



UNITED STATES
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MEMORANDUM TO: Jennivine Rankin, Acting Branch Chief
Licensing Branch 3
Division of Licensing, Siting, and Environmental Analysis
Office of New Reactors

FROM: Adrian Muñiz, Project Manager /RA/
Licensing Branch 3
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Office of New Reactors

SUBJECT: REGULATORY AUDIT RESULTS SUMMARY REPORT –
EMERGENCY CORE COOLING SYSTEMS SUCTION STRAINER
DESIGN FOR THE ADVANCED BOILING-WATER REACTOR DESIGN
CERTIFICATION RENEWAL

Enclosed is the U.S. Nuclear Regulatory Commission staff's Emergency Core Cooling System (ECCS) suction debris strainer design audit report regarding the GE Hitachi (GEH) Advanced Boiling-Water Reactor design certification renewal application (Docket No. 52-045).

This audit was completed remotely using the GEH electronic reading room. The staff examined documentation supporting the proposed ECCS suction debris strainer design and conducted phone conferences with the applicant for clarification of information as part of the staff audit activities.

Docket No. 52-045

Enclosure:
As stated

cc w/encl: See next page

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SUBJECT: REGULATORY AUDIT RESULTS SUMMARY REPORT – EMERGENCY CORE
COOLING SYSTEMS SUCTION STRAINER DESIGN FOR THE ADVANCED
BOILING-WATER REACTOR DESIGN CERTIFICATION RENEWAL

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***via email NRO-002**

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**U.S. NUCLEAR REGULATORY COMMISSION REGULATORY AUDIT SUMMARY REPORT:
GE HITACHI U.S. ADVANCED BOILING-WATER REACTOR DESIGN CERTIFICATION
RENEWAL EMERGENCY CORE COOLING SYSTEM STRAINER DESIGN**

Docket No. 52-045

APPLICANT: General Electric Hitachi (GEH)

LOCATION: U.S. Nuclear Regulatory Commission (NRC) Headquarters by using documents uploaded to the GE Electronic Reading Room (eRR)

DURATION: February 21, 2017 – June 20, 2017

AUDIT TEAM: Harry Wagage, Senior Reactor Engineer, NRC
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1. OBJECTIVE

The objective of the audit is to supplement the NRC staff review of the GEH U.S. Advanced Boiling-Water Reactor (ABWR) Emergency Core Cooling System (ECCS) suction debris strainer design by allowing the reviewers to gain a better understanding of the supporting calculations and other related documents referenced in the GEH evaluation. Review guidance is provided in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition" Section 6.2.2, Revision 5, Standard Review Plan (SRP) Section 6.3, Revision 3, as well as in NRC Regulatory Guide (RG) 1.82, "Water Sources for Long-Term Recirculation Cooling following A Loss-of-Coolant Accident," Revision 4.

2. BACKGROUND

On December 7, 2010, GEH applied to the NRC for the renewal of the ABWR standard plant design certification (DC), which the NRC had issued on June 11, 1997. Because of lessons learned from boiling-water reactor (BWR) operating experience and from the review of Generic Safety Issue -191, "Assessment of [Effect of] Debris Accumulation on PWR Sump Performance," the staff issued requests for additional information (RAIs) to evaluate compliance of the ECCS

Enclosure

design with Title 10 of the *Code of Federal Regulations* (10 CFR) 50.46(b)(5). The staff incorporated these lessons learned into revisions of RG 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident" (Reference 2).

As part of its review, the staff issued RAI 06.03-2, dated December 15, 2015. This RAI focused on the design of the strainer, the analysis for potential chemical precipitates in the debris source term, and long-term cooling of the reactor core. The applicant responded in a letter dated May 27, 2016 (Reference 6), and in revised responses, dated December 19, 2016 (Reference 7), and February 23, 2017 (Reference 10). The staff determined that an audit was needed in order to examine GEH's internal documentation supporting the information provided by GEH in the documents mentioned above.

