheets. The completed spreadsheets will be included in the trip report for each plant.

Reporting Requirements: The results of this audit will be documented in a routine trip report. The trip report will be addressed to the Director, Division of Systems Safety and Analysis, NRR (mail stop O-8E2). A copy of the trip report will be forwarded to the Project Manager for the audited plant. A summary report of the staff's findings on all the audits will be published following completion of the audits.

Completion Schedule: These audits should be completed by May 31, 1999.

Contact: Questions regarding this audit plan should be directed to Rob Elliott at 301-415-1397.

Statistical Data Reporting: Hours expended for this audit, including preparation time, should be reported under TAC number MA0704.

Originating Organization Information

Organization Responsibility: This audit plan was initiated by the Containment Systems and Severe Accident Branch (SCSB).

Resource Estimate: It is estimated that each audit will require approximately 240 hours per audit (120 hours per auditor, with two NRR representatives on each audit). The staff estimates approximately 40 hours at each audit site.

Other: It is anticipated that each audit team will consist of two members of SCSB and two contractor personnel.

Training: No specific training is associated with this audit.

References:

NRC Bulletin 93-02, “Debris Plugging of Emergency Core cooling Suction Strainers,” dated May 11, 1993.

NRC Bulletin 93-02, Supplement 1, “Debris Plugging of Emergency Core cooling Suction Strainers,” dated February 18, 1994.

NUREG/CR-6224, “Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris,” dated October 1995.

NRC Bulletin 95-02, "Unexpected Clogging of Residual Heat Removal (RHR) Pump Strainer While Operating in Suppression Pool Cooling Mode," dated October 17, 1995.

NRC Bulletin 96-03, “Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors,” dated May 6, 1996.

Regulatory Guide 1.82, Revision 2, “Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident,” dated May 1996.

GL 97-04, “Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps,” dated October 7, 1997.

APPENDIX B

Los Alamos Technical Evaluation Report

ON-SITE AUDIT OF DRESDEN NUCLEAR POWER PLANT EMERGENCY CORE COOLING SYSTEM STRAINER BLOCKAGE RESOLUTION