AEOD/E90-09

ENGINEERING EVALUATION REPORT

ADDITIONAL FACTORS AFFECTING THE LIFT SETPOINT OF PRESSURIZER SAFE'.Y VALVES

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Office for Analysis and Evaluation
of Operational Data
U.S. Nuclear Regulatory Commission

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BACKGROUND

NRC Information Notice (IN) No. 89-90 "Pressurizer Safety Valve Lift Setpoint Shift" was issued to inform licensees about potential problems resulting from operating pressurizer safety valves in environments different from those used to establish the lift setpoints of the valves. The IN primarily focused on problems encountered by setting the lift setpoint of the safety valves with steam under the disc, and then operating the valves with a loop seal containing water. In particular, two instances concerning loss of a loop seal at the V. C. Summer plant were described in the IN.

The Reactor Systems Branch (SRXB), Division of Systems Technology of NRR, is also pursuing a multi-plant action with the Westinghouse Owners' Group regarding failures of pressurizer safety valves. However, from discussions with SRXB staff, it appears this effort is also focused upon the loop seal issue, and does not address the additional factors identified in this report that contribute to unexpected changes in the lift setpoint of pressurizer safety valves.

SUMMARY

Licensee root cause analyses of unexpected shifts in the lift setpoint of pressurizer safety valves at V. C. Summer and other nuclear plants identified additional factors that might not have been previously assessed. These factors include:

- changes in temperature of the valve body and bonnet,
- leakage across the valve seat,
- excess loading of the safety valve tailpipe (nozzle loading),
- calibration of reactor coolant system (RCS) pressure control instrumentation, and
- presence of non-condensable gases in the pressurizer vapor space.

The reduction in lift setpoints of pressurizer safety valves could result in primary system leakage, and cause unnecessary challenges to plant safety systems. Conversely, an increase in lift setpoint causes a reduction in safety margin in the protection of the RCS against overpressure transients. Accordingly, these additional factors affecting the lift setpoint of pressurizer safety valves are important, and warrant further attention.

DESCRIPTION OF OCCURRENCES

On May 28, 1989, at the V. C. Summer nuclear plant, a manual reactor trip was initiated following rapid depressurization of the RCS, due to a pressurizer safety valve failing open (Ref. 1). As a result of the analysis of information obtained from the Summer occurrence, the NRC's Office for Analysis and Evaluation of Operational Data (AEOD) initiated searches of available Licensee Event Reports (LERs) to determine generic applicability of the additional factors affecting the pressurizer safety valve failure experienced at Summer. Nuclear Document System (NUDOCS) text searches were performed on LERs issued since 1987 to identify LERs containing the phrase "pressurizer safety valve". NPRDS searches, performed by affected licensees, were also utilized. Unanticipated shifts in the lift setpoints of pressurizer safety valves, due to the factors listed above, were identified at Calvert Cliffs (Ref. 2), Millstone 3 (Ref. 3), Surry 2 (Refs. 4 and 6), Arkansas Nuclear One-2 (Refs. 5 and 10), Sequoyah 1 (Ref. 7), and Diablo Canyon 1 (Ref. 8) and 2 (Ref. 9).

ANALYSIS AND EVALUATION

In-depth licensee root cause analyses of unexpected shifts in the lift setpoints of pressurizer safety valves at nuclear power plants have identified additional factors contributing to setpoint shifts that might not have not been previously assessed. These factors are addressed below:

- Changes in Temperature of the Valve Body and Bonnet

Utilities have indicated that setpoint shifts were found to result from changes in temperature of the pressurizer safety valve body and bonnet. High ambient operating temperature heats the valve body and bonnet, resulting in expansion of the body and elongation of the bonnet. This relieves spring pressure and reduces the lift setpoint of the pressurizer safety valve.

Previous studies and testing of the Calvert Cliffs' pressurizer safety valves determined that the difference in safety valve setpoint between a "cold set" and a "hot set" (a 120 °F change) was in the range of 60-150 psi (Ref. 2).

Personnel at Millstone 3 indicated setting the safety valve lift setpoint at lower than actual inservice operating temperature could cause as much as 50 psi shift (Ref. 3).

At Surry 2, setpoints were determined to be out of tolerance because of failure to compensate for ambient operating temperature during previous adjustments (Ref. 4).

