Attachment 2 to

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AREVA document ANP-3300Q3NP, Revision 0

"Response to Request for Additional Information on Reactor Coolant System Pressure/Temperature and Low Temperature Overpressure Protection System Limits to 54 EFPY for Arkansas Nuclear One, Unit 1"

NON-PROPRIETARY

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AREVA

Response to Request for Additional Information on Reactor Coolant System Pressure/Temperature and Low Temperature Overpressure Protection System Limits to 54 EFPY for Arkansas Nuclear One, Unit 1

ANP-3300Q3NP
Revision 0

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AREVA Inc.

Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	All	Initial Issue

Contents

Nomenclature

(If applicable)-update later

Acronym	Definition
ADAMS	Agencywide Documents Access and Management system
ANO-1/ANO1	Arkansas Nuclear One, Unit 1
ART	Adjusted Reference Temperature
COMS	Cold Overpressure Mitigating System
ERV	Electromatic Relief Valve
°F	Degree Fahrenheit
ft-lb	foot-pound
ID	Inside Diameter
K_{It}	Thermal Stress Intensity Factor
LAR	License Amendment Request
LTOP	Low Temperature Overpressure Protection
P-T	Pressure – Temperature
RAI	Request for Additional Information
RCS	Reactor Coolant System
RPV/RV	Reactor Pressure Vessel/ Reactor Vessel
RVCH	Reactor Vessel Closure Head
TS	Technical Specifications
WEC	Westinghouse Electric Corporation

1.0 INTRODUCTION

By application dated November 21, 2014, as supplemented by letters dated February 6 and March 10, 2015 (Agencywide Documents Access and Management System (ADAMS Accession Nos. ML14330A249, ML15041A073, and ML15071A054, respectively-References 1-3), Entergy Operations, Inc., requested changes to the Technical Specifications (TSs) for Arkansas Nuclear One, Unit No. 1 (ANO 1). The proposed changes revise TS 3.4.3, "Reactor Coolant System (RCS) Pressure and Temperature (P/T) Limits, TS 3.4.9, "Pressurizer," TS 3.4.10, "Pressurizer Safety Valves," and TS 3.4.11, "Low Temperature Overpressure Protection." to update the reactor coolant system (RCS) pressure and temperature (P/T) and low temperature overpressure protection (LTOP) system limits to 54 effective full power years (EFPYs), the end of the current period of extended operation.

Based on the U.S. Nuclear Regulatory Commission (NRC) staff review of the information provided by Entergy (ADAMS Accession Nos. ML14330A249-Reference 1), the NRC staff issued Entergy requests for additional information (RAIs); Entergy responses to the RAIs are provided in References 2 and 3. On March 20, 2015 the NRC issued a subsequent RAI to Entergy (Reference 4) regarding the LTOP system and the proposed revised electromatic relief valve (ERV) setpoint of 553.8 psig (Reference 4). Section 2.1 of this document provides the NRC RAI and the Entergy response.

The methodology used to establish LTOP limit curves (without location adjustments and instrument errors) at 54 EFPY limits the maximum pressure in the vessel to 100% of the isothermal P-T limit curves determined to satisfy equation (1) of ASME Section XI, 2001 Edition with 2002 Addenda, Appendix G-2215 (References 5 and 6). The previous 21 and 32 EFPY the LTOP limit curves (without location adjustments and instrument errors) were provided as 110% of the isothermal P-T limit curves in accordance with ASME Code Case N-514 (Reference 7). The methodologies used to establish the ERV LTOP setpoint and LTOP limit curves at 54 EFPY are provided in Sections 2.1 and 2.2 of this document.

Information considered proprietary to AREVA in the following discussions is enclosed in brackets **[ ]**.

2.0 REQUEST FOR ADDITIONAL INFORMATION

A Draft request for additional information (RAI) regarding the LTOP system was discussed between the NRC and Entergy on March 19, 2015 and the NRC issued the final RAI on March 20, 2015 (Reference 4). The RAI is presented in Section 2.1.1 and the Entergy response is provided in Section 2.1.2. The methodologies used to establish the LTOP pressure limit (i.e., ERV setpoint of 553.8 psig), reported in Reference 1, and LTOP limit curves at 54 EFPY (Section 2.1.2, Figure 1), which are more limiting than the P-T curves for RCS temperatures less than the LTOP enable temperature of 259 °F, are provided in Sections 2.1 and 2.2 below.

