



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

October 19, 2011

Vice President, Operations
Entergy Operations, Inc.
Grand Gulf Nuclear Station
P.O. Box 756
Port Gibson, MS 39150

**SUBJECT: GRAND GULF NUCLEAR STATION, UNIT 1 - AUDIT OF CALCULATIONS
RELATED TO EXTENDED POWER UPRATE (TAC NO. ME4679)**

Dear Sir or Madam:

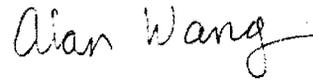
By letter dated September 8, 2010 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML1002660403), Entergy Operations, Inc. (Entergy, the licensee), proposed an amendment to increase the maximum reactor power operating limit authorized in the Facility Operating License No. NPF-29 from 3,898 MWt to 4,408 MWt. In support of the proposed extended power uprate (EPU) amendment, Entergy will replace the steam dryer at Grand Gulf Nuclear Station (GGNS), Unit 1. This replacement steam dryer was designed by General Electric Hitachi (GEH). The fluctuating pressure loading on the steam dryer is based on GEH's Plant Based Load Evaluation (PBLE) methodology and in-plant measurements. An audit of the GEH calculations supporting the changes to the steam dryer was held at the Nuclear Energy Institute and General Electric Company offices in Washington, D.C., on September 19 and 20, 2011, respectively. The audit was needed as GEH stated that the calculations the U.S. Nuclear Regulatory Commission (NRC) staff were interested in reviewing were proprietary and voluminous.

The NRC staff's proprietary version of the Audit Report is provided in Enclosure 1 and a non-proprietary version is provided in Enclosure 2. In addition, the NRC staff has determined additional information is needed to complete this review. The request for additional information is provided in the audit report. Entergy has stated it will respond by October 10, 2011.

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If you have any questions regarding the Audit Report, please contact me at (301) 415-1445.

Sincerely,



Alan B. Wang, Project Manager
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-416

Enclosures:

1. Audit Report (Proprietary)
2. Audit Report (Non-Proprietary)

cc w/Enclosure 2: Distribution via Listserv

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ENCLOSURE 2

AUDIT OF STEAM DRYER CALCULATIONS
SUPPORTING PROPOSED EXTENDED POWER UPRATE FOR
GRAND GULF NUCLEAR STATION, UNIT 1

(NON-PROPRIETARY)

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
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AUDIT REPORT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

AUDIT OF THE STEAM DRYER CALCULATIONS

ENTERGY OPERATIONS, INC.

GRAND GULF NUCLEAR STATION, UNIT 1

DOCKET NO. 50-416

In support of the proposed extended power uprate (EPU) amendment, Entergy Operations, Inc. (Entergy, the licensee), will replace the steam dryer at Grand Gulf Nuclear Station, Unit 1 (GGNS). This replacement steam dryer was designed by General Electric Hitachi (GEH). The fluctuating pressure loading on the steam dryer is based on GEH's Plant Based Load Evaluation (PBLE) methodology and in-plant measurements obtained from main steam line (MSL) strain gauges. GGNS is the first operating nuclear plant to use the PBLE methodology. The Nuclear Regulatory Commission (NRC) staff, supported by its contractors identified on the cover page, performed an audit of GEH's evaluations pertaining to acoustic and structural finite element (FE) models of the GGNS steam dryer. The audit was held at the Nuclear Energy Institute (NEI) and General Electric Company (GE) offices in Washington, D.C., on September 19 and 20, 2011, respectively.

1.0 PURPOSE

The purpose of the audit was to examine and evaluate documents proprietary to GEH.

2.0 AUDIT DETAILS

The agenda for the audit is provided in Section 2.3 of this report. Other documents that will be submitted by the licensee on the docket were also examined. A list of documents examined and/or discussed during the audit is provided in Attachment 1 of this report. The action items resulting from the audit are included in Section 3.0 of this report.

