November 29, 2006

EA-06-291

Mr. Christopher M. Crane
President and Chief Nuclear Officer
Exelon Nuclear
Exelon Generation Company, LLC
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: NRC INSPECTION REPORT 05000461/2006011(DRS); PRELIMINARY GREATER THAN GREEN FINDING FOR CLINTON POWER STATION

Dear Mr. Crane:

The enclosed inspection report discusses a finding that appears to have greater than very low safety significance. As described in Section 1R21.b.1 of the report, with respect to the reactor core isolation cooling (RCIC) water storage tank volume's design analysis, your staff failed to select an appropriate method for calculating the minimum elevation (i.e., the analytical level) of water above the high pressure core spray (HPCS) pump suction line to preclude vortex formation and subsequent air entrainment in the pump's suction. After further evaluation, we concluded that the analytical level would cause significant air entrainment and that HPCS would not be capable of completing its safety function. This finding was previously identified during the safety system design and performance capability inspection as an unresolved item (URI) 05000416/2005002-01(DRS).

In response to this issue, on December 1, 2005, your staff shifted the HPCS and RCIC inventory source to the suppression pool as allowed by your Technical Specifications. The inspectors concluded that vortexing from the suppression pool should not occur due to the depth of the HPCS and RCIC suction lines. We also understand that the RCIC water storage tank was modified on August 12, 2006, to recover RCIC and HPCS vortex margin. This inspection did not include a review of this modification; therefore, this finding specifically focuses on past operability of the HPCS system.

This finding was assessed based on the best available information, including influential assumptions, using the applicable Significance Determination Process (SDP) and was preliminarily determined to be a Greater Than Green finding. We determined the finding was greater than minor because if left uncorrected, it would result in the failure of the HPCS pump due to significant air entrainment as the water level in the RCIC storage tank decreased prior to the suction swapping over to the suppression pool. The finding involved the ability to meet the Mitigating System cornerstone objective of ensuring the availability, reliability, and capability of the HPCS system. The potential loss of function assumed in the Phase 1 analysis resulted in the completion of a Phase 2 and eventually, a Phase 3 analyses. These analyses led to a conservative result with a number of uncertainties and we concluded that further information was required to properly assess the risk. The information required to reduce the uncertainties in the risk evaluation includes additional detail regarding the impact of the risk due to internal fires and floods. Specifically, for fire and flood scenarios where the HPCS system is credited as a mitigating system, we would need information regarding the initiating event frequency and the PRA targets that are affected by the postulated fire or flood. Additionally, to further consider the assumptions used in your risk evaluation, we need detailed information regarding the expected operator actions in response to an increasing suppression pool level and an understanding of the operation of the HPCS injection valve, 1E22F004, including the ability to throttle its position.

The significance determination process encourages an open dialogue between the staff and the licensee; however, the dialogue should not impact the timeliness of the staff's final determination. Before we make a final decision on this matter, we are providing you with an opportunity to attend a Regulatory Conference where you can present to the NRC your perspective on the facts and assumptions the NRC used to arrive at the finding and assess its significance. This conference is currently scheduled for December 19, 2006. We encourage you to submit supporting documentation at least one week prior to the conference in an effort to make the conference more efficient and effective. This conference will be open for public observation. In addition, we would like you to discuss your assessment with respect to previous opportunities to identify and correct this issue.

Please contact Mrs. Ann Marie Stone at (630) 829-9729 within 10 business days of the date this letter to reconfirm the Regulatory Conference arrangements. If we have not heard from you within 10 business days, we will continue with our significance determination and enforcement decision and you will be advised by separate correspondence of the results of our deliberations on this matter.

In accordance with Inspection Manual Chapter (IMC) 0609, we intend to complete our evaluation using the best available information and issue our final determination of safety significance within 90 days of this letter.

The finding is also an apparent violation of NRC requirements and is being considered for escalated enforcement action in accordance with the Enforcement Policy, which can be found on the NRC's Web site at http://www.nrc.gov/reading-rm/adams.html. Since the NRC has not made a final determination in this matter, no Notice of Violation is being issued for this inspection finding at this time. In addition, please be advised that the number and characterization of the apparent violation described in the enclosed inspection report may change as a result of further NRC review.

In addition, one NRC-identified finding of very low safety significance which involved a violation of NRC requirements was identified. However, because this violation was of very low safety significance and because it was entered into your corrective action program, the NRC is treating the issue as a Non-Cited Violation in accordance with Section VI.A.1 of the NRC's Enforcement Policy.

If you contest the subject or severity of the Non-Cited Violation, you should provide a response within 30 days of the date of this inspection report, with the basis for your denial, to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington, DC 20555-0001, with a copy to the Regional Administrator, U. S. Nuclear Regulatory Commission - Region III, 2443 Warrenville Road, Suite 210, Lisle, IL 60532-4352; the Director, Office of Enforcement, U. S. Nuclear Regulatory Commission, Washington, DC 20555-0001; and the Resident Inspector Office at the Clinton Power Station.

