October 18, 2001

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SUBJECT: COMPLETION OF STAFF REVIEWS OF NRC BULLETIN 96-03, "POTENTIAL PLUGGING OF EMERGENCY CORE COOLING SUCTION STRAINERS BY DEBRIS IN BOILING-WATER REACTORS," AND NRC BULLETIN 95-02, "UNEXPECTED CLOGGING OF A RESIDUAL HEAT REMOVAL (RHR) PUMP STRAINER WHILE OPERATING IN SUPPRESSION POOL COOLING MODE" (TAC NUMBER MA0704)

The purpose of this memorandum is to document the closure of multi-plant actions (MPAs) X603 and X502 associated with our review of NRC Bulletin (NRCB) 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors," and NRCB 95-02, "Unexpected Clogging of a Residual Heat Removal (RHR) Pump Strainer While Operating in Suppression Pool Cooling Mode." These two bulletins are related because they both deal with emergency core cooling system (ECCS) suction strainers and ensuring that debris does not clog the strainers preventing the ECCS from performing its safety function. We have concluded that all licensees have sufficiently responded to the requested actions of NRCB 95-02 and NRCB 96-03. As such, the generic and plant specific activities associated with the review of these bulletins are complete. One open issue on hydrodynamic loads remains related to the staff's review of the General Electric (GE) topical report on strainer design. GE intends to revise their topical report and resubmit it to the staff. This review will continue under the topical report TAC number.

Background: The staff first addressed ECCS clogging issues in detail during its review of Unresolved Safety Issue (USI) A-43, "Containment Emergency Sump Performance." The resolution of USI A-43 is documented in Generic Letter (GL) 85-22, "Potential for Loss of Post-LOCA Recirculation Capability due to Insulation Debris Blockage," dated December 3, 1985. The staff concluded at that time that no new requirements would be imposed on licensees. During the 1990's, however, new information arose which challenged the adequacy of the NRC's conclusion that no new requirements were needed to prevent clogging of ECCS strainers in boiling-water reactors (BWRs). In July 1992, an event occurred at Barsebäck, Unit 2, a Swedish BWR, that involved the clogging of two containment vessel spray system (CVSS) suction strainers. The strainers were clogged by insulation that had been dislodged by steam from a safety relief valve (SRV) that spuriously opened. Two of the three strainers on the suction side of the operating CVSS pumps became partially clogged with insulation. The Barsebäck event demonstrated the potential for a pipe break to generate and transport a sufficient amount of the debris to the suppression pool to clog the ECCS strainers.

Similarly, in 1993, two events involving the clogging of ECCS strainers occurred at the Perry Nuclear Power Plant, a domestic BWR. Both Perry events involved clogging of the residual heat removal (RHR) pump suction strainers by debris in the suppression pool. The debris consisted of glass fibers and corrosion products (or "sludge") that had been filtered from the pool by the glass fibers that had accumulated on the strainer. The Perry events demonstrated the deleterious effects on strainer pressure drop caused by the filtration of particulates by fibrous materials adhering to the strainer surface, a previously unrecognized effect.

