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A SCANA COMPANY

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Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Attention: Ms. K. R. Cotton

Dear Sir / Madam:

Subject: VIRGIL C. SUMMER NUCLEAR STATION (VCSNS)
DOCKET NO. 50/395
OPERATING LICENSE NO. NPF-12
CONCLUDING RESPONSE TO GENERIC LETTER 96-06
(TAC NO. M96872)

References:
1. Stephen A. Byrne letter to Document Control Desk, RC-04-0018, January 20, 2004
2. Karen R. Cotton (NRC) letter to Stephen A. Byrne, dated March 28, 2001
3. Stephen A. Byrne letter to Document Control Desk, RC-00-0239, May 11, 2000
4. Gary J. Taylor letter to Document Control Desk, RC-99-0080, May 6, 1999
5. Gary J. Taylor letter to Document Control Desk, RC-98-0202, October 30, 1998
6. L. Mark Padovan (NRC) letter to Gary J. Taylor, dated August 5, 1998
7. Gary J. Taylor letter to Document Control Desk, RC-97-0026, January 28, 1997
8. Gary J. Taylor letter to Document Control Desk, RC-96-0261, October 30, 1996
9. Gary J. Taylor letter to Document Control Desk, RC-96-0032, February 13, 1996

The attached information is provided as follow-up to the information provided by South Carolina Electric & Gas Company (SCE&G) through the January 20, 2004 letter (Reference 1) in regards to the additional information identified by NRC letter of March 28, 2001 (Reference 2). SCE&G provides this information as the concluding response to detailed piping analyses that were performed as a result of previous evaluations completed for the VCSNS Reactor Building Cooling Unit (RBCU) waterhammer condition associated with NRC Generic Letter 96-06.

The results of these analyses are presented by the attached responses.

Should you have questions, please call Mr. Ronald B. Clary at (803) 345-4757.

I certify under penalty of perjury that the foregoing is true and correct.

A072

8/4/04
Executed on

Stephen A. Byrne

JT/SAB/mb
Attachment

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DMS (RC-04-0111)

RESPONSES TO USNRC ADDITIONAL DETAILED INFORMATION PERTAINING TO SOUTH CAROLINA ELECTRIC & GAS (SCE&G) RESPONSE TO GENERIC LETTER 96-06 FOR V.C. SUMMER NUCLEAR STATION (VCSNS)

Karen R. Cotton (NRC) letter to Stephen A. Byrne, dated March 28, 2001 (Reference 2 of this letter) states:

> **"With regard to the information that was submitted, ISL made the following observations:**
>
> - **While your analysis of the column closure waterhammer pulse appeared to be conservative, the effect of the waterhammer pressure pulse on piping and support structures was not evaluated, and**
> - **Your conclusion that condensation-induced waterhammer will not occur in horizontal pipes during fluid draindown because the Froude Number is near or above unity is not supported by test data.**
>
> **Based on our review of the ISL report, we consider the licensee's response to GL 96-06 to be incomplete for the reasons cited above. Additional information that fully addresses these issues is required. With regard to two-phase flow, we are satisfied with the licensee's response and consider this element of GL 96-06 to be closed."**

ISSUE 1:

While your analysis of the column closure waterhammer pulse appeared to be conservative, the effect of the waterhammer pressure pulse on piping and support structures was not evaluated.

RESPONSE 1:

Discussion

SCE&G initiated evaluations of waterhammer conditions in the service water (SW) piping downstream of the reactor building cooling units (RBCUs) as referenced in Generic Letter (GL) 96-06. These evaluations were performed to determine if the as-built design of the SW piping and pipe supports were acceptable to withstand the loads imparted by the waterhammer conditions identified in GL 96-06. As required by the FSAR, load limits were as specified in the ASME Code.