In accordance with 10 CFR 2.390 of the NRC's "Rules of Practice," a copy of this letter, its enclosure and response, if you choose to respond, will be made available electronically for public inspection in the NRC Public Document Room or from the Publically Available Records (PARS) component of NRC's document system (ADAMS) and is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

/RA/

Cynthia Pederson, Director
Division of Reactor Safety

Docket No. 50-461
License No. NPF-62

Enclosure: Inspection Report No. 05000461/2006011(DRS)
w/Attachment: Supplemental Information

cc w/encl: Site Vice President - Clinton Power Station
Plant Manager - Clinton Power Station
Regulatory Assurance Manager - Clinton Power Station
Chief Operating Officer
Senior Vice President - Nuclear Services
Vice President - Operations Support
Vice President - Licensing and Regulatory Affairs
Manager Licensing - Clinton Power Station
Senior Counsel, Nuclear, Mid-West Regional Operating Group
Document Control Desk - Licensing
Assistant Attorney General
Illinois Emergency Management Agency
State Liaison Officer, State of Illinois
Chairman, Illinois Commerce Commission

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Sincerely,
/RA/
Cynthia Pederson, Director
Division of Reactor Safety

Docket No. 50-461
License No. NPF-62

Enclosure: Inspection Report No. 05000461/2006011(DRS)
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Plant Manager - Clinton Power Station
Regulatory Assurance Manager - Clinton Power Station
Chief Operating Officer
Senior Vice President - Nuclear Services
Vice President - Operations Support
Vice President - Licensing and Regulatory Affairs
Manager Licensing - Clinton Power Station
Senior Counsel, Nuclear, Mid-West Regional Operating Group
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REGION III

Docket No:	50-461
License No:	NPF-62
Report No:	05000461/2006011(DRS)
Licensee:	AmerGen Energy Company, LLC
Facility:	Clinton Power Station
Location:	Clinton, Illinois
Dates:	March 6, 2006 through November 17, 2006
Inspectors:	George M. Hausman, Senior Reactor Inspector Laura C. Kozak, Senior Reactor Analyst
Approved by:	Ann Marie Stone, Chief Engineering Branch 2 Division of Reactor Safety

SUMMARY OF FINDINGS

IR 05000461/2006011(DRS); 03/06/2006-11/17/2006; Clinton Power Station; Component Design Bases Inspection.

This report covers a followup inspection of unresolved item (URI) 05000416/2005002-01(DRS). The inspection was conducted by regional inspectors. One greater than Green finding was identified. Additionally, one Green finding involving a Non-Cited Violation was identified. The significance of most findings is indicated by their color (Green, White, Yellow, Red) using Inspection Manual Chapter (IMC) 0609, Significance Determination Process (SDP). Findings for which the SDP does not apply may be "Green" or be assigned a severity level after NRC management review. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described in NUREG-1649, "Reactor Oversight Process," Revision 3, dated July 2000.

A. NRC-Identified and Self-Revealing Findings

Cornerstone: Mitigating Systems

- To Be Determined. A finding of greater than very low safety significance was identified by the inspectors for an apparent violation of 10 CFR Part 50, Appendix B, Criterion III, "Design Control" requirements. Specifically, the licensee failed to adequately address vortexing in the reactor core isolation cooling (RCIC) water storage tank. As a result, the setpoint for the high pressure core spray (HPCS) pump suction source to swap from the RCIC tank to the suppression pool may be too low and result in significant air entrainment such that the HPCS pump would not be capable of completing its safety function. As a corrective action, on December 1, 2005, the licensee shifted the HPCS and RCIC inventory source to the suppression pool as a conservative measure. Vortexing from the suppression pool should not occur due to the depth of the HPCS and RCIC suction lines and the use of the suppression pool as a qualified inventory source was allowed per Clinton's Updated Safety Analysis Report (USAR) and Technical Specifications (TS).

  The finding was greater than minor because if left uncorrected, could result in the HPCS system becoming inoperable due to air entrainment as the water level in the RCIC water tank decreased toward the swapover setpoint. This finding affected the Mitigating Systems cornerstone objective of ensuring the availability, reliability, and capability of systems that respond to initiating events to prevent undesirable consequences (i.e., core damage). This finding was determined to be greater than Green based on the preliminary results of the Phase 2 and Phase 3 analyses. (Section 1R21.b.1)

- Green. A finding of very low safety significance was identified by the inspectors for an Non-Cited Violation of 10 CFR Part 50, Appendix B, Criterion III, "Design Control" requirements. Specifically, in Calculation IP-M-0384, "Evaluation of Vortex in the RCIC [Water] Storage Tank," Revisions 0 and 1, the licensee failed to adequately demonstrate that the RCIC pump would be capable of performing its safety function prior to swapping suction paths from the RCIC tank to the suppression pool. As an immediate corrective action, the licensee aligned the suction path of the RCIC system to the suppression pool.

The finding was greater than minor because the calculation of record was not adequate and there was reasonable doubt of the successful outcome of a re-analysis. The finding was determined to be of very low safety significance because the inspectors answered “no” to all five screening questions in the Phase 1 Screening Worksheet under the Mitigating Systems column. After further analysis, the inspectors concluded that the RCIC pump was operable. (Section 1R21.b.2)

B. Licensee-Identified Violations

None.

REPORT DETAILS

1. REACTOR SAFETY

Cornerstone: Mitigating Systems

1R21 Component Design Bases Inspection (71111.21)

a. Inspection Scope

The inspectors performed an announced inspection to assess the impact of vortexing in the reactor core isolation cooling (RCIC) water storage tank with respect to operability of the RCIC and high pressure core spray (HPCS) systems. The impact of vortexing concern was initially identified during the Clinton safety system design and performance capability (SSDPC) inspection as an unresolved item (URI) and is described in Section 4OA5 of this report (URI 05000461/2005002-01(DRS)). The inspectors reviewed documents and calculations, interviewed personnel and performed an independent assessment of the data with assistance from NRR personnel.

b. Finding

One apparent violation for a finding potentially greater than Green and one Non-Cited Violation for a finding of very low safety significance were identified.

b.1 Potential Inoperability of the HPCS Pump Due to Air Entrainment

Introduction: The inspectors identified a finding, whose significance has yet to be determined, for an apparent violation (AV) of 10 CFR Part 50, Appendix B, Criterion III, "Design Control" requirements. Specifically, the inspectors identified that the licensee failed to adequately address vortexing in the RCIC water storage tank. As a result, the setpoint for the high pressure core spray (HPCS) pump suction source to swap from the RCIC tank to the suppression pool may be too low and result in significant air entrainment such that the HPCS pump would not be capable of completing its safety function.

