UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAY 16 1991

MEMORANDUM FOR: Thomas M. Novak, Director
Division of Safety Programs
Office for Analysis and Evaluation
of Operational Data

FROM: Jack E. Rosenthal, Chief
Reactor Operations Analysis Branch
Division of Safety Programs
Office for Analysis and Evaluation
of Operational Data

SUBJECT: AEOD-T91-05: SETPOINT TESTING OF PRESSURIZER SAFETY VALVES WITH WATER-FILLED LOOP SEALS

There had been no lifts of a presurizer safety valve (PSV) for overpressure protection and only one spurious lift of a PSV on a Westinghouse PWR in ten years. Then in May of 1989, a PSV lifted at the V. C. Summer plant. In August, another PSV lifted at V. C. Summer. In November, a PSV lifted at Surry 2.

In the process of finding the cause for the apparently spurious lifts, it was noted that a new method was used to determine the setpoint of the valves. The new method used water in the loop seal against the seat when determining and setting the setpoint of the PSV at the advice of Westinghouse. Previously, setpoints had been determined with steam against the seat. Westinghouse postulated that the actual setpoint of a valve tested with steam against the seat would be as much as 4-8 percent higher than one tested with a water-filled loop seal, and could result in a setpoint higher than 2485 ± 1% psig. This, Westinghouse concluded, could place a plant in violation of technical specifications (TS) and ASME Code sections III and XI requirements, thus outside of licensing design basis criteria. The phenomenon was called "setpoint shift."

Summer had Westinghouse set their PSVs. A PSV leaked, clearing its loop seal. With steam against the seat, the valve lifted at 2350 psig. The actual valve setpoint had been set too close to the operating pressure.

During the review process to resolve this issue, the NRC staff identified four concerns about the "setpoint shift" theory, which was the basis for the new testing method, and the currently accepted practices. The concerns were: (1) delay time for the loop seal to discharge the water, (2) the effect of the temperature of the valve internals on setpoint, (3) ASME Code requirements to use steam as the test medium, and (4) the dual function of a PSV to relieve pressure and to reseat to maintain RCS integrity.

The quality of setpoint determination is still dominated by the quality of testing procedures, practices, equipment, acceptance criteria, etc. However, the scrutiny that setpoint testing has received as a result of this issue has had a serendipitous side effect: It was shown that carefully controlled standardized tests, specifically designed to render an accurate setpoint, to reproduce the ambient condition that the valve would experience when mounted on the system it relieves, and to give reproducible results do produce more accurate results than the commonly used general setpoint adjustment procedures, even when the testing is done in a laboratory.

This technical review report describes the evolution of the setpoint shift theory from initial promulgation, dissemination to licensees, resultant PSV lifts, notification to the NRC, expression of NRC concerns, and subsequent resolution.

Original signed by

Jack E. Rosenthal, Chief
Reactor Operations Analysis Branch
Division of Safety Programs
Office for Analysis and Evaluation
of Operational Data

Enclosure: As stated

Distribution:

PDR	EJordan	SRubin	AChaffee, NRR
Central File	DRoss	RDennig	PLewis, INPO
ROAB/RF	TNovak	KBlack	DQueener, NOAC
MWegner	VBenaroya	RSavio, ACRS	VChexal, EPRI
EBrown	LSpessard	MTaylor, EDO	
JRosenthal	GZech	KRaglin, TTC	

*See previous concurrence

ROAB:DSP:AEOD	ROAB:DSP:AEOD	C:ROAB:DSP:AEOD
MWegner:rgz	EBrown	JRosenthal
5/15/91*	5/15/91*	5/16/91*

The quality of setpoint determination is still dominated by the quality of testing procedures, practices, equipment, acceptance criteria, etc. However, the scrutiny that setpoint testing has received as a result of this issue has had a serendipitous side effect: It was shown that carefully controlled standardized tests, specifically designed to render an accurate setpoint, to reproduce the ambient condition that the valve would experience when mounted on the system it relieves, and to give reproducible results do produce more accurate results than the commonly used general setpoint adjustment procedures, even when the testing is done in a laboratory.