2.1 Additional RAI

The NRC RAI regarding the change in the ERV LTOP setpoint was issued on March 20, 2015 (Reference 4).

2.1.1 Statement of Additional RAI

"The proposed revised electromatic relief valve (ERV) setpoint is 553.8 psig [pounds per square inch gauge]. The American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI, Appendix G, Paragraph G-2215 states that low temperature overpressure protection (LTOP) systems shall limit the maximum pressure of the vessel to 100% of the pressure determined to satisfy Equation 1 (e.g., the pressure for normal operation heatup or cooldown transients). The minimum allowable pressure for ANO-1 is 508 psig for the 90 deg/hour heatup transient (Table 7-1 of ANP-3300) and 513 psig for the cooldown transient (Table 7-3 of ANP-3300). Please explain how the ERV setpoint meets the ASME Code, Section XI requirements, since the setpoint is greater than the minimum allowable pressure."

2.1.2 Additional RAI Response:

The 54 EFPY LTOP relief valve setpoint (553.8 psig) is based on 100% of the fracture mechanics ASME Section XI, Appendix G, pressure-temperature (P-T) limits for isothermal conditions (Reference 5). Isothermal conditions are defined as an RCS temperature during heatup or cooldown in which there is no through-wall temperature gradient within the RV shell and closure head. The ERV setpoint is the lowest location (i.e., RV beltline, RV nozzle, and RV closure head) corrected RCS pressure based on isothermal conditions. The ERV setpoint is applicable from 60 °F to the enable temperature of 259 °F.

The ERV LTOP setpoint value is revised from 460 psig at 32 EFPY to 553.8 psig at 54 EFPY. The 54 EFPY P-T and LTOP P-T limits (i.e., P-T curves that apply at and below the LTOP enable temperature of 259 °F) were determined using the methodology contained in ASME Section XI, Appendix G 2001 Edition through 2002 Addenda. The 32 EFPY P-T and LTOP P-T limits were determined using the methodology contained in ASME Section XI, Appendix G, 1998 Edition, Supplemented by Code Case N-514 for LTOP (Reference 7).

The 2001 ASME Section XI Code permits the use of the higher K_{Ic} fracture toughness curve and utilizes the new methodology for calculating the stress intensity factors for pressure and radial thermal gradient. In addition, the Adjusted Reference Temperature (ART) for the limiting location at 54 EFPY is an upper shell plate material that has a value of 180°F at the 1/4t postulated flaw depth versus a beltline weld at 32 EFPY with an ART of 212 °F at the 1/4t location (Reference 7). The use of BAW-2308 for the Linde 80 beltline resulted in the reduction of the beltline weld ART such that plate material is controlling at 54 EFPY. Although, the 32 EFPY LTOP setpoint (Reference 14) was based on a slightly higher isothermal Appendix G curve (110% versus 100% for the 54 EFPY LTOP curves), it utilized the older ASME Section XI, Appendix G Code (1989 Edition) for calculating the stress intensity factors, utilized a lower bound K_{Ia} fracture toughness curve and included a more limiting 1/4t ART of 212 °F. Therefore, the ERV enable pressure at 54 EFPY is increased relative to 32 EFPY.

Isothermal conditions are used for LTOP (both ERV setpoint and LTOP P-T limits) because the postulated pressurization events at low temperatures will occur at or very close to a steady state condition. LTOP events occur as the result of equipment malfunction or operator error that results in mass or energy addition to the reactor coolant system. The limiting postulated LTOP event for a B&W plant is failure of a makeup control valve (i.e., mass addition event and not an energy addition event) that results in an RCS pressurization rate of approximately 20 to 30 psi/minute (Reference 5, Figure 5-1), depending on the pressurizer level at the start of the event.