An Arkansas Nuclear One (ANO) Unit 2 pressurizer safety valve was refurbished, and its lift setpoint was adjusted at Wyle utilizing valve temperature profile data supplied by ANO. After installation of the valve at ANO-2, and plant heat-up to hot standby, in-situ testing revealed the setpoint had been reduced 25 psi due to the ambient temperature increase (Ref. 5).

At ANO-2, a pressurizer safety valve temperature profile, provided to Wyle in order for Wyle to simulate inservice temperature conditions when testing the valve lift setpoint, was later determined to be as much as 150 °F lower than actual valve temperatures during service. A discussion between AEOD and ANO-2 personnel revealed that the operating condition temperature profile of the safety valve was obtained by ANO personnel utilizing hand held measuring devices. The licensee concluded installation of thermocouples on the safety valves, and long term temperature monitoring, was necessary for accurate determination of the temperature profile.

At the Westinghouse Western Service Center test facility, a pressurizer safety valve from the Summer plant was subjected to a steam soak test with a loop seal in place. As the valve body and bonnet were heated in an environmental chamber to simulate in plant operating conditions, a reduction of 22 psi (1 percent) was measured in the lift setpoint of the safety valve (Ref. 1).

Discussions with Summer personnel also revealed that elevated temperatures of the valve body and bonnet can be inadvertently created due to installation of insulation on the valve. If the valve is tested and the lift setpoint is adjusted based on an un-insulated condition, addition of insulation after the valve is installed can cause a subsequent unanticipated increase in temperature and resultant decrease in lift setpoint.

During evaluations of corrective actions to obtain accurate lift setpoints on safety valves, licensees determined the following:

- Valve lift setpoint must be set with the same temperature profile that the valve will experience when placed in service.

- Hand held temperature monitoring for determination of valve temperature profile was determined to be inadequate. Installation of thermocouples on the valves, and long term temperature monitoring, were found to be necessary for accurate temperature profile measurement.

- Elevated temperatures of the valve body and bonnet can be inadvertently created if insulation is installed on the valve after the valve has been tested and set in an un-insulated condition. A resultant decrease in setpoint can occur.

- Leakage Across the Valve Seat

At Sequoyah 1, premature lifting of the pressurizer safety valve was determined to be due to seat leakage (Ref. 6). Calculations of the spring force required to maintain closure of the safety valve were based on cross sectional area of the seat and zero leakage. If leakage occurs, the design of the disc and nozzle is such that the cross sectional area of the disc is effectively increased, allowing a lower system pressure to lift the valve.

Similar conditions were experienced at Calvert Cliffs (Ref. 2) and Millstone 3 (Ref. 3).

Experiences at Summer (Ref. 7) and Diablo Canyon (Ref. 8) indicated presence of steam in contact with the Stellite disc causes temperature differences to create localized stresses, warping of the disc, and changes in the effective disc area, causing leaks which affect the lift setpoint.

Discussions with Summer plant personnel revealed that loss of the loop seal on a pressurizer safety valve due to seat leakage also causes steam to heat and expand the valve nozzle. Expansion of the valve nozzle then compresses the valve spring, increasing the valve setpoint. As the valve body then heats up, the body and the bonnet elongate, relieving the spring pressure and resulting in an overall reduction of the safety valve setpoint.

At Surry 2, loss of the loop seal reduced the set pressure to within 30 psi of the actual RCS pressure (Ref. 9).

At Summer, in order to eliminate leakage through the safety valve seat induced by loss of the water loop seal, the utility implemented a design modifications to the Crosby pressurizer safety valves to drain the loop seals, and replace each Stellite disc with Inconel "flexidisc".

- Excess Loading of the Safety Valve Tailpipe (Nozzle Loading)

