Public Service
Electric and Gas
Company

**Stanley LaBruna**

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JUL 1 9 1994

NLR-N94087

United States Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555

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

By letter dated January 24, 1994 (ref: NLR-N93204), Public Service Electric & Gas Company (PSE&G) submitted a supplemental response to NRC Bulletin 88-08. The response addressed completion of a thermal fatigue analysis on the Pressurizer Auxiliary Spray Line and the Reactor Coolant System (RCS) Normal and Alternate Charging Lines. Enclosures 2 and 3 to the January 24, 1994 letter contained Westinghouse WCAP-13898 and WCAP-13899, entitled Evaluation of Salem Units 1 and 2 Charging, Alternate Charging, and Auxiliary Spray Piping per Bulletin 88-08 (Proprietary and Non-Proprietary respectively).

On March 1, 1994, during a telecon between PSE&G, Westinghouse Electric Corporation, and NRC personnel, PSE&G committed to provide additional information to support the January 24, 1994 submittal.

The requested additional information, in question and answer format, is provided in Attachment 1. Attachment 2 contains detailed information, supplied by Westinghouse, which formed the basis for our responses.

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

Sincerely,

S. LaBruna

Attachments

JE14

JUL 19 1994



C Mr. J. C. Stone
Licensing Project Manager

Mr. C. Marschall
Senior Resident Inspector

Mr. T. Martin, Administrator
Region I

Mr. Kent Tosch, Manager IV
New Jersey Department of Environmental Protection
Division of Environmental Quality
Bureau of Nuclear Engineering
CN 415
Trenton, NJ 08625

**ATTACHMENT 1**

The following information was requested:

Q1 Which techniques used in the report (Westinghouse WCAP-13898) are from the Thermal Stratification, Cycling and Striping (TASCS) Program, Final Report, prepared by Westinghouse Electric Corporation for the Electric Power Research Institute (EPRI), Research Project 3153-02, and which techniques are textbook methods?

R1 This question is addressed under "Evaluation Techniques" in the enclosed Westinghouse letter. The techniques described are: "Flow without Stratification", "Height of a Stratified Flow" and "Heat Transfer of a Leakage Flow". Each of these sections provides detailed information regarding what was evaluated and why, as well as describing the methodologies used.

The TASCS program used empirical test data to analyze turbulence penetration into a branch pipe. Analytical methods were employed to model stratification height and determination of heat transfer effects.

Textbook methodologies used in WCAP-13898 are listed below and identify the Sections to which they apply:

- Calculation of heat loss in lines assuming flow without stratification (Section 2.2.1 of WCAP-13898).
- Calculation of base line temperature of the isolable piping section adjacent to the unisolable piping section (Section 2.2.2 of WCAP-13898).
- Determination of the height of the stratified flow (Section 2.3 of WCAP-13898).
- Calculation of the heat transfer of a leakage flow (Section 2.4 of WCAP-13898).

**ATTACHMENT 1 (cont'd)**

Q2 Provide fatigue usage factors for the charging, alternate charging, and auxiliary spray lines.

R2 The fatigue usage factor calculated for the normal and alternate charging lines was 0.947. Fatigue usage for the auxiliary spray lines was calculated to be 0.963 for 24 years or 0.0401 per year. (See page 4 of the Westinghouse letter).

Q3 Provide schematic drawings for the unisolable piping sections of the charging, alternate charging, and auxiliary spray lines.

R3 A schematic drawing is attached to the Westinghouse letter.

# ENCLOSURE 1

**Westinghouse**
**Electric Corporation**

C/o Public Service Electric & Gas Co
Trailer 108
PO Box 236
Hancocks Bridge New Jersey 08038

PSE-94-639
July 8, 1994
RFQ # 9310020
GO# NA-43019
PO# P3-0696053

Mr. Howard Berrick, Principal Engineer
Public Service Electric & Gas Company
P.O. Box 236, M/C N50
Hancocks Bridge, New Jersey 08038

Subject: NRC Review of Westinghouse Report WCAP-13898

Reference: Letter PSE-94-564, Huckabee to Berrick, Subj: NRC Review of Westinghouse Report WCAP-13898, dated April 5, 1994.

Dear Mr. Berrick:

Attached is a revised report for the support of United States Nuclear Regulatory Commission review of Westinghouse Report WCAP-13898.

If you have any questions, please call Pat Strauch at 412-374-6139 or me at 609-339-5343.

