Low Temperature Overpressure Protection System Setpoint Review for Beaver Valley Unit 2 15 EFPY Heatup and Cooldown Curves

Revision 2

I. INTRODUCTION

Westinghouse has developed revised Low Temperature Overpressure Protection System (LTOPS) PORV setpoints for Beaver Valley Unit 2, applicable to 15 EFPY heatup and cooldown curves. The setpoints conservatively incorporate instrument uncertainties and the delta-P between the wide range pressure transmitter and the reactor vessel limiting beltline region. The methodology and resulting setpoints are discussed below.

II. BACKGROUND

Beaver Valley Unit 2 Technical Specifications, in combination with plant administrative controls, currently require that LTOPS be operable below an RCS temperature of 350F. The applicable design basis transients are as follows:

The first transient is a heat addition scenario in which a reactor coolant pump in a single loop is started when the RCS temperature is as much as 50F lower than the steam generator secondary side temperature. This results in a sudden secondary to primary heat transfer and rapid increase in primary system pressure.

The second design basis transient is a mass injection event caused by the failure of the controls for a single charging pump to the full flow condition. The influx of fluid into the relatively inelastic RCS also causes a rapid increase in system pressure.

III. METHODOLOGY/MAJOR INPUT ASSUMPTIONS

Major input assumptions are outlined below.

1. Overshoots during the mass injection event and heat addition event from the current analyses of record (Reference 5) will be used. No reanalysis of the design basis mass injection or heat addition scenarios will be performed. For Beaver Valley Unit 2, analyses of the mass injection and heat addition events have been performed assuming that the RCS is water solid and that the RHRS is isolated (conservative). The RCS temperature assumed for the mass injection event is 70F. The heat addition event has been analyzed for RCS temperatures between 70F and 300F.

2. Pressure overshoots during the design basis events are based on a pressurizer PORV stroke open/close time of 1.65/1.0 seconds.

3. Since the heatup and cooldown curves are generated using the K1C fracture toughness methodology, ASME Code Case N-514 (which permits a 10% relaxation of the Appendix G pressure temperature limits up to the LTOPS enable temperature) is not applicable.

4. Setpoints are selected so that RCS pressures will not exceed the 15 EFPY Appendix G pressure limits down to the reactor vessel temperature of 60F.

5. In order to preserve the single failure criteria, the overshoots are calculated assuming the availability of one PORV during the design basis mass injection and heat addition events, when the RCS is water solid, concurrent with loss of letdown and isolation of the RHRS. The second PORV is assumed to have failed.

6. The maximum allowable setpoints will be derived from steady state heatup and cooldown curves at 15 EFPY. See Section IV-B for more discussion on this topic.

7. The setpoints are applicable to 30% steam generator tube plugging.

8. The setpoints conservatively account for instrument uncertainties associated with the wide range pressure transmitter [ ]^{a,b,c} and wide range temperature [ ]^{a,b,c}, per Reference 6.

9. The setpoints conservatively account for the pressure difference between the wide-range pressure transmitter and the reactor vessel limiting beltline region, identified in Nuclear Safety Advisory letter NSAL-93-005A.

10. Heat transport effects, which are applied to the heat injection transient results and account for a 50F difference between the wide range temperature sensor and the reactor vessel, have also been incorporated.

11. Nine breakpoints are selected as input into the function generator so that the Appendix G limits are not exceeded during the limiting design basis mass injection or heat injection events. Breakpoints are selected such that the gain in each line segment does not exceed 7.55 v/v.

12. A qualitative assessment has been performed with regard to PORV undershoots (margin to the RCP number one seal limit) during water solid operation.

IV. SETPOINT DEVELOPMENT

A. Limiting Overshoots for the Mass Injection and Heat Addition Events

The limiting peak RCS pressures versus PORV setpoints for the mass injection event are tabulated in Table A, assuming mass injection into a water solid RCS from one charging pump with no RHR relief path available. The analysis of record (Reference 5) modeled the following maximum flows from one charging pump as a function of pressure as follows:

RCS Pressure (psig)	Mass Injection Rate (gpm) a,b,c
350	[ ]
400	
450	
500	
550	
650	
750	

The limiting peak RCS pressures versus PORV setpoints for the heat addition event, also from the analysis of record, are tabulated in Table B.

B. *15 EFPY Appendix G Limits*

Reference 3 provides data for the Beaver Valley Unit 2 steady state heatup and cooldown curves at 15 EFPY. Reactor vessel temperatures and corresponding pressure limits are shown respectively in Columns 1 and 2 of Table C. Since LTOPS events are most likely to occur when the reactor vessel is at isothermal conditions, the steady state heatup and cooldown limits have formed the basis for LTOPS setpoint selection for more than a decade and are considered applicable for the current LTOPS setpoint development at 15 EFPY for Beaver Valley Unit 2.

