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LR-N980486
OCT 15 1998

United States Nuclear Regulatory Commission
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Washington, DC 20555

Gentlemen:

REQUEST FOR ADDITIONAL INFORMATION RELATED TO GENERIC LETTER 96-06 RESPONSE FOR SALEM GENERATING STATION UNITS NOS. 1 AND 2 FACILITY OPERATING LICENSES DPR-70 AND DPR-75 DOCKET NOS. 50-272 AND 50-311 (TAC NOS M96860 AND M96861)

REF:
1. NRC Request for Additional Information (RAI) Related to Generic Letter 96-06 Response for Salem Generating Station Units Nos. 1 and 2 Dated July 1, 1998.
2. PSE&G Extension of Response Due Date for RAI Related to Generic Letter 96-06 for Salem Generating Station Units Nos. 1 and 2 PSE&G Letter LR-N980385, Dated August 4 1998.

The Attachment to this letter provides the information requested by the NRC request for additional information (RAI) related to Generic Letter 96-06 "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," (Reference 1). The response is provided in accordance with the response due date documented in Reference 2.

The Attachment restates the NRC individual information requests and follows each request with the associated PSE&G response. We have provided a more detailed description of post-modification testing than previously submitted, as well as, a brief summary of the PSE&G positions on control valve cavitation and station blackout.

If you have any questions, please contact Phil Duca at (609) 339 2381.

Sincerely,

E C Simpson

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Attachment

OCT 1 5 1998

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NRC REQUEST

1. **Provide a summary of post-modification test results, focusing primarily on any anomalies or unexpected conditions that were identified. Describe any actions that were taken to resolve any adverse conditions that were identified.**

PSE&G RESPONSE

A brief summary of Salem Unit 2 modification testing was provided to the NRC staff by PSE&G Letter LR-N970747 dated December 5, 1997. This letter identified a small number of minor differences between the Salem Unit 1 and Unit 2 service water system designs. System integrated testing was not considered warranted for Unit 1 considering the design similarities between the Units as well as the results of the Unit 1 pump coast down tests.

Background

GL 96-06 identified waterhammer and two phase flow vulnerabilities in containment cooling piping. To resolve these issues for Salem, PSE&G installed nitrogen charged accumulator tanks with fast acting discharge valves to maintain the CFCU piping water solid during accidents involving a loss of offsite power (LOOP). A transient hydraulic model of the SW system was used to develop the accumulator tank and discharge valve design. The transient hydraulic model is documented in PSE&G calculations S-C-SW-MDC-1700 and S-C-SW-MDC-1705.

As stated in PSE&G letter LR-N97171 to the NRC dated March 27, 1997, post modification testing was used to validate the hydraulic model and to verify that the modification would maintain solid water conditions in CFCU piping during accident conditions. Once validated, the model was used to accurately predict conditions that cannot be simulated in plant tests. The testing consisted of the following:

1. Component level testing for both Units to ensure system components function as designed and within specified time limits (e.g., valve stroke times).

2. A series of pump coast down tests were completed to determine the pressure decay in the CFCU outlet piping after SW pump trip. The coast down test was repeated for Salem Unit 1 due to the difference in length and diameter of underground piping from the common Unit 1 and 2 intake structure to plant buildings. The coast down test results proved to be essentially identical for both units and were used as inputs into the transient hydraulic model to establish the design requirements for the accumulator tanks and discharge valves.

3. Integrated system testing was performed on one header (i.e., one-half the system) for Unit 2 per DCP 2EC3590, package 16.

Testing Summary

A total of four simulated LOOP tests were performed on Unit 2 header number 22. A summary is provided here based on the test results, which are contained in package 16 of DCP 2EC3590.

Tests Run

Test 1
Summer high flow conditions with the failure of one CFCU outlet valve (SW223) to the full open position. To enable assessment of the dissolved nitrogen effect, maximum accumulator outlet pressure and minimum level were also included.

Test 2
Winter low flow conditions with the failure of one CFCU outlet valve to the full open position. Accumulator tank at minimum pressure and level.

