March 16, 2006

MEMORANDUM TO: A. Randolph Blough, Director
Division of Reactor Safety
Region I

FROM: Cornelius F. Holden, Deputy Director ***/RA/***
Division of Operating Reactor Licensing
Office of Nuclear Reactor Licensing

SUBJECT: FINAL RESPONSE TO TASK INTERFACE AGREEMENT - TIA 2005-002, RELATING TO THE INTEGRITY OF THE REACTOR RECIRCULATION SYSTEM AT HOPE CREEK GENERATING STATION (TAC NO. MC9505)

By letter dated April 21, 2005, the Nuclear Regulatory Commission Region I office submitted Task Interface Agreement (TIA) 2005-002 requesting assistance from the Office of Nuclear Reactor Regulation (NRR) in assessing whether the licensee's corrective actions and supporting analyses associated with a reactor recirculation (RR) system leak were adequate to justify start-up from an unplanned outage at the Hope Creek Generating Station (Hope Creek). PSEG Nuclear LLC (PSEG), the licensee for Hope Creek, conducted a downpower on March 26, 2005, to investigate an increasing trend in unidentified leakage. PSEG identified leakage from a weld that connects a 4-inch decontamination port to the "B" RR system piping. PSEG shut the plant down, repaired the weld, and modified the piping to prevent recurrence.

The TIA requested NRR responses to five questions regarding the licensee's corrective actions. The specific questions related to the licensee's evaluation of high vibrations of the "B" RR pump as a potential cause of the weld failure, the adequacy of evaluations performed by MPR Associates, Inc. (PSEG's contractor) regarding piping modifications, the adequacy of PSEG's vibration analysis for the reactor water clean-up (RWCU) line connected to the RR piping, and the acceptability of PSEG's design practice regarding system isometric stress analyses.

By memo dated May 31, 2005 (Agencywide Documents Access and Management System (ADAMS) accession number ML051430110), NRR issued its draft response to TIA 2005-02. Region I did not have comments on the draft response; however, NRR identified a problem with the evaluation of the RWCU line (Question No. 3 of the TIA). NRR recommended that PSEG provide an additional independent confirmation to support the adequacy of its RWCU vibration analysis. This had been discussed with PSEG, and PSEG stated that the issue would be included in the final root cause analysis report. The licensee completed its re-evaluation of the RWCU piping in May of 2005.

On January 30, 2006, PSEG sent NRR a copy of the revised analyses of the RWCU line. NRR's Division of Engineering, Engineering Mechanics Branch, reviewed the revised analyses and determined that it adequately addressed NRR's concerns. The attachment contains NRR's assessment of the five TIA questions, including consideration of the revised analyses of the RWCU line.

If you have any questions on this matter or the staff's assessment, please contact the NRR Hope Creek project manager, Stewart Bailey, at (301) 415-1321 or snb@nrc.gov.

Principal Contributors: J. Fair
S. Unikewicz

Docket No. 50-354

Attachment:
As Stated

cc w/ attachment: C. Casto
C. Pederson
D. Chamberlain

If you have any questions on this matter or the staff's assessment, please contact the NRR Hope Creek project manager, Stewart Bailey, at (301) 415-1321 or snb@nrc.gov.

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ADAMS Accession Number: ML060520401
* Previous input for Questions 1, 2, 4, and 5 provided 5/16/2005. No significant changes made.

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STAFF ASSESSMENT IN RESPONSE TO

REGION I TASK INTERFACE AGREEMENT 2005-02

THE INTEGRITY OF THE REACTOR RECIRCULATION SYSTEM AT

HOPE CREEK GENERATING STATION

I. INTRODUCTION

By letter dated April 21, 2005, the Nuclear Regulatory Commission Region I office submitted Task Interface Agreement (TIA) 2005-002 requesting assistance from the Office of Nuclear Reactor Regulation (NRR) in assessing whether the licensee's corrective actions and supporting analyses associated with a reactor recirculation (RR) system leak were adequate to justify start-up from an unplanned outage at the Hope Creek Generating Station (Hope Creek). PSEG Nuclear LLC (PSEG), the licensee for Hope Creek, conducted a downpower on March 26, 2005, to investigate an increasing trend in unidentified leakage. PSEG identified leakage from a weld that connects a 4-inch decontamination port to the "B" RR system piping. PSEG shut the plant down, repaired the weld, and modified the piping to prevent recurrence.

The TIA requested NRR responses to five questions regarding the licensee's corrective actions. The specific questions related to the licensee's evaluation of high vibrations of the "B" RR pump as a potential cause of the weld failure, the adequacy of evaluations performed by MPR Associates, Inc. (PSEG's contractor) regarding piping modifications, the adequacy of PSEG's vibration analysis for the reactor water clean-up (RWCU) line connected to the RR piping, and the acceptability of PSEG's design practice regarding system isometric stress analyses.