This technical review report describes the evolution of the setpoint shift theory from initial promulgation, dissemination to licensees, resultant PSV lifts, notification to the NRC, expression of NRC concerns, and subsequent resolution.

Jack E. Rosenthal, Chief
Reactor Operations Analysis Branch
Division of Safety Programs
Office for Analysis and Evaluation
of Operational Data

Enclosure: AEOD-T91- "Setpoint Testing of Pressurizer Safety Valves With Water Filled Loop Seals"

Distribution:

PDR	EJordan	SRubin	AChaffee, NRR
Central File	DRoss	RDennig	PLewis, INPO
ROAB/RF	TNovak	KBlack	DQueener, NOAC
MWegner	VBenaroya	RSavio, ACRS	VChexal, EPRI
EBrown	LSpessard	MTaylor, EDO	
JRosenthal	GZech	KRaglin, TTC	

ROAB:DSP:AEOD	ROAB:DSP:AEOD	C/ROAB:DSP:AEOD
MWegner:rgz	EBrown EJB	JRosenthal
5/ /91	5/15/91	5/16/91

AEOD Technical Review Report

UNIT:	Multiple	TR REPORT NO:	AEOD/T91-05
DOCKET NO:	Multiple	DATE:	May, 1991
LICENSEE:	Multiple	EVALUATOR/CONTACT:	Mary Wegner
NSSS/AE:	Westinghouse/Multiple		

SUBJECT: SETPOINT TESTING OF PRESSURIZER SAFETY VALVES WITH WATER-FILLED LOOP SEALS

SUMMARY:

There had been no lifts for overpressure protection and only one spurious lift of a pressurizer safety valve (PSV) on a Westinghouse pressurized water reactor (PWR) in ten years. Then in May of 1989, a PSV lifted at the V.C. Summer plant. In August, another PSV lifted at V. C. Summer. In November, a PSV lifted at Surry 2.

In the process of finding the cause for these apparently spurious lifts, it was noted that a new method was used to determine the setpoint of the valves. Setpoint testing of steam-service spring-actuated safety valves had previously been done with steam or nitrogen under the seat.

The previously accepted point of view expressed in WCAP-10105 was that a PSV which was set on saturated steam and then mounted on a water-filled loop seal would lift at its setpoint and discharge its loop seal before relieving RCS pressure. Allowing for the dynamic response of the system, the final RCS pressure would be more than the setpoint of the valve plus accumulation, but within the safety limits of the RCS (around 2700 psig).

The new method used water in the loop seal with steam against the water when determining the setpoint as recommended in a letter from the Westinghouse Electric Company. The "setpoint shift" theory postulated that the setpoint of a steam-set PSV subsequently mounted on a water-filled loop seal would increase by 4% to 8% because of the difference in temperature of the valve internals with water in the loop seal vs. steam. This, Westinghouse concluded, could place a plant in violation of technical specifications (TS) and ASME Code sections III and XI requirements, thus outside of licensing design basis criteria.

Summer had Westinghouse set their PSVs. A PSV leaked, clearing its loop seal. With steam against the seat, the valve lifted at 2350 psig. The actual valve setpoint had been set too close to the operating pressure.

Both the new "setpoint shift" theory and the "accepted point of view" had weaknesses as follows:

1. The new theory did not address the delay time for the loop seal discharge.

2. The old theory did not address the temperature difference but the new theory, which postulated the shift, was formulated from the results of tests that were not designed to isolate temperature effects from the other variables of setpoint determination.

3. The ASME Code requirements for setpoint testing were for steam service valves to be tested on steam "or other compressible fluids with the results correlated to steam." Since water is not a compressible fluid, the new method was not compatible with the Code.

4. The PSV has two functions: (a) it must lift to relieve overpressure which was addressed by both theories; and (b) it must reseat to maintain RCS integrity which was not addressed by either theory. Three apparently spurious lifts of the PSVs increased the risk of a small-break loss-of-coolant accident from a stuck-open PSV.