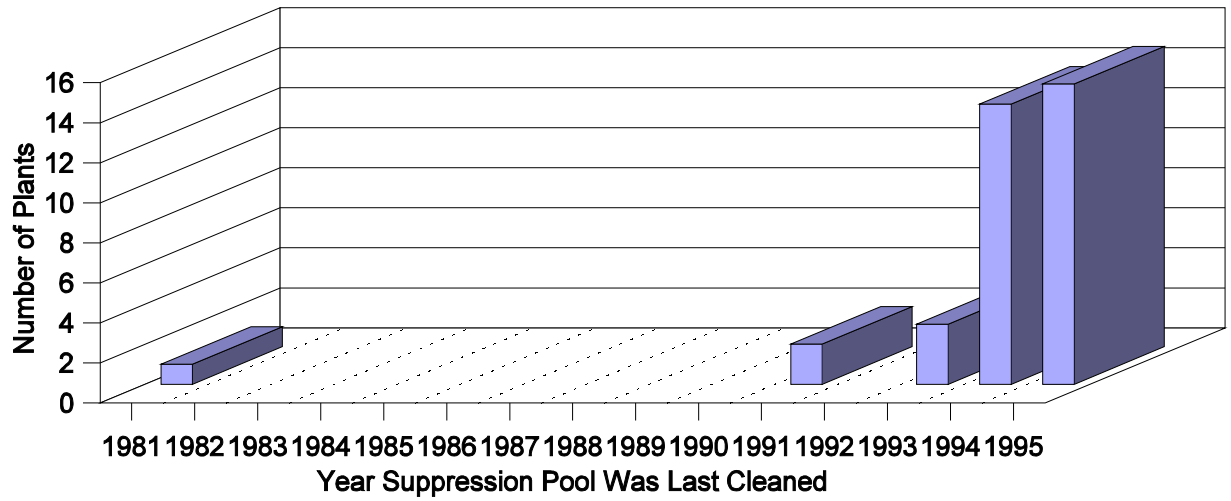
The Barsebäck and Perry events led to the development of NRCB 96-03. The draft of NRCB 96-03 was released for a 60 day public comment on July 31, 1995 (*Federal Register*, Volume 60, No. 146, Page 39021). During the public comment period, NRC staff resources were diverted from NRCB 96-03 to the development of NRCB 95-02 due to an event at Limerick Generating Station, Unit 1. On September 11, 1995, Limerick Unit 1 was operating at 100 percent power when one SRV spuriously opened. Operators were unable to close the SRV, and a manual reactor scram was initiated. During the event, two loops of of suppression pool cooling were operated to remove heat being released into the pool. During the event, operators observed fluctuating motor current and flow on the "A" loop of suppression pool cooling. Cavitation was the apparent cause, and the loop was secured. The "A" pump was checked and successfully restarted with no further problems observed. Following the event, a diver inspected the condition/cleanliness of the strainers and suppression pool. The diver found both "A" loop strainers almost entirely covered with a thin mat of debris, consisting mostly of fibers and sludge. The "B" loop strainers had a similar covering, but less of it. Analysis showed that the mat primarily consisted of iron oxides and polymeric fibers. The fiber source was not identified, but the licensee determined that they did not originate within the suppression pool, and contained no trace of either fiberglass or asbestos. This event demonstrated the importance of foreign material exclusion (FME) practices to ensure adequate suppression pool cleanliness. In addition, it re-emphasized that materials other than fibrous insulation could clog strainers.

NRCB 96-03 was issued on May 6, 1996. It requested BWR licensees to implement appropriate procedural measures and plant modifications to minimize the potential for clogging of ECCS suction strainers by debris generated during a LOCA. Regulatory Guide 1.82, Revision 2,
(RG 1.82), "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," was also issued to provide guidance on plant-specific analyses to evaluate the ability of the ECCS to provide long-term cooling consistent with the requirements of 10 CFR 50.46.

Evaluation of Responses to NRCB 95-02: On October 17, 1995, we issued NRCB 95-02 to all holders of BWR operating licenses or construction permits. It was issued because the staff was concerned that BWR licensees had inadequately maintained suppression pool cleanliness. The concern arose out of the Limerick event described above because prior to the event, Limerick had never cleaned the Unit 1 suppression pool. Some of the debris that clogged their strainers had apparently been left in the pool during plant construction. Clearly, debris in the suppression pool threatened the ability of the pumps drawing suction from the suppression pool to adequately perform their safety functions. NRCB 95-02 was specifically issued to:

1- Alert addressees to complications experienced during the Limerick event.
2- Request addressees to assess the operability of their ECCS and other pumps that draw suction from the suppression pool to perform their safety function on the basis of suppression pool/suction strainer cleanliness, and the effectiveness of the addressee's FME practices. In addition, addressees were requested to implement appropriate procedural modifications and other actions (e.g., suppression pool cleaning), as necessary, to minimize foreign material in the suppression pool and containment. Addressees were requested to verify their operability evaluation through appropriate testing and inspection.
3- Require that addressees report to the NRC whether and to what extent they complied with the requested actions. A second report was required upon completion of confirmatory test(s) and inspection(s) to provide the test results, verify that addressees have complied with the requested actions, or indicate completion of any proposed alternative actions.

Figure 1: NRCB 95-02 Responses on Last Suppression Pool Cleaning



Addressees were requested to respond to the NRCB 95-02 within 30 days. We received responses for 37 BWRs. The Containment Systems and Severe Accident Branch (SCSB) performed an initial screening of all responses. Figure 1 summarizes the bulletin responses as to when licensees had last cleaned their suppression pools (as of the date of their initial responses to NRCB 95-02).

Figure 1 clearly shows that BWR licensees had, in fact, been cleaning their suppression pools. One exception was Nine Mile Point, Unit 1 (NMP-1). Figure 1 does not include Big Rock Point because their design does not have a suppression pool, and Browns Ferry, Unit 1, who was in an extended shutdown at the time of their response. Tennessee Valley Authority (TVA), the licensee for Browns Ferry, stated in their response that they would address the bulletin issues for Unit 1 before restarting the plant.

