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OFFICE OF NUCLEAR REACTOR REGULATION

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Wilmington, North Carolina

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910/675-5000

Nuclear Industry Activity: Nuclear fuel assemblies and related reload core designs, core components, safety analyses, and services

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Enclosure 2

1 INSPECTION SUMMARY

During this inspection, the NRC inspectors reviewed activities associated with General Electric (GE) Nuclear Energy's design interface with licensees that implemented the average power range monitor-rod block monitor-technical specifications (hereafter referred to as ARTS) modification. The ARTS modification allowed licensees to bypass the rod block monitor (RBM) for a rod withdrawal error (RWE) above 30 percent power (hereafter referred to as RWE event) if the core had sufficient minimum critical power ratio (MCPR) margin.

The inspectors focused on evaluation and implementation of RBM operability to prevent exceeding fuel cladding 1 percent plastic strain limits (hereafter referred to as strain limits) in the boiling water reactor fuel cores of the ARTS plants during an RWE event. The inspectors examined technical specifications (TS) actions to ensure RBM operability during an RWE event to keep fuel cladding from exceeding the strain limits and associated MOP limits. The inspectors also assessed GE's monitoring of the effectiveness of its design control program.

The inspection bases were as follows:

- Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to Part 50 of Title 10 of the Code of Federal Regulations (10 CFR Part 50).
- 10 CFR Part 21, "Reporting of Defects and Noncompliance."
- GE Nuclear Energy Quality Assurance Program Description NEDO-11209-04A, Revision 8, dated March 31, 1989, and associated implementing procedures.

During this inspection, the inspectors noted three instances in which GE failed to conform to NRC requirements imposed upon it by NRC licensees. These nonconformances are discussed in Section 3.1 and 3.3 of this report.

2 STATUS OF PREVIOUS INSPECTION FINDINGS

This inspection was limited in scope to address GE's design interface with licensees. Previous inspection findings were not evaluated.

3 INSPECTION FINDINGS AND OTHER COMMENTS

3.1 Design Interface with ARTS Licensees

a. Inspection Scope

The inspectors assessed the adequacy of GE's design interface with ARTS licensees regarding RBM operability during an RWE event. The inspectors examined GE's RWE analyses and supplemental reload licensing reports (SRLRs) and GE's interaction with licensees regarding the assumptions and results of its analyses.

b. Observations and Findings

The RWE event assumes erroneous withdrawal of the highest worth rod from full in to full out at any time during the operating cycle. To protect against this event and keep the fuel from reaching a 1 percent plastic strain during an RWE event, the RBM monitors control rod movements and initiates a rod block during a RWE in which the local power exceeds a predetermined setpoint. The 1 percent plastic strain of the cladding is conservatively defined as the threshold below which fuel damage due to fuel clad overstraining is not expected to occur.

GE uses conservative mechanical overpower (MOP) limits to assure compliance with strain limits. GE started using MOP limits in 1987 after a study showed that the fuel assemblies in the error cell in newer fuel designs could potentially exceed the strain limits during an RWE event. Using the MOP limits in the RWE analysis added a margin of protection against exceeding the strain limits. GE determined that if fuel assemblies did not exceed the MOP limits during an RWE event, they would not exceed the strain limits. If the RWE analysis indicated that the MOP limits would be exceeded, licensees could take credit for RBM operability, perform an exact site-specific analysis to ascertain whether the strain limits would be exceeded without RBM operability, or reconfigure the core design to avoid exceeding the MOP limits during an RWE event.

The MCPR limits were imposed to avoid fuel damage due to severe overheating of the fuel cladding. The ARTS modification allowed licensees to bypass the RBM for an RWE event if the core had sufficient MCPR margin. GE determined that for certain ARTS plants during certain fuel cycles the RBM needed to be operable to prevent exceeding the MOP limits during an RWE event, even if the MCPR margin was within the design parameters established by the ARTS modification.

