Enclosure 7 to AEP-NRC-2020-01

LTR-SCS-19-50, Revision 0, "D.C. Cook Unit 1 Low Temperature Overpressure Protection System (LTOPS) Analysis for 48 EFPY", dated March 5, 2020, Attachment 2 Only (Non-Proprietary)

LTR-SCS-19-50-NP
Rev. 0

Attachment 2

D.C. Cook Low Temperature Overpressure Protection System (LTOPS) Analysis for 48 EFPY

1.0 Introduction

The Low Temperature Overpressure Protection System (LTOPS) provides Reactor Coolant System (RCS) pressure relief capability during low temperature operation (i.e., Modes 4, 5, and 6) to minimize the potential for challenging reactor vessel integrity limits (i.e., 10 CFR 50, Appendix G limits) when operating at low temperature conditions. At D.C. Cook, in accordance with Technical Specification LCO 3.4.12, the pressurizer Power Operated Relief Valves (PORVs), with reduced lift settings, and/or the Residual Heat Removal (RHR) suction relief valve provide a method of LTOP for the potential overpressure transients. The LTOPS PORV setpoints are selected in accordance with the NRC approved methodology in Reference 5 such that the peak pressure during the design basis Mass Injection (MI) and Heat Injection (HI) transients will not exceed the isothermal Appendix G Pressure-Temperature (P-T) limits.

Updated P-T limits have been developed for D.C. Cook Unit 1 through the 60-year end of license extension (EOLE) period, which are valid for operation through 48 EFPY (Reference 1). Therefore, an LTOPS analysis was performed in Reference 2 to establish the LTOPS configuration, relief valve setpoints, and operating limitations necessary to protect the revised P-T limits at 48 EFPY. This scope of work was proposed in Reference 10.

1.1 Limits of Applicability

The results of this report are applicable to D.C. Cook Unit 1 with the 60-year EOLE P-T limits defined in Reference 1 valid up to 48 EFPY and the key analysis inputs defined in Section 2.0.

1.2 Open Items

None.

2.0 Input Parameters and Assumptions

Key input parameters for the analysis were requested in Reference 3 and the AEP response was provided in Reference 4. The key input parameters and analysis assumptions are summarized as follows.

2.1 Key Inputs

Design Basis MI Transient

Currently, the D.C. Cook technical specifications define separate LTOP relief requirements depending whether one or two charging pumps are capable of injecting. Per Reference 4, AEP requested for this to be simplified for this analysis by defining a single set of LTOPS requirements that can accommodate the MI resulting from two charging pumps injecting. The design basis MI flow rate as a function of cold leg (or RCS) pressure confirmed in Reference 4 is shown in Table 1.

Table 1: MI Flow Rate vs. RCS Pressure

[ ] a,c

The MI transient was analyzed to develop PORV setpoint overshoots and undershoots for MI flow rates of [ ]^{a,c} gpm with PORV setpoints ranging from [ ]^{a,c} psig. This range of flow rates is adequate to cover the design basis MI transient at D.C. Cook Unit 1. The results of the MI transient parametric analyses are summarized in Section 5.1.

Design Basis HI Transient

The HI transient is defined as the startup of one RCP with the SG secondary side a maximum of 50°F hotter than each of the RCS cold leg temperatures. Prior to the RCP start, all loops are inactive and the entire RCS primary side (except for stagnant water in the SG tubes) is assumed to be 50°F cooler than the secondary side. For this analysis, RCS/SG temperatures of 60/110°F, 100/150°F, 150/200°F, 200/250°F, 250/300°F, and 300/350°F were analyzed to bound the range of temperatures applicable to LTOP. The results of the HI transient parametric analyses are summarized in Section 5.1.

Wide Range Pressure and Temperature Uncertainties

In accordance with the Reference 5 methodology, pressure and temperature uncertainties were applied during the development of the LTOPS PORV setpoints. The wide range temperature and pressure uncertainties were provided in Reference 4 as follows.

- Pressure uncertainty = [ ]^{a,c} psi
- Temperature uncertainty = [ ]^{a,c} °F

Pressure Drop between Reactor Vessel and Pressure Transmitter

The following values were calculated in Reference 6 and were confirmed valid for this analysis in Reference 4.

- For 4 RCPs running = [ ]^{a,c} psid
- For 2 RCPs running = [ ]^{a,c} psid
- For 1 RCP running = [ ]^{a,c} psid

D.C. Cook currently utilizes the following restrictions on RCP operation:

- Zero RCPs may be operating at RCS Temperatures (T_{RCS}) < 100°F
- No more than one RCP may be operating at 100°F $\leq T_{RCS} \leq$ 140°F
- All four RCPs are allowed to operate at T_{RCS} > 140°F

The LTOPS analysis performed herein conservatively assumes all four RCPs operating for the MI transient. The conditions for the design basis HI transient can only be established with zero RCPs running; then, the transient is initiated by starting one RCP. Therefore, by definition, the maximum ΔP that needs to be accounted for during the design basis HI transient is that associated with one RCP operating. The analysis does not impose or credit any restrictions on the number of RCPs that are allowed to be running.