SCSB performed detailed reviews of 11 plants, including NMP-1 and wrote safety evaluations on those responses. Since no safety issues were identified in either the preliminary or the detailed reviews, and it was learned that utilities had been cleaning their suppression pools, SCSB redirected its resources into the completion of NRCB 96-03. The lead project manager (PM) for NRCB 95-02 began conducting the rest of the NRCB 95-02 reviews. He and other PMs from the Division of Licensing Project Management (DLPM) completed an additional 21 reviews leaving five plants currently open. These plants are Grand Gulf, Perry, Fitzpatrick, and Hatch 1 and 2.

We have concluded that it is appropriate to close this MPA and the remaining five open TACS without further review for the following reasons:

1- Over 85% of the BWRs have been reviewed in detail with no safety concerns identified.
2- Of the five remaining plants, I have visited two (Perry and Grand Gulf), and personally inspected their suppression pools. I found both pools to be extremely clean. In both cases, I could clearly see the bottom of the pool, the strainers, and other suppression pool structures from the catwalk. I was unable to identify any foreign material in either pool.
3- As part of the review of NRCB 96-03, a detailed audit of Grand Gulf was performed including FME procedures. The audit team concluded that Grand Gulf has implemented an appropriate inspection program to ensure the operability of the ECCS (relative to strainer and suppression pool cleanliness). They have also implemented appropriate foreign material control procedures to limit the potential for clogging the ECCS with materials brought into the drywell or wetwell during outage operations.
4- Temporary Instruction (TI) 2515/125, “Foreign Material Exclusion Controls,” was issued on August 25, 1994 to determine whether licensees have implemented effective procedures to prevent foreign material from inadvertently entering safety systems during maintenance activities, outages, and routine operations. After reviewing the FME controls at Fitzpatrick and Hatch in response to TI 2515/125, resident inspectors for both plants concluded that the licensees’ FME controls were adequate. In addition, the resident inspector for Hatch stated that a recent inspection of the Unit 1 torus did not identify any significant debris.

In general, our review found that the concerns raised by the events at Barsebäck and Perry, and the NRC’s focus on strainer issues, had raised awareness of foreign material issues among BWR licensees. This heightened awareness resulted in increased attention being given to suppression pool cleanliness even before the issuance of the bulletin. This is evidenced by the fact that most of the plants had cleaned their suppression pools within the three years prior

to the bulletin. Limerick had already cleaned the Unit 2 suppression pool prior to the Unit 1 event, and Unit 1 was scheduled for cleaning at the next refueling outage at the time of the event. Only NMP-1 had not cleaned their suppression pool, and they committed to do so at the next outage of sufficient duration in response to the bulletin. It should not be construed that NMP-1 had any less sensitivity to the issue than the other BWR licensees. Their analysis of their own plant led them to conclude that they did not need to clean their pool again. In 1981, they had drained and cleaned the entire torus. Since then, they have minimized any potential to introduce debris into the torus. Any items inadvertently dropped by workers into the torus pool were retrieved by divers. NMP-1 uses mostly reflective metallic insulation (RMI), and therefore, NMP-1 concluded that they were not likely to introduce fibrous material into the torus during outages. On this basis, they had concluded that there was no need to clean their torus again. However, as noted above, they committed to do so in response to NRCB 95-02.

Evaluation of Responses to NRCB 96-03: As noted above, following the issuance of NRCB 95-02 and initial review of the responses, SCSB redirected its effort into the completion and issuance of NRCB 96-03. The public comments were resolved and the bulletin was issued on May 6, 1996. Specifically, we issued NRCB 96-03 to request addressees 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. The bulletin identified three resolution options. These options were to install one of the following: a large capacity passive strainer design, a self-cleaning strainer design, or a backflush system. All addressees were required to submit the following written reports:

1- Within 180 days of the date of the bulletin, a report indicating whether the addressee intended to comply with the requested actions. This report was to include a description of planned actions and mitigative strategies to be used, the implementation schedule, and any proposed technical specifications (TS). If a licensee did not intend to comply with these actions, a detailed description of the safety basis for their decision was required. A detailed description of a licensee's plan of action was only required if an alternative course of action was proposed. The detailed description for any proposed alternative action was to include the schedule, safety basis, and any proposed TS.

2- Within 30 days of completion of all requested actions, a report confirming completion and summarizing any actions taken.