Test 3
Summer high flow condition with failure of AC control power on one bus causing two CFCU outlet valves to initially open then close when the associated CFCU trips. Accumulator tank at minimum pressure and level.

Test 4
Summer high flow conditions with the failure of one of two parallel accumulator tank fast acting valves to open. Accumulator tank at minimum pressure and level.

Results

The first two tests proved to be the most limiting and identified several anomalies. These items are identified in the following paragraphs:

Item 1

While the primary objective to maintain conditions below saturation in piping associated with the CFCUs was met, the automatically isolated, non-safety piping in the Turbine Generator Area (TGA) experienced column separation at the highest elevation and a small amount of water hammer when the SW pumps were restarted. It resulted in sheet gasket joint leaks at the Main Turbine Lube Oil Cooler and minor damage to a small number of non seismic supports on associated piping. Testing was resumed only after the cause of the condition was understood and it was verified that additional testing would not cause a recurrence. A review of the system design was conducted to confirm that there were no other locations where a similar condition could occur.

Item 2.

The minimum CFCU pressure during the first two seconds of the test (i.e. immediately before the accumulator was able to increase pressure) was lower than predicted by the model in some cases. Although the minimum pressure observed during testing (16 psia from test 2) was still well above saturation at this early point in an accident (approximate saturation of 2 psia) an explanation was required. Investigation revealed that the fast acting valves had opened as designed, however, there was a significant variation in the pre-test CFCU pressure for CFCUs in low flow. It was determined that while the magnitude of the initial pressure drop agreed well between the model prediction and the test (i.e the model was slightly more conservative) there was an unexpected field variation in the SW65 valve position that caused the difference.

Further investigation revealed that the SW65 valve had only two positions. In the normal condition (i.e. low CFCU service water flow) it is set about 1/3 open to provide a significant pressure drop in the flow path. This design feature forces flow through the small diameter (2") CFCU motor cooler (MCU) parallel flow path. On the accident signal, the air is automatically vented from the valve operator causing the valve to stroke full open. The higher accident flow rate provides sufficient pressure drop across the CFCU to provide flow to the MCU.

Since this valve is located in the outlet piping, for an operating CFCU flow path it also establishes the normal (i.e. pre-event) pressure in the associated piping. Note that a non-operating CFCU is at a higher pre-event pressure since it is open to full supply header pressure with only the outlet (SW223) valve closed.

It was found that the SW65 valve was an air operated valve that simply achieved a fixed position by a pre-set regulator to positioner air pressure, which was subject to large uncertainties. A solution was implemented immediately after completion of integrated testing for the addition of a closed limit stop. The change was completed prior to the restart of Salem Unit 2 via package 18 of design change 2EC3590. It was also incorporated into the corresponding Unit 1 design change (1EC3668).

The final result was that the pressure drop across the SW65 is consistent and the transient model accurately predicts the performance of the system.

Item 3

When the accident sequencer restarts CFCU in low speed, the outlet flow control valves (SW223) were observed to initially stroke full open rather than to the high service water flow setpoint as previously assumed. Depending on system pressure, flows of over 3500 gpm are possible compared to the accident setpoint flow of about 2650 gpm. Prior analysis had evaluated the full open condition only due to single failures.

The accumulator tanks begin pressurizing the system rapidly after the initiation of a LOOP event. The initial response of the SW223 is to stroke full closed when the CFCU is stopped. The valves receive a signal to re-open 5 seconds after the accident sequencer starts the CFCU in low speed or approximately 38 to 42 seconds after the event start.

The initial high flow results in a lower CFCU pressure than predicted but this is after the most critical time period for column separation water-hammer since the service water pumps have already restarted. The pumps in combination with other system flow demands are still able to maintain CFCU saturation margins during the period when the CFCUs are full open (about 2-3 minutes). After this time flow returns to the setpoint value. The transient hydraulic calculations were revised to recognize the observed valve response.

Item 4

The flow rates for the CFCU inlet and outlet flow orifices were observed to diverge after each test due to trapped nitrogen in the outlet orifice instrument taps. In each case the outlet flow orifice measurements were artificially higher than the inlet orifice.