Using the NRC requested conservatism; preliminary waterhammer analysis loads were quite severe. The high waterhammer loads on the piping were primarily due to a vacuum bubble formed in the SW piping downstream of RBCU outlet valves, XVG03107A/B-SW, during switch over of the RBCU cooling from the SW system to the IC system as the water in the pipe gravity drained down to the SW pond after valve XVG03107A/B-SW was closed. Upon RBCU cooling switch back to the SW system, this bubble would dramatically collapse upon the opening of the valve XVG03107A/B-SW and the start of the SW booster pumps. Based on these results, it was determined that action must be taken to remove the vacuum bubble created during the drain down. VCSNS elected to inject air into the SW piping downstream of the valve XVG03107A/B-SW to remove the vacuum bubble. The air in the piping in lieu of a vacuum tends to act as a cushion within the bubble as the booster pumps are energized. This significantly reduces the waterhammer loads on the piping.

As a result of this determination, SCE&G has injected air into the SW piping. System operating procedures have been revised to require air injection after system realignment from the RBCU cooling by the SW system to cooling by the IC system.

The preliminary analysis noted above indicated that the waterhammer loads on the piping and supports would be satisfactory with air injected in the piping downstream of XVG03107A/B-SW. This preliminary analysis was performed for the RBCU train A piping. At the time, it was assumed that the waterhammer event in the train A piping configuration was governing and the results of this analysis would envelope the results of the analysis of train B piping. This was later proven to be an erroneous assumption as noted below.

The analysis for the waterhammer event in the train A piping was completed and verified. As expected, the as-built piping and supports were determined to be satisfactory per the requirements of the ASME Code. A similar analysis of the train B piping was then started. The analysis is performed in three phases in series. The first phase is the development of the waterhammer loads on the piping. The second is the pipe stress analysis to determine the adequacy of the piping to accept the waterhammer loads. Both of these phases were completed satisfactorily, i.e. the train B piping was determined to be satisfactory per the requirements of the ASME Code. The third phase is the qualification of the pipe supports for the waterhammer loads. During this phase, the degraded condition of two train B supports was identified. The design of pipe supports SWH0145 and SWH0148 has been determined to be unacceptable to accommodate the waterhammer loads based on design basis requirements of the ASME Code. All other pipe supports within train B have been determined to be acceptable to accommodate the waterhammer loads based on design basis requirements of the ASME Code.

Details of Degradation

SWH0145 - Box Guide - Support member stresses are acceptable. Weld stress at the channel (C4x5.4 - Item 2) attachment point to the existing W8x31 does not meet Code upset, emergency or faulted allowables.

SWH0148 - Box Guide - The stress in the 3/4" structural member attachment bolts do not meet the upset allowable shear stress based on A307 allowable shear. However, the bolt shear stress does satisfy emergency and faulted allowables.

NRC Generic Letter 91-18, Revision 1, describes actions to address non-conforming and degraded conditions such as noted for these supports. The supports must be revised to restore their capability to satisfy the design basis requirement of the ASME Code during the waterhammer conditions noted previously. This restoration is scheduled to be performed in VCSNS Refuel 15. In the interim, SCE&G has determined that the supports will continue to perform their design basis function per the criteria of GL 91-18. This evaluation is documented in VCSNS Condition Evaluation Report (CER) C-04-1550.

The stress in the 3/16" weld of support SWH0145 does not satisfy faulted condition limits. However, G.L. 91-18, in Section 6.1, states "Determine the basis for declaring the affected system operable through: a. analysis, b. test or partial test, c. operating experience, d. engineering judgment." With these basis parameters in mind, in regards to the high stress in the weld of SWH0145, the following are noted:

- The water hammer condition included in this analysis is assumed to occur during normal operating conditions when the RBCU Train B is aligned to the SW system from the IC system. Over the past twenty two years of operation, this alignment has occurred at least four times a year. A test of the RBCU cooling via the SW system is performed each quarter. Therefore, this water hammer event must have occurred numerous times. No evidence of support failures within this piping system has been identified. In addition, as noted previously, NCN-03-4519 requires the injection of air into SW system to eliminate the vacuum bubble and significantly reduce the water hammer loads. Therefore, any water hammer events that have occurred this year, or will occur in the future, will be of a magnitude that is significantly reduced from those events that may have occurred during the first twenty-two years of operation.