Description: During the Clinton's SSDPC inspection, the inspectors reviewed Calculation IP-M-0384, "Evaluation of Vortex in the RCIC [Water] Storage Tank," Revisions 0 and 1. The purpose of the calculation was to determine the appropriate analytical level (i.e., elevation of water) where vortexing would occur above the HPCS and RCIC pumps' suction lines. The analytical level was then used as a design input to calculate the automatic RCIC water storage tank to suppression pool low level swapover setpoint for the HPCS and RCIC pumps.

The inspectors noted that the methodology used in Calculation IP-M-0384, Revisions 0 and 1, was not appropriate. Specifically, using a correlation developed by Dr. Reddy et.al. in a paper titled, "Vortices at Intakes in Conventional Sumps," the licensee determined a vortex may occur at 19.5 inches above the centerline of the RCIC pipe and about 44 inches above the centerline of the HPCS pipe. The licensee then evaluated this result using Figure 13.b of NUREG/CR-2772, "Hydraulic Performance of Pump Suction Inlets for Emergency Core Cooling Systems in Boiling Water Reactors," which showed the results of a series of tests conducted with a tank at a constant submergence (measured from the centerline) of 24 inches for a 24 inch diameter horizontal inlet (See Attachment to this report). The figure shows that at low Froude numbers, air entrainment in the suction piping was not observed; however, at a Froude number of 1.06, about 0.8 percent air entrainment was observed (assuming no strainer). The licensee drew a straight line from point (0.8,0) [without strainer] to (1.06,0.08) [without strainer] and used this linear relationship in their evaluation. Specifically, as the RCIC tank level decreased to the swapover point, the licensee determined the void fraction at the pipe based on this linear relationship. The licensee then evaluated the amount of time needed for this air to transport to the pump and determined the expected void fraction at the pump. The licensee concluded that at 9.36 inches above the HPCS pipe centerline, the HPCS pump would experience 2 percent air entrainment. The licensee concluded that the analytical vortex limit was 9.36 inches corresponding to about 740 foot elevation in the RCIC tank. The inspectors questioned why the licensee assumed a linear relationship because the experimental data did not indicate or predict a linear relationship with respect to increasing Froude number (decreasing submergence) and void fraction. Because submergence was held constant in the NUREG experiment, the inspectors concluded the methodology used in Calculation IP-M-0384, Revisions 0 and 1, did not account for the actual fluid configuration where air ingestion into the HPCS and RCIC pumps' suction lines would potentially occur. The licensee was unable to provide adequate technical justification for the methodology used and stated the calculation would be revised to consider other methods applicable to this configuration that were more readily accepted by the industry. The licensee entered the finding into their corrective action program as Condition Report (CR) 429583, "NRC SSD&PC RCIC [Water Storage] Tank Vortex Issue," dated December 1, 2005, to evaluate (i.e., perform an operability evaluation) and revise the affected documentation. As a precautionary step, the licensee shifted the HPCS and RCIC inventory source to the suppression pool, a qualified inventory source allowed per Clinton's USAR and TS. Vortexing from the suppression pool should not occur due to the depth of the HPCS and RCIC suction lines.

In December 2005, the licensee revised Calculation IP-M-0384 (Revision 1B) and using a correlation developed by Lubin and Springer (Encyclopedia of Fluid Mechanics, Chapter 41, "Hydrodynamics of Outflows from Vessels, Volume 2, 1986), determined that vortexing would occur when tank level was about 12 inches above the HPCS pipe inlet (about 20 inches from centerline). With the swapover setpoint at about 2 inches above the pipe inlet, the licensee concluded that air entrainment was possible as the HPCS pump drew water from the RCIC water storage tank. As a result, the licensee developed a RELAP5 model, MWMECH-2995-003, of the HPCS suction piping from the RCIC water storage tank to the suppression pool to evaluate the introduction and transport of air in the HPCS suction piping. The inspectors had not completed a review of the licensee's re-analysis by the end of the SSDPC inspection and the issue was considered an URI as described in Section 4OA5 of this report.

During this follow-up inspection, the inspectors reviewed the Calculation IP-M-0384, Revision 1B, and the RELAP5 model, MWMECH-2995-003, Revision 0 in detail. The purpose of IP-M-0384, Revision 1B was to determine the vortex limit and the impact on pump performance. This information was used to define the case studies used in MWMECH-2995-003, Revision 0. For determination of the onset of air entrainment, the licensee referenced a paper, "Air Entrainment in a Partially Filled Horizontal Pump Suction Line," written by R. C. Sanders, et al. This paper documented experiments dealing with the onset of air entrainment for low flow water systems and justification to drop water level to near the top of a pipe inlet without significant air entrainment. The authors developed equations to determine the onset of air entrainment and the observation of 2 percent or more (by volume) entrained air. The authors also concluded that vortices formed at water levels significantly higher than the onset of air entrainment. The inspectors had the following concerns with respect to the licensee's use of this study:

1. Unlike the study performed for NUREG/CR-2772, the 2 percent or more (by volume) air determination was based on visual observation; not measurement. There was no indication of how the "visual observation" was done or what repeatability or reliability could be given to the amount of air attributed to be two percent entrainment. In addition, there was no indication that any calibration efforts were made to actually quantify the amount of air entrainment or to provide any type of uncertainty to the measurement.