2.1 Audit Locations

Monday, September 19, 2011
NEI Main Office, 1776 "Eye" ("I") Street, NW, Washington, D.C. 20006

Tuesday, September 20, 2011
General Electric Office, 1299 Pennsylvania Avenue, NW, Washington, D.C. 20004

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2.2 Audit Attendees

<u>NRC:</u>	Chakrapani Basavaraju, Terri Spicher, and Alan Wang
<u>NRC Contractors:</u>	Vik Shah (Argonne National Laboratory) and Steve Hambric (Penn State)
<u>Entergy:</u>	Jerry Burford and Mike Withrow
<u>GEH:</u>	Patricia Campbell, Tim Niggel, Mark Blue, Dan Pappone, Michael James, and Tao Wu
<u>Betti Engineering/GEH:</u>	Enrico Betti

2.3 Audit Agenda

The NRC staff and its contractors discussed and evaluated the seven agenda items listed below with members of GEH and Entergy. This discussion is summarized in Section 2.4 of this report. The discussion regarding two additional items is summarized in Section 2.4 of this report.

The agenda for audit of the GGNS EPU documents associated with the GEH boiling-water reactor (BWR) steam dryer methodology is provided below.

While preparing the safety evaluation for the Grand Gulf extended power uprate license amendment request, the NRC staff has determined the need for clarification and additional information in order to complete its review regarding the steam dryer evaluations. The NRC staff, with support from its contractors, would like to conduct an audit on September 19-21, 2011. The NRC staff will be focusing on the following items associated with the GEH BWR steam dryer methodology:

- In-plant MSL measurements,
- Acoustic modeling of steam in the MSLs, the reactor pressure vessel (RPV), and the steam dryer,
- Mapping of acoustic loads onto structural models of the steam dryers,
- Filtering of MSL measurements, dryer pressure loads, and dryer stresses,
- Structural FE modeling, including submodeling of high-stress regions,
- End-to-end bias errors and uncertainties, and
- Corrective Action Requests for the last 3 years.

The NRC staff, therefore, requests an audit of the GEH PBLE methodology, the GEH steam dryer FE modeling methodology, the interface between the PBLE and FE models, the in-plant MSL measurements, and all associated bias errors and uncertainties, specifically associated with the GGNS EPU application.

The NRC staff requests that GEH arrange for all models and data associated with its Quad Cities Nuclear Power Station, Unit 2 (QC2) and Susquehanna Steam Electric Station (SSES), Units 1 and 2 benchmarks, as well as its GGNS replacement dryer analyses, to be available

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digitally during the audit, as well as technically cognizant personnel to answer technical questions associated with the models and data. Computers with Matlab and Microsoft Excel should be made available to the NRC staff to examine the data with support from GEH personnel.

The NRC staff's audit will focus on the following specific items. GEH is requested to make available the following items during the audit:

1. Raw MSL measurements (time histories and frequency spectra) from the QC2 and SSES benchmarking studies and the GGNS plant, as well as any subsequent filtering and final filtered signals, along with methods used to confirm correct and accurate measurements.
2. Acoustic models of the MSLs (with branch lines and safety relief valves), RPV, and dryers of the QC2, SSES, and GGNS plants, including any additional models used to establish accuracy and convergence, and evidence of consistent modeling procedures between the benchmark and GGNS models. The models should be accompanied by easy to interpret drawings of the RPVs and MSLs, including critical dimensions (RPV diameter, height, dome geometry; MSL entry geometries and downstream geometries, SRV locations). [REDACTED] entries and [REDACTED] should be available for easy examination using codes like Microsoft Excel or Matlab. Documents verifying the acoustic models.
3. Software used to map acoustic loads on to the dryers, as well as plots and comparisons of oscillatory pressures in the acoustic models and structural models along the dryer/steam interface, on both the interior and exterior of the dryers. Verification and validation documents for the software.
4. Structural FE models of the QC2, SSES, and GGNS steam dryers including transition from shell to solid element modeling, along with mesh convergence studies, and evidence of consistent modeling procedures between the benchmark and GGNS models. Submodels, when used to reduce peak stresses, should also be available for examination.
5. Unfiltered frequency spectra and time histories of measured dryer pressures, strains, and accelerations for the QC2 and SSES benchmarks, along with any filtering procedures used to adjust the spectra, and the final filtered spectra and time histories. Simulated unfiltered data to compare directly to the measured data (time series and spectra) and how it was subsequently filtered and processed to determine the final PBLE bias errors and uncertainties [REDACTED].
6. Unfiltered frequency spectra and time histories of calculated GGNS dryer stresses, based on unfiltered [REDACTED] and PBLE/FE models, along with any filtering or exclusions and subsequent final filtered results.
7. Corrective Action Reports (CARs) generated during the last 3 years pertaining to GGNS and Economic Simplified Boiling Water Reactor (ESBWR) steam dryer design and

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evaluation methodology including the QC2 and SSES benchmarking. The licensee's technical evaluation (corrective action program evaluations and engineering evaluations).