3. REGULATORY AUDIT BASIS

The audit is based on the following regulatory requirements:

- 10 CFR Part 52, Appendix A, "Design Certification Rule for the U.S. Advanced Boiling Water Reactor."
- 10 CFR 52.47, "Contents of applications; technical information,"
- 10 CFR 52.57, "Application for renewal"
- 10 CFR 52.59, "Criteria for renewal"
- 10 CFR 50.46(b)(5), "Long-term cooling"
- 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 10, "Reactor Design"
- GDC 35, "Emergency core cooling"
- GDC 38, "Containment heat removal"

The staff used the following guidance:

- SRP Section 6.2.2, Revision 5
- SRP Section 6.3, Revision 3
- SRP Section 15.6.5, Revision 3
- RG 1.82, Revision 4

4. REGULATORY AUDIT SCOPE

The primary scope of this audit was to examine design specifications and design reports of ECCS strainers and related documentation to verify that the component design is in accordance with the methodology and criteria described in the GE-Hitachi ABWR Design Control Document (DCD) Tier 2. The audit focused on confirmation that the design of the ECCS strainers aligned with RG 1.82 and that the design requirements had been properly translated to design specifications and design reports to ensure that construction will conform to the design requirements.

In addition, the staff also focused on documents that described how the GEH ABWR design met the regulatory requirements of the ECCS with respect to:

- ECCS strainer sizing
- ECCS strainer structural design
- Chemical Effects
- In-vessel downstream effects

The staff conducted this audit in accordance with the guidance provided in NRO-REG-108, "Regulatory Audits" (Reference 5).

Table 1 provides the documents in the scope of the audit.

Table 1. List of Documents Audited

Item	Document Name on ERR	Document
1	DBR-0017510 Rev. 1.pdf	DBR-0017510, "ABWR ECCS Suction Strainer Performance Evaluation," Rev. 1, October 16, 2014 (<i>GEH/GNF Proprietary</i>)
2	"CP1-ECA-0023 R0 ABWR ECCS Suction Strainer Design-GE Optimized Stacked Disk.pdf PROPRIETARY.pdf"	CP1-ECA-0023, "ABWR ECCS Suction Strainer Design Change - GE Optimized Stacked Disk," Rev. 0, December 20, 2016 (<i>GEH/GLE/GNF Proprietary</i>)
3	Calc RHR E11-2113 NPSH Rev 1.pdf	31113-0E11-2113, "Residual Heat Removal System – Pump NPSH Calculation," Rev. 1, December 2, 2008 (<i>GE Proprietary</i>)
4	Calc 31113-0E51-2121 RCIC NPSH.pdf	31113-0E51-2121, "Reactor Core Isolation Cooling System – Pump NPSH Calculation," Rev. 0, October 22, 2008 (<i>GE Proprietary</i>)
5	31113-0E22-2106 HPCF Pump Total Head Calc.pdf	31113-0E22-2106, "High Pressure Core Flooder System – Pump Total Head Calc." Rev. 0, January 12, 1998 (<i>GEH Proprietary</i>)
6	105E2586r4.pdf	DWG. No. 105E2586, "ASSEMBLY: SUCTION STRAINER RHR," Rev. 4, December 3, 1997 (<i>GEH Proprietary</i>)
7	24A5849r8.pdf	24A5849, "FABRICATION OF ECCS SUCTION STRAINER SYSTEM," Rev.8, September 8, 2003 (<i>GEH Proprietary</i>)
8	24A5822r7.pdf	24A5822, "ECCS SUCTION STRAINERS, PIPING, AND SUPPORTS," Rev. 7, July 21, 1999 (<i>GEH Proprietary</i>)
9	DRF_A60_00051_Vol_1_File_sn 0131ve-2.pdf	DRF No.: A60-00051, Verification Record No.: GE-2000-0772 (<i>GEH/GNF Proprietary</i>)