- The water hammer loads were developed in the analysis by the computer program RELAP5. It is well recognized within the industry that this program produces conservative results (high loads).

- The design of the support is for a 3/16" weld on only the outside and inside of the channel web and not on the channel flanges. A 3/16" weld is very small. Typically, a welder will lay out a weld of a larger size. Also, it is likely that the weld extended onto the channel flanges. The stress in a 1/4" weld was only 9% over the faulted allowable. This indicates that if a 1/4" weld does exist and slightly extends onto the channel flanges, the stress in the weld would satisfy faulted limits.

Based on the above, SCE&G has determined that support SWH0145 is operable and will perform its design basis function, but is in a degraded condition.

The stress in the bolts of support SWH0148 due to the loads from the water hammer conditions previously identified satisfies the stress limits for the emergency condition.

Since the emergency limits are more stringent than the faulted limits, the stress in the bolts also satisfies the faulted limits. Therefore, support SWH0148 is determined to be operable and will perform its design basis function, but is in a degraded condition

No interim compensatory actions are required.

Summary

SCE&G, using the NRC requested conservatism, has performed an analysis of waterhammer conditions in the SW piping from the RBCUs. Based on the results of this analysis, air was injected into the piping downstream of valves XVG03107A/B in order to eliminate the vacuum bubble. Using the NRC requested conservatism and the vacuum bubble eliminated (air injected), train A RBCU piping and supports satisfy the design basis requirements of the ASME Code. Again using the NRC requested conservatism and the vacuum bubble eliminated (air injected), analysis of train B RBCU piping indicates that pipe supports SWH0145 and SWH0148 on the SW discharge piping from RBCU train B do not satisfy design basis requirements of the ASME Code. During system realignment of cooling to the Train B RBCU from the IC System to the SW system, a waterhammer event could occur that would place these supports in a degraded condition.

Restoration of the affected pipe supports is scheduled to be performed in VCSNS Refuel 15. In the interim, the supports will continue to perform their design basis function as noted. The supports are to be considered degraded, but operable per the criteria of GL 91-18.

ISSUE 2:

> Your conclusion that condensation-induced waterhammer will not occur in horizontal pipes during fluid draindown because the Froude Number is near or above unity is not supported by test data.

RESPONSE 2:

As enclosure to the Karen R. Cotton (NRC) letter to Stephen A. Byrne, dated March 28, 2001 (Reference 2 of this letter), Information Systems laboratories wrote in Section 4.2 (page 4) of their report regarding the VCSNS GL 96-06 submittal:

"The potential for producing a stratified condition of steam and subcooled water in horizontal pipes and subsequent bubble collapse type condensation (condensation induced waterhammer) was also evaluated by the licensee. The licensee concluded that because the Froude number for the fluid drainage was near or above unity, the potential for condensation induced waterhammer does not exist in the V.C. Summer Nuclear Station RBCU Piping. The licensee's conclusion was based on test results presented in FAI/96-75. However, the results of more recent tests, performed as part of the EPRI/Industry collaborative project show, that the condensation induced waterhammer pressures are independent of the rate of drainage, expressed as a Froude number."

Condensation-Induced Waterhammer Potential and severity for VCSNS

The following discussion addresses the potential for and severity of condensation induced waterhammer (CIWH) in the VCSNS RBCU headers.

a. System Pressure Threshold for CIWH

The NRC has acknowledged in a letter to EPRI, "NRC Acceptance of EPRI Report TR-113594, Resolution of Generic Letter 96-06 Waterhammer Issues," Volumes 1 and 2, dated 4/3/02, in regard to CIWH that:

"...Potential damage from this type of waterhammer is a function of the steam pressure that acts to drive the water plugs together. Piping damage from this type of waterhammer typically occurs in Feedwater and other high pressure piping systems where steam pockets might form. In NUREG 6519, "Screening Reactor Steam/Water Piping Systems for Water Hammer" dated September 1997, Griffith reports that in most cases system pressure must be greater than 100 psia before any damage will occur due to CIWH. Cooling water systems that are used to remove heat from containment air coolers usually operate well below this pressure threshold."