Pressurizer PORV Characteristics, Stroke, and Delay Times

The pressurizer PORV characteristics and the stroke and delay times were provided in Reference 4.

- Valve full open C_V = [ ]^{a,c} gpm/$\sqrt{psi}$
- Opening Stroke time = [ ]^{a,c} seconds
- Closing Stroke Time = [ ]^{a,c} seconds
- Delay Time = [ ]^{a,c} seconds
- PORV backpressure = [ ]^{a,c} psig

RHR Suction Relief Valve Characteristics

The following RHR System characteristics were confirmed in Reference 4 unless otherwise noted.

- Nominal lift setting = 450 psig (Reference 4 and LCO 3.4.12)
- Setting tolerance = 3%
- Full open pressure = 495 psig (i.e., 10 % accumulation)
- Valve capacity = Table 2 (see Reference 9)
- RHR system design pressure = 600 psig
- RHR system analytical pressure limit = 660 psig (110 % of design pressure)
- RHR pump head [ ]a,c (Note 1)
- PRT backpressure = 100 psig prior to disk rupture, 0 psig after disk rupture
- Pressure drop from the reactor vessel to RHR relief valve inlet = [ ]a,c psi (Note 2)
- Autoclosure interlock status = Deleted

Notes:

1. Reference 4 determined that the RHR pump head is [ ]b,c psi, which is less than the maximum acceptable value of [ ]a,c psi.
2. Reference 9 determined that the pressure drop in the line from the RHR piping to the suction relief valve is [ ]a,c ft at a flow rate of [ ]a,c gpm. This equates to [ ]a,c psi for 60°F water. The assumed flow rate of [ ]a,c gpm conservatively bounds the maximum RHR suction relief valve capacity of [ ]a,c gpm for an inlet pressure of [ ]a,c psig and zero backpressure (Table 2). This pressure drop in the relief valve inlet piping needs to be added to a pressure drop from the RHR piping back to the reactor vessel. Since the wide range pressure transmitters are located at the RHR connection to the hot leg, the pressure drops calculated in Reference 6 are representative of this additional pressure drop. Therefore, assuming all four RCPs in operation, the maximum pressure drop from the reactor vessel midplane to the RHR suction relief valve inlet is [ ]a,c psi ([ ]a,c psi ΔP in relief valve inlet line + [ ]a,c psi from RV midplane to RHR connection).

Table 2: RHR Suction Relief Valve Capacity

a,c

Appendix G Limits

The steady-state (isothermal) Appendix G limits for D.C. Cook Unit 1 applicable for 48 EFPY are summarized in Table 3. Per Reference 5, steady-state P-T limits are used for LTOPS setpoint analysis. Note that the limits shown in Table 3 do not include instrumentation uncertainties; however, these uncertainties are included in the setpoint development as shown in Section 5.2.

Table 3: Steady-State Appendix G Limits D.C. Cook Unit 1 for 48 EFPY

D.C. Cook Unit 1 for 48 EFPY			
RCS Temperature (°F)	**Appendix G Limit (psig)**	**RCS Temperature (°F)**	**Appendix G Limit (psig)**
60	618	155	703
65	619	160	714
70	621	165	725
75	621	170	738
80	621	175	753
85	621	180	768
90	621	185	786
95	621	190	805
100	621	195	826
105	621	200	850
110	621	205	876
115	621	210	905
120	621	215	936
125	621	220	971
130	621	225	1010
135	621	230	1053
140	621	235	1101
145	621	240	1153
148	621	245	1211
148.1	690	250	1275
150	694	300	2430

Pressurizer PORV Piping limit

In addition to the Appendix G limits, an 800 psig pressure limit is included to address pressurizer PORV piping loading considerations associated with subcooled water discharge. This limit is recognized as an operational consideration that is accommodated by the LTOPS in Reference 5. The PORV piping has been generically evaluated for the water hammer loads associated with cyclic water relief at up to 800 psig. Therefore, when the plant is operated water solid, the LTOPS settings ensure that the pressure does not exceed the design value of 800 psig.

2.2 Key Assumptions

The following key assumptions are applicable for the D.C. Cook Unit 1 LTOPS analysis:

1. It is assumed that the RCS is enclosed by a non-yielding, inelastic boundary. The pressurizer is assumed to be in a water solid condition with the water at the same subcooled temperature as the remainder of the RCS. [ ]a,c.
2. Only one PORV was credited to mitigate the low temperature overpressure event to meet the single failure criteria.
3. All MI cases are analyzed at an RCS temperature of 60°F, which is the minimum RCS temperature corresponding to the bolt up temperature (Reference 1). [ ]a,c.
4. For the HI transient, the entire RCS primary side, with the exception of the water in the SG tubes, is conservatively assumed to initially be 50°F cooler than the SG secondary side temperatures in all four SGs.
5. A single-phase, sub-cooled water discharge through the PORV was assumed.
6. Letdown flow is conservatively assumed to be isolated during the MI and HI transients. [ ]a,c.
7. The PORV C_V as a function of lift is assumed to vary linearly.
8. It is assumed that a pressurizer steam bubble will exist for operation at temperatures above the LTOPS arming temperature of 297°F.