2.4 Audit Discussion on Agenda Items

The focus of the audit is GEH's PBLE procedure, as applied to the GGNS replacement steam dryer. The NRC and its contractors initiated the audit by working with GEH to find and evaluate all CARs associated with the replacement steam dryer flow-induced vibration analyses. The NRC team combined the information found in these CARs with the items from the audit agenda.

Matlab and Sysnoise software were also made available by GEH during the audit. Listed below is a summary along with the action items. A consolidated list of the action items is presented in Section 3.0.

1. MSL measurements

The [REDACTED], which is tighter than uncertainty from QC2 benchmark, and is acceptable.

QC2 MSL signals are filtered to remove [REDACTED] Hz, but also use [REDACTED] that rolls off input signals above [REDACTED] Hz. However, [REDACTED]. Therefore, the PBLE [REDACTED] QC2 dryer pressures, leading to [REDACTED]. Since no other MSL signals of GGNS or other plants are filtered, the PBLE is conservative since the [REDACTED]. It is noted that the [REDACTED] terms are not affected by this filtering, since [REDACTED].

2. Acoustic models

a. Consistency of geometry, acoustic models and structural models for QC2, SSES, and GGNS has been verified within GEH.

b. Mesh resolution issues:

i. The QC2 acoustic model does not rigorously satisfy the [REDACTED] requirement, with [REDACTED]. However, the ESBWR Safety Evaluation Report (SER) accepted by the NRC shows that [REDACTED].

Since all future acoustic meshes will adhere to [REDACTED] criterion leading to higher loads, with the [REDACTED] still applied, the [REDACTED] QC2 acoustic mesh is acceptable.

ii. The initial GGNS acoustic mesh did not comply with [REDACTED], and ignored the [REDACTED] (CAR 52126).

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However, this was assessed in the submission, with higher loads due to a [REDACTED] included as a bias error.

- c. The acoustic models of QC2, SSES, and GGNS have [REDACTED] inaccuracies (CARs 53032 - SSES and 53060 - QC2), and we could not determine if the errors led to conservative or non-conservative dryer loads and stresses.
 - i. GEH action: submit quantitative assessment of the impact of the [REDACTED] on the GGNS dryer loads.
- d. The NRC staff and contractors examined peak drive frequencies (caused by RPV and dryer volume acoustic modes) and amplitudes of the nozzle to dryer transfer functions [REDACTED]. The frequencies, transfer function amplitudes, and general transfer function behavior are reasonable, and are fairly consistent plant to plant. The NRC did not find any significant issues with the transfer functions.
 - i. QC2 - [REDACTED] acoustic mesh (less than [REDACTED] over [REDACTED] pressure gradient regions)
 - 1. Nozzle area: [REDACTED] as modeled.
 - 2. Peaks at frequencies [REDACTED] Hz.
 - 3. Amplitudes between [REDACTED]
 - a. Divide by actual area - get pressure/volume velocities ranging from [REDACTED] Pa/m³/s.
 - ii. SSES
 - 1. Nozzle area: [REDACTED] m² modeled.
 - 2. Peaks at frequencies [REDACTED] Hz.
 - 3. Amplitudes between [REDACTED] Pa/m/s
 - a. Divide by actual area - get pressure/volume velocities ranging from [REDACTED] Pa/m³/s.

