Public Service
Electric and Gas
Company

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U.S. Nuclear Regulatory Commission
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SUPPLEMENTAL INFORMATION
NRC GENERIC LETTER 96-06
LICENSE CHANGE REQUEST S96-13, CFCU RESPONSE TIME
SALEM GENERATING STATION UNIT NO. 1 AND 2
DOCKET NOS. 50-272 AND 50-311

Gentlemen;

Public Service Electric & Gas (PSE&G) has provided information regarding proposed modifications to address Generic Letter (GL) 96-06 in correspondence dated January 28, March 27, April 24 and June 3, 1997. (LR-N97072, LR-N97171, LR-N97268, and LR-N97353). In the most recent submittal, PSE&G identified the single failure of an SW65 control valve in its throttled position would result in local cavitation at the valve. This matter was discussed with representatives of the NRC Staff in a conference call on June 4 and 6, 1997. At the conclusion of that discussion, the Staff requested that PSE&G docket additional information regarding the structural adequacy of the SW65 valves and associated piping during the period of cavitation.

In support of this request, PSE&G hereby submits Attachment 1 consisting of a technical analysis and safety assessment of the condition described above. On the basis of the information provided therein, PSE&G believes that containment cooling and containment integrity requirements will be satisfied following a design basis accident, with a coincident failure of a single SW65 control valve.

Should you have any questions regarding this request or the information contained in Attachment 1, please feel free to contact me.

Sincerely,

E C Simpson

A072

Attachment

C Mr. H. Miller, Administrator - Region I
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REF: LR-N97365

STATE OF NEW JERSEY)
) SS.
COUNTY OF SALEM   )

E. C. Simpson, being duly sworn according to law deposes and says:

I am Senior Vice President - Nuclear Engineering of Public Service Electric and Gas Company - and as such, I find the matters set forth in the above referenced letter, concerning Salem Generating Station, Unit 1 and 2, is true to the best of my knowledge, information and belief.

E C Simpson

Subscribed and Sworn to before me this 12th day of June, 1997

Notary Public of New Jersey Kimberly Jo Brown

KIMBERLY JO BROWN
NOTARY PUBLIC OF NEW JERSEY
My Commission expires on My Commission Expires April 21, 1998.

Background

In a recent submittal (LR-N97353 dated June 3, 1997), PSE&G described modifications being accomplished to eliminate the potential for two-phase flow and/or waterhammer development as a result of a single failure of a Containment Fan Coil Unit (CFCU) motor cooler flow control valve (i.e., SW65 valve). This potential was created due to the lack of repeatability associated with the previous method of valve positioning (i.e., pneumatically positioned based on regulator setpoint). The modification consisted of installation of a mechanical stop as a positive means of establishing valve position. During development of this modification, PSE&G determined that while two-phase flow and waterhammer will be eliminated by the modification; the single failure of an SW65 control valve in its throttled position would result in local cavitation at the valve outlet. This condition was further discussed in conference calls on June 4 and 6, 1997 where PSE&G characterized the condition as expected cavitation typical of a control valve under high flow, with a normal pressure recovery within a short distance downstream of the valve. Plant arrangements include a minimum of about 12 pipe diameters of straight vertical, 10-inch piping from the valve to the nearest elbow.

Safety Assessment

Design Analysis

A simplified one-line schematic of a typical CFCU and SW65 valve piping arrangement is provided as Figure 1. Figure 2 is a detailed illustration of a typical piping arrangement in the vicinity of the SW65 valve.

PSE&G calculation S-2-SW-MDC-1728 was prepared to document the basis for the set position of the SW65 valves and includes an evaluation of the effect of a failure of an SW65 valve to reposition following a design basis accident. Using valve vendor information and with consideration of field setup uncertainties, the calculation determines that the lowest possible flow rate through the valve would be about 1500 gpm. The maximum CFCU outlet temperature at this flow rate was determined to be 203 °F (i.e., Pv = 12.3 psia) with a corresponding valve outlet pressure of approximately 12.7 psia. Under these conditions (i.e., SW65 valve downstream pressure being greater than the associated vapor pressure), it is concluded that cavitation will be localized at the valve itself and two-phase flow will not develop. Fluid conditions in this region would be highly turbulent, thereby inhibiting bulk void formation which could lead to column separation and potential waterhammer. Any vapor bubbles that might be transported away from the valve throat and into the flow stream, would be condensed in the downstream piping as a result of the normal pressure recovery and increasing static head in the vertical downcomer

Vapor collapse in the downstream piping would also be enhanced by mixing with the colder 2-inch CFCU Motor Cooler Unit (MCU) return line (approximately 120 °F), which would be flowing at a higher than normal rate (estimated >200 gpm) if the SW65 failed to reposition. The MCU return pipe connects to the main 10-inch CFCU return pipe approximately 12 inches downstream of the SW65 valve. Although the calculation did not credit this mixing effect, the reduced temperature of the mixture would serve to further increase the margin to saturation at the outlet of the SW65 valve.