The issues of delay time for the loop seal to discharge the water, and the effect of the temperature of the valve internals on setpoint are expected to be resolved in an Owners' Group submittal. Testing designed to establish time temperature differential effect on set pressure by Westinghouse Owners' Group subsequently established a 0.5% to 1.0% change in set pressure for all loop seal temperatures.

A recent ASME ruling on requirements to use steam as the test medium resolves the test medium issue.

The issue of the dual function of a PSV to relieve pressure and to reseat to maintain RCS integrity will also be addressed in the submittals expected from the Owners' Group and by the use of steam as the test medium.

The quality of setpoint determination is still dominated by the quality of testing procedures, practices, equipment, acceptance criteria, etc. However, the scrutiny that setpoint testing has received as a result of this issue has had a serendipitous side effect: It was shown that carefully controlled standardized tests, specifically designed to render an accurate setpoint, to reproduce the ambient condition that the valve would experience when mounted on the system it relieves, and to give reproducible results [the same valves tested according to the procedure has the same results without regard to technician, laboratory, etc.] do produce more accurate

results than the commonly used general setpoint adjustment procedures, even when the testing is done in a laboratory.

DISCUSSION

In the 10 years (1979-1989) following the TMI accident, there was one premature lift of a PSV on a Westinghouse PWR when the setpoint was determined without a water-filled loop seal. This one lift occurred because the setpoint spring was not properly seated when its setpoint was determined. No PSV on a Westinghouse PWR is known to have failed to lift when challenged regardless of setpoint testing method.

From correspondence and reports, it is believed that the practice of setting PSVs with water-filled loop seals began in 1988. From May 28, 1989 to November 7, 1989, less than six months, there were three PSV lifts on the pressurizer with the reactor at power or in hot shutdown. Each had the setpoint determined with a water-filled loop seal. Additionally, leaking and simmering have occurred on a number of plants both with and without a loop seal regardless of testing methods. The three PSV lifts are described in the following paragraphs.

V. C. Summer 05/28/89 LER 395/89-011

While operating at 100% power within normal operating temperature and pressure, the C-PSV lifted causing a rapid depressurization of the RCS. The reactor was manually scrammed when the RCS pressure decreased to 1900 psig. The PSV reclosed prior to RCS pressure reaching the safety injection (SI) setpoint.

Prior to this incident, the setpoint for each of the three PSVs had been set with the loop seal filled with water. All three PSVs were lifted *in situ* following installation on the pressurizer. The C-PSV had a history of weepage past the seat and, within 3 hours of the lift, experienced four separate actuations of the "Pressurizer Safety Valve Open" annunciator and changes in the tailpipe temperature.

The C and B PSVs were removed and replaced with spares which had also been set with water-filled loop seals. (The B-PSV had experienced minor leakage.) Both were sent to a testing lab to evaluate their conditions and to refurbish and reset them.

V. C. Summer 08/25/89 LER 395/89-015

Following the May event, thermocouples were installed to monitor the PSV body inlet temperature. A rapid increase in the temperature was considered indicative of loss of loop seal. A special instruction was issued which required a shutdown if the PSV body inlet temperature reached 450° F. At 0945 hours on August 25, 1989, the temperature on the body

inlet of the A-PSV exceeded 400° F. At 1000 hours, the "PSV Temperature Limit Exceeded" alarm sounded and plant shutdown was commenced at 0.5% per minute. This was quickly increased to 3% per minute, but at 1003 hours the PSV lifted, depressurizing the RCS. A manual scram was taken at 1004. The lowest system pressure was 1950 psig.

Surry 2 10/12/89 LER 281/89-013

Due to a leaking drain valve, water was drained from the loop seal on the B-PSV and the valve began to leak. The PSV had previously been setpoint tested on steam. The unit was shut down to preclude a premature lift and to allow maintenance on the valve.

Surry 2 11/07/89 LER 281/89-017

The PSVs were setpoint tested at a laboratory with the loop seal filled with water and reinstalled on the unit. While pressurizing for a post-maintenance test with the C-PSV installed on the pressurizer, the C-PSV lifted when RCS pressure reached 2335 psig and reseated at 2255 psig. The valve may have been leaking for 14 hours before the lift.