The inspectors reviewed activities associated with GE's design interface with ARTS licensees regarding RBM operability during a potential RWE event at ARTS plants. The inspectors assessed GE's interaction with Detroit Edison Company (DECo) for Fermi Atomic Nuclear Plant Unit 2 (Fermi); with Southern Nuclear Operating Company (SNOC) for Edwin I. Hatch Nuclear Plant, Units 1 and 2 (Hatch); with Carolina Power & Light Company (CP&L) for Brunswick Steam Electric Plant, Units 1 and 2 (Brunswick); with Philadelphia Electric Company for Limerick Generating Station, Units 1 and 2 (Limerick); with Nebraska Public Power District for Cooper Nuclear Station (Cooper); with IES Utilities (IES) for Duane Arnold Energy Center (Duane Arnold); and with Boston Edison Company for Pilgrim Nuclear Power Station, Unit 1 (Pilgrim). The inspectors' review of factors pertaining to RBM operability at ARTS plants is summarized below:

(1) FERM I

Cycle 3 commenced June 1, 1991. Cycle 4 commenced November 1, 1992 and concluded with the turbine trip event in December 1993. In April 1992, DECo audited GE's activities regarding fuel design control

for Fermi Cycle 4 (DECo Report 92-018, dated May 6, 1992). DECo determined that based on GE's RWE analysis there was a potential for the fuel cladding exceeding its MOP limits if the RBM was not operable and control rod patterns deviated from GE's recommended normal operation cycle patterns. GE had not informed DECo that the MOP limits at Fermi could be exceeded if the RBM was bypassed, and that the Fermi TS 3/4.1.4.3 (in accordance with the ARTS modification) allowed bypassing of the RBM. DECo recommended that GE analyze both Cycle 3 and 4 cores to either affirm or refute the validity of the RWE analysis with respect to MOP limits in intermediate control rod patterns, and whether the Fermi TS 3/4.1.4.3 "contained adequate operational restraints."

GE analyzed Fermi Cycles 3 and 4 and informed DECo that for Cycle 3 the MOP limits were not exceeded. GE also informed DECo that, for Cycle 4, the MOP limits for GE-11 fuel would be exceeded but that the strain limits would not be exceeded because of a substantial conservative margin between the MOP limits and the strain limits. GE concluded that for Cycle 4 the RBM did not need to be operable, and that the TS 3/4.1.4.3 RBM operational requirements were adequate.

DECo audited GE on December 7 through 10, 1993 (DECo Report QA-94-1006, dated January 10, 1994), and again determined that GE had not adequately communicated design changes to DECo. GE had not informed DECo that Fermi's TS basis for RBM operability required consideration of the MOP limits. The inspectors determined that the Fermi reload analysis for Cycle 4 provided in the SRLR 23A7075 Revision 0, dated April 1992, did not address RBM operational requirements for not exceeding the MOP limits. In November 1994, as part of its response to DECo's audit observation, GE issued letters to inform all ARTS licensees that they should consider the strain limits and associated MOP limits when evaluating RBM operability for the ARTS modification.

For Cycle 5, GE informed DECo that the MOP limits could be exceeded. In preparation for Cycle 5, GE's RWE analyses, dated November 11, 1993, and June 22, 1994, indicated that the RBM needed to be operable to prevent the MOP limits from being exceeded. Cycle 5 commenced on December 17, 1994. In May 1995, DECo requested GE to further evaluate the need for RBM operability. On August 22, 1995, during Cycle 5, GE completed an RWE analysis using the actual core loading and control rod patterns and concluded that the MOP limits were not exceeded and that the RBM did not need to be operable.

For Cycle 6, GE informed DECo that the RBM was required to be operable. Based on the PANACEA analyses, GE informed DECo that the MOP limits for fuel GE-11 would be exceeded within the error cell during an RWE event if the RBM was not operable. The SRLR for Cycle 6, issued in November 1996, stated: "At least one RBM channel must be operable when moving rods in order to protect for mechanical overpower limits." The inspectors considered the SRLR to be inadequate in that it did not reference the 30% power level for RBM operability and addressed operability of only one RBM channel.

During the inspection, GE informed the inspectors that the strain limits were not exceeded at Fermi during the above operational cycles. However, the inspectors concluded that GE did not adequately inform DECo of the need to consider the strain limits and the associated MOP limits in addition to the MCPK limits when evaluating RBM operability for an RWE event. DECo actions regarding implementation of appropriate TS revisions for Cycles 5 and 6 are addressed in section 3.2 b of this report.