Very truly yours,

JM Huckabee

Jeff Huckabee
Special Sales Representative
Power Systems Field Sales

Attachment

cc: Dilip Bhavnani - M/C N51

**ADDITIONAL INFORMATION IN SUPPORT
OF
UNITED STATES NUCLEAR REGULATORY COMMISSION
REVIEW OF WESTINGHOUSE REPORT WCAP-13898**

Westinghouse report WCAP-13898, "Evaluation of Salem Units 1 and 2 Charging, Alternate Charging and Auxiliary Spray Piping per NRC Bulletin 88-08" was issued in December 1993 to address the issue of potential valve leakage occurring in susceptible piping systems at Salem. The conclusion of this report for the normal and alternate charging lines is that the cumulative fatigue usage for design transients and postulated isolation valve leakage transients is less than 1.0 for the life of the plant, therefore, no additional actions are required to satisfy bulletin requirements. The conclusion for auxiliary spray lines is that the cumulative fatigue usage for design transients and postulated isolation valve leakage transients is less than 1.0 for 24 calendar years, assuming a worst case scenario of continuous isolation valve leakage at the critical leakage flow rate, and six occurrences of the inadvertent auxiliary spray transient. Therefore, continuing assurance of auxiliary spray piping integrity will be required after 24 calendar years for each unit.

The United States Nuclear Regulatory Commission is currently reviewing WCAP-13898. During a telephone conference call between NRC staff, Public Service Electric and Gas Co. personnel and Westinghouse personnel on March 1, 1994, the NRC had requested additional information to facilitate their review process. Specifically, the following information was requested:

- Which techniques used in the report are from the Electric Power Research Institute's Project 3153-02 Report TR-103581, entitled "Thermal Stratification, Cycling, and Striping (TASCS)", March 1994, and which techniques are "textbook" methods.

- Fatigue usage factors for the charging, alternate charging and auxiliary spray lines.

- Schematic drawings for the unisolable piping sections of the charging, alternate charging and auxiliary spray lines.

The purpose of this letter is to provide the information requested by the NRC.

**Evaluation Techniques**

To assess the impact of potential isolation valve leakage on the structural integrity of the susceptible piping systems at Salem Units 1 and 2, heat transfer, stress and fatigue evaluations were performed, as discussed below.

**Flow without Stratification**

The source of leakage for the lines is the regenerative heat exchanger, which has a discharge temperature of 490oF, under normal operating conditions. Should any of the closed isolation valves leak during normal operation, the leakage could significantly cool from the discharge temperature depending on the leak rate, piping length and insulation thermal conductivity and thickness.

To evaluate the charging lines (normal and alternate) of Units 1 and 2, the longest pipe length, highest insulation thermal conductivity and thinnest insulation thickness were conservatively used to envelop the four lines. The same approach was used to envelop the Units 1 and 2 auxiliary spray lines. The charging and auxiliary spray analyses therefore calculated a maximum heat loss of the leakage flow to the environment, as it flows from the regenerative heat exchanger to the unisolable piping. This resulted in a maximum stratification temperature difference in the unisolable piping sections.

The calculation of this heat loss to the environment was performed using the heat transfer equations for flow without stratification

**Height of a Stratified Flow**

Section 2.3 of WCAP-13898 discusses the height of the stratification flow. It was assumed that the interface thickness between the hot and cold water is very small, such that the hot and cold water are separated into two areas. This is conservative in terms of the effects on piping stress. To proceed with the analysis of the isolation valve leakage, the height of the leakage flow had to be determined. Once this was identified, leakage fluid velocity and other pertinent fluid variables could be calculated as a function of leakage flow rate.

The basis for determining the height of a stratified flow is open channel flow theory, which may be found in a fluid mechanics textbook. Using the relationships for the Froude number (which relates inertial and buoyancy forces) and the volumetric flow rate ($Q = VA$), and accounting for fluid buoyancy, a simple formula was obtained which defined the geometry of the stratified flow as a function of flow rate, fluid density difference (i.e., temperature difference), and pipe inside diameter (see equation in Section 2.3 of WCAP-13898). The resulting critical depth (yc) is effectively the depth of a gravity-driven flow at the exit of a pipe. A linear regression fit of test data, including both low temperature and high temperature measurements, yielded a simple correlation between the interface height (H) and the critical depth:

$$H = 1.33 \text{ yc}$$

Figures 2-16 and 2-17 of WCAP-13898 provide leakage height (H) vs. leakage flow rate for the charging and auxiliary spray lines.

## Heat Transfer of a Leakage Flow

Given that the leakage height and temperature (vs. flow rate), and the baseline temperature near the unisolable piping could be determined as discussed above, the next step in the evaluation of the isolation valve leakage was to calculate the heat transfer of the leakage flow, i.e., to determine the amount of preheating that the leakage would experience before entering the unisolable piping. This is discussed in Section 2.4 of WCAP-13898.

A simple heat balance was the basis for the heat transfer solution. Heat transfer between the cold leakage flow and the hot water was conservatively assumed to be negligible. The leakage flow is assumed to preheat by heat energy conducting through the pipe metal and convecting to the leakage flow.

A standard heat transfer coefficient was used assuming free convection from the pipe to the water. The resulting relationship was compared to testing fatigue. This is the location within the unisolable piping sections where stratification temperature differential would be maximized, since the leakage would either mix or heat up beyond this point.

