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United States Nuclear Regulatory Commission
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Gentlemen:

NRC BULLETIN 88-08
THERMAL STRESSES IN PIPING CONNECTED TO THE RCS
SALEM GENERATING STATIONS
UNIT NOS. 1 AND 2
DOCKET NOS. 50-272 AND 50-311

On August 18, 1994, during a telephone conversation between Public Service Electric & Gas Company (PSE&G), Westinghouse Electric Corporation and NRC personnel, additional clarification was provided regarding the PSE&G response to NRC Bulletin 88-08, in particular with regard to the use of the Thermal Stratification, Cycling, and Striping (TASCS) methodology as documented in EPRI Report TR-103581.

The Attachment to this letter documents the key clarifications discussed on August 18, 1994 and provides the results of additional evaluations. By letter dated January 24, 1994 (ref: NLR-N93204), PSE&G submitted a supplemental response to NRC Bulletin 88-08, based on Westinghouse report WCAP-13898 which utilizes the TASCS methodology. By letter dated July 19, 1994 (ref: NLR-N94087), PSE&G provided additional information regarding the PSE&G response to NRC Bulletin 88-08, as requested by the NRC. The Attachment clarifies some of the information provided in the July 19 submittal.

Should there be any questions with regard to this submittal, please do not hesitate to contact us.

Sincerely,

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ATTACHMENT 1

SUPPLEMENTAL INFORMATION REGARDING
PSE&G RESPONSE TO NRC BULLETIN 88-08

1. Background

By letter dated March 1, 1993 (ref: NLR-N93028), Public Service Electric & Gas Company (PSE&G) provided its response to NRC Bulletin 88-08. As part of that response, PSE&G committed to perform thermal and fatigue analysis of the Auxiliary Spray and Alternate Charging lines.

The results of those analyses were forwarded to the NRC with PSE&G letter dated January 24, 1994 (ref: NLR-N93204), together with Westinghouse Electric Corporation reports WCAP-13898 and WCAP-13899, entitled Evaluation of Salem Units 1 and 2 Charging, Alternate Charging, and Auxiliary Spray Piping per NRC Bulletin 88-08 (Proprietary and Non-Proprietary, respectively).

These results indicate a cumulative fatigue usage of less than 1.0 for the normal and alternate charging lines. The cumulative usage factor for the auxiliary spray line was calculated to be less than 1.0 for 24 calendar years. Thus, PSE&G concluded that no further action would be required for the normal and alternate charging lines to satisfy this Bulletin. PSE&G committed to re-evaluate the Salem Unit 1 auxiliary spray line by December 31, 1998 and the Salem Unit 2 auxiliary spray line by December 31, 2002.

By letter dated July 19, 1994 (ref: NLR-N94087), PSE&G provided answers to questions posed by the NRC regarding PSE&G response to NRC Bulletin 88-08 and in particular, on the use of the EPRI Thermal Stratification,Cycling, and Striping (TASCS) methodology, which was not yet available to the NRC.

On August 18, 1994, during a telephone conference between PSE&G, Westinghouse and NRC personnel, several additional questions were discussed regarding the reliance of the PSE&G analysis on the TASCS methodology.

The purpose of this Attachment is to provide additional information and clarification as requested by the NRC during the August 18, 1994 telephone conference.

2. Availability of EPRI TASCS Report

The EPRI manager for the TASCS project, Mr. J.H. Kim, has confirmed that the EPRI Report TR-103581, Thermal Stratification, Cycling and Striping (TASCS), will be provided to the NRC. This commitment is documented in PSE&G letter dated September 13, 1994 from Mr. Vijay Chandra to Mr. Kim.

Based on telephone conversation between Mr. Chandra and Mr. Kim on September 21, 1994, the administrative and legal process required for this release will begin at EPRI the week of September 26.

This action is expected to resolve NRC's concern regarding access to the TASCS report and its methodology, and will allow the NRC to review the detailed technical bases for the PSE&G fatigue analysis.