The Westinghouse Letter 10/18/89

On October 18, 1989, the Westinghouse Electric Corporation submitted to the NRC a copy of the letter, entitled "Pressurizer Safety Valve Set Pressure Deviation" which had previously been forwarded to licensees of Westinghouse designed PWRs. The issue identified in the letter was described thusly: "Based on the testing performed at the WSC [Westinghouse's Western Service Center, a testing facility for safety valve setpoint determination], it has been determined that set pressure changes as a function of temperature. Plants setting their valves on steam and installing them on hot or cold water loop seals have a resultant set pressure higher than 2485 psig ± 1%." This, Westinghouse concluded, could place a plant in violation of TS and ASME Code Sections III and XI requirements. Thus the plant would be outside of licensing design basis criteria.

Also, information provided in a meeting with the Owners' Group, Westinghouse, and NRC staff on October 27, 1989, established that for a loss of load/turbine trip, licensing basis criteria may not be met for a valve set on steam and subsequently mounted on a water-filled loop seal unless credit is taken for reactor trip on turbine trip or operation of the power-operated relief valves (PORVs). For this scenario, with the valve set at 2485 ± 1% psig on steam, the ultimate pressure could be greater than 2485 ± 10% psig (in violation of technical specifications and ASME Code criteria) but less than 2485 ± 20% psig preserving the integrity of the RCS boundary.

The Letter describes the lift sequence of a PSV with a water-filled loop seal as follows:

1. RCS setpoint reaches the setpoint and the disc begins to lift off the seat discharging the loop seal.

2. When the loop seal is drained, steam will heat the valve internals an additional 200 - 250° F. causing the setpoint to be reduced by 4% to 8%.

3. The valve will simmer briefly, then pop (lift rapidly to full travel), relieving the overpressure condition.

4. The valve will reseat when the RCS pressure has been relieved the appropriate amount as determined by the valve's internal adjusting ring settings.

The principle difference between the Westinghouse test method and other testing methods is the use of a water-filled loop seal during testing. The principle reason for the difference, according to Westinghouse, is the temperature experienced by the valve internals when exposed to either water or steam. "Thus, setting the valve at plant ambient air with steam as a media (*sic*) and installing it on a loop seal filled with 300° F. water can result in a set pressure 4% to 8% higher than anticipated".

Conversely, if a loss of loop seal occurs with the PSV set according to Westinghouse's recommendations, the affect on PSV response was stated as follows: "If the loop seal is lost as a result of a transient lifting the PSV, the PSV is exposed to steam at the valve seat and a reduction in set pressure due to the increase in temperature is experienced." Also, "if the loop seal is lost during normal plant operations, the PSV is exposed to steam at the valve seat and a reduction in set pressure due to the increase in temperature is experienced. The reduction of the valve's set pressure from the nominal value of 2500 psia to a level which opens during normal plant operation is bounded for one PSV as defined by the current analysis of an inadvertent opening of a PSV."

The tests conducted at the WSC which led to this submittal were sponsored by the licensees for Diablo Canyon and V. C. Summer for the purpose of establishing the setpoint for their PSVs. The loop seal was filled with water, body and bonnet temperatures were raised to duplicate plant conditions, and the loop seal was heated to the appropriate temperature. The setpoint was established using saturated steam with the valves gagged to permit only limited travel of the disc. [PSVs are tested with a variety of media under differing conditions *in situ* and on a test stand. Most commonly, they are tested in a laboratory using steam without a loop seal.]

At the October 27, 1989, meeting, the NRC staff expressed concerns with the "setpoint shift" theory which included the following:

1. The delay time for the loop seal to drain was ignored by the setpoint drift theory.

2. The validity of the tests for determining temperature effects on setpoint determination was questioned since the tests were not designed to determine temperature effects. Also the relationship of WCAP-10105 to the current theory was questioned.

3. The concern about a SBLOCA from a stuck-open PSV was not addressed by the setpoint shift theory.

4. The use of a water-filled loop seal in setpoint determination was questioned because of the ASME requirement to use steam to set steam-service valves.