Item	Document Name on ERR	Document
10	Debris_31113-0A51-2104.pdf	31113-0A51-2104, "S/P Suction Strainer – Pipe Break Insulation Debris Calc," Rev. 0, August 20, 1999 (<i>GEH Proprietary</i>)
11	RHR Strainer - FINAL.pdf	DBR-0017510 R0 (Design and Sizing for ABWR ECCS Suction Strainer) (<i>GEH Proprietary</i>)
12	Prototype_Drawing_105E1887_1.pdf	DWG. No. 105E1887, "WELDEMENT: ECCS SUCTION STRAINER PROTOTYPE," Rev. 1, October 14, 1996 (<i>GE Proprietary</i>)
13	USBWR Strainer Stats20080213.pdf	PLM Object 0000-0081-3039 R1 (Affected Plant Evaluations) (<i>GEH Proprietary</i>)
14	PRC0743feb14signed.pdf (NEDE-33878P Reference 4)	GE-SSE-2008-003, "PRC 07-43-BWR Suction Strainer LTR Head Loss," February 14, 2008 (<i>GEH Proprietary</i>)
15	0000-0080-3041 R0 PRC0743EvaluationReport.pdf (NEDE-33878P Reference 3)	"Technical Evaluation Potentially Reportable Condition 0743," dated 2/8/2008 (<i>GEH Proprietary</i>)
16	NEDC-33302P_R0.pdf	NEDC-33302P, "Fiber Insulation Effects with Defender Lower Tie Plate," Rev. 0, March 2007 (<i>GNF Proprietary</i>)
17	NEDC-32721P-A Rev2.pdf	NEDC-32721P-A, "Licensing Topical Report: Application Methodology for the General Electric Stacked Disk ECCS Suction Strainer," Rev. 2, March 2003 (<i>GE Proprietary</i>)
18	USBWR Strainer Stats20080213wFormulas.pdf	0000-0080-3039 R1 - with Formulas (<i>GEH Proprietary</i>)
19	USBWR Strainer Stats20080520 wFormulas.pdf	0000-0080-3039 R2 Calculation Formulas (<i>GEH Proprietary</i>)
20	USBWR Strainer Stats20080520.pdf	0000-0080-3039 R2 Calculation (<i>GEH Proprietary</i>)
21	Information on InorganicZinc.pdf	Compilation of pages from DCD markups, RAI responses, and NEDO-13686-A, describing the treatment of IOZ coating as a debris source.
22	2017-4-18 Information on InorganicZinc.pdf	Same document as above, with editorial corrections.

Item	Document Name on ERR	Document
23	DRF_A60_00051_Vol_1_File_sn 0131ve-2	Verification Record No.: GE-2000-0772, Document to be verified: ECN No. CN08868, Purchase Specification and Data Sheet Revisions.
24	GEH PI E22-00110-00_11 Crush Pressure, Rev. 3 dated April 1999	GENE E12-00153-02 Revision 3, dated April 1999, "Appendix B Strainer Crush Pressure Distribution in Presence of DBRIS Load"
25	NEDO-21888R2-1	NEDO-21888 81NED282 "Mark I Containment Program Load Definition Report", Rev. 2 dated November 1981
26	Prototype_Drawing_105E1887_1	Dwg. No. 105E1887 "ECCS Suction Strainer Prototype"
27	E21-00138-01.pdf	Note to DRFs E11-0091 and E21-00138 Analysis for Crush Pressure
28	NEDC-32976P, Rev. 3	"SAFER/GESTR-LOCA Loss of Coolant Accident Analysis," January 2011
29	Reference 12 of NEDO-32686-A	10 CFR 50.59 Safety Evaluation of the GE11 and GE13 Fuel Bundle Debris Filter
30	10 CFR Part 21 Communication SC08-02	BWR Suction Strainer LTR Head Loss

5. OBSERVATIONS AND RESULTS

5.1 ECCS Strainer Sizing Evaluation

The staff audited the applicant's calculations for debris generation, transport, and strainer head loss to confirm that the applicant followed the methodologies provided in the staff approved licensing topical report (TR), NEDO-32686-A and NEDC-32721P-A (References 8 and 9). The staff confirmed that the applicant evaluated debris generation and transport for the limiting line break for a reference ABWR plant (Items 9 and 10 of Table 1) consistent with NEDO-32686-A. The applicant used a strainer design of an existing residual heat removal (RHR) system pump of another reference BWR plant for all ABWR ECCS pump suction strainers (RHR, high pressure core floodor (HPCF), and RCIC) (Item 6 of Table 1).