3. Susceptibility of Salem Units 1 and 2 Normal Charging, Alternate Charging and Auxiliary Charging Lines to Thermal Stratification and Cycling

PSE&G's position regarding the thermal stratification and cycling concerns described in NRC Bulletin 88-08 as applied to the charging, alternate charging and auxiliary spray lines is summarized as follows:

Normal Charging Line

The normal charging line has continuous flow and is thus not currently susceptible to the thermal stratification and cycling concerns of NRC Bulletin 88-08. Consistent with the original plant design, PSE&G eventually plans to reverse the roles of the normal and alternate charging lines. To address this future concern, PSE&G has evaluated the susceptibility of the normal charging line in a manner equivalent to the evaluation of the alternate charging line, discussed below.

The conclusions regarding the alternate charging line presented below are also applicable to the normal charging line. Specifically, significant thermal stratification and cycling for the normal charging line are considered very unlikely because of the high temperature source of leakage flow, and the lack of problems reported for similar lines. A fatigue analysis has been performed to confirm that even under extremely conservative assumptions regarding leakage flow and cycling period, the cumulative usage factor for these lines is still less than 1.0.

Alternate Charging Line

Thermal stratification and cycling resulting in fatigue failure in the unisolable section of the alternate charging line is not considered credible for the following reasons:

- The source for the potential thermal gradients is the hot (495°F) water downstream of the regenerative heat exchanger, rather than the cold water that led to the failures reported in NRC Bulletin 88-08.

  For the Salem configuration, it is postulated that potential leakage of this hot water past the closed isolation valve would be cooled by the pipe exposed to ambient conditions as it flows between the isolation valve and the check valve before entering the unisolable piping downstream of the check valve. The rate of cooling would depend on the postulated leakage flow rate.

  For high leakage flow rates, there would be little cooling as the leakage flows between the isolation valve and the check valve, and the resulting temperature difference would be small as the leakage flow mixes with the reactor coolant water downstream of the check valve. For very low leakage flow rates, the cold water flow would be heated up by the hot pipe wall immediately upstream of the check valve and by the check valve itself and again the resulting temperature difference between the leakage flow and the Reactor Coolant System (RCS) would be low.

  Specific calculations of the worst case temperature difference and worst case flow are presented in the WCAP-13898, previously submitted by PSE&G. These are approximately 165°F at approximately 0.11 gpm for the charging and alternate charging lines. Each of these values are considerably less severe than the worst case temperature difference, near 450°F for Farley and Tihange and the isolation valve leak flow rate of 1 gpm reported for the Farley failure. (Tihange valve leak rate was not reported in the available references).

- <u>There have been no reported instances of cracking or failure in normal charging, alternate charging and auxiliary charging lines where the potential source of leakage flow is hot water.</u>

  To determine the operating experience with normal charging, alternate charging, and auxiliary spray lines, functionally similar to the corresponding Salem lines, PSE&G has performed a survey of utility responses to NRC Bulletin 88-08 and has examined other available reports published by EPRI, NRC and others. (Specific references are provided in Section 5).

  PSE&G has identified no instances of cracking or failure in any U.S. or foreign plant for such lines whose source of leakage flow is hot water. The apparent problem free condition of these lines after many years of operation in numerous installations have, in most instances, been confirmed by ultrasonic techniques consistent with the requirements of NRC Bulletin 88-08. This operating history provides reasonable assurance, independent of specific fatigue calculations, that thermal cycling and fatigue failure in such lines are not likely.

- <u>A very conservative fatigue analysis indicates a usage factor less than 1.0 for the design life of the plant.</u>

  The fatigue analysis reported in WCAP-13898 is highly conservative in that:

  - It assumes that the postulated isolation valve leakage occurs continuously, for the life of the plant, and at the worst case leakage of 0.11 gpm.

  - It assumes that the mixing of the colder leakage with the hotter RCS heated section is quasi-stable; i.e., the cold water is assumed to lay stably at the bottom of the pipe just long enough (several minutes) to reach a steady state temperature stratification in the pipe, followed by a mixing and heating that lasts just long enough (several minutes) to reach a steady state uniform temperature in the pipe.

    In fact, the actual conditions at this location are not expected to be quasi-stable at all, because of the relative proximity of the RCS pipe and its associated high velocity flow and turbulence.