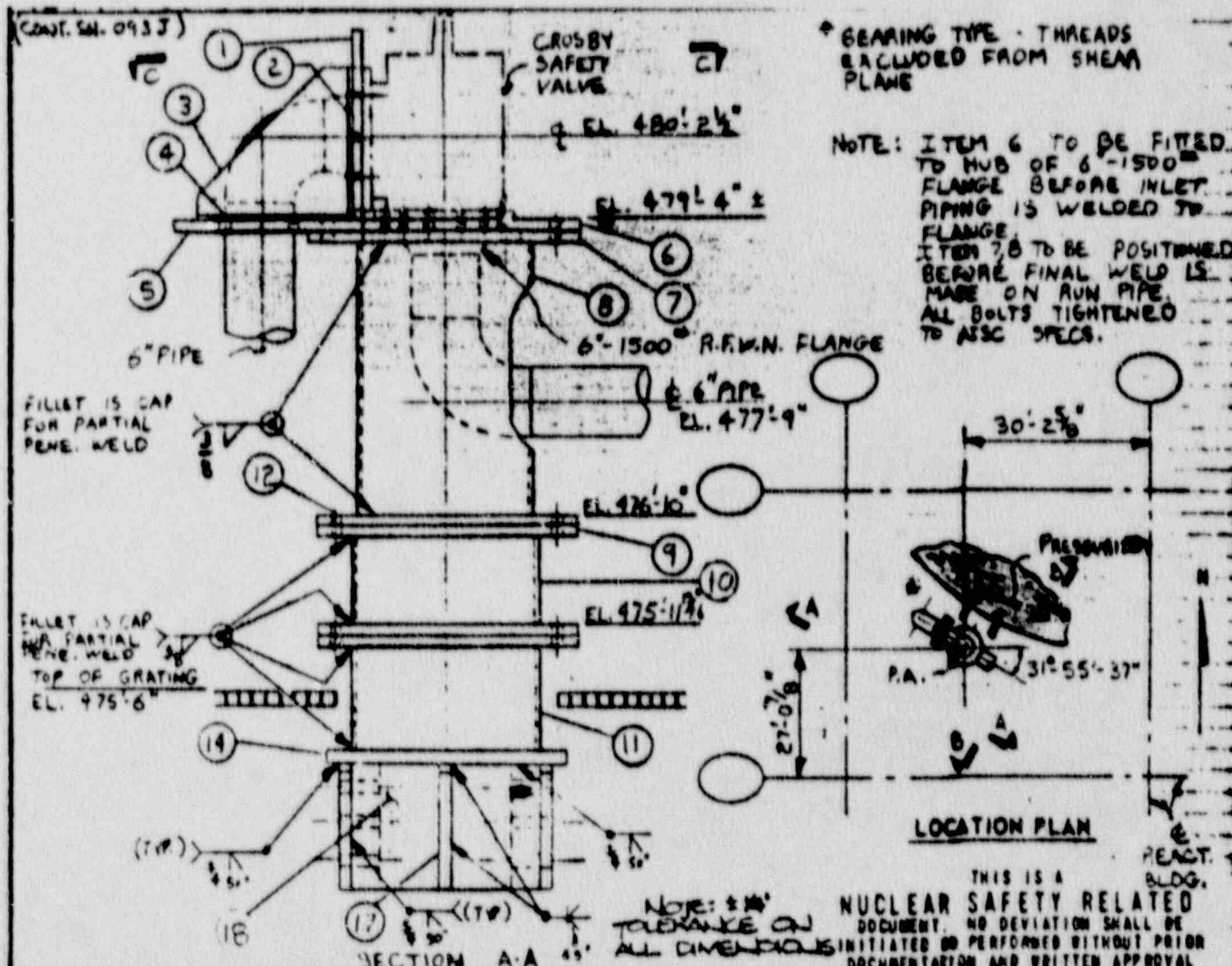
At Summer, the pressurizer safety valve structural support was attached to the pressurizer (see Enclosure 1). The safety valve tailpipe was designed to pass through a mounting plate (Item 5) with a gap of 1/16 to 1/8 inch all around. Normal pressurizer heat-up caused elongation of the pressurizer, which lifted the safety valve structural support upward. As the other end of the 50 to 60-foot long 6-inch pressurizer safety valve tailpipe is supported along its length and attached to the pressurizer relief tank (quench tank), stress was induced into the body of the safety valve when the pressurizer elongated.

Deformation of the irregular flame cut surfaces in the hole of the mounting plate where the plate contacted the tailpipe flange were apparent. Licensee calculations determined the stress levels in the valve body were 4,925 psi. Although this stress level was only approximately 18 percent of allowable, the licensee concluded some disc-to-nozzle misalignment resulted in seat leakage. The non-symmetrical pattern of steam leakage degradation of the disc and nozzle seating surfaces identified during valve disassembly also confirmed that some misalignment was present.

At ANO Unit 2 (Ref. 10), a pressurizer safety valve setpoint reduction was attributed, in part, to high valve loading from restrained thermal expansion and dead weight loads from the tailpipe. Although calculated loads were within the manufacturer's allowable stress, the valve vendor indicated the loads were high enough to cause leakage and result in reduction in the lift setpoint by allowing steam to escape into the huddling chamber of the valve.

