April 15, 2005

MEMORANDUM TO: Brian Sheron
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SUBJECT: HOPE CREEK GENERATING STATION, NRR STAFF REVIEW OF PSEG NUCLEAR INC.'S CAUSAL DETERMINATION AND CORRECTIVE ACTIONS FOR THE FAILURE OF A WELD THAT CONNECTS A 4-INCH DECONTAMINATION CONNECTION TO THE "B" RECIRCULATION LOOP PIPING (YT020050058; TAC MC6613)

This memorandum documents the Nuclear Regulatory Commission (NRC), Office of Nuclear Reactor Regulation (NRR) staff's assessment of PSEG Nuclear Inc.'s (PSEG or the licensee) causal determination and corrective actions related to a recent failure of a weld between a 4-inch decontamination connection and the "B" loop recirculation piping at Hope Creek Nuclear Generating Station (Hope Creek). Specifically, it documents NRR's conclusions regarding the relation between the "B" recirculation pump vibration, caused by a potentially bowed shaft, and the failure of the decontamination pipe weld.

The restart assessment presented below is the result of: Region I inspection activities; NRR reviews of material provided by the licensee; internal NRC discussions between NRR, Region I (including resident inspectors), and Office of Nuclear Regulatory Research staff; and, discussions with the licensee and its contractors. More detailed answers to questions that Region I requested NRR assistance in addressing will be provided through the task interface agreement process.

Background:

Following restart from the fall 2004 refueling outage (1R13) in February 2005, Hope Creek experienced an upward trend in unidentified reactor coolant system leakage within the drywell. The leakage increased from 0.15 gallons per minute (gpm) to 0.73 gpm. Although this was below the Technical Specification (TS) limit of 5 gpm for unidentified leakage, Hope Creek commenced a downpower on March 26, 2005 to identify and repair the leak.

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Following the unit downpower, plant personnel entered the drywell and identified a steam leak at an insulated decontamination connection on the reactor recirculation system on the suction side of the “B” reactor recirculation pump. The decontamination connection, which is sealed with a bolted blank flange/cover during plant operations, is a pipe approximately 7.5 inches long and 4 inches in diameter. This pipe is welded to a weldolet in the reactor recirculation (RR) system piping and is designed to be used on an infrequent basis during outage periods when a hose is bolted to the flange and chemicals are flushed through it to decontaminate the piping system.

The licensee made the decision to transition the plant to cold shutdown to repair the leak. After the plant reached cold shutdown, the licensee was able to remove insulation from the piping and further inspect the leak source. It was determined that the leak was coming from an approximately 4-inch long circumferential through-wall crack in the pipe-to-weldolet weld at the decontamination connection.

Hope Creek Re-Start Assessment

Specific Actions Regarding the 4-inch Line Failure:

- PSEG demonstrated that the likely cause of failure of the weld connecting the 4-inch diameter decontamination pipe stub to the 28-inch "B" loop reactor recirculation (RR) piping was high-cycle fatigue due to the first natural mode frequency of the pipe stub (approximately 125 Hz) being in resonance with the RR pump vane passing frequency (5 times the pump shaft rotational speed of approximately 1500 rpm, or 5X).

- The pump vibration data showed that shaft condition did not significantly contribute to the weld failure because the highest pump shaft vibration occurs at 25 Hz (1X) which causes negligible stress in the 4-inch pipe weld.

- The 4-inch diamteter 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.

- The material test results provided a plausible explanation of the circumstances that caused the weld to fail by showing that the crack initiated at a subsurface planar discontinuity (possibly years earlier) and propagated approximately 90% through wall before stopping. The recent changes in pump operating speed may have contributed to the recent failure of the remaining ligament by exciting the resonant frequency of the 4-inch pipe stub.

Review of Other Recirculation System Components to Vibration-Induced Fatigue Failure:

- PSEG expanded its inspection to include a number of welds in RR branch piping using a variety of non-destructive examination (NDE) methods (ultrasonic testing (UT), penetrant testing (PT), radiographic testing, and visual testing) and found no indications of additional fatigue cracking. The staff believes that the expanded inspection sample provides a reasonable level of assurance that the population of welds in the RR branch

lines are acceptable. In addition, the staff determined that PSEG has completed the required inspections in accordance with Section XI of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, and the NRC-approved inservice inspection (ISI) program.

- The vibration monitoring program, previously formalized by an NRC confirmatory action letter dated January 11, 2005 to monitor the “B” RR pump shaft, remains in place to alert PSEG if the pump shaft degrades. Thus far, there has been no indication of deterioration of the pump shaft.

- Vibration levels for large bore recirculation piping and piping attachments (i.e., 12 inches and higher) were monitored and found to be within analyzed limits established by the applicable General Electric (GE) design analysis. PSEG reported that the GE analysis reviewed the system response over a wide range of frequencies (including the 5X frequency).

- Throughout the plant life, the licensee has performed NDE examinations (PT and UT) of the large bore piping welds in accordance with their approved ISI program. In addition, the inspector selected four areas for review that were believed to have experienced previous elevated vibration levels (relative to other portions of the RR system) and noted that the associated welds had been previously examined and found to be acceptable.

- For the remaining 4-inch butt-welded connections (excluding the decontamination lines) PSEG performed a modal analysis of the reactor water cleanup (RWCU) lines to identify any additional susceptible locations. PSEG indicated that the modal analysis did not identify any susceptible locations. Although the staff did not completely agree with PSEG’s analysis methodology, the staff accepted the licensee’s conclusion that the RWCU lines are unlikely to be susceptible to the high frequency vibrations. This judgement is based on the flexibility of the attached RWCU piping runs which should filter part of the high frequency response, 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 PT and UT and no flaws were identified. However, NRR recommends that PSEG provide additional independent confirmation to support the technical adequacy of its RWCU vibration analysis. The licensee agreed to preform supplemental vibration analysis of the RWCU line as part of its complete root cause analysis report, which will be reviewed by the NRC.

- PSEG discussed the susceptibility of the small bore lines connected to the RR piping to vibration fatigue. Some fatigue - related problems have occurred on these lines in the past. PSEG had previously implemented multiple actions including modifications, NDE, and analysis to address this problem. PSEG performed dynamic analysis of the small bore lines on the RR pump suction piping where the previous fatigue failures had occurred to demonstrate that the stresses in the modified small bore lines were within acceptable limits. The staff did not identify any particular concerns with PSEG’s actions to address the small bore piping. In addition, PSEG conducted NDE (PTs) on 20 small bore lines during this outage and did not identify any adverse indications.

- PSEG confirmed, during a conference call on April 6, 2005, that there were no additional lines or connections to the RR system other than the large bore, 4-inch or small bore

lines (i.e., less than or equal to 1 inch) discussed above. Additionally, PSEG provided information and discussed their rationale for concluding that the RR piping system response to the 5X frequency harmonic bounded the response for other frequency harmonic levels. The NRC staff finds the licensee's conclusion to be reasonable.

In addition, the staff noted a number of additional programs and processes designed to prevent and detect leakage of this type. These included: quality, design and fabrication standards; ISI program requirements to periodically monitor (on a sampling basis) the integrity of the safety-related piping systems; on-line leakage monitoring equipment designed to detect small amounts of leakage; and TS limits and operating procedures to prevent continued plant operation with excessive leakage.

Based on the above, the staff concluded that PSEG implemented reasonable corrective actions to minimize the potential for a similar RR piping leakage event.

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