3.0 Description of Analyses and Evaluations

The LTOPS pressure relief capabilities are provided by two pressurizer PORVs, with reduced lift settings, and/or the RHR suction relief valve. Alternately, a sufficiently sized RCS vent can provide protection when the RCS is depressurized. When the pressurizer PORVs are credited for LTOP, two PORVs are required to be operable, but only a single PORV is credited in the analysis to accommodate a single active failure (Reference 12, item 3). The RHR relief valve is a spring loaded water relief valve that does not require any actuation signals or motive power to operate. They are thus defined as passive components and are not subject to single active failures.

The RHR suction relief valve and/or pressurizer PORVs are required to mitigate the potential overpressure events that can occur during relatively low temperature RCS operation to ensure that both the reactor vessel Appendix G limits and the RHR piping limit are protected. The potential overpressure transients that that must be considered consist of MI and HI transients defined in Section 2.1.

The LTOPS PORV setpoints are determined using the NRC approved methodology in Reference 5. Parametric analyses of the design basis MI and HI transients are performed using the LOFTRAN code. The purpose of these parametric analyses is to generate the transient pressure response data consisting of the PORV setpoint overshoot and undershoots. The LTOPS PORV setpoints are calculated based upon the PORV setpoints overshoot and undershoot data and the LTOPS setpoint acceptance criteria described in Section 4.0.

References 7 and 8 describe the basis and methodology for using the RHR suction relief valve to provide LTOP. Per Reference 4, the autoclosure interlock has been removed from the RHR suction isolation valve at D.C. Cook. Therefore, the RHR system cannot be spuriously isolated from the RCS, thus making the RHR relief valve a suitable option to provide LTOP. The Reference 2 analyses have been performed to demonstrate the acceptability of the RHR setting and capacity to provide protection against the design basis LTOP transients.

The RHR suction relief valve is guaranteed to achieve full capacity at 110% of the nominal set pressure (i.e., 495 psig). As long as the RHR suction relief valve capacity meets or exceeds the required relief capacity during the design basis LTOPS transients, the pressure at the inlet to the relief valve will not exceed 495 psig. Therefore, if the RHR suction relief valve has sufficient capacity, the peak pressure at the reactor vessel mid-plane will be the 495 psig accumulation pressure plus the applicable pressure drop back to the vessel. Similarly, the peak pressure in the RHR system will be the 495 psig accumulation pressure plus the RHR pump head.

For the mass injection transient, evaluating the RHR relief capacity consists of a straightforward comparison of the pump curve to the RHR relief valve capacity. For the heat injection transient, the required relief capacity corresponds to the fluid expansion rate. The fluid expansion rate during the HI transient is dependent upon of the RCS conditions at the initiation of the heat injection transient. Therefore, to determine the required relief capacity during the HI transient, the transient will be analyzed for a range of initial RCS conditions to determine the required relief capacity for the transient.

4.0 Acceptance Criteria

The following acceptance criteria from Reference 5 are used to determine the LTOPS PORV setpoints:

1. The peak RCS pressure resulting from the design basis MI and HI transients shall not exceed the minimum of the steady-state adjusted Appendix G limits and the PORV piping limit.
2. The minimum RCS pressure resulting from the design basis MI and HI transients should not drop below the RCP No. 1 Seal ΔP limit.

If there is a conflict between satisfying the upper limits (i.e., the minimum of the Appendix G limits and the piping limit) and the lower limits (i.e., the RCP No. 1 Seal ΔP limit), the upper pressure limits will take precedence. Furthermore, since D.C. Cook Unit 1 sets both PORVs to the same LTOPS setting, both PORVs will open during a best estimate LTOP event. Since the analyses herein only credit a single PORV, the resultant minimum RCS pressures following an LTOP actuation will be lower during a best estimate LTOP event than those shown in Tables 4 and 5. Therefore, criterion #2 may be challenged following LTOP actuations. An RCP No. 1 seal ΔP limit violation is not a nuclear safety issue. The RCP seals are designed to withstand momentary or incidental contact. Redundant plant indicators provide information as to the health of the seal, and any damage would be detected, and the plant operator could take the necessary corrective actions.

The following acceptance criteria are used to demonstrate the acceptability of the RHR suction relief valve:

1. The peak pressure in the reactor vessel must not exceed the Appendix G limit.

   This criterion is conservatively met if the installed valve capacity exceeds the required capacity for the design basis MI and HI transients with consideration of the applicable pressure drop from the reactor vessel to the RHR suction relief valve inlet.

2. The pressure at the RHR pump discharge must not exceed 110% of the RHR system design pressure (i.e., 660 psig, Reference 4).

   This criterion is conservatively met if the installed valve capacity exceeds the required capacity for the limiting MI and HI transients, with consideration of the RHR pump head.