Table 1 summarizes the actions taken by each licensee. All licensees installed option 1, large capacity passive strainer designs. Four different vendor designs were utilized: the GE stacked disk strainer design, the Performance Contracting, Inc. "Sure-Flow" stacked disk strainer design, the Enercon toroidal strainer, and the Asea Brown-Boveri (ABB) strainer design. Total installed strainer surface area per plant are also shown on Table 1.[1]

At the time of the issuance of the bulletin, the BWROG was developing topical report NEDO-32686, "Utility Resolution Guidance for ECCS Suction Strainer Blockage" (the URG). The purpose of the URG is to provide utilities with (1) guidance on evaluation of the ECCS

[1] For most cases, the surface areas shown in table 1 are for the low pressure systems only. Some plants replaced the high pressure strainers also, but these surface areas are not included in this table. However, for the toroidal strainers, the total surface area shown does include the high pressure systems also.

potential strainer clogging issue for their plant, (2) a standard industry approach to resolution of the issue that is technically sound, and (3) guidance that is consistent with the requested actions in this bulletin for demonstrating compliance with 10 CFR 50.46. The URG included guidance on a calculational methodology for performing plant-specific evaluations of potential strainer blockage. The staff stated in NRCB 96-03 that it considered the URG to be an important part of the implementation of the final resolution of this issue. On November 20, 1996, the BWROG submitted the URG to the NRC for review. The staff approved the URG in a safety evaluation report dated August 20, 1998. In response to NRCB 96-03, all affected BWR licensees have designed their new large-capacity passive strainers consistent with the criteria in the approved URG.

As indicated above, the staff considered the URG to be a very important part of the strainer issue resolution. During the development of NRCB 96-03, we decided not to perform detailed reviews of every plant. As a result, the reporting requirements for the bulletin do not contain detailed descriptions of licensees' proposed resolutions. Instead, the staff developed a strategy for reviewing the implementation of NRCB 96-03 requested actions via a generic review combined with a sampling of plants. Specifically, the staff first reviewed the URG. The approval of the URG provided a baseline evaluation process for determining how much strainer area was needed for each plant. The second component of the staff's review included detailed audits of four sites to ensure that the application of the URG guidelines was consistent with the staff's basis for approval of the URG.

The staff conducted audits of four sites: Limerick Generating Station, Units 1 and 2; Dresden Nuclear Power Station, Units 2 and 3; Duane Arnold Energy Center; and Grand Gulf Nuclear Station. The reports for each site audit are available in ADAMS. The accession numbers are ML003684437 for Limerick, ML010930074 for Dresden, ML012610017 for Duane Arnold, and ML012560213 for Grand Gulf. The results of these audits showed that these licensees had adequately designed their ECCS strainers to withstand the high debris loads anticipated during a LOCA. No safety concerns were identified at any of the plants. On the basis of the audit findings and results of the staff's review of the URG, we do not consider it necessary to perform any additional detailed reviews of licensee resolutions.

In addition to the review work cited above, the staff performed a number of additional plant reviews related to the strainer clogging resolution. These reviews were not originally planned as part of the review work for NRCB 96-03, but were necessary to support achieving a timely resolution to the strainer blockage issue. Specifically, a number of plants requested review of their plant-specific strainer sizing criteria because they were planning to procure or install new strainers prior to the anticipated approval of the URG. The staff reviewed the information provided by these licensees and provided safety evaluations. Other licensees requested license amendments related to the use of containment pressure credit in their ECCS NPSH calculations. As part of these license amendment reviews, the staff reviewed the strainer sizing criteria and strainer performance characteristics, and performed confirmatory calculations to verify the amount of containment pressure credit requested is appropriate. Safety evaluations were also prepared in support of these license amendments. Still other licensees requested public meetings with the staff to share the details of their proposed resolutions, and to solicit staff feedback. A couple of licensees also invited the staff to visit their plant. Table 1 details the level of NRC review each plant received.

A large amount of work was performed by both the staff and the industry in support of the

resolution of this issue. This work included numerous test programs, both by the NRC and the industry. The attachment to this memorandum is Los Alamos National Laboratory (LANL) Report LA-UR-01-1595, “BWR ECCS Strainer Blockage Issue: Summary of Research and Resolution Actions,” dated March 21, 2001. This report summarizes the efforts of the NRC, the NRC’s contractors, and the industry to resolve the BWR ECCS strainer clogging issue.