Licensee corrective actions included re-analysis of tailpipe configurations, removal of tailpipe mounting plates, and modification of tailpipe supports and hangers.

ENCLOSURE 1



SOUTH CAROLINA ELECTRIC & GAS COMPANY VIRGIL C. SUMMER NUCLEAR STATION UNIT #1	FOR SIGNATURES AND REVISIONS SEE SHEET LETTER A FOR THE PIPE SUPPORT INDICATED BELOW.						
GILBERT ASSOCIATES, INC. ENGINEERS & CONSULTANTS READING, PA.	04	4461	S-321-601	SHEET 093 B	PIPE SUPPORT MK-RCH-093	9.
	DRAWING NUMBER			DESCRIPTION		REV.

- Calibration of RCS Pressure Control Instrumentation

At Summer, evaluations of "as found" conditions after the May 28, 1989, event (Ref. 1), determined that the RCS (pressurizer) pressure control instrumentation, and associated control room indication, were about 0.6 percent low. The instrumentation was found to be within calibration tolerances, and the inaccuracy was therefore considered normal.

With this instrumentation inaccuracy, the control room indication, and input to RCS pressure control, was about 15 psi low. Actual pressurizer pressure was thus 2250 psig, rather than the indicated (and control room controller setpoint of) 2235 psig. While instrumentation inaccuracy was minor, and within calibration tolerances, it nonetheless resulted in somewhat higher than expected RCS operating pressure which contributed to the unexpected lifting of the pressurizer safety valve at Summer.

Greater instrumentation inaccuracies could cause unknown higher RCS operating pressures, contributing to unexpected lifting of pressurizer safety valves.

- Presence of Non-condensable Gases in the Pressurizer Vapor Space

Summer personnel informed AEOD staff that thermocouples installed on the inlet piping to the valves at Summer indicated a large temperature gradient along the pipe to the valves. As saturated steam would produce a uniform temperature along the pipe, the temperature gradient led the licensee to presume a large concentration of non-condensable gases from the pressurizer was present under the valve seat.

Preliminary information from the licensee indicated various concentrations of non-condensable gases in the vapor space impact the following:

- The condensation rate into the loop seal, as non-condensable gases inhibit the steam condensation process that makes the loop seal.
- The leak tightness of the valve, as the inherent smaller molecular size of non-condensable gases such as hydrogen can initiate seat leakage easier than a steam/water mixture.

Millstone 3 also indicated leakage of non-condensable gases past the valve seats may have contributed to setpoint drift (Ref. 3). Utility testing of pressurizer safety valves revealed that a valve which passed a steam leak test would not necessarily pass an air leak test. The licensee hypothesized that this leakage, over time, might have caused some of the setpoint drift experienced at Millstone.

FINDINGS AND CONCLUSIONS

Loss of loop seal, and the resultant effect upon the lift setpoint of the pressurizer safety valves, were addressed in IN No. 89-90. The IN primarily focused on problems encountered by setting the lift setpoint of safety valves with steam under the seat, and then operating the valves with a loop seal containing water.

Additional factors contributing to unexpected shifts in the lift setpoints of pressurizer safety valves that might not have not been previously assessed include:

- changes in temperature of the valve body and bonnet,
- leakage across the valve seat,
- excess loading of the safety valve tailpipe,
- calibration of RCS pressure control instrumentation, and
- presence of non-condensable gases in the pressurizer vapor space.

The reduction in lift setpoints of pressurizer safety valves could result in a plant trip, and cause unnecessary challenges to plant safety systems. Conversely, an increase in lift setpoint causes a reduction in safety margin in the protection of the RCS against overpressure transients. Accordingly, these additional factors affecting the lift setpoint of pressurizer safety valves need to be considered as part of maintaining the performance of the valve within the technical specifications limits.