5.0 Results and Conclusions

5.1 PORV Setpoint Overshoots and Undershoots

The pressure overshoot and undershoot are defined as the peak pressure minus the assumed PORV setpoint and the assumed PORV setpoint minus the minimum pressure during the transient, respectively.

Table 4 shows the summary of overshoots and undershoots for the MI flow rate vs. RCS pressure data from Table 1. The values in Table 4 are calculated at the minimum LTOPS temperature (i.e., the bolt-up temperature), which is slightly limiting for the MI transient.

The overshoot and undershoot pressures resulting from the HI events are shown in Table 5 as a function of setpoint pressure and RCS/SG temperature with 50°F temperature differential between the SG and RCS.

Table 4: Mass Injection Pressure Overshoots/Undershoots Summary

a,c

Table 5: D.C. Cook Unit 1 Heat Injection Pressure Overshoots/Undershoots Summary

a,c

a,c

a,c

5.2 PORV Setpoints Determination

Using the results of the LTOPS design basis MI and HI parametric transient analyses from Tables 4 and 5, the LTOPS maximum allowable PORV setpoints valid up to 48 EFPY are determined. LTOPS PORV setpoints for D.C. Cook Unit 1 are selected such that the LTOPS acceptance criteria, as defined in Section 4.0, are met. The maximum allowable PORV setpoint is determined based on the adjusted Appendix G limit or the PORV piping limit, whichever is more limiting. The adjusted Appendix G limit is the Appendix G limit minus the transmitter ΔP and wide range pressure instrument uncertainty (see Table 6).

A summary of the maximum allowable LTOPS PORV setpoint calculations and associated limits for the MI transient is shown in Table 7 and for the HI transient in Table 8. The maximum allowable PORV setpoints for the MI and HI transients are plotted as a function of indicated RCS temperature in Figure 1. The final maximum allowable PORV setpoint is determined such that it bounds both the MI and HI transient maximum allowable PORV setpoints. It should be noted that LTOPS PORV setpoints are shown up to 300°F, which is conservatively above the LTOPS enable temperature described in Section 5.4. Although a pressurizer steam bubble is not required by TS LCO 3.4.9 until Mode 3 (i.e., RCS temperatures ≥ 350°F), it is expected that a steam bubble will be required by plant operating procedures prior to disarming the LTOPS such that the PORV piping limit is not a concern and the pressurizer safety valves are available for overpressure protection per LCO 3.4.10 without being subjected to water relief.

Figure 1 also shows the current D.C. Cook LTOPS PORV setting of 435 psig. This indicates that the current LTOPS PORV setpoint will continue to protect the 48 EFPY isothermal P-T limits against the design basis HI transient across the full range of temperatures applicable to LTOP. However, the LTOPS PORV setpoint would need to be reduced drastically to accommodate the MI transient at indicated RCS temperatures < 210°F. The LTOPS setting necessary to provide this protection is 240 psig, which is judged to be impractical as there would be insufficient operating region to perform heatup and cooldown operations. Therefore, the RHR suction relief valve evaluation in Section 5.3 will demonstrate that the RHR suction relief valve is capable of providing protection against the MI transient such that the existing LTOPS PORV setpoint can be maintained.

Table 6: Adjusted Appendix G Limits for D.C. Cook Unit 1 for 48 EFPY

a,c

[ ] a,c

Table 7: D.C. Cook Unit 1 Maximum Allowable Setpoint Determination for the MI Transient

a,c

[ ]a,c

Table 8: D.C. Cook Unit 1 Maximum Allowable Setpoint Determination for the HI Transient

a,c

a,c

a,c

Figure 1: D.C. Cook Unit 1 Maximum Allowable LTOPS PORV Setpoint

(includes Pressure and Temperature Uncertainties)

5.3 RHR Suction Relief Valve LTOP Evaluation

As discussed in Sections 2.0 and 3.0, the RHR suction relief valve is a spring loaded water relief valve that is guaranteed to achieve full capacity at 110% of the nominal set pressure (i.e. 495 psig). The RHR suction relief valve is required to maintain the RHR system pressure below 110% of the design pressure (660 psig). Additionally, when credited as a pressure relief capability for LTOP, the RHR suction relief valve must maintain the pressure in the reactor vessel below the isothermal Appendix G P-T limit.

As long as the RHR suction relief valve capacity meets or exceeds the required relief capacity during the design basis LTOPS transients, the pressure at the inlet to the relief valve will not exceed 495 psig. Therefore, the RHR suction relief valve evaluation primarily focused on determining if the RHR suction relief valve has sufficient capacity to relieve the design basis transients. When the relief valve has sufficient capacity, the peak pressure at the reactor vessel mid-plane will be the 495 psig accumulation pressure plus the applicable pressure drop back to the vessel and the peak pressure in the RHR system will be the 495 psig accumulation pressure plus the RHR pump head.