By memo dated May 31, 2005 (Agencywide Documents Access and Management System (ADAMS) accession number ML051430110), NRR issued its draft response to TIA 2005-02. Region I did not have comments on the draft response; however, NRR identified a problem with the evaluation of the RWCU line (Question No. 3 of the TIA). NRR recommended that PSEG provide an additional independent confirmation to support the adequacy of its RWCU vibration analysis. This had been discussed with PSEG, and PSEG stated that the issue would be included in the final root cause analysis report. The licensee completed its re-evaluation of the RWCU piping in May of 2005.

On January 30, 2006, PSEG sent NRR a copy of the revised analyses of the RWCU line. NRR's Division of Engineering, Engineering Mechanics Branch, reviewed the revised analyses and determined that it adequately addressed NRR's concerns.

The following discussion provides NRR's assessment of the five TIA questions, including consideration of the revised analyses of the RWCU line. For Question Nos. 1, 2, 4, and 5, the responses are unchanged from the draft response provided on May 31, 2005. The response to Question 3 has been updated to reflect the revised analyses of the RWCU line.

II. BACKGROUND

The unidentified leak rate had been trending upward at Hope Creek since February 8, 2005. On March 26, PSEG shut down the plant to investigate the cause for the leakage and identified an approximate 4-inch long, through-wall, circumferential crack in the butt weld connecting a

4-inch diameter chemical decontamination line to the “B” RR piping. PSEG investigated this problem and documented the root cause(s) and associated corrective actions in the “B-Reactor Recirculation Decontamination Connection Leak - Cause Determination Report,” dated March 27, 2005.

PSEG attributed the crack to the propagation of a subsurface weld discontinuity by metal fatigue. The fatigue was attributed to the 5X harmonic piping vibration levels that were applied to the RR piping by rotation of the five-vane RR pump impeller. The weld discontinuity was not identified on the original construction radiographs and was also not visible on the digitally-enhanced image of the original radiograph. The weld that failed was in the scope of Hope Creek’s in-service inspection program but had never been selected for examination.

III. NRR STAFF RESPONSE TO REGION REQUEST

Region I requested NRR’s review of five issues. The NRR review of each issue is summarized below.

Request 1:

> What role did the RR pump speed play in the RR piping leak? Did the "B" RR pump vibration, due to a shaft bow condition, contribute to the failure of the decontamination line connection?

NRR Response:

PSEG’s contractor, MPR, performed a finite element analysis of the decontamination line (MPR Calculation C-0142, Attachment 16). The results of the finite element analysis indicate that the natural frequency of the decontamination line was about 122 Hz. This frequency is very close to the vane passing frequency (5X) of the RR pump at the pump operating speed during full power operation (approximately 1500 rpm). As a consequence, the RR piping vibration associated with the 5X frequency was significantly amplified in the decontamination line. The MPR analysis of the decontamination line indicated that a significant amplification of the RR piping vibration level was necessary to cause crack propagation in the 4-inch decontamination line attachment weld (MPR Calculations C-0142, Attachment 17 and 1108-0002-08).

During operations, core thermal power is controlled by varying and adjusting both control rod position and RR pump speed. Therefore, during the course of operation at 100% power, an RR pump operates intermittently at specific speeds between 1480 and 1510 rpm. Therefore, any time the RR pump operated at 1500 rpm, the decontamination line was in resonance with the vane passing frequency. Since pump speed varies, this resonant condition existed intermittently over the course of operation. The intermittent operation of the RR pump at the decontamination line resonant frequency led to intermittent growth of the high-cycle fatigue crack.

The RR pump vibration associated with the shaft bow occurs at the 1X frequency (approximately 25 Hz). The RR piping vibration associated with the 1X frequency was not amplified in the decontamination line. The MPR analysis of the decontamination line indicated that the RR piping vibration associated with 1X frequency would impose negligible stress on the

attachment weld and would not have caused a fatigue crack to propagate in the attachment weld.

NRR concludes that the MPR analyses demonstrated that the RR pump shaft vibration was not a significant contributor to the decontamination line attachment weld failure.

Request 2:

> Did the MPR Associates, Inc. report (contained within the PSEG Causal Analysis Report) adequately review the frequency response of the modified 4-inch “A” and “B” decontamination lines to ensure a low susceptibility of the modified lines to a similar type of piping failure?

NRR Response:

The NRR staff reviewed the MPR report and found that it adequately addressed the frequency response of the modified 4-inch “A” and “B” decontamination lines. The 4-inch diameter pipe stub in the "B" RR loop was modified by reducing the length of straight pipe from 7.5 inches to 3.75 inches, thereby increasing the first natural mode frequency of the modified 4-inch pipe stub to 179 Hz and eliminating the resonant effects of the RR pump vane passing (5X) frequency. The 4-inch pipe stub in the "A" RR loop was similarly modified to increase the margin from its natural frequency to the RR vane passing frequency. NRR concludes that the modifications will ensure low susceptibility of the decontamination lines to a similar type of failure.