C. *Adjustments for Pressure Uncertainties*

[ ] a,b,c

D. *Adjustments for Delta-P*

[ ] a,b,c

E. *Temperature Uncertainties and Heat Transport Effects*

Temperature uncertainty and streaming effects on RCS cold leg wide range temperature indication have been calculated by Westinghouse to be [ ]^{a,b,c}. Heat transport effects, which account for reactor vessel being [ ]^{a,b,c} colder than the temperature at the wide range temperature sensor are also incorporated into the maximum allowable setpoint development for those setpoints applicable to the heat injection event.

F. PORV Maximum Allowable Setpoints

[a,b,c]

It should be noted that current Beaver Valley Unit 2 administrative controls restrict the number of RCPs operable when LTOPS is enabled, as follows:

$T_{RCS} \leq 100F$	0 RCPs running
$T_{RCS} > 100F$ and $T_{RCS} \leq 160F$	1 RCP running
$T_{RCS} > 160F$ and $T_{RCS} \leq 190F$	2 RCPs running
$T_{RCS} > 190F$	3 RCPs running

Due to setpoint limitations as a result of the reactor vessel flange requirements, there is no operational benefit achieved by restricting the number of reactor coolant pumps running, to less than two pumps, below an indicated RCS temperature of 190F. Therefore, the PORV setpoints shown in Table D will protect the Appendix G limits for the following combinations of RCPs:

$T_{RCS} \leq 190F$	0 - 2 RCPs running
$T_{RCS} > 190F$	3 RCPs running

Finally, the recommended LTOPS arming temperature, that will protect both the Appendix G limits and the PORV piping is 350F. The administrative arming temperature at Beaver Valley Unit 2 is 367F, which is conservative.

G. Margin to the Reactor Coolant Pump Number One Seal Limit

The upper pressure limit for LTOPS is defined by the Appendix G limit, after consideration of all uncertainties and the delta-P between the wide range pressure transmitter and reactor vessel limiting region. The low limit on pressure during the design basis LTOPS mass injection and heat injection transients is established based on operational consideration for the RCP number one seal which requires a nominal differential pressure across the seal faces for proper film-riding performance. As part of the LTOPS setpoint evaluation, margin to the reactor coolant pump number one seal limit is evaluated.

Based on the analyses of record (Reference 5), this limit corresponds to a differential pressure across the seal of 200 psid, which corresponds to the gage pressures shown in Table E. As demonstrated in Table E, pressure undershoot below the PORV setpoint during a design basis mass injection or heat injection event can exceed 100 psi. Therefore, with the PORV setpoints developed for the 15 EFPY heatup and cooldown curves, there is the potential for RCS pressure to violate the RCP number one seal limit at the lowest RCS temperatures.

While analysis has not been performed that models the simultaneous relief from two PORVs, undershoots below the PORV setpoint can be significantly higher if both PORVs actuate during an LTOPS event, and it is anticipated that the pump seal limit would be exceeded. However, staggering the PORV setpoints minimizes the likelihood that both PORVs will actuate simultaneously during credible LTOPS events. In addition, WCAP-14040-NP-A (Reference 7) indicates that when there is insufficient range between the upper and lower pressure limits to select PORV setpoints that provide protection against violating both limits, then the setpoint selection that provides protection against the upper limit violation takes precedence.

H. Peak RCS Pressure versus RCS Temperature

A tabulation of peak RCS pressure versus RCS temperature is provided in Table F. The peak pressures are the maximum RCS pressures that would be expected to occur during either of the design basis mass injection or heat injection events, after consideration for all uncertainties (regardless of whether measured temperature is higher or lower than RCS temperature) and the pressure difference between the wide range pressure transmitter and the reactor vessel limiting beltline region.

V. CONCLUSIONS

Maximum allowable LTOPS PORV setpoints have been developed based on the 15 EFPY heatup and cooldown curves for Beaver Valley Unit 2. The setpoints conservatively incorporate applicable instrument uncertainties and the delta-P between the wide range pressure transmitter and the reactor vessel limiting beltline region. Furthermore, since the 15 EFPY heatup and cooldown curves are based on the K1C fracture toughness methodology, ASME Code Case N-514 has not been incorporated.

With the restrictions previously identified on the number of RCPs running, the setpoints shown in Table D and Figure 1 will prevent RCS pressure from exceeding the 15 EFPY Appendix G limits after consideration of all instrument uncertainties and the delta-P between the wide range pressure transmitter and the reactor vessel limiting beltline region.