REFERENCES

1. South Carolina Electric & Gas Company, "Manual Reactor Trip Due to Pressurizer Safety Valve Failure," Licensee Event Report 89-11, Revision 1, Docket 50-395, January 23, 1990.
2. Baltimore Gas and Electric, "Pressurizer Safety Valves 200 and 201 Setpoints Out of Specification," Licensee Event Report 87-06, Revision 1, Docket 50-317, January 5, 1989.
3. Northeast Utilities, "Early Lifting of Pressurizer Safeties for Undetermined Reasons," Licensee Event Report 87-09, Revision 2, Docket 50-423, September 30, 1988.
4. Virginia Electric and Power Company, "Pressurizer Safety Valve Setpoints Outside of Allowable Limits," Licensee Event Report 86-15, Revision 1, Docket 50-281, March 12, 1987.
5. Arkansas Power & Light Company, "Setpoint Discrepancies for Pressurizer Code Safety Valves Discovered During In-Situ Testing Following Heatup After Refueling Outage," Licensee Event Report 88-12, Docket 50-368, July 21, 1988.
6. Tennessee Valley Authority, "Pressurizer Safety Relief Valve Inoperable Requires Reactor

Shutdown," Licensee Event Report 84-31, Docket 50-327, June 1, 1984.

7. Pacific Gas & Electric Company, "Pressurizer and Main Steam Line Code Safety Valves Outside Technical Specification Setpoint Tolerance Limits Due To Indeterminate Causes," Licensee Event Report 88-18-01, Docket 50-275, June 27, 1989.
8. Pacific Gas & Electric Company, "Leakage Past Pressurizer Safety Relief Valve 8010A," Licensee Event Report 89-06, Docket 50-323, September 26, 1989.
9. Virginia Electric and Power Company, "'C' Pressurizer Safety Valve Lifted Below Technical Specification Limit," Licensee Event Report 89-17, Docket 50-281, December 1, 1989.
10. Arkansas Power & Light Company, "Pressurizer Code Safety Valves Discovered Outside Technical Specifications Required Lift Settings Due To Indeterminate Cause," Licensee Event Report 86-12-01, Docket 50-386, September 15, 1988.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

October , 1990

NRC INFORMATION NOTICE NO. 89-90, SUPPLEMENT 1:

ADDITIONAL FACTORS AFFECTING THE LIFT SETPOINT OF PRESSURIZER SAFETY VALVES

Addressees:

All holders of operating licenses or construction permits for pressurized water reactors (PWRs).

Purpose:

NRC Information Notice (IN) No. 89-90 "Pressurizer Safety Valve Lift Setpoint Shift", was issued to inform licensees about potential problems resulting from operating pressurizer safety valves in environments different from that used to establish the safety valve lift setpoints. The IN primarily focused on problems encountered by setting the safety valve lift setpoints with steam under the seat, and then operating the valves with a loop seal containing water.

The purpose of this information notice supplement is to inform addressees of additional factors affecting the lift setpoint of pressurizer safety valves. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice supplement do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

On May 28, 1989, a manual reactor trip was initiated at the V. C. Summer plant following rapid depressurization of the reactor coolant system (RCS), due to a pressurizer safety valve failing open. The reactor trip was initiated at approximately 2000 psig, but the safety valve reseated prior to reaching the safety injection initiation setpoint of 1850 psig. RCS pressure was then stabilized at approximately 2000 psig.

Licensee root cause analyses of unexpected shifts in pressurizer safety valve lift setpoints at nuclear power plants have identified additional factors contributing to setpoint shifts that might not have not been previously assessed. These include:

- changes in temperature of the valve body and bonnet,
- leakage across the valve seat,
- excess loading of the safety valve tailpipe (nozzle loading),
- calibration of reactor coolant system (RCS) pressure control instrumentation, and
- presence of non-condensable gases in the pressurizer vapor space.

The NRC Office for Analysis and Evaluation of Operational Data has published an Engineering Evaluation of this issue titled "Additional Factors Affecting the Lift Setpoints of Pressurizer Safety Valves," AEOD/E90- . This evaluation reviewed recent operational experience associated with setpoint shifts in pressurizer safety valves, and provided information on licensee evaluations of potential causes in setpoint shift.

Discussion:

- Changes in Temperature of the Valve Body and Bonnet

Utilities have indicated that setpoint shifts were found to result from changes in temperature of the pressurizer safety valve body and bonnet. High ambient operating temperature heats the valve body and bonnet, resulting in expansion of the body and elongation of the bonnet. This relieves spring pressure and reduces the lift setpoint of the pressurizer safety valve.

At Calvert Cliffs, it was determined that the difference in safety valve setpoint between a "cold set" and a "hot set" (a 120 °F change) was in the range of 60-150 psig. Personnel at Millstone 3 found that setting the safety valve lift setpoint at lower than actual inservice operating temperature could cause as much as 50 psi shift. An Arkansas Nuclear One (ANO) Unit 2 pressurizer safety valve was refurbished and adjusted at Wyle, and installed at ANO-2. After plant heat-up to hot standby, the safety valve was found to have a 25 psig reduction in lift setpoint due to the ambient temperature increase.