(2) HATCH

For Hatch Unit 1 Cycles 16 and 17, and Unit 2 Cycles 13 and 14, GE informed SNOC that the MOP limits would be exceeded during an RWE event if the RBM was not operable. A GE memorandum to SNOC, dated October 31, 1994, stated that the "1 percent plastic strain is met, if one channel of the RBM remains operable." In addition, on October 31, 1994, GE informed SNOC by letter that they should consider the strain limits and associated MOP limits when evaluating RBM operability for the ARTS modification. GE's SRLR for Hatch 1 Cycle 16 and 17, and Hatch 2 Cycles 13 and 14 informed Hatch of necessary protective measures but failed to clearly address the conditions under which the RBM should be operable. During the inspection, GE informed the inspectors that based on its analyses the MOP limits had been exceeded for Hatch Unit 1 Cycles 16 and 17, Unit 2 Cycle 13, and Cycle 14. The strain limits were not exceeded during these cycles. SNOC's actions regarding implementation of appropriate TS revisions are addressed in section 3.2 b of this report.

(3) PILGRIM, LIMERICK, COOPER

Based on the SRLRs for these plants, the RBM did not need to be operable for Pilgrim Cycle 12, Limerick Unit 1 Cycles 6 and 7, Limerick Unit 2 Cycle 4 and 5, and Cooper Cycle 18. The inspectors determined that the MOP limits were not exceeded during these cycles. In November 1994, GE issued letters to these licensees indicating that they should consider the strain limits and associated MOP limits when evaluating RBM operability for the ARTS modification.

(4) BRUNSWICK AND DUANE ARNOLD

In January 1995, GE conducted an RWE analyses for the Brunswick Cycle 10 and Duane Arnold Cycle 14 and determined that the MOP limits would be exceeded if the licensees bypassed the RBMs. Based on the inspectors review of GE's design documents, GE did not inform these licensees that the MOP limits would be exceeded. Based on GE's RWE analysis, the MOP limits were exceeded at Brunswick. On April 1, 1997, CP&L issued a 50.72 notification (Event No. 32058) regarding RBM operability.

In March 1997 (before the NRC inspection), GE reviewed reload design documents to determine which ARTS plant cycles resulted in exceeding the strain limits. Based on its review of prior RWE analyses, GE

notified CP&L and IES by letter dated March 11, 1997, that the Brunswick Cycle 10 and Duane Arnold Cycle 14 GE-10 fuel had exceeded the MOP limits. GE did not inform the inspectors during the inspection that the MOP limits were exceeded for these two plants.

Subsequent to the inspection, GE performed a cycle-specific analysis for both plants. In a letter dated April 25, 1997, GE informed the NRC that the strain limits were not exceeded at Brunswick and Duane Arnold. On May 9, 1997, the inspectors contacted GE staff by telephone to ask why licensees were not informed in January 1995, and why the inspectors were not informed during the March 1997 inspection that based on GE's RWE analyses, Brunswick and Duane Arnold had exceeded the MOP limits. GE stated that it did not inform the licensees or the NRC because GE's "generic" RWE analysis had indicated that the strain limits would not be exceeded. CP&L and IES's actions regarding implementation of appropriate TS revisions are addressed in section 3.2 b of this report.

Based on the above review, the inspectors determined that GE did not adequately inform licensee design organizations implementing the ARTS modification of the need to consider the strain limits and the associated MOP limits in addition to the MCPR limits when evaluating RBM operability for an RWE event. GE's SRLRs for ARTS plants did not adequately address requirements for RBM operability with regard to the MOP limits. This inadequate interface between GE and ARTS licensees contributed to (1) the failure of licensees to ensure through their TS that the RBM was operable to protect fuel cladding at applicable plants, and (2) occasions during Fermi Cycles 4 and 5, Hatch Unit 1 Cycles 16 and 17, Hatch Unit 2 Cycles 13 and 14, Brunswick Cycle 10, and Duane Arnold Cycle 14 when based on GE's RWE analyses the fuel cladding had exceeded its MOP limits and had the potential of exceeding its strain limits. This constitutes Nonconformance 99900003/97-01-01.