As calculated in Section 2.1, the maximum pressure drop from the reactor vessel midplane to the RHR suction relief valve inlet with four RCPs running and a conservative [ ]^{a,c} gpm relief flow is [ ]^{a,c} psi. Therefore, as long as the RHR suction relief valve capacity is not exceeded, the maximum pressure in the reactor vessel would be [ ]^{a,c} psig (495 psig accumulation pressure + [ ]^{a,c} psi ΔP). Since this peak pressure is below the lowest Appendix G P-T limit of 618 psig, the RHR suction relief valve will meet the LTOP acceptance criterion as long as the valve capacity is not exceeded by the design basis MI and HI transients.

An RHR pump head of [ ]^{b,c} psi was provided in Reference 4. Therefore, as long as the RHR suction relief valve capacity is not exceeded, the maximum pressure in RHR system would be [ ]^{a,c} psig (495 psig accumulation pressure + [ ]^{b,c} psi pump head). Since this peak pressure is below the RHR system pressure limit of 660 psig, the RHR suction relief valve will protect the RHR system as long as the valve capacity is not exceeded by the design basis MI and HI transients.

Based on the above, the RHR suction relief valve will protect both the reactor vessel Appendix G P-T limit and 110% of the RHR design pressure as long as the valve capacity is not exceeded during the design basis MI and HI transients. Table 2 summarizes the RHR suction relief valve capacity as a function of temperature from Reference 9, which was confirmed to remain valid in Reference 4.

The RHR suction relief valve capacity listed in Table 2 is evaluated for the design basis MI and HI transients as follows.

5.3.1 Mass Injection Transient

As discussed in Section 2.1, the design basis MI transient consists of the flow from two charging pumps injecting with letdown isolated. The design basis MI flow rate as a function of cold leg (or RCS) pressure is shown in Table 1. Interpolating the design basis MI flow rate at a conservatively low RCS pressure of 495 psig results in an injection flow of [ ]^{a,c} gpm. The actual RCS cold leg pressure would be higher at the RHR suction relief valve accumulation pressure (e.g., [ ]^{a,c} psig), resulting in a lower injection flow rate. The injection flow rate of [ ]^{a,c} gpm is less than the RHR suction relief valve capacity with a 100 psig Pressure Relief Tank (PRT) backpressure across all temperatures at which the RHR system can be aligned (i.e., RCS temperatures < 350°F), which bounds the range of LTOP applicability (i.e., $60°F \leq T_{RCS} \leq 297°F$). Therefore, the RHR suction relief valve can protect both the isothermal reactor vessel Appendix G P-T limit and 110% of the RHR system design pressure against the design basis MI transient across all applicable conditions.

5.3.2 Design Basis Heat Injection Transient

Various cases of the design basis HI transient were analyzed to determine the required relief capacity of the RHR suction relief valve at RCS conditions across the range of LTOP applicability. Figure 2 illustrates the fluid expansion rate (or required relief rate) as a function of time for each of the cases analyzed. Table 9 summarizes the peak fluid expansion rates, which represent the required relief capacity, for each of the cases analyzed. Figure 3 plots the RHR relief capacity data from Table 2 along with the required relief capacity from Table 9.

As shown in Figure 3, the required relief capacity exceeds the installed RHR relief capacity for HI transients initiated at higher RCS temperatures. The installed relief capacity with a PRT backpressure of 100 psig is exceeded for HI transients initiated from a minimum indicated RCS temperature of 150°F. This temperature is increased to 166°F with credit for the installed relief capacity after the PRT rupture disc fails. Above these temperatures, the RHR suction relief valve is not capable of providing sole protection against the design basis HI transient. Therefore, two pressurizer PORVs will be required to be operable to above this temperature to provide protection against the design basis HI transient if no RCPs are running. As shown in Section 5.2, a single PORV with the current LTOPS PORV setting of 435 psig is capable of protecting the Appendix G P-T limits against the HI transient for the full range of temperatures applicable to LTOP.

For situations where the RHR system is aligned to the RCS at temperatures above 166°F, 110% of the RHR system design pressure will be protected from the design basis HI by the pressurizer PORVs (which are required to be operable for LTOP if no RCP is running) and/or a pressurizer steam bubble, working in conjunction with the RHR suction relief valve.

Table 9: Required RHR Suction Relief Valve Capacity for the HI Transient

a,c

a,c

Figure 2: Fluid Expansion Rate as a Function of Time

a,c

Figure 3: Installed RHR Relief Capacity and Required RHR Relief Capacity for the HI Transient as a Function of RCS Temperature

5.3.3 Analysis of HI Transients that can Occur with RCPs Running

As shown in Section 5.3.2, the RHR suction relief valve is unable to provide protection against the design basis HI transient initiated at indicated RCS temperatures greater than 150°F. However, the design basis HI transient can only occur from an initial condition in which no RCPs are running. If even a single RCP is running, sufficient flow will be maintained through each SG to keep the secondary side temperature coupled to the primary side temperature. Therefore, AEP may choose to credit this by recognizing that if at least one RCP is running, then the RHR suction relief valve is capable of providing LTOP over the full range of applicability. The pressurizer PORVs would then only be required to be operable if RCS temperature is greater than 150°F and no RCPs are running. These are the conditions in which the design basis HI transient can occur where the RHR suction relief valve cannot provide protection.