At ANO-2, the pressurizer safety valve temperature profile, provided to Wyle in order for Wyle to simulate inservice temperature conditions when testing the valve lift setpoint, was later determined to be as much as 150 °F lower than actual valve temperatures during service. Investigations revealed that the operating condition temperature profile of the safety valve was obtained by ANO personnel utilizing hand held measuring devices. The utility concluded installation of thermocouples on the safety valves, and long term temperature monitoring, was necessary for accurate determination of temperature profile.

Summer plant personnel revealed that elevated temperatures of the valve body and bonnet can also be inadvertently created due to installation of insulation on the valve. If the valve is tested and the lift setpoint is adjusted based on an un-insulated condition, addition of insulation after valve is installed can cause a subsequent unanticipated increase in temperature and resultant decrease in lift setpoint.

During evaluations of corrective actions to obtain accurate lift setpoints on safety valves, licensees determined the following:

- Valve lift setpoint must be set with the same temperature profile that the valve will experience when placed in service.

- Hand held temperature monitoring for determination of valve temperature profile was determined to be inadequate. Installation of thermocouples on the valves, and long term temperature monitoring, were found to be necessary for accurate temperature profile measurement.

- Elevated temperatures of the valve body and bonnet can be inadvertently created if insulation is installed on the valve after the valve has been tested and set in an un-insulated condition. A resultant decrease in setpoint can occur.

- Leakage Across the Valve Seat

At Sequoyah 1, premature lifting of the pressurizer safety valve was determined to be due to seat leakage. Calculations of the spring force required to maintain closure of the safety valve were based on cross sectional area of the seat and zero leakage. If leakage occurs, the design of the disc and nozzle is such that the cross sectional area of the disc is effectively increased, allowing a lower system pressure to lift the valve. Similar conditions were experienced at Calvert Cliffs and Millstone 3.

Experiences at Summer and Diablo Canyon indicated presence of steam in contact with the Stellite disc causes temperature differences to create localized stresses, warping of the disc, and changes in the effective disc area, causing leaks which affect the lift setpoint.

Loss of the loop seal on a pressurizer safety valve at Summer due to seat leakage also caused steam to heat and expand the valve nozzle. Expansion of the valve nozzle then compresses the valve spring, increasing the valve setpoint. As the valve body heated up, the body and the bonnet elongated, relieving the spring pressure and resulting in an overall reduction of the safety valve setpoint.

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At Summer, in order to eliminate leakage through the safety valve seat induced by loss of the water loop seal, the utility implemented a design modifications to the Crosby pressurizer safety valves to drain the loop seals, and replace each Stellite disc with Inconel "flexidisc".

- Excess Loading of the Safety Valve Tailpipe (Nozzle Loading)

At Summer, the pressurizer safety valve structural support is attached to the pressurizer. The safety valve tailpipe was designed to pass through a mounting plate with a gap of 1/16 to 1/8 inch all around. Normal pressurizer heat-up caused elongation of the pressurizer, which lifted the safety valve structural support upward. As the other end of the pressurizer safety valve tailpipe is supported along its length and attached to the pressurizer relief tank (quench tank), stress was induced into the body of the safety valve when the pressurizer elongated. Although this stress level was only approximately 18 percent of allowable, the utility concluded some disc-to-nozzle misalignment resulted in seat leakage.

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Utility corrective actions included re-analysis of tailpipe configurations, removal of tailpipe mounting plates, and modification of tailpipe supports and hangers.

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Greater instrumentation inaccuracies could cause unknown higher RCS operating pressures, contributing to unexpected lifting of pressurizer safety valves.

- Presence of Non-condensable Gases in the Pressurizer Vapor Space

Thermocouples installed on the inlet piping to the valves at Summer indicated a large temperature gradient along the pipe to the valves. As saturated steam would produce a uniform temperature along the pipe, the temperature gradient led the licensee to presume a large concentration of non-condensable gases in the pressurizer was present under the valve seat.

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This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate NRR project manager.

Charles E. Rossi, Director
Division of Operational Events Assessment
Office of Nuclear Reactor Regulation

Technical Contact: L. Mark Padovan, AEOD
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Attachment: List of Recently Issued NRC Information Notices