Accumulator tank calculations had included an evaluation of the effect of nitrogen on measured flow due to the volume fraction of gas entrained in the flow, not the effect of nitrogen trapped in the taps. The divergence in flow in the test was observed to be about 20 to 40 gpm (about 1.1% of actual flow at this time) with spikes as high as 80 gpm.

The divergence due to nitrogen is considered acceptable for the following reasons. First, and most important, the CFCU flow is controlled on the inlet orifice where the pressure is higher during the entire transient. The inlet orifice provides a control signal to modulate the outlet SW223 valve to the accident setpoint flow rate while the outlet orifice provides indication. The higher pressure at the inlet orifice is attributable to downstream CFCU pipeline losses as well as the low elevation of the orifice in relation to the CFCU (about 40 feet lower). The higher pressure has the affect of keeping nitrogen in solution and any error in that flow measurement is minimal. In addition, even though the flow measurements were observed to be slightly offset, it is still reliable. There were no problems observed with the flow measurements behaving in an unexpected fashion (e.g. erratic swings in measured flow).

Based on the above discussion, it was concluded the hydraulic model accurately predicts the flow response in the CFCUs during a LOOP and that any divergence in measured flow due to the presence of nitrogen is acceptable regarding CFCU performance.

Conclusions

In general, the tests concluded that the comparisons between the test data and the hydraulic model predictions demonstrated that the model was accurate with respect to predicting the response of the CFCU piping conditions following a LOOP. For each test sequence, the comparisons between the test data and model predictions were either very good, or the differences could be readily explained by differences between actual and assumed valve positions and strokes.

The integrated test results were subsequently incorporated into the transient hydraulic model (S-C-SW-MDC-1705) by including validation cases. The accumulator tank process parameter calculation (S-C-SW-MDC-1700), which uses the transient model to evaluate scenarios, as well as other supporting calculations, were also revised. Revision of these calculations to include test results confirmed that the accumulator tank modifications were sufficient to prevent waterhammer or two-phase flow under accident conditions.

NRC REQUEST

2. The staff is continuing its review to determine whether cavitation associated with the flow control valves (SW223) and outlet valves (SW65) for the containment fan coil units is acceptable. Provide any additional information that you may have that characterizes the magnitude and duration of cavitation that could develop, and the ability of the affected components to withstand the effects of cavitation (e.g., post-modification test results, vendor information, additional analyses that have been completed).

PSE&G RESPONSE

The information contained in PSE&G letters LR-N97268 (dated April 24, 1997), LR-N97353 (June 3, 1997) and LR-N97365 (June 12, 1997) provides a complete technical discussion of the PSE&G cavitation experienced at control valves SW65 and SW223. The basis for the specific values provided in the technical discussions are contained in sections of several PSE&G calculations and an engineering evaluation. These include portions of calculation S-C-SW-MDC-1700 and Engineering Evaluation S-C-SW-MEE-1138 (Salem Generic Letter 96-06 Evaluation).

Conclusions

Based on NUREG/CR-6031 methods, cavitation forces are not significantly affected by changes in temperature during the accident mode. Bulk voiding, which was a dominant concern of NRC GL 96-06, has been prevented by the accumulator tank modification. The collapse of large voids, can result in large forces that may present operability concerns, while cavitation typically results in long term wear / vibration, which is effectively mitigated at Salem by component and material selection, as well as, a comprehensive GL 89-13 visual inspection program.

There is considerable operating experience with valve cavitation in severe services for the Salem Service Water system. This experience has resulted in mitigation through the use of erosion resistant materials, rugged valve and piping designs, as well as, multiple stages of pressure breakdown where feasible.

NRC REQUEST

3. The staff is continuing to review the impact of waterhammer and two-phase flow on the coping analysis for station blackout. Rather than accepting potential failures due to waterhammer, it would be more desirable to manage restoration of service water flow such that waterhammer is avoided as much as possible. Describe any measures that can be taken in this regard to avoid the occurrence of a severe waterhammer following a station blackout event..