It should be noted that the referenced calculation is very conservative. The containment temperature profile used to calculate the CFCU outlet temperature assumes a LOCA+LOOP with a vital bus failure. This scenario minimizes containment cooling capability. If the SW65 is the postulated failure, containment cooling is maximized as a result of three SWS pumps and five CFCUs (e.g., 4 operable, 1 degraded) being available in addition to the two Containment Spray pumps. Additionally, the CFCU outlet temperature is determined using zero heat exchanger thermal fouling at a 90 °F service water inlet temperature. Zero fouling exists only for a short period following cleaning which occurs at each refueling outage. Additionally, service water maximum inlet temperatures are typically less than 85 °F.

On the basis of the analysis discussed above, PSE&G concludes that the failure of an SW65 valve will not result in waterhammer or two-phase flow in the associated CFCU piping loop.

SW65 Valve Performance

A review of the SW65 valve failure data reported to the Nuclear Plant Reliability Data System (NPRDS) was conducted. This data reflects failures observed during normal operation and surveillance testing from December 1984 to present. PSE&G has been testing the CFCU accident response function on a quarterly basis since 1991. Prior to that time, the accident mode test was performed at each refueling outage. The failures were readily detectable with installed control room instrumentation.

A total of ten failures were reported during the period evaluated. Of these ten failures, only two cases relate to the SW65 valve failing to reposition on demand and both are attributed to valve positioner failures. Three of the remaining failures resulted in either a failure to achieve a full open position or slow opening due to blockage of the positioner vent path. If the valve fails to open fully, the cavitation condition downstream of the valve would be less severe than that associated with the valve failing as is. Slow opening of the valve would result in a short period of cavitation at the beginning of the transient, with recovery occurring as the valve moves to the full open position. As a result of PSE&G overall review of CFCU time response testing, requirements for timing several additional valves, including the SW65s, are being added to the In-Service Test (IST) program. Of the remaining five failures, three were due to improper alignment of the valve and actuator following routine maintenance. Such failures are readily detectable during post maintenance operability testing and would be corrected prior to declaring the equipment operable. The remaining two failures are discounted on the basis that one was associated with a flange leak at the valve and the other was not repeatable.

On the basis of this review, PSE&G concludes that the failure of an SW65 valve to open is reasonably low and would be readily detectable during quarterly CFCU Surveillance testing since one of the primary test objectives is to demonstrate that post-accident design flow can be achieved. Response time testing of these valves as a quarterly IST program requirement provides additional assurance that degraded performance will be identified and corrected prior to a functional failure.

Plant Specific Cavitation Experience

The Service Water System (SWS) provides normal as well as design basis accident plant cooling. The head capacity of the system pumps is accordingly sized to accommodate high flow demands with a minimum number of available pumps for an accident with a single failure. This head capacity is not required during normal operations and as such the control elements (i.e. control valves or restrictive orifice plates) in each flow path are required to provide a significant amount of pressure drop. The system also must support a wide range of flow in several critical paths such as the CFCUs and Component Cooling Heat Exchangers (CCHX), which limits the use of fixed restrictive devices typically used in steady flow applications. These factors plus the open system discharge path, which provides only a small amount of backpressure, make control valve cavitation inevitable. As a consequence, PSE&G has accumulated substantial operating experience with SWS control valve cavitation at the Salem Units.

This experience is applicable to the SW65 situation in that similar butterfly type valves are used as control valves at several locations. Examples include the 14-inch CCHX, outlet throttle valves (SW379 and 383), and the 20-inch Turbine Auxiliary Cooling (TAC) Heat Exchanger outlet throttle valves (ST64). These applications normally operate with very little backpressure, particularly in winter months when flow demand is low. An assessment of the extent of control valve cavitation using the methodology of NUREG/CR-6031 (i.e. similar to that discussed in PSE&G letter LR-97353) has been made for each of these applications. The corresponding values of sigma are 1.13 for the SW379 and SW383, and 1.19 for the ST64. Comparing these sigma values to Figure 4.1 of NUREG/CR-6031 indicates that both applications are operating with severe cavitation, approaching choked flow conditions. To date, there has not been a catastrophic failure of either the piping or control valve at either of these locations.