Observation: The VCSNS RBCU system operates well below the 100 psia threshold for CIWH.

b. Minimum Horizontal Pipe Length Threshold for CIWH

In "Initiation of Waterhammer in Horizontal and Nearly Horizontal Pipes Containing Steam and Subcooled Water," Journal of Heat Transfer, Vol. 106, November 1984, it is demonstrated that CIWH does not occur in pipe segments with lengths less than 24 diameters. However, in horizontal pipe of length greater than 48 diameters, CIWH always occurred. The tests were performed at near atmospheric conditions. Therefore, as noted by NUREG 6519, a horizontal pipe segment must be at least 24 pipe diameters for CIWH to occur

Observation: The VCSNS RBCU return header piping has only one 10-inch piping segment of sufficient horizontal length (approximately 20 feet) that satisfies the 24-diameter minimum length criterion for CIWH. This is a 23-ft segment at elevation 512 ft. on A train. This particular segment is not a continuous straight run but instead is subdivided by a 30-degree elbow and a 45-degree elbow in the same horizontal plane. The bends would likely prevent continuous CIWH stratified void conditions from developing along the entire length. There is only one horizontal segment inside containment that satisfies the approximately 30.5-ft minimum length criterion for 16-inch pipe. This is the 47.4-ft segment located at 495-ft elevation downstream of the A train RBCUs. Yet it is still within the 24-to-48 pipe diameter range where CIWH is possible, but not completely assured. The only other segments of sufficient horizontal length are outside containment at elevation 457-ft (train A) and 453-ft (train B). These latter segments do not uncover (are not exposed to steam) during the assessed LOCA/MSLB scenarios.

When valve stroking and initial air venting is accounted for, the current analysis shows that the RBCU return header does not drain down enough to expose the longer horizontal segments to steam voids.

c. Reduction in CIWH Pressures with Increasing Pipe Size

From the 4/3/02 NRC letter to EPRI, "NRC Acceptance of EPRI Report TR-113594, Resolution of Generic Letter 96-06 Waterhammer Issues," Volumes 1 and 2, Enclosure Section 2.2.2:

"Cooling water systems supplying the containment air coolers for actual plants are generally larger than the 4-inch diameter that were used in the EPRI tests. Based on the results of a scaling analysis, EPRI concluded that lower CIWH pressures would be expected for larger pipe sizes."

Observation: The VCSNS RBCU piping ranges from 10-inch to 16-inch in diameter. Peak pressures (should CIWH occur) will be significantly reduced compared to the EPRI tests on 4-inch piping.

Column-Closure Waterhammer Bounds CIWH When Certain Conditions Exist

The NRC states in the aforementioned 4/3/02 letter to EPRI, Enclosure Section 2.2.1:

..."As a result of the testing and analyses that were completed, EPRI concluded that a CIWH in most low pressure cooling water systems for the containment air coolers would not be severe enough to cause any significant damage. EPRI also concluded that the CCWH [column closure waterhammer] would typically be more severe in magnitude and duration than the CIWH, and generally would form the more limiting case."

..."EPRI conducted a series of tests in order to evaluate the potential severity of CIWH on low-pressure cooling systems, such as those that provide cooling for the containment air coolers. The test section was 4 inches in diameter and approximately 22 feet in length, providing a long horizontal pipe section for CIWH to take place. Steam pressures were limited to 15 psig. Tests were initiated by simultaneously opening valves to permit steam to enter one end of the horizontal pipe and water to exit the other end. Horizontal stratified flow conditions were produced, and from this CIWH occurred. The resulting pressure pulses were recorded by pressure transducers located throughout the system. The waterhammer pressures were found to be relatively low (less than 200 psig). Those pulses having the highest peak pressures were found to have the shortest duration and consequently, the impulse loads were approximately constant for all of the CIWH pressure pulses that were generated. As a result of the testing and analyses that were completed, EPRI concluded that a CIWH in most low pressure cooling water systems for the containment air coolers would not be severe enough to cause any significant damage. EPRI also concluded that the CCWH [column closure waterhammer] would typically be more severe in magnitude and duration than the CIWH, and generally would form the most limiting case."