Therefore, during any design basis mass injection or heat injection event, peak RCS pressure can conservatively be considered to be less than or equal to the applicable Appendix G limit over the full range of temperatures when LTOPS is enabled.

VI. REFERENCES

[a,b,c]

3. WCAP 15139 "Beaver Valley Unit 2 Heatup and Cooldown Curves for Normal Operation at 15 EFPY using Code Case N-626", T. Laubham, January 1999.

4. Westinghouse Owners Group letter OG-95-54, L. Bush, 6-16-95.

[a,b,c]

7. WCAP 14040-NP-A, Rev. 2, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves", J.D. Andracheck et al, January 1996.

8. Beaver Valley Technical Specifications Section 3-4.4.9.

TABLE A

LIMITING PEAK PRESSURES FOR MASS INJECTION EVENTS

(Mass Injection from 1 Charging Pump)

Temp. =	60F
Set Pressure (psig)	Peak Pressure (psig)
400	
450	
500	
600	
700	

a,b,c

Notes: Overshoots for the mass injection event have conservatively been adjusted to account for steam generator tube plugging levels up to 30%.

TABLE B

LIMITING PEAK PRESSURES FOR HEAT ADDITION EVENTS

Temp.=	70F
Set Pressure (psig)	Peak Pressure (psig)
400	
450	
500	
600	
700	

a,b,c

Temp.=	120F **
Set Pressure (psig)	Peak Pressure (psig)
400	
450	
500	
600	
700	

a,b,c

Temp.=	120.1F **
Set Pressure (psig)	Peak Pressure (psig)
400	
450	
500	
600	
700	

a,b,c

Note**: The 15 EFPY heatup and cooldown curves are limited by the vessel flange up to a temperature of 120F. The overshoot resulting from the heat injection event at 120.1F is conservatively taken to be equal to the overshoot analyzed at 150F. However, since the mass injection transient is more limiting at this temperature, there is no adverse impact to the calculated setpoints.

TABLE B, CONT'D

LIMITING PEAK PRESSURES FOR HEAT ADDITION EVENTS

Temp.=	200F
Set Pressure (psig)	Peak Pressure (psig)
400	
450	
500	
600	
700	

a,b,c

Temp.=	250F
Set Pressure (psig)	Peak Pressure (psig)
400	
450	
500	
600	
700	

a,b,c

Temp.=	300F
Set Pressure (psig)	Peak Pressure (psig)
400	
450	
500	
600	
700	

a,b,c

TABLE C: 15 EFPY STEADY STATE APPENDIX G LIMITS

RCS Temperature (degree F)	Pressure Limit (psig)	Limit less Uncertainty of [ ]^{a,b,c}	Limit with 0 RCPS Running (psig)	Limit with 1 RCP Running (psig)	Limit with 2 RCPS Running (psig)	Limit with 3 RCPS Running (psig)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
60	621					
65	621					
70	621					
75	621					
80	621					
85	621					
90	621					
95	621					
100	621					
105	621					
110	621					
115	621					
120	621					
120.1	907					
125	935					
130	966					
135	1001					
140	1039					
145	1081					
150	1127					
155	1179					
160	1235					
165	1298					
170	1367					
175	1444					
180	1528					
185	1622					
190	1725					
195	1839					
200	1966					
205	2105					
210	2259					
215	2430					
250	2430					
300	2430					

a,b,c

Note: Maximum Appendix G limit reported at 215F. Appendix G limit taken to be constant at temperatures greater than 215F.

TABLE D: MAXIMUM ALLOWABLE PORV SETPOINTS [1]

Temperature (degree F)	Setpoint PORV #2 (psig)	Setpoint PORV #1 (psig)
60	455	418
137	455	418
167	465	428
177	470	432
190	485	441
200	510	460
210	624	547
367	624	547
425	2335	2335

(1) The PORV setpoints shown in Table D will protect the Appendix G limits for the following combinations of RCPs:

$T_{RCS} \leq 190F$	0 - 2 RCPs running
$T_{RCS} > 190F$	3 RCPs running

TABLE E
MARGIN TO THE REACTOR COOLANT PUMP NUMBER ONE SEAL LIMIT

RCS Temperature (degree F)	a,b,c	PORV #1 Setpoint (psig)	a,b,c	a,b,c
60		418		
150		421		
200		460		
250		547		
350		547		