On December 27, 1989, the NRC published IN 89-090, "Pressurizer Safety Valve Lift Setpoint Shift," which described the three spurious PSV lifts, the Westinghouse position as described in the October 18, 1989 letter and presented at meetings, and licensees' actions to that date. The IN was considered an interim measure to alert licensees to the issue and the NRC concerns with the proposed resolution.

During subsequent meetings with the NRC in 1989, 1990, and January 29, 1991, the Owners' Group addressed the relationship of WCAP-10105 to setpoint shift. It was at this time that the validity of the WSC tests were raised. The Owners' group then committed to do tests designed specifically to determine temperature effects on setpoint determination. Testing which was devised to evaluate the temperature differential effect on setpoint determination established that, rather than the previously stated 4% to 8% change, only a 0.5% to 1.0% change in setpoint would occur for the expected loop seal temperature range. This new data correlates well with information supplied by the licensee for the Summer Nuclear Plant. Their consultant had shown a 2% maximum setpoint change over a temperature range of 300°F.

The SBLOCA concern was addressed by recommending that setpoint testing be done to a "steam equivalent setting." This meant that the valves would have a 2485 $\pm$ 1% psig setpoint with steam against the seat.

Westinghouse also requested a clarification on intent for the test media from the ASME Code Committee for Section III and the O&M Subcommittee. The response from the Section III Interpretations Special Committee was that the valves were steam service and should be set on steam and the effects of the loop seal on valve performance were to be addressed in the

Overpressure Protection Report.[1] The response from the O&M Subcommittee was "Par. 8.1.1.1[2] requires that valves designed to operate on steam be set pressure tested on saturated steam."[3]

A submittal is expected from each licensee whose PSVs are mounted on a water-filled loop seal which will address specific plant conditions.

It is anticipated that each licensee will commit to PSV setpoint testing in accordance with the ASME position and reaffirm their previous submittal in which WCAP-10105 was used to answer Item II.D.1, but with modifications to include the new "Operability of Safety and Relief Valves," NUREG-0737, *Clarification of TMI Action Plan Requirements*, information developed by Westinghouse which suggests that the final RCS pressure for the bounding overpressure event would be above 110 percent but within 120 percent.

Supplement 1 to NRC Information Notice No. 89-90: "Pressurizer Safety Valve Lift Setpoint Shift", was issued April 3, 1991 to alert licensees to possible problems resulting from operating pressurizer safety valves in environments different from that used to establish the safety valve lift setpoints.

ANALYSIS

As described in the summary there were four technical issues whose effects on PSV setpoint were not understood. These issues were (1) delay time for the loop seal to discharge the water, (2) the effect of the temperature of the valve internals on setpoint, (3) ASME Code requirements to use steam as the test medium, and (4) the dual function of a PSV to relieve pressure and to reseat to maintain RCS integrity.

On points one and two, WCAP-10105 did not address the relationship of the temperature of the valve internals to the setpoint, nor did the Letter address the time lag from the start of the discharge of the loop seal to the completion of its discharge during which the system pressure continues to rise.

Resolution of these points is expected to come in an Owners' group submittal incorporating parts of WCAP-10105 on the time lag with updated information from testing done at the

---

1 Reported in memorandum from Frank C. Cherny to Robert L. Baer dated January 10, 1991.

2 Of Part 1 of OM-1987

3 Letter from G. M. Eisenburg, Secretary, O&M Committee, ASME; to E. M. Petrosky, Engineer, Westinghouse Electric Corporation dated March 11, 1991

WSC which established that the temperature differential effect on set pressure was a 0.5% to 1.0% change in set pressure for all loop seal temperatures.

The ASME has ruled on the test media (point three) and the Owners' group is expected to comply.

With respect to point four, a safety valve fulfills two purposes, (1) over-pressure protection and (2) RCS integrity. The valve is designed to open at a predetermined pressure to relieve a quantity of steam to reduce the system pressure and to reclose at a predetermined pressure to maintain RCS integrity.