PSE&G RESPONSE

The scenario that could lead to a waterhammer in the CFCUs is discussed in detail by PSE&G letter LR-N97171 dated March 27,1997. The scenario involves the complete loss of all AC power (SBO) on one Unit with the other Unit in an orderly shutdown. An accident is not taken concurrent with this event, however, a single failure is postulated on the non-SBO Unit.

With the accumulator tank installation, the scenario that would result in a waterhammer in the CFCUs first requires the specific single failure of "C" vital bus on the non SBO Unit resulting in the loss of the remaining emergency control air compressor (ECAC). Loss of the ECAC will eventually result in the loss of control air on both Units until the SBO compressor can be started by the operators. The SBO compressor is started manually within an hour of the onset of the event.

The SW534/535 accumulator discharge valves are designed to close about 1 minute after a loss of power to prevent direct nitrogen discharge into the system. They are held closed by dedicated air accumulator bottles during the SBO scenario. However, the SW223 control valves are designed to close on a loss of power and control air is used to keep them closed. As a result, during an SBO the SW223 valves may reopen if air pressure bleeds down prior to the SBO air compressor starting. With the accumulator tanks isolated, the CFCU discharge piping would drain and column separation would occur.

One of the possible SBO recovery scenarios involves power restoration using the onsite emergency diesel generators (EDG's). Restoration of required equipment is accomplished manually under this scenario and, restoration of the service water system is a priority since it is the cooling source for the EDG's. If CFCU outlet piping column separation has occurred, then a waterhammer will occur when a pump is restarted.

In order to prevent a waterhammer, the CFCU flow path would need to be isolated manually by local access to valves in the penetration area before starting the EDG.

Prior to the restart of Salem Unit 2, an Engineering Evaluation (S-C-SW-MEE-1236) was prepared to demonstrate that local access to the CFCU containment isolation valves SW58 and SW72 was possible during the SBO scenario. The evaluation noted indications that would still be available (e.g. containment sump level) to alert the operators of a failure in order to initiate isolation actions.

However, in order to prevent CFCU waterhammer from occurring, these actions would become mandatory prerequisite and there would be a resulting delay in vital power restoration to the plant. Restoration of vital AC power at this point should be the higher priority and therefore this type of delay is not justified.

<u>Applicable SBO Regulatory Requirements</u>

The Salem SBO coping analyses were performed using the NUMARC 87-00 guidance, which provide the following clarification on containment isolation:

- Penetrations which would have to be closed (i.e. normally open, fail open containment isolation valves) to achieve containment isolation should be provided with position indication and closure capability, which is independent of the preferred AC or Class 1E power sources.

1. The CFCU cooling loop containment isolation valves, have installed open/closed limit switches powered from reliable sources (DC) with indication in the control room. Following the onset of the SBO scenario indication will be available in the control room.

- Containment integrity need only be established if core damage is imminent

1. The Salem coping analysis concludes that adequate core cooling is available for the duration of the SBO event and therefore core damage is not expected.

2. The current SBO Emergency Operating Procedures (EOPs)send operators to close CFCU containment isolation valves on high containment radiation indication.

<u>Conclusions</u>

The following conclusions summarize the response to RAI item 3:

- Regulatory commitments are met by demonstrating the capability of establishing containment integrity in the CFCU flow path during the SBO scenario.

- Loss of containment integrity is not likely due to CFCU waterhammer. As outlined in prior correspondence (LR-N96401, dated December 11, 1996) the piping pressure boundary has been upgraded to 6% molybdenum stainless steel and there has been applicable plant waterhammer experience without severe piping failures. On this basis, there is a reasonable expectation that the piping would remain functional.

- With respect to management of restoration of service water flow, the start of an EDG to restore power should be the priority. The potential delay of the start of an EDG while operators manually isolate the CFCU penetrations is not justified.

- Even if the feasibility of modifications could be demonstrated, PSE&G does not believe that further complex design modifications to mitigate a highly improbable scenario are advisable.