The LTOP LCO needs to ensure overpressure protection is provided for any overpressure transient that can occur under the allowed operating conditions. The design basis HI transient resulting from an RCP start is analyzed because it bounds all other heatup transients initiated at low temperatures. To support elimination of the RCP start HI transient if RCP(s) are running, less severe HI transients need to be evaluated to demonstrate that the RHR relief valve can provide protection.

As part of the original development of the LTOPS in Reference 13, the following HI transients were studied:

- Inadvertent actuation of the pressurizer heaters
- Loss of Decay Heat Removal (DHR)
- RCP start with the SG secondary side 50°F hotter than the primary side
- RCP start with cold charging and seal injection water accumulated in the pump suction leg

The two HI transients that result from an RCP start with temperature asymmetry were more severe than the other transients. These two transients can be removed from consideration if at least one RCP is running and Reference 13 showed that the loss of DHR transient is the next most severe HI transient. This section will analyze various cases of the loss of DHR and other HI transients to demonstrate that the RHR suction relief valve has adequate capacity to provide LTOP against all potential HI transients if at least one RCP is running.

Description of Analyses and Assumptions:

<u>Loss of DHR</u>

As described above and in Reference 13, the loss of Decay Heat Removal (DHR) is expected to be the most severe LTOP heatup transient that can occur from an initial condition with at least one RCP running. The following describes the conservative modeling of this transient as well as sensitivity cases that were analyzed to determine the required relief capacity.

a,c

[ ]a,c

The following sensitivity cases of the loss of DHR transient were analyzed:

[ ]a,c

Additional HI Transients

To revalidate the results of Reference 23 as well as provide quantified relief rates for additional types of HI transients, the following cases were analyzed:

- Plant heatup from continuous RCP heat from four pumps running ([ ]^{a,c} MWt) from a water solid initial condition. No other heat sources were modeled, and assumptions were similar to those described for the loss of DHR cases.
- Inadvertent pressurizer heater actuation ([ ]^{a,c} kW) with RCP heat from four pumps running. No other heat sources were modeled, and assumptions were similar to those described for the loss of DHR cases.

Results

The results of each additional HI transient are summarized in Table 10 and Figure 4. These results confirm that the loss of DHR transient bounds pressurizer heater actuation and RCP heat input transients. Figure 5 illustrates the relief rates for the loss of DHR cases as a function of RCS temperature. This demonstrates that for the same heat input rate, the relief rate is primarily a function of RCS temperature. Lower heat input rates extend the time to hot leg saturation and the peak relief at the time of saturation is lower. Therefore, analyzing the loss of DHR from 60°F through hot leg saturation bounds the relief capacity for a loss of DHR transient initiated at any temperature within the range of temperatures applicable to LTOP. Figure 6 shows the relief rates for the pressurizer heater actuation and RCP heat input transients.

The results show that the peak relief rates for each transient are well within the relief capabilities of the RHR suction relief valve. Therefore, if at least one RCP is running, the RHR suction relief valve is capable of providing protection against any potential HI transients. Section 5.3.1 showed that the RHR suction relief valve has sufficient capacity to protect against the design basis MI transient. Therefore, the RHR suction relief valve is capable of providing LTOP over the full temperature range of LTOP applicability if at least one RCP is running at temperatures above 150°F. If all RCPs are stopped at temperatures greater than 150°F, the pressurizer PORVs are required to be operable to provide LTOP against the design basis HI transient.

Table 10: Results of the HI Transients that can Occur with at Least One RCP Running

a,c

a,c

Figure 4: Relief Rates as a Function of Time for Additional HI Transients

a,c

Figure 5: Relief Rates as a Function of RCS Tavg for Loss of DHR HI Transients

a,c

Figure 6: Relief Rates as a Function of Time for Bounded HI Transients

5.4 LTOPS Arming / Enable Temperature

The LTOPS enable temperature was calculated in Reference 11 using the methods of ASME Code Case N-641 to be [ ]^{a,c} °F (without uncertainty). With the temperature uncertainty of [ ]^{a,c} °F applied, the minimum arming/enable temperature is 297°F. The technical specifications currently specify an LTOP enable temperature of 266°F, which is no longer conservative. Therefore, Technical Specifications LCO 3.4.10 and 3.4.12 need to be updated to reflect a minimum enable temperature of 297°F.

