March 28, 2001

Mr. Stephen A. Byrne
Vice President, Nuclear Operations
South Carolina Electric & Gas Company
Virgil C. Summer Nuclear Station
Post Office Box 88
Jenkinsville, South Carolina 29065

SUBJECT: V. C. SUMMER NUCLEAR POWER STATION - REVIEW OF THE LICENSEE'S RESPONSE TO GL 96-06 CONCERNING WATERHAMMER AND TWO-PHASE FLOW (TAC NO. M96872)

Dear Mr. Byrne:

Generic Letter (GL) 96-06, "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," dated September 30, 1996, included a request for licensees to evaluate cooling water systems that serve containment air coolers to assure that they are not vulnerable to waterhammer and two-phase flow conditions. South Carolina Electric & Gas Company (SCE&G, the licensee) provided its assessment of the waterhammer and two-phase flow issues for the Virgil C. Summer Nuclear Station (VCSNS) in a letter dated January 28, 1997, and additional information was provided in letters dated August 5, 1998, and May 11, 2000. The information that was submitted by SCE&G was reviewed by Information Systems Laboratories, Inc. (ISL), under contract to the NRC (NRC-03-95-026, Task 240). ISL has completed its review, and the results are documented in the enclosed Letter Report No. 240-10, dated June 2000. 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.

The GL 96-06 issue concerning thermal overpressurization is being evaluated as a separate issue, and was not included within the scope of this review.

Sincerely,

/RA/

Karen R. Cotton, Project Manager, Section 1
Project Directorate ll
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-395

Enclosure: As stated

cc w/encl: See next page

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Karen R. Cotton, Project Manager, Section 1
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Letter Report No. 240-10

Review Of Virgil C. Summer Unit No. 1 Waterhammer And Two-Phase Flow Analysis

Hossein P. Nourbakhsh
25 East Loop Road
Stony Brook, NY 11790

June 2000

Prepared for:
U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation

Under Consultant Agreement No. 5401-240
From Information Systems Laboratories, INC.
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Rockville, MD 20852

Contract N0. NRC-03-95-026, Task 240,
TAC M96872

Attachment

1. INTRODUCTION

NRC Generic Letter 96-06 (GL 96-06) " Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions"[1] included a request for licensees to evaluate cooling water systems that serve containment air coolers to assure that they are not vulnerable to Water hammer and two-phase flow conditions. More specifically, the issues of concern are :[1]

"(1) Cooling water systems serving the containment air coolers may be exposed to the hydrodynamic effects of waterhammer during either a loss-of-coolant accident (LOCA) or a main steam line break (MSLB). These cooling water systems were not designed to withstand the hydrodynamic effects of Waterhammer and corrective actions may be needed to satisfy system design and operability requirements.

(2) Cooling water systems serving the containment air coolers may experience two-phase flow conditions during postulated LOCA and MSLB scenarios. The heat removal assumptions for design-basis accident scenarios were based on single-phase flow conditions. Corrective actions may be needed to satisfy design and operability requirements."

The South Carolina Electric and Gas Company (SCE&G) provided its assessment for the Virgil C. Summer Nuclear Station (VCSNC), Unit 1, in a letter dated January 28, 1997. [2] Parts of the licensee's submittal addresses waterhammer and two-phase flow conditions. The licensee was requested to provide additional information in a letter dated August 5,1998.[3] The licensee's response was provided in a letter dated October 30,1998.[4]

Information Systems Laboratories (ISL), Inc. was requested (NRC-03-95-026, Task Order No. 240) to assist the NRC staff in reviewing the waterhammer and two-phase flow analyses that has been completed by the licensee for the Virgil C. Summer, Unit1, in response to GL 96-06. The objective of the review was to determine whether or not the analyses are adequate and conservative in all respects.