From Enclosure Section 2.2.3 of the aforementioned 4/3/02 NRC letter to EPRI:

> *"The CCWH tests performed by EPRI produced much higher pressures and loadings than those of the CIWH tests. EPRI concluded that for plant conditions that are within the bounds of the test data, CCWH will be bounding and plant-specific CIWH analyses need not be performed. As specified [in] Section 4.2.1 of the [EPRI] UM, this conclusion is only applicable in systems that meet the following conditions:*
>
> - *The system pressure at the time of the postulated CIWH must be less than 20 psig.*
> - *The system has not been degassed.*
> - *The piping has been shown by test, analysis, or operating experience to be able to withstand a CCWH following LOOP, LOOP with LOCA, or LOOP with MSLB, without significant degradation."*

From Enclosure Section 3 of the aforementioned 4/3/02 NRC letter to EPRI:

> *"Based on the tests that were conducted and review of CIWH information that was available, EPRI determined that CIWH events in the low-pressure cooling water systems for the containment fan coolers will be bounded by CCWH for most situations. Section 4.2.1 of the UM lists the specific criteria that systems must satisfy in order to apply this conclusion. We agree that the information contained in Section 7 of the TBR [EPRI Technical Basis Report] adequately supports this conclusion and consequently, we focused our evaluation on the proposed methodology for analyzing CCWH events."*

The VCSNS RBCU system meets the criteria established by EPRI (and endorsed by the NRC) for CCWH being more severe than CIWH:

- **The system pressure at the time of the postulated CIWH must be less than 20 psig.**

  The RBCU system pressure starts out at approximately 30-55 psia with the industrial cooling water pumps supplying the RBCUs. On LOOP/ESFAS actuation, the industrial cooling water supply is isolated and the service water booster pumps are started after being sequenced on the emergency diesel generator 1E electrical buses. Sergeant & Lundy Technical Report SL-5102, submitted by Reference 3 of this letter, shows through Figures A1-1, A2-1, A3-1, and A4-1 that system pressure decreases to less than 10 psia in less than ten seconds when a service water (SW) pump coast down time of ten seconds is assumed. For the "cold" transient (LOOP without concurrent LOCA or MSLB), the pressure remains near this minimum value as the return piping gravity drains to the SW pond. For the "hot" transient (LOOP with concurrent LOCA or MSLB), steam generation in the RBCU cooling coils causes system pressure to rise to no greater than 30 psia (15 psig).

Since it has been shown that the maximum pressure during the drain-down/CIWH phase does not exceed 20 psig, this criterion is satisfied.

- **The system has not been degassed.**

  The VCSNS SW/RBCU system has no provision for continuous degassing that would remove dissolved noncondensable gasses in the water. Therefore this criterion is satisfied.

- **The piping has been shown by test, analysis, or operating experience to be able to withstand a CCWH following LOOP, LOOP with LOCA, or LOOP with MSLB, without significant degradation.**

  This last criterion is the objective of the current RELAP5-based force-time history analysis and subsequent structural evaluation. Additionally, SW system operating experience over the life of the plant suggests that CCWH is not a problem for the SW booster pump cold start scenario. Walkdowns and inspections of the RBCU piping over the life of the plant have revealed no signs of adverse stress to the piping, components, or supports.

Summary

The hydrodynamic loads in the SW piping downstream of the RBCUs following a postulated LOCA-MSLB inside containment assuming Loss of Offsite Power (LOOP) have been conservatively determined. The scenarios considered and method used is appropriate. This analysis along with the subsequent piping stress and support evaluations support resolution of GL 96-06 concerns.