Request 3:

> Did PSEG’s modal analysis for the reactor water clean-up (RWCU) 4-inch line and PSEG engineering calculation, SC-0223, Revision One, “Evaluation of Post-Modified Pipe Vibrations of the Reactor Recirculation Instrument Lines,” provide a reasonable basis to conclude that these lines had a low susceptibility to a similar type of piping failure?

NRR Response:

PSEG performed a modal analysis of the RWCU lines to identify any additional susceptible locations. PSEG indicated that the modal analysis did not identify any susceptible locations. The analysis used a 1g (measure of acceleration) spectrum input at frequencies near the 5X frequency. The 1g input was selected to bound the RR piping measured accelerations. The NRR staff believes that the analysis should have used the amplified response to the 1g input, which would be higher than 1g. Although the NRR staff did not completely agree with PSEG’s analysis methodology, the NRR staff judged that the RWCU lines were unlikely to be susceptible to the high frequency vibrations. This judgement was based on the flexibility of the attached RWCU piping runs which should filter part of the high frequency response as well as past operating experience of the RWCU piping and the low vibrational stresses reported in PSEG’s modal analysis. In addition, all 4-inch butt welded lines were examined by penetrant testing and ultrasonic testing and no flaws were identified. However, NRR recommended that PSEG provide additional independent confirmation to support the technical adequacy of its RWCU vibration analysis. PSEG had stated that they would perform an independent

assessment and include the results in the final root cause analysis report. The licensee's contractor, MPR, completed the re-evaluation of the RWCU piping in May of 2005.

The revised RWCU vibration analysis consisted of MPR Calculation 1108-0502-0002, Revision 0, "Vibration Acceleration Calculation of Hope Creek RWCU System Piping," Attachment 17 to C-1843, Revision 0, "Finite Element Harmonic Analysis of RWCU System Piping from Recirculation Loop A," Attachment 17 to C-1844, Revision 0, "Finite Element Harmonic Analysis of RWCU System Piping from Recirculation Loop B," and Calculation 1108-0002-03, Revision 1, "RWCU Piping Stresses from Reciculation System Vibration." These calculations determine the magnitude and frequency of vibration at the location where the RWCU piping connects to the RR piping, amplify that vibration along the RWCU line, and calculate the resulting piping stresses. The NRR technical staff reviewed these calculations and determined that they address the staff's concerns. Therefore, NRR concludes that the licensee's analyses provide a reasonable basis to conclude that the RWCU lines have a low susceptibility to a similar type of piping failure at the current operating conditions.

Request 4:

> Did PSEG provide sufficient information to demonstrate that the 5X frequency harmonic was the predominate contributor to the vibration induced fatigue piping problem at Hope Creek?

NRR Response:

As discussed in the response to the Region's Request 1, the MPR analysis (provided by PSEG) indicated that significant amplification of the RR piping vibration was necessary to cause a fatigue crack to propagate in the decontamination line attachment weld. The analysis demonstrated that significant amplification of the decontamination line would be caused by the 5X frequency harmonic when the pump was operated near 1500 rpm. NRR concludes that MPR analyses adequately demonstrated that the 5X frequency harmonic was the predominate contributor to the fatigue failure of the decontamination line attachment weld.

Request 5:

> The 4-inch attachments to the RR system were not included in the original system isometric stress analysis. Was this an acceptable design practice?

NRR Response:

It was standard industry practice to decouple small branch lines from main piping runs for the analysis of piping systems in order to limit the size of the dynamic analysis model. This design practice is acceptable as long as the small branch line does not have a significant impact on the dynamic response of the main piping run. The small branch line is then evaluated separately. Typical industry practice for decoupling a branch line from the main piping run is when the ratio of moment of inertia of the main piping run to the moment of inertia of the branch line is greater than 25. The ratio of the moment of inertia of the RR main loop to the moment of inertia of the 4-inch decontamination line is much greater than 25. Therefore, NRR concludes that the stress

analysis model of the RR main loop, which did not include the 4-inch decontamination line, was consistent with standard industry design practice and is acceptable.

IV. CONCLUSION

The staff has reviewed the material provided by PSEG regarding their corrective actions and supporting analyses associated with an RR system leak. Overall, the NRR staff concludes that PSEG's corrective actions and associated evaluations were adequate to support a restart of the Hope Creek Unit. However, with regard to PSEG's modal analysis for the RWCU 4-inch line and PSEG's engineering calculation, SC-0223, Revision One, the NRR staff did not completely agree with PSEG's analysis methodology. NRR recommended that PSEG provide additional independent confirmation to support the technical adequacy of its RWCU vibration analysis. Notwithstanding this staff recommendation, the NRR staff judged that the RWCU lines were unlikely to be susceptible to the high frequency vibrations.

PSEG re-analyzed the RWCU piping in May of 2005. NRR has reviewed the revised analyses and determined that 1) it resolved the NRR's concerns, and 2) it provides a reasonable basis to conclude that the RWCU lines have a low susceptibility to a similar type of piping failure at the current operating conditions.