By comparison, the SW65 valve has a calculated sigma value of 1.0 until the swapover to recirculation cooling is accomplished. Swapover to recirculation cooling reduces the SW65 valve differential pressure (DP) as significant flow is diverted to the CCHXs. For the large break Loss of Coolant Accident (LOCA), this time is on the order of 30 minutes. Also during this time, the combined effect of the CFCUs and Containment Spray (CS) has terminated the containment temperature rise and temperature is steadily decreasing. Sigma increases to 1.08 shortly after the onset of the event due to the initial temperature reduction which occurs as the containment cooling systems begin to function. Upon completion of the swapover to recirculation cooling, sigma increases to 1.29. It should be noted that the rate of containment temperature decrease is greater for the SW65 valve single failure (i.e., maximum cooling capability being available) thereby reducing the period during which severe cavitation conditions occur. On the basis of this comparison, it is PSE&G's judgment that plant specific experience with control valve cavitation supports a conclusion that catastrophic structural failure will not occur as a result of the short duration dynamic conditions induced by cavitation at the SW65 valve.

The predominate historical concern with cavitation in the Salem Service Water System has been material wastage of the piping system. Material wastage of the pressure boundary was of particular concern prior to upgrading the piping from carbon steel to 6 % molybdenum stainless steel. The best example is provided by the outlet butterfly control valves at 12CCHX which, until a redesign of the control system in 1996, provided the full flow path pressure drop (typically more than 110 psig) in a very low backpressure condition. A review of maintenance records for the 12CCHX indicates that the identical outlet piping on each half of this heat exchanger experienced high outlet piping material wastage (i.e. carbon steel), which resulted in pinhole leaks that required either repair or replacement approximately once per year. The piping upgrades, completed for this component in the first half of 1992, substantially mitigated material wastage downstream of control valves as a problem. The 6% molybdenum material is expected to exceed the cavitation erosion resistance of 316 stainless steel, which according to Figure 7.2 of NUREG/ CR-6031 is more than 20 times more resistant than the original plain carbon steel. The use of improved materials which are resistant to the effects of cavitation minimizes the development of conditions which would predisposition the piping to potential structural failure.

Performance of the control valves themselves can also be affected by the severe service. Periodic monitoring to support early detection and mitigation of degraded conditions within the SWS is accomplished through the Service Water Reliability Improvement Program which PSE&G has implemented. This program addresses the issues raised in NRC Generic Letter 89-13 by requiring periodic inspection, In-Service Testing and preventative maintenance to ensure that equipment function is not compromised. The author of NUREG/CR-6031 was also contacted in regard to the potential for catastrophic SW65 valve failure. He indicated that based on the information provided by PSE&G relative to this application, and many hours of testing butterfly valves in similar or more severe conditions of cavitation, catastrophic valve failure was unlikely.

To a much lesser extent, cavitation induced vibration failure of small diameter connections and instrument tubing have also been observed to occur. These failures occurred after substantial periods of operation. The shortest time to failure identified in this review was a vibration induced piping weld crack that occurred in a vent connection downstream of valve 2SW308. This failure occurred after 9 months of service and was corrected through a redesign of the connection. This time frame is substantially longer than the post-accident operational period during which localized cavitation at the SW65 would occur (i.e., on the order of 24 hours based on the limiting containment temperature profile).

It is worth emphasizing that the SW65 valves do not experience cavitation at normal operating conditions. As such, the piping, valve and local branch connections have minimal predisposition to fatigue failure. As can be seen on Figure 2, the SW65 valve is located in a straight return run of vertical 10-inch pipe at approximately elevation 105' in the containment building. The routing is straight since it only passes through this elevation (elevation 100') from the CFCU base elevation of 130' to the next level down (elevation 78') where it exits the containment (approximately elevation 95'). The pipe is well supported with a full anchor (i.e. 6 way restraint) at elevation 127' above the SW65 valve and a close fit guide below (1/8 to 1/16 inch clearances) at elevation 98'. A review of the calculated stresses imposed by dynamic loading from a design basis earthquake plus deadweight and pressure, shows a maximum stress of 6199 psi versus an allowable stress of 39260 psi. As such, substantial margins exist to accommodate the additional loading which would occur as a result of local cavitation.