The applicant calculated the suction strainer head loss for the RHR strainer based on the highest debris loading and using a head loss correlation given in NEDC-32721P-A, which is a revised version of that in NEDO-32686-A. This correlation was developed for a different strainer design using results of tests conducted using different debris loading than the ABWR design. However, in the safety evaluation (SE) for NEDC-32721P-A, the staff has previously addressed the validity of this correlation for different designs than that which was tested:

GE adopted an empirical means for correlating the test data. Because GE chose to correlate head loss in term of superficial parameters (such as circumscribed velocity) that are easy to determine in plant applications, concerns were identified regarding the generic applicability of the GE correlation, especially application beyond the test range. However, upon further review the staff believes that GE introduced sufficient margin to compensate for any deficiencies in the correlation. Therefore, the staff concluded that this margin would allow GE to apply its correlation within a narrow range beyond the range for which the test data was obtained. LANL also conducted independent analyses to evaluate the applicability of GE methodology to each of the plant applications cited in GE's submittals. Based on the results of these calculations, the staff concluded that the use of GE's hydraulics design method is acceptable for all the plants with exception noted above.

The staff confirmed during the audit that the ABWR strainer flowrate and debris loading were within the range of values that were applicable to the BWR strainer designs (Item 13 of Table 1). Therefore, based on the SE for NEDC-32721P-A and the audit, the staff identified that the applicant used the NEDC-32721P-A correlation for ABWR strainer head loss within applicable bounds.

The audit provided the information necessary for the staff to understand the applicant's evaluation of strainer sizing provided in the applicant's December 19, 2016, RAI response (Reference 7). The staff requested no additional information as a result of the audit.

5.2 ECCS Strainer Structural Evaluation

During the audit of the ECCS strainer design, the NRC staff examined design specifications and design documents pertaining to the ECCS strainers, as listed in Table 1 "List of Documents Audited," to verify that the component is designed in accordance with the methodology and criteria described in the ABWR DCD Tier 2. The NRC staff identified that the design specification and design documents incorporated the provisions specified in the ABWR DCD, and addressed component operating experience. In addition, the NRC staff had the following observations:

- In Doc 24A5822r7 "ECCS Suction Strainers, Piping and Support" Revision 7, dated December 26, 1996, Section 4.3.8.3 showed only three load combinations of Service Levels A, B and D for the ECCS strainers (Item 8 of Table 1). The staff requested the applicant to provide a justification of no load combination of Service Level C. In the NRC audit discussion held on May 2, 2017, the applicant stated that the design specification is applicable to the standard plant ABWR. Plant specific data sheets will provide any additional loads and load combinations. While Service Level C is not specifically listed in generic Design Specification 24A5822, this load combination is bounded by the Service Level D conditions for the RHR strainers audited under this activity. The staff found that the applicant's response was acceptable since the applicant provided a justification of Service Level C; therefore, this item is considered closed.
- In Doc 24A5849r8, "Fabrication of ECCS Suction Strainer System" Revision 8, dated December 26, 1996, Section 3.3.1.1, the applicant indicated that the strainers shall be fabricated using American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code (BPV Code) as a guide (Item 7 of Table 1). The staff observed that the

design specification (Doc 24A5822r7) of the ECCS strainers specified ASME Code, Section III to be the strainers' construction code. The staff requested the applicant to provide a clarification if code stamping is not required for ECCS strainers. In response to the staff's request, the applicant stated that strainers, piping, and supports are classified as Nuclear Safety-related, Seismic Category I. The strainers, piping, and supports do not form a part of the pressure boundary, but for quality reasons, the ASME BPV Code, Section III, Subsection NG, NC and NF, respectively, will be used as guides in the fabrication. Therefore, ASME stamping is not required. Neither ASME Code symbol stamping nor an ASME Certificate of Authorization is required for the strainers. The applicant provided clarification of the code stamping for the ECCS strainers as discussed above; therefore, this item is considered closed.