2. The licensee interpreted the "2 percent or more" observation as an absolute 2 percent. The licensee then extrapolated the data to determine that when water level dropped to the inlet level of the pipe, the air entrainment would be 5 percent. As a conservative measure, the licensee assumed that 5 percent air entrainment would occur 1 inch above the pipe inlet and change to 100 percent at the inlet. While this assumption of 100 percent may be conservative, the inspectors concluded that the assumption of 5 percent was not supported because: (1) the licensee did not provide justification for a straight line extrapolation; and (2) the observed "2 percent or more" was likely greater than 2 percent.

3. As stated, the experiments were performed to determine the effects of low flow conditions. The resulting formulas were applicable for Froude numbers less than 1.4. For a HPCS design flow of 5880 gpm, the Froude number was 1.72; the licensee stated it was acceptable to use the equations because the values were close and the behavior of the air entrainment function should not alter drastically within the range of interest. The inspectors concluded that this position was not supported. Furthermore, the Clinton Froude number of 1.72 was considerably beyond the bounds.

4. To further justify the acceptability of extrapolating beyond the experimental 2 percent or more (by volume) air entrainment, the licensee determined the Froude number based on submergence and compared that result against Figure 13.b of NUREG/CR-2772. The inspectors did not agree with this approach for the following reasons:

a. The licensee determined that the Froude number (if determined from submergence instead of diameter of the pipe) was 1.84 at the predicted 2 percent air entrainment. The licensee plotted this point in Figure 13.b and concluded that since this point was well below a straight line (developed by the licensee), the void fraction did not increase as fast as the Froude number. The inspectors disagreed with the basis for the licensee's conclusion because the licensee did not provide justification for assuming a linear relationship between points (0.8, 0.0) and (1.06, 0.8) from the figure (the experimental data did not indicate or predict a linear relationship with respect to increasing Froude number and void fraction).

b. The licensee determined that the onset of air entrainment would occur at about 16 inches above the centerline of the pipe. The inspectors determined that the Froude number (based on submergence and a flow rate of 5880 gpm) for the onset of air entrainment would be about 1.66. With a Froude number this large, Figure 13.b would predict air entrainment of at least 0.8 percent - at least the same as that found in the experiment. Using the figure in this manner and assuming the linear relationship as described above, showed that predicted onset of air entrainment was not conservative.

c. The inspectors noted that Figure 13.b of NUREG/CR-2772 plotted the Froude number and void fraction observed during a series of tests. The data showed that at a constant submergence (measured from the centerline) of 24 inches for a 24 inch diameter horizontal inlet, a void fraction of 0.8 was measured for a Froude number of 1.06. Because the data was derived for a specific configuration, the inspectors concluded that its use for other submergence values may not be applicable.

d. The inspectors applied the point (Froude = 1.06, Void Fraction = 0.8) (the experimental data in NUREG/CR2772) to those equations used by the licensee. Assuming a pipe diameter of two-feet (conservative to assume the inner diameter is equal to the outer diameter), the inspectors determined the Froude number remained at 1.06. Applying the equations developed by Sanders, et al, the inspectors determined that the <u>onset</u> of air entrainment was predicted to occur at 33 inches from the bottom of the pipe or 21 inches from the centerline. This prediction significantly contradicts the observed data obtained in the NUREG where air entrainment was actually observed at 24 inches above the centerline.

   Similarly, the inspectors determined the <u>formation</u> of a vortex using the equation derived by Kubie described in IP-M-0384, Revision 1B for the data point from Figure 13.b of NUREG/CR-2772. The inspectors calculated that a vortex would form at about 26 inches above the centerline of pipe. This result is not consistent with the observations from the Sanders, et al study which concluded that vortices formed at water levels significantly higher than the onset of air entrainment. Although the predicted formation of a vortex (26 inches) and the predicted onset of air entrainment (21 inches) differ, the actual results from NUREG/CR-2772 showed 0.8 percent of actual air entrainment very close to the predicted formation of a vortex (24 inches compared to 26 inches). Therefore, the inspectors concluded that based on the significant differences in the predicted and observed data, it appeared that the actual minimum submergence which results in the onset of vortex formation, was likely dependent upon the physical arrangement of the system. Therefore, anything less than a conservative bounding submergence level appeared to need site specific testing or a closer correlation to support a more realistic value.

As stated above, in MWMECH-2995-003, Revision 0, the licensee developed three case studies which varied the assumed air entrainment at the suction point to determine the impact on the HPCS pump. The inspectors had the following concerns:

1. For the first case study, the licensee assumed that air entrainment would be five percent at one inch above the pipe inlet. This was derived using equations developed by Sanders, et al. Based on the above discussion, the licensee did not demonstrate that these equations were acceptable for their application. Therefore, the inspectors did not consider the first case study valid.

2. The second case study assumed that air entrainment would be nine percent at one inch above the inlet pipe. While doubling an assumption appeared conservative, in this case, the original value was not supported. Therefore, the inspectors did not consider the second case study as a bounding case.