Table 1: Summary of Strainer Modifications Made in Response to NRCB 96-03

Plant Name, Plant Type and Containment Type	**Stacked Disk Strainer Designs**			Other Strainer Design	Type of Review Performed by the Staff	Approximate Total Strainer Area (Ft^2) per Plant	Strainer Vendor
	Bolt-on	Supplemental Supports	Ring Girder Mounted				
Browns Ferry 2 & 3 BWR/4, Mark I	X				1,2,5	1192	GE
Brunswick 1 & 2 BWR/4, Mark I	X	X			1,4	1575	PCI
Clinton BWR/6, Mark III				Toroidal	1	6057	Enercon
Cooper BWR/4, Mark I	X				1,7	2164	GE
Dresden 2 & 3 BWR/3, Mark I	X				1,6	475	PCI
Duane Arnold BWR/4, Mark I	X				1,6	1359	GE
Fitzpatrick BWR/4, Mark I			X		1,2	2928	PCI
Fermi 2 BWR/4, Mark I	X				1	2322	GE
Grand Gulf BWR/6, Mark III				Toroidal	1,2,6	6253	Enercon
Hatch 1 & 2 BWR/4, Mark I	X				1,3	1110	GE
Hope Creek BWR/4, Mark I			X		1,3	3788	PCI
LaSalle 1 & 2 BWR/5, Mark II	X				1,2	500	PCI
Limerick 1 & 2 BWR/4, Mark I				X	1,6	2715	ABB
Monticello BWR/3, Mark I			X		1,7	1224	PCI
NMP-1 BWR/2, Mark I			X		1	1286	PCI
NMP-2 BWR/4, Mark II	X				1	1412	GE
Oyster Creek BWR/2, Mark I	X				1,3	1425	GE
Peach Bottom 2 & 3 BWR/4, Mark I				X	1,2,3	3550	ABB
Perry BWR/6, Mark III				Toroidal	1,2,7	5326	Enercon

Plant Name, Plant Type and Containment Type	**Stacked Disk Strainer Designs**			Other Strainer Design	Type of Review Performed by the Staff	Approximate Total Strainer Area (Ft^2) per Plant	Strainer Vendor
	Bolt-on	Supplemental Supports	Ring Girder Mounted				
Pilgrim BWR/3, Mark I			X		1,2,5,7	1340	PCI
Quad Cities 1 & 2 BWR/3, Mark I	X				1,2,5	832	PCI
River Bend BWR/6, Mark III	X	X			1,2	2424	GE
Susquehanna 1 & 2 BWR/4, Mark II	X				1	1340	GE
Vermont Yankee BWR/4, Mark I			X		1,2	2488	PCI
WNP-2 BWR/5, Mark II	X				1	825	PCI

Key for Type or Review Performed by the Staff

1) Review of licensee response to NRCB 96-03 only.
2) Meeting with licensee to discuss licensee's proposed resolution and strainer sizing criteria.
3) Review of strainer sizing criteria including performance of confirmatory calculations of estimated debris loadings.
4) Review of strainer sizing criteria and strainer performance characteristics (i.e., head loss), including performance of confirmatory calculations.
5) Review of strainer sizing criteria and strainer performance characteristics, including performance of confirmatory calculations in support of license amendment for containment pressure credit in NPSH calculations.
6) Detailed audit of plant resolution of the strainer blockage issue.
7) Site visit.

As can be seen from Table 1, the staff performed significantly more plant-specific review work than the original planned four site audits. In general, our overall conclusions are that the industry has done an outstanding job in achieving resolution of the strainer clogging issue. Only four sites installed less than 1100 ft^2 of strainer area. These four sites use primarily reflective metallic insulation (RMI), and have very little fibrous insulation in containment. RMI without the presence of fibrous materials has a significantly lower impact on head loss compared to fibrous insulation and sludge debris beds. Our reviews have also found that licensees have designed their strainers conservatively, adding additional margin to account for uncertainties and any potential problems that may be identified in the future (e.g., coatings)

Conclusion: On the basis of efforts described above, we have concluded that all licensees have sufficiently responded to the requested actions of NRCB 95-02 and NRCB 96-03. No further review activity is required. As such, the generic and plant specific review activities associated with these reviews are complete. This concludes our efforts on generic TAC Number MA0704.

Attachment: As stated

Conclusion: On the basis of efforts described above, we have concluded that all licensees have sufficiently responded to the requested actions of NRCB 95-02 and NRCB 96-03. No further review activity is required. As such, the generic and plant specific review activities associated with these reviews are complete. This concludes our efforts on generic TAC Number MA0704.

Attachment: As stated

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