In Doc 24A5822r7 "ECCS Suction Strainers, Piping and Support" Rev. 7, the applicant specified that the ECCS strainers are designed in accordance with ASME Code, Section III. DCD Tier 2, Section 6.C "Containment Debris Protection for ECCS Strainers" did not provide the information of construction codes and standards of the ECCS strainers. The staff requested the applicant provide in the DCD Tier 2, Section 6.C the description of construction code and standards for ECCS strainer design. In response, the applicant stated that the ASME safety classification for the ECCS (RHR, HPCF and RCIC) components were provided in DCD Tier 2, Table 3.2-1, Classification Summary. However, the staff found that there was no information of safety classification for ECCS (RHR, HPCF and RCIC) strainers as listed in DCD Tier 2, Table 3.2-1. RAI 06.2.2-1 was issued to request the applicant to provide the information of safety classification for ECCS (RHR, PHCF and RCIC) strainers to be included in DCD Tier 2, Table 3.2-1. Subsequently, the applicant provided the staff with the RAI 06.2.2-1 response (Agencywide Documents Access Management System (ADAMS) Accession No. ML17167A161). Therefore, this audit item is considered closed. The staff's evaluation of this RAI response will be documented in the SE associated with this review item.

Based on the above, the staff concluded that design specifications and design documents of ECCS strainers are consistent with the methodology and criteria described in the ABWR DCD Tier 2, Section 6.2.2.

5.3 Chemical Effects Evaluation

The response to RAI 06.03-2, Revision 2, dated February 23, 2017 ADAMS Accession No. ML17055C495), describes the transport assumption for "zinc chemical debris that could result from corrosion of inorganic zinc coating." The staff examined the documents in order to determine the form of this zinc chemical debris and how it was quantified. However, the staff found no indication in the audited documents that the inorganic zinc (IOZ) coating was evaluated for chemical effects (i.e., a debris source originating from corrosion of the zinc). In all documents, the IOZ was treated as part of the particulate debris according to the industry guidance in Section 3.2.2.2.1.1, Table 3, of NEDO-32686-A (Reference 8). The ABWR uses the bounding values of particulate debris from the guidance, which are 47 pounds of untopcoated IOZ and 85 pounds of IOZ coated with epoxy.

Since this particulate debris is not a chemical effect, the staff concluded that the statement about IOZ chemical effects in the response to RAI 06.03-2 was a misunderstanding, and this was confirmed with GEH in an audit status teleconference on May 2, 2017. Therefore, the audit provided the information necessary for the staff to understand the applicant's treatment of IOZ as a debris source. GEH provided additional information about the consideration of chemical

effects from zinc in the response to RAI 06.03-3 on chemical effects from all sources (Reference 12). That response, dated August 23, 2017 (ADAMS Accession No. ML17236A059), superseded the response to RAI 06.03-2 with respect to zinc chemical effects.

5.4 In-vessel Downstream Effects Evaluation

During the audit, the staff examined reference documents which support the GEH downstream effects evaluation. The GEH downstream effects evaluation is described in TR NEDE-33878P, "ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," which was submitted in the Revision 2 response to RAI 06.03-2 (Reference 10). Subsequent Revisions 1, 2, and 3 to NEDE-33878P were transmitted by separate letters (References 11 through 13).