3. For the third case, the licensee assumed a 2 percent air entrainment at the predicted point of void formation, 12 inches above the top of the pipe. The case further assumed 12 percent air entrainment at the top of the pipe. The licensee determined that the pump would experience 5 percent air entrainment for a short period of time with no observed degradation or problems with the pump. However, the inspectors concluded that the licensee had not supported the assumption that the vortex at 12 inches about the top of the pipe would be 2 percent.

   In contrast, using a more conservative bounding analysis (Dr. Reddy, et.al.)[1], the inspectors determined that based on Fr = 1.468 (assumes flow rate of 5010 gpm), vortex inception could occur at 21.8 inches above the inlet of the pipe. Based on this, the inspectors could not conclude that an assumption of 2 percent air entrainment at 12 inches above the top of the pipe was reasonable.

Therefore, based on the above, the inspectors concluded the licensee had not demonstrated that the HPCS system would be capable of performing its function before

[1]In the paper, "Vortices at Intakes in Conventional Sumps," the authors state that vortex inception is possible when submergence (s) divided by the diameter of the pipe (d) is less than the Froude number (Fr). In this formula, submergence is measured from the top of the pipe. In Revision 0 and 1 of Calculation IP-M-0384, the licensee used a more conservative formula (s/d = Fr +1) used to ensure a vortex-free operation.

the suction was swapped from the RCIC water storage tank to the suppression pool.
Analysis: The inspectors determined that failure to select an appropriate method for calculating the onset on vortexing at the intake of the HPCS and RCIC pumps' suction lines from the RCIC water storage tank and subsequently demonstrate the HPCS system would be capable of performing its safety function was a performance deficiency warranting a significance evaluation. The inspectors further determined that the issue was within the licensee's ability to foresee and correct and could have been prevented because the licensee identified a concern related to vortexing in 1998.

The inspectors concluded that the finding was greater than minor in accordance with IMC 0612, "Power Reactor Inspection Reports," Appendix B, "Issue Screening," issued on September 30, 2005. Specifically, if left uncorrected, this finding would result in the HPCS system becoming inoperable due to air entrainment as the water level in the RCIC water tank decreased toward the swapover setpoint. This finding affected the Mitigating Systems cornerstone objective of ensuring the availability, reliability, and capability of systems that respond to initiating events to prevent undesirable consequences (i.e., core damage).

The inspectors completed a significance determination of this finding using IMC 0609, Appendix A, "Determining the Significance of Reactor Inspection Findings for At - Power Situations," dated November 22, 2005. The inspectors answered "yes" to screening Question 2 in the SDP Phase 1 Screening Worksheet under the Mitigation Systems Cornerstone column. Specifically, this finding resulted in the HPCS system being incapable of performing its function and being inoperable beyond the limiting condition for operation. Thus a Phase 2 evaluation was required.

In the Phase 2 SDP evaluation, the inspectors assumed that the HPCS pump was unavailable for a period of one year and that the pump was not recoverable. The result of the Phase 2 evaluation was a finding of high significance (Red). The dominant sequence involved a stuck open or inadvertently open safety-relief valve, followed by the failure of the HPCS system due to air entrainment, failure of RCIC due to random failure, and the failure of operators to depressurize the reactor. The RIII Senior Reactor Analyst (SRA) determined that the results of the Phase 2 evaluation were overly conservative and that a Phase 3 SDP evaluation was required.

For the Phase 3 SDP evaluation, the SRA used the NRC's simplified plant analysis risk (SPAR) model to estimate the risk associated with the finding. The suction transfer function of the HPCS system was assumed to fail due to air entrainment and was not recoverable. The same duration of one year that was used in Phase 2 was used in the Phase 3 evaluation. The model was quantified for all initiators with the exception of the station blackout (SBO) sequences. The inspectors and the SRA determined that the preferred source of water for the HPCS system during an SBO event was the suppression pool. Operator training and procedures would direct manual suction swapover to the suppression pool early in the event, well before vortexing and air entrainment would be a concern. In all other scenarios, the RCIC storage tank was the preferred source of water. Therefore, vortexing and air entrainment was a concern for all other scenarios. The dominant scenarios included a loss of offsite power (LOOP) with failure of decay heat removal and late injection, a loss of the reserve auxiliary transformer (LRAT) followed by the failure of all high pressure injection and the failure

to depressurize the reactor, and a loss of main feedwater (LOMFW), also followed by a loss of all high pressure injection and the failure to depressurize the reactor.
In addition to using the SPAR model to evaluate the risk of the finding due to internal events, the SRA evaluated the contribution from fire events and internal flooding. The SRA used information from the licensee's Internal Plant Examination (IPE) and Internal Plant Examination for External Events (IPEEE) to estimate the risk contribution from fire and flood. Additionally, for fire events, the SRA used information from the licensee's Appendix R safe shutdown report to determine what PRA-related equipment could be affected by a fire in areas where HPCS was the credited safe shutdown system. Using these sources of information, the SRA determined that fire and flood events could contribute to the overall risk of the finding. However, the result was uncertain due to the lack of detailed information available in the IPE and IPEEE regarding important fire and flood scenarios. Therefore, the finding is being characterized as a preliminary Greater than Green finding pending further review of the delta CDF contribution from fire and internal flooding events.

The licensee also performed a risk evaluation of the finding using different assumptions than the NRC's evaluation. These different assumptions included the effect of HPCS suction transfer on high suppression pool level prior to vortexing in the RCIC tank and the potential for operators to throttle HPCS flow such that vortexing would not be a concern. Also, the licensee's evaluation of the risk contribution from large early release frequency was different than the NRC's result using IMC 0609 Appendix H, "Containment Integrity Significance Determination Process." The NRC determined that additional information regarding the assumptions used by the licensee would be necessary to change the assumptions used in the NRC's preliminary significance determination.