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iii. GGNS – original

1. Nozzle area: [REDACTED] m² as modeled.
2. Peaks at frequencies [REDACTED] Hz [REDACTED], [REDACTED] Hz (at one location only).
3. Amplitudes between [REDACTED] Pa/m/s
 - a. Divide by actual area – get pressure/volume velocities ranging from [REDACTED] Pa/m³/s.
4. Peak in GGNS transfer function amplifies [REDACTED] Hz SRV tones (conservative).

iv. GGNS - refined – added drain channel volumes and refined mesh

1. Nozzle area: [REDACTED] m² as modeled.
2. Peaks at frequencies [REDACTED] Hz.
3. Same amplitude range, but peaks increase at [REDACTED] and [REDACTED] Hz significantly.

e. [REDACTED] – based on [REDACTED] SSES and GGNS

- i. [REDACTED] at about [REDACTED] up to [REDACTED] Hz, and [REDACTED] above [REDACTED] Hz.
- ii. [REDACTED] complex and oscillatory up to [REDACTED] Hz, and [REDACTED]
- iii. [REDACTED] (at [REDACTED] due to initial bug in PBLE. Should be conservative, and was approved during ESBWR.
 1. GEH action: provide a write-up on why using [REDACTED] for all other dryers is conservative, citing previously accepted ESBWR SER.

3. Load mapping – structural vs. acoustic models – QC2, SSES, GGNS

- a. The audit team viewed the low frequency (LF) and high frequency (HF) comparisons for SSES and GGNS, which looked fine, but do not give a quantitative assessment of load mapping errors over key regions and [REDACTED] frequency ranges.

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- b. A review of the CAR 49314 shows that the load mapping procedure leads to errors in [REDACTED] of the dryer model in the GGNS original dryer analysis. Even though irrelevant to the GGNS replacement dryer, the CAR indicates that the overall procedure has [REDACTED] which may apply to QC2, SSES, and GGNS.
 - i. GEH showed contour plots over several views for each narrow frequency band used in bias error and uncertainty calculations, which seem fine for low and high frequency regions.
 - ii. GEH action: Show integrated total forces and moments over selected dryer regions, and [REDACTED] as function of frequency (same frequencies and regions used in Bias and Uncertainty Factor (BUF) [REDACTED] calculations).
- c. Ensure acoustic and structural models are aligned.
 - i. QC2 – not based on an Inventor model. GEH and its subcontractors had to manually ensure the models were aligned. There might be some mismatch (gap) between the models.
 - ii. SSES – both models are based on a common 'inventor' CAD model, and therefore must be aligned.
 - iii. GGNS – both models are based on a common 'inventor' CAD model, and therefore must be aligned.
- 4. Structural FE models – QC2, SSES, GGNS
 - a. Methodology for choosing and assessing locations of peak stresses.
 - b. Need to ensure that any changes in meshing/modeling procedures for GGNS are conservative with respect to benchmark meshing (CAR 53718).
 - i. GEH action: provide a write-up on FE structural meshing procedure, justification that GGNS meshing procedures are conservative with respect to SSES benchmarks
 - c. Global modeling – GEH described the shell element-to-solid element transition methodology used in the finite element modeling of the dryer. (CAR 51627). The methodology is technically sound and, therefore, acceptable.
 - i. GEH action: provide a write-up on the methodology, including the description of [REDACTED] [REDACTED] are determined.

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d. Submodeling

- i. Confirm that the linear path selected to determine the stresses for each of the GGNS submodels (using solid elements) provides the [REDACTED], which will, in turn, result into the [REDACTED].

5. Measured dryer pressures, strains, accelerations; bias errors and uncertainties

- a. [REDACTED] PBLE bias errors and uncertainties are defined in MFN 09-509, which is Reference 3 to Appendix F of the GGNS submission [1], and previously approved by the NRC in the ESBWR SER.
- b. Although GEH is applying [REDACTED] to its FE models, they are benchmarking the PBLE based on [REDACTED] measurements. There is no justification yet submitted for using [REDACTED] for benchmarking, instead of [REDACTED] (CAR 52126).
 - i. GEH action: submit benchmarking of limited set of [REDACTED] at several power levels, prove that [REDACTED].
- c. Examination of the SSES dryer strains and accelerations reveals the dominant signals are due to tones at [REDACTED].
 - i. GEH action: explain how tones from [REDACTED] will be accounted for in GGNS, perhaps by comparing SSES and GGNS in-plant measurement.