In its March 19, 1997, letter to the NRC, GE stated that its "communications to licensees in the SRLR have not been adequate." GE also stated that, in part, it (1) had sent letters to all customers apprising them that the RBM is required to ensure that the MOP limits were not exceeded, (2) had revised technical design procedure (TDP) 0035 to clarify required utility communications, and (3) planned to review the SRLR format and revise the GESTAR II standard format, if necessary, and make further revisions to TDP-0035 if necessary to be consistent with the final SRLR format.

c. Conclusions

The strain limits were not exceeded at the ARTS plants. GE's design interface with licensees was weak, as noted in the nonconformance herein. GE did not adequately inform ARTS licensees of the conditions for RBM operability, contributing to the ARTS licensees' failure to implement RBM protection for fuel during potential RWE events. SRLRs did not clearly identify conditions for RBM operability. Based on GE's RWE analyses, the

fuel cladding had exceeded its MOP limits and had the potential of exceeding its strain limits at Fermi, Hatch, Brunswick, and Duane Arnold.

3.2 TECHNICAL SPECIFICATIONS (TS) ACTIONS

a. Inspection Scope

The inspectors examined TS actions taken by GE and ARTS licensees to ensure RBM operability during an RWE event to protect exceeding the strain limits and associated MOP limits.

b. Observations and Findings

DECo audited GE in 1992 and 1993 and observed GE's failure to inform DECo (and other ARTS licensees) that the MOP limits would be exceeded if the RBM was not operable during an RWE event. In November 1994, GE informed all ARTS licensees of the need to consider RBM operability to not exceed strain limits.

During Cycle 5, GE informed DECo that the RBM must be operable. In Section 10 of the Cycle 5 SRLR, dated December 1993, GE stated that "at least one channel of the RBM must be operable when moving rods in order to meet the MOP limits for an RWE event." GE's memorandum to DECo, dated June 22, 1994, regarding the Cycle 5 analysis stated: "GE still recommends that at least one RBM channel be operable when moving rods." However, DECo did not revise the Fermi TS; rather, in May 1995 DECo requested GE to further evaluate the need for RBM operability. On August 22, 1995, GE concluded that the MOP limits were not exceeded during Cycle 5.

In preparation for Cycle 6, DECo addressed RBM operability by placing a statement in the core operating limits report (COLR). The NRC resident inspectors became aware of DECo's use of the COLR in this manner and on November 22, 1996, the NRC informed DECo by telephone that the addition of this statement to the COLR without a corresponding request to amend the TS would not comply with the requirements of 10 CFR 50.36. The NRC permitted DECo to start up using administrative controls after the licensee submitted the TS amendment request on December 2, 1996, to require RBM operability above 30 percent power. The TS amendment (No. 112 to facility operating license No. NPF-43) was issued on May 15, 1997.

For Hatch Unit 1 Cycles 16 and 17, and Unit 2 Cycles 13 and 14, GE informed SNOC that the MOP limits would be exceeded during an RWE event if the RBM was not operable. A GE memorandum to SNOC dated October 31, 1994, stated that the "1 percent plastic strain is met, if one channel of the RBM remains operable." SNOC did not revise the Hatch TS.

In January 1995, GE's RWE analysis indicated that the Brunswick Cycle 10 and Duane Arnold Cycle 14 GE-10 fuel would exceed the MOP limits. Based on documents provided to the inspectors, GE did not inform licensees of the potential for exceeding the MOP limits. In March 1997, GE informed

CP&L and IES that based on its RWE analyses the fuel at Brunswick and Duane Arnold had exceeded its MOP limits. CP&L and IES did not revise the Brunswick and Duane Arnold TS.