5.5 Summary of Results and Conclusions

The design basis MI and HI transients were analyzed and used for LTOP evaluations of the pressurizer PORVs and RHR suction relief valve for the updated P-T limits to 48 Effective Full-Power Years (EFPY) as described in Sections 5.1 through 5.4. The following conclusions were drawn:

- A single pressurizer PORV (both PORVs are required to be operable with one assumed to fail), with the current maximum allowable LTOP pressurizer PORV setting of ≤ 435 psig, is capable of providing the following protection (Section 5.2 and Figure 1):
    - The design basis HI transient is protected over the full temperature range applicable to LTOP (i.e., $60 \leq T_{RCS} \leq 297$°F).
    - The design basis MI transient from two CCPs injecting is protected for indicated RCS temperatures ≥ 210°F. Below this temperature, alternate means of LTOP (i.e., an RCS vent or the RHR suction relief valve) are required to be operable.
    - The LTOPS PORV setpoint reduction necessary to protect against the MI transient at the lowest temperatures of LTOP applicability was judged to be impractical as there would be insufficient operating region to perform heatup and cooldown operations.
- The RHR suction relief valve, with the current nominal lift setting of 450 psig, is capable of providing the following protection (Section 5.3):
    - The design basis MI transient from two CCPs injecting is protected over the full temperature range where the RHR system can be aligned (i.e., $T_{RCS} \leq 350$°F), which bounds the applicable LTOP temperature range (i.e., $60 \leq T_{RCS} \leq 297$°F).
    - The design basis HI transient is protected for indicated RCS temperatures ≤ 150°F. Above this temperature, two pressurizer PORVs are required to be operable to provide this protection.
    - For situations where the RHR system is aligned to the RCS at temperatures above 166°F, 110% of the RHR system design pressure will be protected during a design basis HI transient by the pressurizer PORVs (which are required to be operable for LTOP) and/or a pressurizer steam bubble, working in conjunction with the RHR suction relief valve.
    - With at least one RCP running, sufficient flow and heat transfer is maintained through each SG such that the conditions associated with the design basis HI transient cannot occur. The analyses in Section 5.3.3 demonstrated that the RHR suction relief valve is capable of providing protection against the remaining HI transients that can occur with at least one RCP running over the full temperature range where the RHR system can be aligned (i.e., $T_{RCS} \leq 350$°F).

- When the RCS is depressurized, LTOP can be provided by an RCS vent of ≥ 2.0 square inches or any single pressurizer PORV blocked open. This includes protection against the design basis MI transient resulting from two CCPs injecting.
- The analysis does not credit or impose any limitations on the maximum number of RCPs allowed to be in operation throughout the range of LTOP applicability.
- Accumulators must be isolated or maintained at a pressure less than the maximum RCS pressure allowed by the P-T limit curves for the existing RCS cold leg temperature.
- The minimum LTOPS arming/enable temperature (including temperature uncertainty) is 297°F (Section 5.4).

Based on the above conclusions, the LTOP acceptance criterion to protect the isothermal Appendix G P-T limits is met with the following minimum relief capabilities required to be operable (See Figures 7 and 8):

- For $60 \leq T_{RCS} \leq 150$°F with zero through four RCPs running:
    - The RHR suction relief valve, with a setpoint ≤ 450 psig, is required to be operable and will protect against both the MI and HI transients.
- For $150 < T_{RCS} < 210$°F:
    - With zero RCPs running:
        - The RHR suction relief valve, with a setpoint of ≤ 450 psig, is required to be operable and will protect against the MI transient; and
        - Two pressurizer PORVs, with lift settings ≤ 435 psig, are required to be operable and will protect against the HI transient.
    - With at least one RCP running:
        - The RHR suction relief valve, with a setpoint ≤ 450 psig, is required to be operable and will protect against both the MI and HI transients.
- For $210 \leq T_{RCS} \leq 297$°F:
    - With zero RCPs running:
        - Two pressurizer PORVs, with lift settings ≤ 435 psig, are required to be operable and will protect against both the MI and HI transients.
    - With at least one RCP running:
        - The RHR suction relief valve, with a setpoint ≤ 450 psig, is required to be operable and will protect against both the MI and HI transients; or
        - Two pressurizer PORVs, with lift settings ≤ 435 psig, are required to be operable and will protect against both the MI and HI transients.