6. The SSES2 steam dryer has recently experienced some cracking which might be due to fatigue. The licensee is requested to provide any preventive measures or design changes to GGNS dryer in light of the cracking observed in SSES2.

The NRC staff requests that Entergy submit a report after the evaluation of SSES2 steam dryer cracking is completed, explaining whether there are any areas of the GGNS replacement dryer that need to be modified or further analyzed based on the final results and conclusions of the SSES evaluations.

- a.
 - i. GEH action: explain any GGNS dryer design changes to prevent the cracking observed in SSES2. Some of this might be covered in an RAI response.

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7. Calculated GGNS dryer stresses – time histories and Spectra

a. CAR 50169 (lug stresses)

GEH provided a checklist and procedure (DRF 0000-0109-0408, Section 0000-0112-3093 R0) and compliance Table Revision 1 – Steam Dryer Regulatory Requirements for Dryer Analyses (52 pages). The checklist was comprehensive and would avoid errors in the dryer analysis. The table mentions [REDACTED] pounds per square inch (psi) (instead of [REDACTED] psi) as an acceptance criterion for fatigue assessment of the steam dryer components that may generate loose parts. However, this criterion is used for the ESBWR design and not the GGNS replacement dryer design. This observation was communicated to the GEH staff.

b. GEH action: provide confirmation that the range of peak stress intensity is assumed to be [REDACTED] over time history (this was cited in ESBWR submission). Please explain whether the conservatism introduced by this assumption is quantified for the GGNS and/or SSES dryers.

c. CAR 52763 reveals that incorrect FE dimensions were included in the original analysis: [REDACTED], not yet corrected.

i. GEH action: assess the impact of this modeling error on stresses

d. The NRC reviewed GEH's stress reduction factor justifications, including the one which reduces the stresses to [REDACTED] of those in main model (a region of fairly low stress). However, this was not the limiting location. This topic is discussed above under 4 d (i).

i. GEH action: Provide a summary of the GGNS reanalysis of the replacement steam dryer stresses. Include a list of changes made for the reanalysis and provide a comparison with the relevant stresses calculated in the original analysis submitted to the NRC.

8. Corrective Action Reports and DRFs

Based on NRC's request, GEH conducted a keyword search for all CARs of interest. The NRC audit team identified follow-on actions (as described above) associated with several CARs.

During the audit, the NRC staff was informed by Entergy that GEH has reanalyzed the GGNS replacement dryer. Action: The licensee was requested to explain whether the reanalysis led to any changes in the design of the replacement dryer.

Also, the audit team requested for several DRFs related to the replacement dryer original analysis (submitted September 2010) and reanalysis (yet to be submitted). Most

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of these are related to items not included on our original audit list, including trending of stresses to EPU conditions. GEH provided the following documents for review.

Document	Section
DRF-0000-0109-0408	0120-8682
DRF-0000-0093-5727	0106-2262
DRF-0000-0093-5727	0121-479
DRF-0000-0109-0408	0114-1149, 0119-7952, 0120-3881, 0120-8539, 0120-9020
DRF-0000-0125-1506	
DRF-0000-0126-8302	
DRF-0000-0128-9666	
DRF-0000-0129-7181	
DRF-0000-0130-0842	
DRF-0000-0130-9183	
DRF-0000-0131-0351	
DRF-0000-0131-1235	
DRF-0000-0132-3474	
DRF-0000-0128-5076	

- 9. During the audit, GEH stated that there is some conservatism in its GGNS dryer stress assessment, which is not quantified.
 - a. GEH action: provide a list of conservatisms and approximate quantification (if available) in the GEH GGNS and/or SSES steam dryer stress evaluation.

3.0 ACTION ITEMS

- 1. inaccuracies in acoustic model: The licensee is requested to submit GEH's quantitative assessment of the impact of the errors on the GGNS dryer loads.
- 2. Acoustic term: The licensee is requested to provide a justification on why the use of is conservative for all other dryers, citing previously accepted ESBWR SER.
- 3. Load mapping – structural vs. acoustic models: The licensee is requested to show integrated total forces and moments over selected dryer regions, and , as function of frequency (for the same frequencies and regions used in Bias and Uncertainty Factor (BUF) narrow-band calculations).
- 4. Structural FE models: The licensee is requested to provide a write-up on FE structural meshing procedure and a justification that GGNS meshing procedures are conservative with respect to SSES benchmarks.
- 5. Structural FE models: The licensee is requested to provide a write-up on the methodology, including a description of how the , for transition from shell element to solid element, are determined.