Figure 1: Beaver Valley Unit 2 Maximum Allowable Setpoints at 15 EFPY

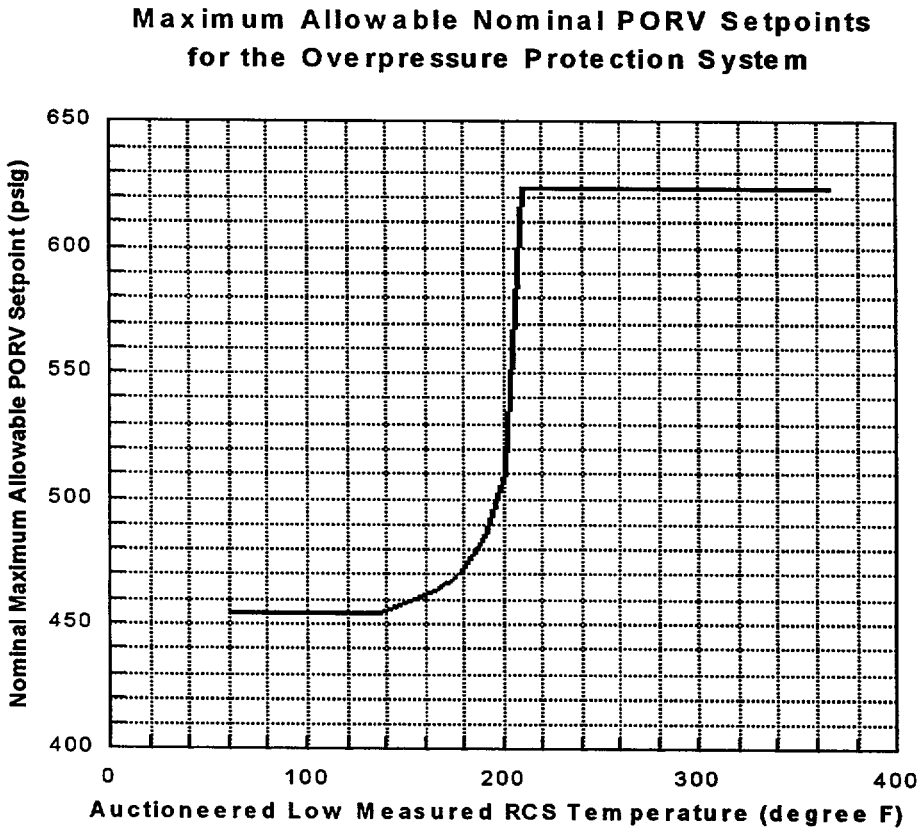

TABLE F: MAXIMUM EXPECTED PEAK PRESSURE VERSUS RCS TEMPERATURE

RCS Temperature (degree F)	Peak Pressure (psig)	Appendix G Limit (psig)
60	621	621
120	621	621
150	752	800
200	765	800
250	781	800
300	800	800
350	800	800

Attachment B

Summary Description of Changes
Incorporated in the Revised Westinghouse Report

Note: Changes 2-7 described below are identified in the report by revision bars.

1. Brackets have been incorporated into the proprietary version of the report to correctly identify the proprietary information. Corresponding deletions of the proprietary information have been made to the non proprietary report where required to make the reports consistent. This change has no technical impact on the report.

2. In the second paragraph of Section C on page 3 the word "load" in the fourth line was revised to "loadings". This was a change due to editorial preference that has no technical impact on the report.

3. In the fourth paragraph of Section F on page 4, the order of the original last two sentences was reversed. A new sentence was also added at the end of the paragraph that provides descriptive material concerning the conservatisms in the analysis and the expected pressure overshoot with a reference to Table D in the report. The additional description is based on the PORV setpoint analysis and provides information regarding the expected pressure overshoot. This change was made to provide additional supporting information to the report that reinforces the adequacy of the PORV setpoints and does not alter the conclusions of the report.

4. In the sixth paragraph of Section F on page 4 the presentation of the RCP temperature limits is revised to improve the clarity of this information. The changes to the presentation of this information are minor and have no effect on the adequacy of the PORV setpoints or the conclusions of the report.

5. At the bottom of page 4 the equality and inequality expressions in the two RCP temperature limits are revised to be consistent with item 5 above. This change makes the references to RCP temperature limits consistent in the report and does not affect the PORV setpoints or conclusions of the report.

6. At the top of page 5 two sentences were added as a conclusion to Section F. The information contained in these sentences reinforce the adequacy of the PORV setpoints described in the report. The additional sentences provide supporting information that does not revise the PORV setpoints or affect the conclusions of the report.

7. At the end of the text on page 12 the equality and inequality expressions in the two RCP temperature limits are revised to be consistent with items 4 and 5 above. This change makes the references to RCP temperature limits consistent in the report and does not affect the PORV setpoints or conclusions of the report.