Conclusion

In summary, PSE&G concludes that two-phase flow, waterhammer, and structural failure due to cavitation induced stresses in the CFCU discharge piping downstream of the SW65 control valve will not occur for the following reasons:

- downstream fluid pressures are greater than the fluid vapor pressure as determined using conservative analysis input assumptions,
- downstream mixing shortly beyond the SW65 valve further promotes vapor bubble collapse,
- piping arrangements support pressure recovery and prevent vapor accumulation,
- the SW65 failure rates are reasonably low and readily detectable during quarterly testing,
- response time testing will improve detection of degraded valve performance,
- control valve cavitation experience at Salem is extensive and well understood by the plant staff,
- a very small number of fatigue related failures in small bore piping connections have occurred and only after extended periods of operation,
- normal operating conditions at the SW65 do not predisposition the valve, piping or branch connections to fatigue induced failure, and
- substantial margins to allowable stresses existing in the SW65 piping and support structure.

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Figure 1
LR-N97365

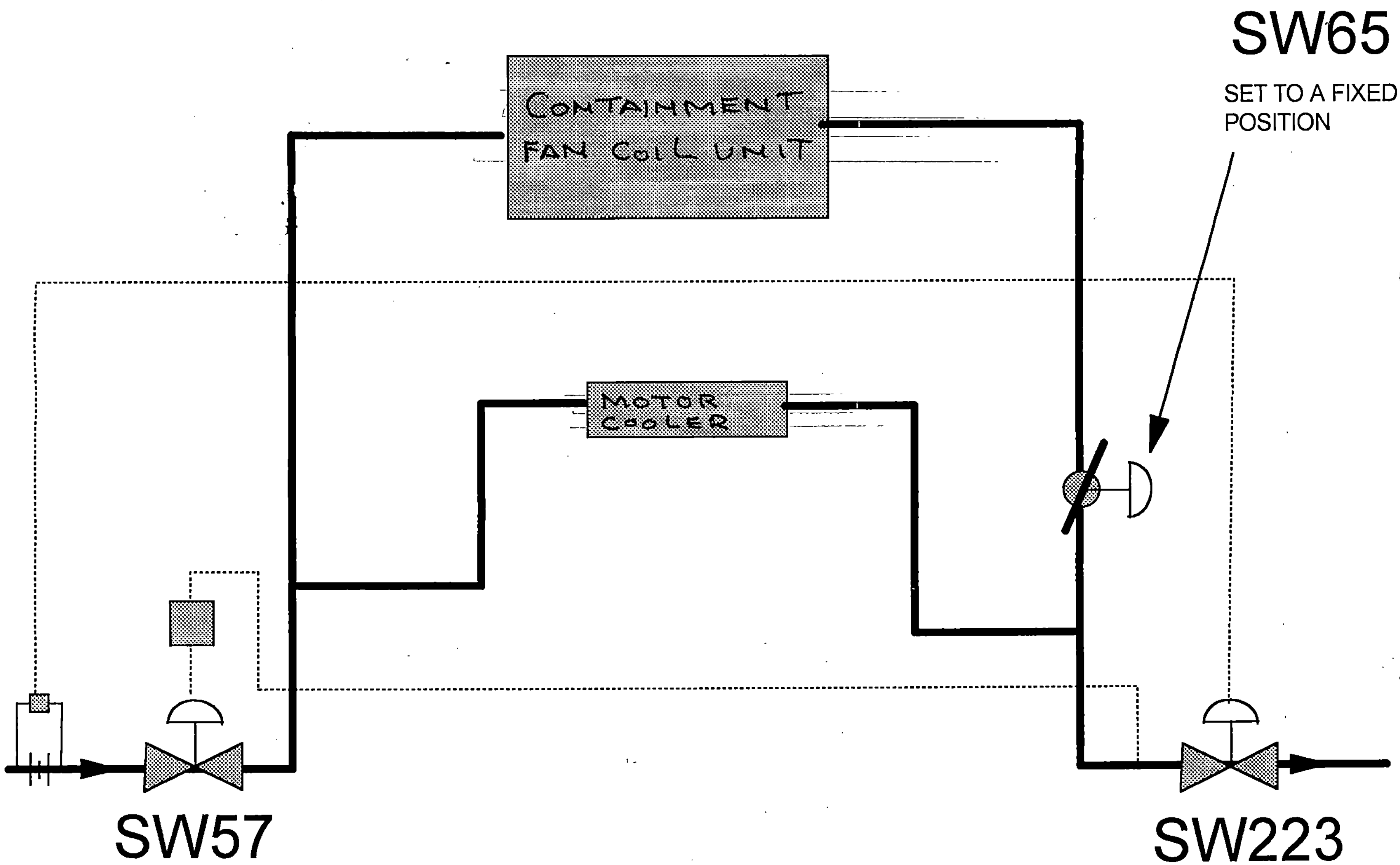

Figure 2
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