The inspectors asked GE why they did not explicitly inform ARTS licensees to revise their TS to ensure RBM operability for an RWE event. On May 1, 1997, during a telephone conversation with the inspector, GE agreed to inform licensees of the need to examine or consider revisions to their TS, as applicable, with respect to RBM operability.

c. Conclusions

Fermi and Hatch apparently knew that the RBM must be operable for a potential RWE but did not revise their TS to require RBM operability for an RWE event. Other ARTS licensees, including Brunswick and Duane Arnold, were informed by GE in November 1994 of the need to consider RBM operability to not exceed strain limits but did not revise their TS. GE's failure to explicitly inform licensees to revise their TS to ensure RBM operability during an RWE is considered a weakness.

3.3 DESIGN CONTROL

a. Inspection Scope

The inspectors reviewed the adequacy of GE's RWE analyses and GE's assessment of its design control program.

b. Observations and Findings

The inspectors determined that GE modified peaking factors when the MOP limits were exceeded in the RWE analyses, and applied alternate rod patterns in addition to normal rod patterns in the RWE analyses without documented instructions or procedures. The inspectors also determined that GE changed design parameters for its peak cladding temperature (PCT) analysis by revising the theoretical fuel pellet density values without procedures for tracking the removal of conservatisms in the PCT analysis. GE's use of the incorrect fuel pellet densification value had resulted in a lower peak cladding temperature. When GE corrected the densification value, the Loss of Coolant Accident analysis of the BWR-6 plant indicated an unacceptable increase of the PCT. GE revised the theoretical density values to reduce the PCT without issuing any documented instructions or procedures for using the revised density values. This constitutes Nonconformance 99900003/97-01-02.

Subsequent to the inspection, in its March 19, 1997, letter to the NRC, GE stated that, as part of its corrective actions, it (1) revised TDP 0035 to improve its communication with licensees on the need for RBM operability, (2) implemented an explicit requirement for MOPs calculations for all fuel types, (3) plans to review TDPs for other areas of improvement, e.g., added guidance on local peaking factor adjustments, and (4) plans to document conservatisms used in its analyses.

DECo audited GE in 1992 and 1993 and observed several deficiencies regarding design control, including GE's failure to inform DECo (and other ARTS licensees) that the MOP limits would be exceeded if the RBM was not operable during an RWE event. The inspectors determined that GE took corrective actions for specific deficiencies but did not conduct followup action, including reaudit of the design control area, to determine the effectiveness of the program. This constitutes Nonconformance 9990C003/97-01-03. During the inspection, GE stated that it planned to perform an internal audit to address the effectiveness of its design program. In its March 19, 1997 letter to the NRC, GE stated that its corrective actions included (1) strengthening its requirements for annual adequacy reviews of TDPs; planning to perform adequacy reviews during the second quarter of 1997, and (2) performing a QA followup audit of a revised adequacy review process scheduled for late 1997.

The inspectors observed that GE's generic analysis of MOP limits for RWE events at ARTS plants may not be valid for cores containing GE 8x8 fuel or GE-10, -11, -12, and -13 fuel not included in the 1987 assessment of generic MOP limits. GE informed the inspectors that in March 1997 it began conducting cycle-specific RWE analyses for all plants and all fuel types. No immediate safety concerns were identified.

The inspectors reviewed GE's PANACEA analysis and observed that GE evaluated UO_2 rods rather than Gadolinium (Gd) rods in an error cell for an RWE event. The generic GESTR-M strain analysis indicated that the Gd rods were more limiting than the UO_2 rods. Consideration of the UO_2 rods but not the Gd rods in the error cell for the PANACEA analyses may not identify the limiting rod for the strain limits. The inspectors also observed that the PANACEA analyses considered planned rod patterns for certain cycles but did not include possible alternate rod patterns. Use of only planned rod patterns for certain analyses may not identify the most limiting operation within the error cell for the analyzed cycle because alternate rod patterns may be used. The inspectors determined that exclusion of Gd rods and alternate rod patterns was a weakness in GE's PANACEA analyses.