This dual function was addressed as a part of the TMI lessons learned in two specific issues:

1. Operability of safety and relief valves, NUREG-0737, Item II.D.1, and
2. Probability of a SBLOCA, NUREG-0737, Item II.K.3.2

In response to these requirements, a series of tests were conducted under the direction of the Electric Power Research Institute (EPRI) and sponsored by the PWR industry. The Westinghouse Owners' Group reviewed the EPRI data and reported on the acceptability of safety valve performance as observed in the tests described in WCAP-10105, "Review of Pressurizer Safety Valve Performance as Observed in the EPRI Safety and Relief Valve Test Program." The WCAP was submitted to the NRC "to provide closure of the pressurizer safety valve operability issue."

WCAP-10105 describes a lift sequence for a PSV with a water-filled loop seal as follows:

1. RCS pressure reaches the setpoint and the disc begins to lift off the seat discharging the loop seal but not lowering system pressure.

2. After a period of time (0-2 seconds), the loop seal will be discharged, but the RCS pressure will have continued to rise to a maximum determined by the ramp rate and the time to discharge the loop seal.

3. The valve will simmer briefly, then pop (lift rapidly to full travel), relieving the overpressure condition.

4. The valve will reseat when RCS pressure has been relieved the appropriate amount as determined by the valve's internal adjusting ring settings.

Subsequently, most licensees with Westinghouse designed PWRs submitted plant-specific details and the II.D.1 item for their facilities was evaluated using the WCAP and those plant-

specific details. The general conclusion was that the licensee had provided acceptable submittals reconfirming that General Design Criteria 14, 15, and 30 of Appendix A to 10 CFR 50 had been met.

WCAP-9804, "Probabilistic Analysis and Operational Data in Response to NUREG-0737 Item II.K.3.2 For Westinghouse NSSS Plant" stated that there had been no operational lifts of PSVs on Westinghouse PWRs. [The only PSV lift for overpressure protection occurred in a Combustion-Engineering PWR in 1990, several years after the report]. Because there were no lifts, there was no statistically valid safety valve probability of failure to reclose per demand. Therefore, the value used for PSVs was the same as that for the PORV. That value was $1x10^{-3}$ failure to reclose on demand. Spurious opening of the safety valve was not considered. In all the events described in this report, the PSVs reclosed; however, there is insufficient data to affirm or refute the assumed reliability of the valve to reclose.

Overall, the conclusions of WCAP-10105 were reaffirmed, except that the final RCS pressure for the loss of load/turbine trip scenario might be higher than the figures given in the WCAP but still less than 120% of the system design.

FINDINGS AND CONCLUSIONS

The issues of delay time for the loop seal to discharge the water, and the effect of the temperature of the valve internals on setpoint are expected to be resolved in an Owners' Group submittal. This will incorporate parts of WCAP-10105 on the delay time with updated information from testing done at the WSC which established the time temperature differential effect on set pressure as a 0.5% to 1.0% change in set pressure for all loop seal temperatures.

The ASME ruling on requirements to use steam as the test medium resolves the test medium issue.

The issue of the dual function of a PSV to relieve pressure and to reseat to maintain RCS integrity will also be addressed in the submittals expected from the Owners' Group and by the use of steam as the test medium.

The temperature differential which was the *raison d'être* for the new testing method because it was expected to introduce a set pressure change of 4% to 8% was found to play a minor role, 0.5% to 1.0% set pressure change, in setpoint determination. Pressurizer safety valves will be set on steam [or nitrogen with results correlated to steam] as before.

The quality of setpoint determination is still dominated by the quality of testing procedures, practices, equipment, acceptance criteria, etc. However, the scrutiny that setpoint testing has

received as a result of this issue has had a serendipitous side effect: It was shown that carefully controlled standardized tests, specifically designed to render an accurate setpoint, to reproduce the ambient condition that the valve would experience when mounted on the system it relieves, and to give reproducible results [the same valves tested according to the procedure has the same results without regard to technician, laboratory, etc.] do produce more accurate results than the commonly used general setpoint adjustment procedures.