This letter report summarizes the results of the review that was performed and conclusions that were reached. Section 2 provides background information regarding the design characteristics of the containment fan cooling system in Virgil C. Summer, Unit 1. The event considered for this evaluation is discussed in Section 3. Sections 4 and 5 provide the review results of the waterhammer and two-phase flow analyses, respectively. Section 6 provides a brief summary together with conclusions.

2. DESCRIPTION OF REACTOR BUILDING COOLING UNITS AT VIRGIL C. SUMMER NUCLEAR STATION

The Reactor Building Cooling Units (RBCUs) provide cooling by recirculating the containment atmosphere across air- to-water heat exchangers. The Service Water System (SWS) provides cooling water for the RBCUs.

The licensee indicated that waterhammer , in the form of column separation and rejoining, has been known to occur in the SWS. Prior to the issuance of Generic Letter 96-06, modifications were made to cooling water systems to address this problem. The opening and closing logic for the SW inlet and outlet valves to the reactor building were modified. These modifications tied the opening and closing of these valves to the starting and stopping of the Service Water Booster Pump (SWBP). Additionally the SWBP recirculation line was procedurally maintained open.

3. SEQUENCES OF EVENTS CONSIDERED FOR EVALUATION

A design basis LOCA with simultaneous initiation of a Loss Of Offsite Power (LOOP) has been considered for this evaluation. The licensee indicated that the FSAR LOCA temperature provide the bounding high temperature conditions for RBCU heatup. Therefore, the selection of LOCA/LOOP (rather than MSLB/LOOP) as a bounding scenario for evaluating the responses of the containment cooling system is appropriate.

On a LOCA/LOOP scenario, the non-safety related electric loads (industrial cooling, fast speed RBCU fans, etc.) would loose power. The following assumed key time parameters during the initial time period following the accident is from Reference 4.

Time	Description
0. sec	LOCA +LOOP
10 sec	Interruption of cooling water (SW pump coast-down) (sensitivity analysis was performed with10 sec. coast-down time)
41.5 sec	SWBP start time

A complete failure modes and effect analysis (FMEA) was not performed by the licensee . However, a comprehensive/bounding set of operational transients and single active failure scenarios were considered for identification of limiting scenarios.

4. WATERHAMMER ANALYSIS

A LOCA concurrent with a LOOP causes interruption of cooling water flow soon after initiation of the event, while the associated fans would coast down for a much longer time. Continuation of air flow over the coils would cause the water in the cooler tubes to boil until cooling flow resumes. Column separation also occurs whenever the SWBPs are secured.

During refill of the containment coolers , hydrodynamic loads could be experienced due to column closure (water column rejoining) waterhammer. There is also a potential for producing a stratified condition of steam and subcooled water in the horizontal pipes and subsequent bubble collapse type waterhammer (condensation induced waterhammer).

SCE&G has adressed these waterhammer issues for the Virgil C. Summer in response to GL96-06. The review results of waterhammer analyses are provided below for each of the two waterhammer mechanisms.

4.1 Column Closure Waterhammer

The hydrodynamic loading due to water column rejoining during system refill has been evaluated by SCE&G. The licensee's selection of SWBP cold start scenario as the limiting column closure waterhammer is appropriate.

Column separation occurs whenever the SWBPs are secured . On the RBCU inlet side (SWBP discharge side), the SWBP discharge check valve is closed and maintains a full column.[4] Also, SW pressure at the suction of the SWBPs (bottom of the column) is sufficient to maintain a full column. On the RBCU discharge side, a void of approximately 15 feet is created due to gravity head. Upon start of the SWBP, the water column will close. The magnitude of column closure waterhammer that would occur was calculated by the licensee to be 666 psig in the 10-inch return line, 265 psig for the 8-inch lines, and 274psig for the 16-inch line. This calculation was performed for the limiting case scenario of all flow from a SWBP going to a single RBCU.