## Fatigue Usage Factors

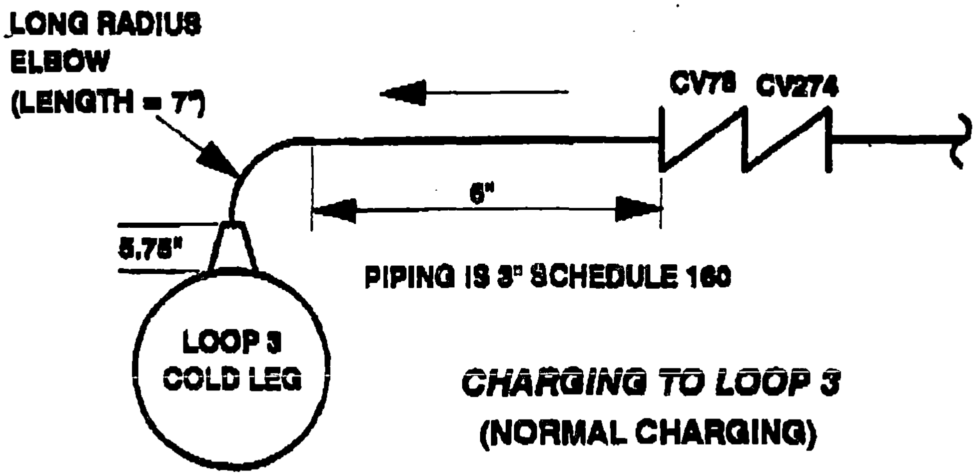
For both the charging and auxiliary spray lines, postulated valve leakage stress cycles were assumed to occur at five minute cycles (which is the minimum period for maximization of alternating stress) at the critical location (check valve outlet weld) and at the maximum possible temperature differential.

Fatigue usage for the normal and alternate charging lines was calculated to be 0.947 for the conservatively postulated valve leakage transients in conjunction with design transients, as discussed in Section 3.3.1 of WCAP-13898. Fatigue usage for the auxiliary spray lines was calculated to be 0.963 for 24 years, or 0.0401 per year, for the conservatively postulated valve leakage transients in conjunction with design transients (including six occurrences of the inadvertent auxiliary spray transient), as discussed in Section 3.3.2 of WCAP-13898.

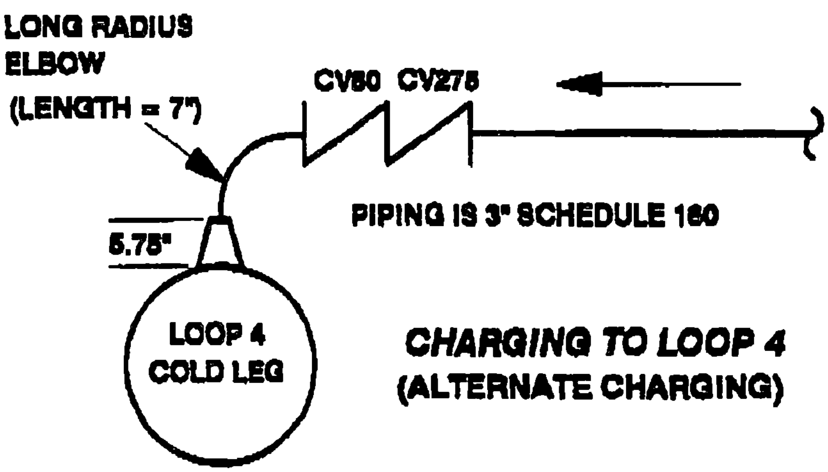
## Unisolable Piping Schematic Drawings

A schematic drawing of the unisolable piping sections of the charging, alternate charging and auxiliary spray lines is attached.

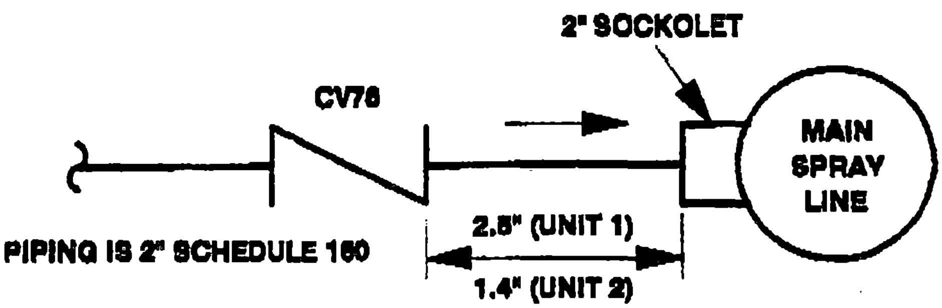
# SALEM CHARGING AND AUXILIARY SPRAY LINES
# UNISOLABLE PIPING SECTIONS




*CHARGING TO LOOP 3*
(NORMAL CHARGING)




*CHARGING TO LOOP 4*
(ALTERNATE CHARGING)




*AUXILIARY SPRAY LINE*