The inspectors assessed the initial conditions assumed in cycle-specific accident analyses. One example reviewed involved a Fermi turbine trip event with nominal reactor steam dome pressure assumed for the start of the transient. The inspectors examined whether the safety analysis was bounding and the MCPR limit was sufficient if a transient would be initiated from a higher pressure within the bounds of the TS operating limits. In response to questions by the inspectors, GE performed a sensitivity study to evaluate the effect on the thermal margin of pressure variations of plus or minus 20 psi, including cases with GE-9 and GE-13 fuel. The results indicated a pressure sensitivity of a small delta critical power ratio (CPR)/initial critical power ratio (ICPR) over this pressure range. Higher initial pressure resulted in a lower delta CPR/ICPR. In reviewing safety analysis methods, the NRC examines assumptions regarding the initial conditions of the analyses and whether operating limits derived from the analyses provide bounding protection for all operating conditions permitted by the plant TS. Since the

thermal margin is dependent on several operating parameters that do not vary independent of pressure, thermal margin sensitivity to pressure reduction is not necessarily indicative of the thermal margin sensitivity to overall off-nominal plant operating conditions for large pressure increments. No concerns were identified.

The inspectors observed that in late February 1997, Tennessee Valley Authority determined that the Browns Ferry Nuclear Plant Emergency Operating Procedures (EOPs) revision for GE 9x9 fuel had not considered all the input parameters affected by the new fuel design. The input parameters are specific to fuel type and would be used by the licensee to calculate plant specific curves or limits to maintain Emergency Procedure Guidelines (EPGs) specified action levels. Input parameters for EOP calculations are contained in Appendix C of NEDO-31331, Revision 4, issued March 1987. At the time of issuance of revision 4, GE 9x9 fuel was not in use by any licensee. Upon incorporation of 9x9 fuel, licensees apparently did not recognize that certain parameters identified as "generic data" in EPG Appendix C were affected by fuel type. The parameters were four steam-cooling-related input parameters and two shutdown boron weight-related input parameters. In response to the event, GE issued Services Information Letter (SIL) 529, Supplement 1, on March 14, 1997, informing BWR customers of the fuel type-specific nature of the input parameters and recommending that potentially affected plants reevaluate their EPG calculations if the fuel design has changed since the Appendix C calculations. The SIL also provided a list of calculations which may be impacted by revised input parameters.

c. Conclusions

GE did not have documented instructions or procedures to control modifications in RWE analyses when MOP limits were exceeded. GE's generic MOP limits evaluations need to be replaced with cycle-specific analyses. The PANACEA fuel strain analysis was weak.

3.4 Entrance and Exit Meetings

In the entrance meeting on March 10, 1997, the NRC inspectors discussed the scope of the inspection, outlined the areas to be inspected, and established interactions with GE management. In the exit meeting on March 14, 1997, the inspectors discussed their findings and observations.

4 PARTIAL LIST OF PERSONNEL CONTACTED

General Electric Nuclear Energy

Chris Monetta, Manager, Nuclear Quality Assurance
Glen Watford, Manager, Nuclear Fuel Engineering
James Klapproth, Manager, Product Definition
Steve Congdon, Manager, Nuclear Technology
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Robert Rand, Principal Engineer, Nuclear Fuel
Fran Bolger, Principal Engineer, Nuclear Fuel
Barry R. Fischer, Technical Program Engineer, Nuclear Fuel

ITEMS OPENED, CLOSED, AND DISCUSSED

Opened

99900003/97-01-01	Para 3.1 b	NON	inadequate design interface
99900003/97-01-02	Para 3.3 b	NON	inadequate procedures
99900003/97-01-03	Para 3.3 b	NON	inadequate assessment of design effectiveness

ACRONYMS USED

ARTS	Average Power Range Monitor-Rod Block Monitor-Technical Specifications
GE	General Electric
RBM	Rod Block Monitor
RWE	Rod Withdrawal Error
RWE Event	Rod Withdrawal Error above 30 percent power
MCPR	Minimum Critical Power Ratio
TS	Technical Specifications
SRLR	Supplemental Reload Licensing Report
MOP	Mechanical Over Power
TDP	Technical Design Procedure
COLR	Core Operating Limits Report
PCT	Peak Cladding Temperature
Gd	Gadolinium
UO ₂	Uranium Dioxide
CPR	Critical Power Ratio
ICPR	Initial Critical Power Ratio
EPOs	Emergency Operating Procedures
EPGs	Emergency Procedure Guidelines
SIL	Services Information Letter