The performance deficiency was evaluated to determine if it met the criteria for an old design issue. The NRC IMC 0305, "Operating Reactor Assessment Program," Section 04.07, defines an "Old Design Issue" as a finding that involves a past design-related problem in an engineering analysis or installation of plant equipment, that does not reflect a performance deficiency associated with an existing program or procedure. Section 06.06(a), provides guidance for the treatment of old design issues, and states that the NRC may refrain from considering safety significant findings if the issue satisfies, in part, the following criteria: the issue was licensee identified and was not likely to have been previously identified by on-going licensee efforts. In this case, the inspectors determined that a current performance deficiency existed; that the issue was NRC-identified and that the licensee had an opportunity to appropriately address the issue in 1994 when calculation IP-M-0384 was created and in 1998 when it was revised. Therefore, because this design-related finding did not satisfy IMC 0305 criteria, it is not considered to be an old design issue and is being treated similar to any other inspection finding, in accordance with IMC 0305, Section 06.06(a). This guidance is consistent with Section VII.B.3 of the NRC Enforcement Policy.

Enforcement: Title 10 Part 50, Appendix B, Criterion III states, in part, that measures shall be established to assure that applicable regulatory requirements and the design basis, as defined in § 50.2 and as specified in the license application, for those structures, systems, and components to which this appendix applies are correctly translated into specifications, drawings, procedures, and instructions.

Criterion III further states that design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program.

Title 10, Part 50.2 states, in part, that “design bases” means that information which identifies the specific functions to be performed by a structure, system, or component of a facility, and the specific values or ranges of values chosen for controlling parameters as reference bounds for design. These values may be: (1) restraints derived from generally accepted "state of the art" practices for achieving functional goals; or (2) requirements derived from analysis (based on calculation and/or experiments) of the effects of a postulated accident for which a structure, system, or component must meet its functional goals.

Contrary to the above, as of August 12, 2006, the licensee did not ensure the adequacy of design of the HPCS system by performance of design reviews or by use of alternate or simplified calculational methods. Specifically, the nominal trip setpoint for the initiation of suction swapover from the RCIC tank to the suppression pool, a controlling parameter to ensure continued function of the HPCS pump during swapover, was 740.19 foot elevation as determined by Calculation IP-C-0061 as derived by calculation IP-M-384, Revisions 0, 1, and 1B. However, this calculated value did not prevent air entrainment into the suction of the HPCS pump and subsequent loss of function of the HPCS pump.

Pending final determination of the safety significance, this finding is considered an apparent violation of NRC requirements (AV 05000461/2006011-01).

b.2 <u>Potential Inoperability of the RCIC Pump Due to Air Entrainment</u>

<u>Introduction</u>: The inspectors identified a finding of very low safety significance and a Non-Cited Violation of 10 CFR Part 50, Appendix B, Criterion III, “Design Control” requirements. Specifically, the inspectors identified that in the calculation of record, the licensee failed to adequately demonstrate that the RCIC pump would be capable of performing its safety function prior to swapping suction paths from the RCIC tank to the suppression pool. As an immediate corrective action, the licensee aligned the suction path of the RCIC system to the suppression pool.

<u>Description:</u> As described above, the inspectors noted that the methodology used in Calculation IP-M-0384, Revisions 0 and 1, was not appropriate. Specifically, using a correlation developed by Dr. Reddy et.al., the licensee determined a vortex may occur at 19.5 inches above the centerline of the RCIC pipe. The licensee then evaluated this result using Figure 13.b of NUREG/CR-2772 and after assessing the data, concluded that at 9.12 inches above the RCIC pipe centerline, the RCIC pump would experience 2 percent air entrainment. The inspectors concluded the methodology used in Calculation IP-M-0384, Revisions 0 and 1, did not account for the actual fluid configuration where air ingestion into the RCIC pump suction lines would potentially occur. The licensee was unable to provide adequate technical justification for the methodology used and entered the finding into their corrective action program as Condition Report (CR) 429583, “NRC SSD&PC RCIC [Water Storage] Tank Vortex

Issue," dated December 1, 2005, to evaluate (i.e., perform an operability evaluation) and revise the affected documentation. As a precautionary step, the licensee shifted the HPCS and RCIC inventory source to the suppression pool, a qualified inventory source allowed per Clinton's USAR and TS. Vortexing from the suppression pool should not occur due to the depth of the HPCS and RCIC suction lines.

The inspectors noted that Revision 1B of IP-M-0384 did not address the RCIC system. Using a conservative bounding analysis (Dr. Reddy, et.al.)[2], the inspectors determined that vortex inception was predicted to occur at 10.8 inches above the top of the pipe (assumes 600 gpm, Fr =1.88, D = 5.76 inches). With the swap-over initiated at about 8 inches above the top of the pipe, the inspectors concluded that air entrainment was possible for RCIC when RCIC was in the injection phase. However, because of the volume of water in the suction pipe prior to the pump and the short time period between vortex inception and swapover (about 1.4 minutes), the inspectors concluded that the operability of RCIC was not impacted as a result of this vortexing concern. In addition, when RCIC is placed in pressure control operation, the discharge is recirculated to the RCIC water storage tank; thus, vortexing would not be a concern.

Analysis: The team determined that the failure to adequately demonstrate that the RCIC pump would be capable of performing its safety function prior to swapping suction paths from the RCIC tank to the suppression pool was a performance deficiency warranting a significance evaluation. The team concluded that the finding was greater than minor because it was similar to example 3j of Appendix E in IMC 0612, "Power Reactor Inspection Reports." Specifically, the calculation of record was not correct and there was reasonable doubt of the successful outcome of a re-analysis. This finding affected the Mitigating System cornerstone.