The GEH evaluation of downstream effects of debris addresses blockage of flow paths within the reactor vessel and fuel assemblies. The evaluation conclusions are based largely on calculations performed for a foreign ABWR plant and tests performed on a fuel bundle lower tie plate debris filter, which GEH considers bounding for ABWR fuel. The staff audited both the foreign plant calculation (which assumes GE14 fuel) and the test report (for GNF2 fuel), as well as the generic 10 CFR 50.59 SE for the GE11 and GE13 fuel bundle debris filters referred to in TR NEDE-33878P and in NEDO-32686-A, the Utility Resolution Guide for ECCS Suction Strainer Blockage. Since all of these fuel types are of more recent design than the fuel referenced in the certified ABWR design, and have variations in the number of fuel rods, grid spacer design and number, lower (bundle inlet) and upper tie plate design, and fuel enrichment and poison loading, the staff in-vessel downstream effects audit included other documents listed in Table 1 so that potential impacts on the long-term cooling analyses could be assessed. The staff was able to conclude from the audit that the GEH evaluations of ECCS performance with debris included sufficient conservatism to compensate for differences in fuel bundle design. These evaluations are consistent with RG 1.82, Revision 4.

6. CONCLUSION

Based on the information and calculations, the NRC staff concluded that the applicant has a supporting base for the GEH ABWR ECCS suction debris strainer design as described in the ABWR DCD and the responses to staff RAIs.

The audit is considered complete. The staff gained additional understanding for the review and no other outstanding issues were identified. The staff found no additional documents necessary for audit.

7. REFERENCES

1. "GE-Hitachi ABWR Design Control Document Tier 1 & 2, Rev. 6," February 19, 2016 (ADAMS Accession No. ML16214A015).
2. RG 1.82 "Water Sources for Long-Term Recirculation Cooling Following A Loss-Of-Coolant Accident," Revision 4, 2012 (ADAMS Accession No. ML111330278).
3. SRP Section 6.2.2, "Containment Heat Removal Systems," Revision 5 (ADAMS Accession No. ML070160661).
4. SRP Section 6.3, "Emergency Core Cooling System," Revision 3 (ADAMS Accession No. ML070550068).

5. NRO-REG-108, "Regulatory Audits," April 2, 2009 (ADAMS Accession No. ML081910260).
6. Letter MFN-16-034 from Jerald G. Head, GEH, to the USNRC, Response to Request for Additional Information 06.03-2, May 27, 2016 (ADAMS Accession No. ML16148A101).
7. Letter MFN-16-034, Revision 1, from Jerald G. Head, GEH, to the USNRC, Revised response to Request for Additional Information 06.03-2, December 19, 2016 (ADAMS Accession No. ML16358A445).
8. NEDO-32686-A, "Utility Resolution Guide for ECCS Suction Strainer Blockage," Boiling Water Reactor Owners' Group, October 1998.
9. NEDC-32721P-A, Revision 2, "Application Methodology for the General Electric Stacked Disk ECCS Suction Strainer," March 2003 (GE Proprietary).
10. Letter M170046, "Request for Additional Information Letter Number 8 Related to Chapter 6 for GE-Hitachi Nuclear Energy Advanced Boiling-Water Reactor Design Certification Rule Renewal Application- GEH Response to RAI 06.03-2, Revision 2," February 23, 2017 (ADAMS Accession No. ML17055C593).
11. M170126, "Request for Additional Information Letter Number 8 Related to Chapter 6 for GE-Hitachi Nuclear Energy Advanced Boiling-Water Reactor Design Certification Rule Renewal Application – Revision 1 of NED-33878 (Relates to GEH Response to RAI 06.03-2)," May 11, 2017 (ADAMS Accession No. ML17132A026).
12. M170209, "NRC Requests for Additional Information Letter Numbers 11 and 13 Related to Chapter 6 for GE Hitachi Nuclear Energy Advanced Boiling Water Reactor Design Certification Rule Renewal Application – GEH Revised Response to RAI 06.03-3 and Responses to RAIs 06.03-4 through 06.03-9," August 23, 2017 – transmits NEDE-33878, Revision 2 (ADAMS Accession No. ML17236A059).
13. M180068, "GE Hitachi Nuclear Energy Advanced Boiling Water Reactor Design Certification Rule Renewal Application – Additional Information for GEH Response to RAIs 06.03-4 through 06.03-9," March 28, 2018 – transmits NEDE-33878, Revision 3 (ADAMS Accession No. ML18092A293).