In summary, significant thermal stratification and cycling for the alternate charging line (and normal charging line) is considered very unlikely because of the high temperature source of leakage flow, and the lack of problems reported for similar lines. A fatigue analysis has been performed to confirm that even under extremely conservative assumptions regarding leakage flow and cycling period, the cumulative usage factor for these lines is still less than 1.0.

<u>Auxiliary Spray Line</u>

Thermal stratification and cycling resulting in fatigue failure in the unisolable section of the auxiliary spray line is not considered credible for the following reasons:

- <u>The length of unisolable piping is extremely short and would not support periodic stratification and mixing.</u>

  The auxiliary spray piping between the check valve and the main spray line is an extremely short horizontal run: approximately 2.5 inches for Unit 1 and about 1.4 inches for Unit 2, as indicated in the sketches previously provided to the NRC by PSE&G. The length to diameter ratio of the longer (Unit 1) unisolable spray line pipe at Salem is about 2. Such a short length of pipe will remain completely mixed whenever there is high velocity flow in the main spray line and thus cannot sustain the periodic thermal stratification and mixing than could lead to high cycle fatigue.

  Data from a variety of sources indicate that such short lengths would remain fully mixed and no stratification would occur. Specifically:

  - Testing reported in the TASCS report (Reference 2) indicates that highly turbulent mixing occurs for a range of lengths with a minimum turbulent penetration of 3 or 4 pipe diameters in all cases.

  - Testing reported in Reference 4, indicates highly turbulent mixing within about 7 pipe diameters of the header pipe.

  - Testing reported in Reference 5, defines a zone within 4-6 pipe diameters of the main pipe as a zone of much turbulence and mixing that remains essentially at the temperature of the main pipe fluid.

- Testing conducted by Westinghouse for the Turkey Point auxiliary spray line and alternate charging line indicated that, for the condition with flow in the main spray line, there will be turbulent mixing of the assumed valve leak flow and that thermal stratification under such flow conditions is unlikely. These results have been reported to the NRC in Reference 6. The configuration of the Turkey Point auxiliary spray line is similar to that at Salem - a short horizontal 2-inch pipe connected to a 4-inch main spray header. The length of the Turkey Point pipe is about 5 pipe diameters. The conclusion for Turkey Point should apply at least as strongly for the shorter Salem line.

- One of the potential corrective actions considered for the North Anna and Surry safety injection lines was to relocate the first check valve on unisolable branches to the RCS to within a distance of 4 pipe diameters (Reference 7).

- The failures that have been reported at Farley and Tihange were at distances of at least 8 and 4 pipe diameters from the main RCS pipe, respectively. (Estimated, based on information presented in Reference 1.)

The available data indicates that very short lengths such as the auxiliary spray line at Salem are not susceptible to the thermal stress concerns of NRC Bulletin 88-08.

- <u>The source for the potential thermal gradients is the hot (495°F) water downstream of the regenerative heat exchanger, rather than the cold water that led to the failures reported in NRC Bulletin 88-08.</u>

The discussion presented above for the alternate charging line applies equally well to the auxiliary spray line.

Specific calculations of the worst case temperature difference and worst case flow are presented in WCAP-13898 previously submitted by PSE&G. These are approximately 183°F at approximately 0.11 gpm for the auxiliary spray line. Each of these values are considerably less severe than the worst case temperature difference near 450°F for Farley and

Tihange and the leak flow rate of 1 gpm reported for Farley. (Tihange valve leak rate was not reported in the available references.)

- <u>There have been no reported instances of cracking or failure in normal charging, alternate charging and auxiliary charging lines where the potential source of leakage flow is hot water.</u>

The discussion presented above for the alternate charging line applies equally well to the auxiliary spray line. The apparently problem free condition of these lines after many years of operation in numerous installations provides reasonable assurance, independent of specific fatigue calculations, that thermal cycling and fatigue failure in such lines are not likely.