The team completed a significance determination of this finding using IMC 0609, Appendix A, "Significance Determination of Reactor Inspection Findings for At - Power Situations." The team answered "no" to all five screening questions in the Phase 1 Screening Worksheet under the Mitigating Systems column. The inspectors concluded that the RCIC pump would have remained operational had it been called upon. Therefore, the team concluded that the finding did not represent an actual loss of a safety function and the finding screened out as having very low safety significance or (Green).

The team concluded this finding did not have a cross-cutting aspect.

Enforcement: Title 10 Part 50, Appendix B, Criterion III states, in part, that measures shall be established to assure that applicable regulatory requirements and the design basis, as defined in § 50.2 and as specified in the license application, for those structures, systems, and components to which this appendix applies are correctly translated into specifications, drawings, procedures, and instructions.

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[2]In the paper, "Vortices at Intakes in Conventional Sumps," the authors state that vortex inception is possible when submergence (s) divided by the diameter of the pipe (d) is less than the Froude number (Fr). In this formula, submergence is measured from the top of the pipe. In Revision 0 and 1 of Calculation IP-M-0384, the licensee used a more conservative formula (s/d = Fr +1) used to ensure a vortex-free operation.

Criterion III further states that design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program.

Contrary to the above, as of August 12, 2006, the licensee did not ensure the adequacy of design of the RCIC system by performance of design reviews or by use of alternate or simplified calculational methods. Specifically, the methodology used in calculation IP-M-384, Revisions 0 and 1, which determined the RCIC tank water level corresponding to 2 percent air entrainment at the suction of the RCIC pump, was not acceptable. The methodology used in Calculation IP-M-0384, Revisions 0 and 1, did not account for the actual fluid configuration where air ingestion into the RCIC pump suction lines would potentially occur. The licensee was unable to provide adequate technical justification for the methodology used. Because this violation was of very low safety significance and it was entered into the licensee's corrective action program (CR 429583), this violation is being treated as an Non-Cited Violation, consistent with Section VI.A.1 of the NRC Enforcement Policy (NCV 05000461/2006011-02(DRS)).

4OA5 Other Activities

(Closed) URI 05000461/2005002-01(DRS): Vortex Analysis Methodology Not Appropriate. The inspectors identified an URI concerning the RCIC water storage tank volume's design analysis. As described above, this issue was considered an URI pending completion of the NRC's review. Based on the information discussed in Section 1R21b of this report, an AV of 10 CFR Part 50, Appendix B, Criterion III, "Design Control" requirements was identified. Therefore, this URI is closed.

4OA6 Meetings

.1 Exit Meeting

The inspectors presented the inspection results to Mr. B. Hanson and other members of licensee management at the conclusion of the inspection on November 17, 2006. The inspectors asked the licensee whether any materials examined during the inspection should be considered proprietary. No proprietary information was identified.

.2 Interim Exit Meetings

An interim exit conference call was conducted by telephone with Mr. R. Weber and other members of licensee management on October 12, 2006.

ATTACHMENT: SUPPLEMENTAL INFORMATION

ATTACHMENT: SUPPLEMENTAL INFORMATION

KEY POINTS OF CONTACT

Licensee
B. Hanson, Site Vice President
R. Frantz, Regulatory Assurance
T. Hable, Probabilistic Risk Analyst
S. Lakebrink, Design Engineering Supervisor
J. Lindsey, Training Director
R. Peak, Site Engineering Director
D. Schavey, Operations Director
P. Simpson, Regulatory Assurance Manager
C. VanDenburgh, Nuclear Oversight Manager
O. Villarreal, Nuclear Oversight Supervisor

Nuclear Regulatory Commission
B. Dickson, Senior Resident Inspector
M. Ring, Chief, Projects Branch
A.M. Stone, Chief, Engineering Branch 2
D. Tharp, Resident Inspector

LIST OF ITEMS OPENED, CLOSED AND DISCUSSED

Opened

05000416/2006011-01(DRS)	AV	Potential Inoperability of the HPCS pump due to Air Entrainment (Section 1R21.b.1)

Closed

05000416/2006011-02(DRS)	NCV	Potential Inoperability of the RCIC Pump Due to Air Entrainment (Section 1R21.b.2)
05000416/2005002-01(DRS)	URI	Vortex Analysis Methodology Not Appropriate (Section 4OA5)

Discussed
NONE

LIST OF DOCUMENTS REVIEWED

The following is a list of documents reviewed during the inspection. Inclusion on this list does not imply that the NRC inspectors reviewed the documents in their entirety but rather that selected sections of portions of the documents were evaluated as part of the overall inspection effort. Inclusion of a document on this list does not imply NRC acceptance of the document or any part of it, unless this is stated in the body of the inspection report.