The licensee stated that the waterhammer analyses were performed with FORTRAN coded algorithms which directly solve the governing heat transfer and fluid motion equations for the affected piping network. The details of this evaluation were not originally provided for review. However, based on a review of additional information[5] that was provided , the methodology used by the licensee to predict the magnitude of column closure waterhammer

pressure pulse was found to be consistent with NUREG/CR-5220[6]. While analysis for evaluation 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.

The licensee also stated that the in-plant post-modification testing included the SWBP cold start transient. The pressure vs time traces showed that while pressure spikes were evident, they were limited in number, magnitude, and duration. The maximum pressure achieved was reported to be 200 psig. This was reported to be substantially less than the maximum pressure (404.5 psig most limiting) allowed under ASME B&PV Code, Section III, 71 edition, W'73 addenda, subsection NC-3612.3 "Allowance for Variations from Design Conditions." The licensee also stated that a post-test walkdown inspection confirmed no evidence of damage to or displacement of the piping, components or supports.

4.2 Condensation Induced Waterhammer in Horizontal Lines

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 water hammer does not exist in the V.C. Summer Nuclear Station RBCU piping. The licensee's conclusion was made based on the test results presented in FAI/96-75[7]. However, the results of more recent tests, performed as a part of EPRI/Industry collaborative project, show that the condensation induced waterhammer pressures are independent of the rate of drainage, expressed as a Froude number.

5. TWO-PHASE FLOW ANALYSIS

The issue of two-phase flow in containment air cooling system was also evaluated by the licensee. Based on the brevity of the two-phase flow condition and the absence of flow control valves or components (in the affected piping), the licensee appropriately concluded that two-phase flow is not a concern for the Virgil C. Summer Nuclear Station, Unit 1 fan cooler system.

6. SUMMARY AND CONCLUSIONS

The waterhammer and two-phase flow analysis that was completed by the licensee for the Virgil C. Summer Nuclear Station, Unit 1, in response to GL96-06, was reviewed. The licensee's selection of SWBP cold start scenario as the limiting column closure waterhammer is appropriate.

The methodology used by the licensee to predict the magnitude of column closure waterhammer pressure pulse was found to be consistent with NUREG/CR-5220[6]. While analysis for evaluation 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.

The potential for condensation induced waterhammer was also evaluated. Because the Froude number for the fluid drainage was near or above unity, the licensee concluded that the potential for condensation induced water hammer does not exist in the V.C. Summer Nuclear Station RBCU piping. However, the results of recent tests, performed as a part of EPRI/Industry collaborative project, show that the condensation induced waterhammer pressures are independent of the rate of drainage, expressed as a Froude number.

The issue of two-phase flow in containment air cooling system was also evaluated by the licensee. the licensee's conclusion that the two-phase flow is not a concern for the Virgil C. Summer Nuclear Station, Unit 1 fan cooler system was found to be adequately justified.

7. REFERENCES

1. Nuclear Regulatory Commission (NRC), " Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," NRC Generic Letter 96-06, 1996.

2. South Carolina Electric and Gas Company," Response To Generic Letter 96-06, Virgil C. Summer Nuclear Station," RC-97-0026, January 28, 1997.

3. Nuclear Regulatory Commission (NRC), " Request for Additional Information Generic Letter (GL) 96-06," Letter from L. Mark Padovan to Gary J. Taylor, August 5, 1998.

4. South Carolina Electric and Gas Company, "Response to Request for Additional Information Regarding Response for Generic Letter 96-06," RC-98-0202, October 30, 1998

5. South Carolina Electric and Gas Company, "Response to Request for Additional Information Regarding GL 96-06," RC-00-0239, May 11, 2000.

6. Izenson, M.G.,P.H. Rothe and G.B. Wallis, " Diagnosis of Condensation- Induced Waterhammer," NUREG/CR-5220, October 1998.

7. Henry, R. E., "Evaluation of Possible Water Hammer Loads in the Service Water System for DBA Conditions", Fauske and Associates Inc. Report FAI/96-75, Dated October16, 1996, Presented at the NEI GL 96-06 Industry Meeting on October 29, 1996.

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