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6. Measured dryer pressures, strains, accelerations, bias errors and uncertainties: The licensee is requested to submit benchmarking of limited set of [REDACTED] at several power levels, prove that [REDACTED].
7. Consideration of [REDACTED] The licensee is requested to explain how tones from [REDACTED] will be accounted for in GGNS. The explanation could be based on a comparison of SSES and GGNS in-plant measurements.
8. Consideration of the dryer cracking experience from SSES2: The licensee is requested to provide any preventive measures or design changes to GGNS dryer in light of the cracking observed in SSES2 steam dryer.

The NRC staff also requests that ENTERGY submit a report after the evaluation of SSES2 steam dryer cracking is completed, explaining whether there are any areas of the GGNS replacement dryer that need to be modified or further analyzed based on the final results and conclusions of the SSES evaluations.

9. GGNS dryer stresses: The licensee is requested to provide confirmation that the range of peak stress intensity is assumed to be [REDACTED] over time history (this was cited in ESBWR submission) for the GGNS steam dryer calculations. The licensee is also requested to explain whether the conservatism introduced by this assumption is quantified for the GGNS and/or SSES dryers.
10. GGNS steam dryer stresses: [REDACTED] as noted in CAR 52763. The licensee is requested to determine the impact of this modeling error on dryer stresses.
11. GGNS steam dryer stresses: The licensee is requested to provide a summary of the GGNS reanalysis of the replacement steam dryer stresses. This summary should include a list of changes made for the reanalysis and a comparison of the relevant stresses from reanalysis with those calculated in the original analysis submitted to the NRC. The licensee is also requested to explain whether the reanalysis led to any changes in the design of the replacement dryer.
12. Conservatism in steam dryer stresses: The licensee is requested to provide a list of conservatisms and approximate quantification where appropriate in the GGNS and/or SSES steam dryer stress evaluations performed by GEH.

4.0 CONCLUSIONS

1. During the audit, the NRC staff was informed by the licensee that GEH has reanalyzed the GGNS replacement dryer. The staff was also informed by GEH that the conclusion

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reached in the original steam dryer analysis regarding the acceptability of the GGNS replacement steam dryer for the EPU operation is not affected.

The licensee is requested to explain whether the reanalysis led to any changes in the design of the replacement dryer.

- 2. There are sufficient errors and omissions in the originally submitted analysis requiring the licensee to submit a summary of its reanalysis of the GGNS replacement dryer, including: (1)

[REDACTED]; (2) [REDACTED]; and (3) [REDACTED]

5.0 DOCUMENTS REVIEWED

Documents requested and made available by GEH during the audit:

- | | |
|--------------------|--------------------|
| DRF-0000-0109-0408 | DRF-0000-0129-7181 |
| DRF-0000-0093-5727 | DRF-0000-0130-0842 |
| DRF-0000-0093-5727 | DRF-0000-0130-9183 |
| DRF-0000-0109-0408 | DRF-0000-0131-0351 |
| DRF-0000-0125-1506 | DRF-0000-0131-1235 |
| DRF-0000-0126-8302 | DRF-0000-0132-3474 |
| DRF-0000-0128-9666 | DRF-0000-0128-5076 |

GEH Corrective Action Reports (CARs)

- | | |
|-----------|-----------|
| CAR 49314 | CAR 50169 |
| CAR 51627 | CAR 52126 |
| CAR 53032 | CAR 53060 |
| CAR 53718 | |

Principal Contributor:

Date: October 19, 2011

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If you have any questions regarding the Audit Report, please contact me at (301) 415-1445 or Alan.Wang@nrc.gov.

Sincerely,

/RA/

Alan B. Wang, Project Manager
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-416

Enclosures:

- 1. Audit Report (Proprietary)
- 2. Audit Report (Non-Proprietary)

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