CALCULATIONS

Number	Description/Title	Date/Revision
01HP15	Develop HPCS Pump Curves & Compare w/Resistance Curves for OP Modes A, B, C, CC, E, F, G, & H	2
IP-C-0061	Setpoint for RCIC H_20 Storage TK - Low Level	0A
IP-M-0384	Eval of Vortex in the RCIC H_20 Storage TK	0, 1, and 1B
IP-O-0049	TS Indicator Loop Uncertainty Eval of Suppression Pool or RCIC H_20 Storage TK Level	1 and 1A

CORRECTIVE ACTION PROGRAM DOCUMENTS ISSUED PRIOR TO INSPECTION

Number	Description/Title	Date/Revision
19971345	Assumptions Used in HPCS Pump Vortexing Calculation	October 25, 1997
00435174	Need to Recover RCIC and HPCS Vortex Margin	December 19, 2005

REFERENCES

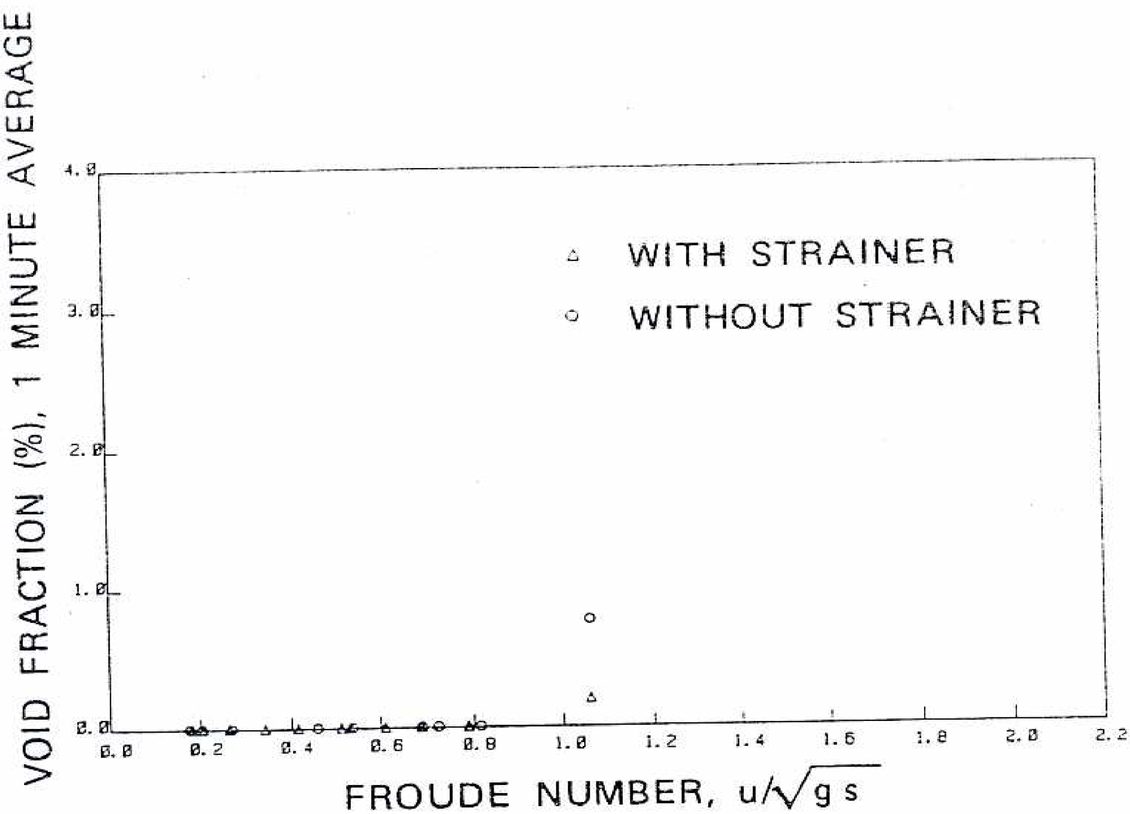
Number	Description/Title	Date/Revision
-------------------	Vortices at Intakes in Conventional Sumps by Dr. Y. R. Reddy & J. A. Pickford (H_2O Power)	March 1972
-------------------	Small Scale ECCS Suction Strainer Performance Testing Final Test Report	June 4, 1999
-------------------	Alternate Computation of CPS RCIC Vortex Limits Using VYC-184 Methods (Preliminary)	December 6, 2005
8020 VMT 1F-7564 (218 HPCS)	Technical Manual for Vertical HPCS Pump	March 15, 1979
ANSI/HI 9.8	Hydraulic Institute American National Standard for Pump Intake Design	1998
NUREG / CR 26760	Air Entrainment in a Partially Filled Horizontal Pump Suction Line by R. C. Sanders, JPGC 2001/PWR 19010	June 2001

LIST OF ACRONYMS USED

ADAMS	Agency-wide Document Access and Management System
AV	Apparent Violation
CFR	Code of Federal Regulations
CPS	Clinton Power Station
CR	Condition Report
DRS	Division of Reactor Safety
HPCS	High Pressure Core Spray
IMC	Inspection Manual Chapter
NCV	Non-Cited Violation
NRC	U. S. Nuclear Regulatory Commission
NUREG	NRC Technical Report Designation
PARS	Publically Available Records System
RCIC	Reactor Core Isolation Cooling
SDP	Significance Determination Process
TS	Technical Specifications
URI	Unresolved Item
USAR	Updated Safety Analysis Report

Figure 13.b from NUREG/CR2772, "Hydraulic Performance of Pump Suction Inlets for Emergency Core Cooling Systems in Boiling Water Reactors." This graph depicts the results of experiments on vortexing. A 24 inch suction pipe and a constant submergence of 24 inches were used. Flowrates were varied. The figure shows that at low Froude numbers, air entrainment into the suction piping was not observed; however, at a Froude number of 1.06, about 0.8 percent air entrainment was observed.

The licensee drew a straight line from point (0.8,0) [without strainer] to (1.06,0.08) [without strainer] and used this linear relationship in their evaluation.



b. VOID FRACTIONS (AIR-WITHDRAWALS)