- <u>An overly conservative fatigue analysis indicates a usage factor less than 1.0 for 24 years of operation.</u>

The fatigue analysis for the auxiliary spray line reported in WCAP-13898 is overly conservative in that:

- It assumes that a credible mechanism exists for the mixing of the colder leakage with the hotter RCS heated section in a quasi-stable fashion; i.e., the cold water is assumed to lay stably at the bottom of the pipe just long enough (several minutes) to reach a steady state temperature stratification in the pipe, followed by a mixing and heating that lasts just long enough (several minutes) to reach a steady state uniform temperature in the pipe.

  In fact, as discussed above, the actual conditions at this location are expected to be fully turbulently mixed because of the close proximity of the main spray pipe and its associated high velocity flow and turbulence.

- It assumes that the postulated isolation valve leakage occurs continuously, for the life of the plant, and at the worst case leakage of 0.11 gpm.

- It uses a two-dimensional model representing a cross-section of the auxiliary spray line piping. A more accurate three-dimensional model that takes into account axial conduction along the pipe would be expected to result in lower peak stresses.

Consequently, the actual usage factor for the auxiliary spray line is expected to be considerably less than calculated in WCAP-13898.

In summary, significant thermal stratification and high cycle fatigue for the auxiliary spray line are not considered credible because of the very short length of unisolable piping, the high temperature source of leakage flow, and the lack of problems reported for similar lines. The previously reported fatigue calculation for the auxiliary spray line is considered overly conservative.

4. Dependence of the PSE&G Response on the TASCS Methodology

The NRC had previously requested clarification regarding the degree of dependence of the PSE&G response to NRC Bulletin 88-08 on the EPRI TASCS methodology. An initial response was provided in PSE&G letter dated July 19, 1994 (ref: NLR-N94087) which forwarded the detailed Westinghouse response as Enclosure 1 and provided a short summary in Attachment 1. Additional clarification is provided. Specifically, the TASCS methodology was used to determine the height of the stratified flow (Section 2.3 of WCAP-13898) and to calculate the heat transfer of the leakage flow (Section 2.4 of WCAP-13898). Both of these calculations are elements in the detailed fatigue analysis described in WCAP-13898.

The fatigue analysis depends in part on the TASCS methodology, as indicated above. In addition, the turbulent penetration data obtained in the TASCS program, together with similar data reported in References 4, 5, and 6, are used primarily to provide assurance that the very short lengths of piping for the auxiliary spray line will remain fully mixed.

As described above, PSE&G considers that the thermal stratification and cycling resulting in fatigue failure are not considered credible because of the high temperature source of leakage flow, the lack of problems reported in the unisolable section of the normal and alternate charging line and auxiliary spray line, the very short lengths of unisolable piping for the auxiliary spray line and the conservative fatigue analysis of the normal and alternate charging lines.

5. References

1. "Review of Thermal Stratification Operating Experience," Special Study Report AEOD/S902, dated March 1990, prepared by Nelson T. Su, Office for Analysis and Evaluation of Operating Data, USNRC, forwarded by memorandum dated March 5, 1990 from Thomas M. Novak to Charles E. Rossi.

2. Thermal Stratification, Cycling, and Striping (TASCS), EPRI Report TR-103581, March 1994

3. NRC docket information was examined with regard to response to NRC Bulletin 88-08 for the following plants:

   - Beaver Valley
   - Calloway
   - D.C. Cook
   - Calvert Cliffs
   - Davis Besse
   - Farley
   - Kewaunee
   - North Anna & Surry
   - Perry
   - Point Beach
   - Prairie Island
   - San Onofre Unit 1
   - San Onofre Units 2,3
   - Sequoyah
   - Trojan
   - Turkey Point
   - Vogtle
   - Wolf Creek

4. "Flow Recirculation Data for Closed-Ended Branch Piping (Deep Cavity Flow)" by R.D. Coffield, J. Gilmore, ANS Transactions, 60 (1989), 676-677.

5. "Thermal Stratification and Fatigue of Piping in Nuclear Power Plants" by D.A. Van Duyne, et.al., 1990 ASME Pressure Vessel and Piping Conference, Nashville.

6. Attachment 2 to letter dated May 4, 1989 from Florida Power and Light Company to U.S. NRC regarding NRC Bulletin 88-08.

7. Attachment 1 to letter dated March 15, 1989 from Virginia Electric and Power Company to U.S. NRC regarding NRC Bulletin 88-08