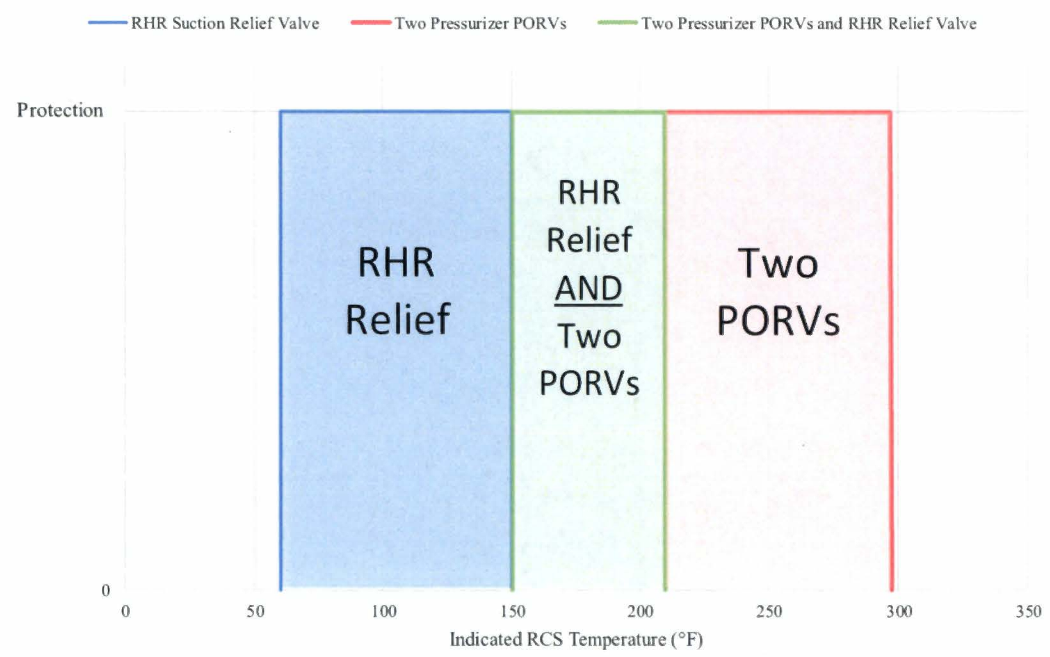

Figure 7: D.C. Cook Unit 1 Minimum Required Relief Capabilities for LTOP with Zero through Four RCPs Running

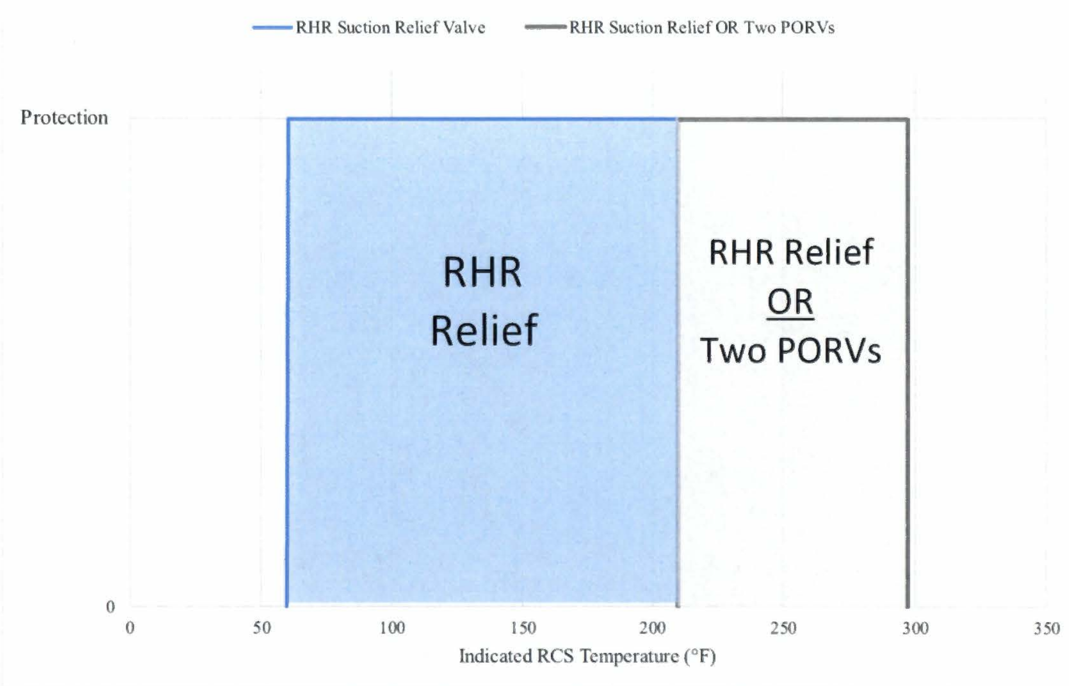

Figure 8: D.C. Cook Unit 1 Minimum Required Relief Capabilities for LTOP with at Least one RCP Running

6.0 References

1. WCAP-18455-NP, Rev. 1, "D.C. Cook Unit 1 Heatup and Cooldown Limit Curves for Normal Operation," February 2020.

a,c

2. [ ]

3.

4.]

5. WCAP-14040-A, Revision 4, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves," May 2004.

a,c

6. [ ]

7. WCAP-11640, Revision 0, "Cold Overpressure Mitigation System Deletion Report," March 1988.

8. WCAP-11736, Revision 0.0, "Residual Heat Removal System Autoclosure Interlock Removal Report for the Westinghouse Owners Group," February 1988.

9. WCAP-13235, Revision 0, "Donald C. Cook Units 1&2 Analysis of Low Temperature Overpressurization Mass Injection Events with Pressurizer Steam Bubble and RHR Relief Valve," March 1992.

a,c

10. [

11.]

12. NUREG-0800, BTP 5-2, Rev. 3, "Overpressurization Protection of Pressurized-Water Reactors while Operating at Low Temperatures," March 2007. (ML070850008)

13. WCAP-10529, Revision 1, "Cold Overpressure Mitigating System, November 1985.