The LTOP P-T limits are obtained by reducing the isothermal P-T limits generated in accordance with ASME Section XI, G-2215, by the expected pressurization of the RCS due to mass addition over a 10-minute operator action interval based on the limiting LTOP event (i.e., failed open makeup valve). The contribution to RCS pressurization by energy addition over a 10-minute interval is negligible compared to makeup mass addition. The LTOP P-T limit curves are lower than the HU/CD P-T curves reported in Figures 7-1 through 7-3 of ANP-3300, Revision 1, and are imposed as operating restrictions by ANO-1 during heatup and cooldown at temperatures at and below the LTOP enable temperature. The ERV setpoint of (553.8 psig) ensures that 100% of the steady state fracture mechanics ASME Section XI, Appendix G, pressure-temperature (P-T) limits for isothermal conditions will not be exceeded at and below the LTOP enable temperature (259 °F).

Because of restrictions that preclude water-solid operation of the pressurizer (i.e., a steam or nitrogen bubble is maintained with the reactor vessel head on); the B&W plant design is not likely to exceed Appendix G limits due to LTOP based on review of operating data in Section 2.3. In addition, use of isothermal conditions for LTOP is consistent with the methodology used by WEC for evaluation of Cold Overpressure Mitigating System (COMS), Reference 9.

Therefore, the ASME Section XI Appendix G derived isothermal limits are applicable and used in the development of the LTOP set-point. The ASME Section XI Appendix G isothermal limits are derived using Paragraph G-2215, Equation 1. Since the ERV setpoint is equal to the minimum allowable pressure for isothermal conditions, the setpoint meets the ASME Code, Section XI requirements.

2.1.3 ANO-1 LTOP (ERV Setpoint and Limit Curves)-Reference 5

Figure 1 – LTOP Pressure-Temperature Limits

2.2 B&W Plant LTOP Methodology

The methodology applicable to B&W plants for establishment of LTOP P-T limits for temperatures at and below the LTOP enable temperature is provided below. The LTOP methodology includes the following elements.

- Definition of reactor vessel pressure limit
- Definition of enable temperature
- Definition of LTOP transients
- Consequences of LTOP events
- Definition of methods to protect the reactor vessel pressure limit

Definition of the Reactor Vessel Pressure Limit for LTOP

Per ASME Section XI, Appendix G, 2001 edition through 2002 Addenda, LTOP systems are required to limit the maximum pressure in the vessel to 100% of the pressure determined to satisfy the Equation 1 limits on fracture toughness. Thus, the calculational methodology is identical to those used in the Appendix G calculations. The use of steady state temperatures (also known as isothermal), rather than the transient resulting from technical specification heatup and cooldown limits is based on the likelihood that LTOP events occur during steady-state operations. The use of steady state or isothermal condition as an LTOP initiation event is consistent with the approach used by a recent P-T submittal by another B&W plant (References 12 and 13) and WEC-designed plants (Reference 9).

In the past, the use of a 10% increase in pressure above the Appendix G limit was justified by ASME Code Case N-514. The Code Case allowed the use of 110% of the ASME Section XI, Appendix G RCS pressure limits, when determining LTOP limits. This code case is no longer applicable, and 100% of the ASME Section XI, Appendix G RCS pressure limit, is now used as the limit.

Definition of Enable Temperature

ASME Section XI, Appendix G, Article G-2215 defines the LTOP enable temperature. For the ANO One Unit 1 plant, the RT_{NDT} of the limiting material is 180 °F. The RT_{NDT} plus 50 °F value corresponds to 230 °F. The maximum transient condition fluid temperature occurs during heatup at 90 °F/hour when the maximum temperature difference of 29°F is calculated between the metal temperature (at RT_{NDT} plus 50 °F or 230 °F) and the fluid temperature. This results in an enable temperature of 230 °F plus 29 °F or 259 °F.

Definition of LTOP Transients

LTOP events occur as a result of equipment malfunction or operator error that results in mass or energy addition to the reactor coolant system. In the B&W plant operating history up to 2015, only once have the technical specification Appendix G limits been violated due to an LTOP event. Because of restrictions that preclude water-solid operation of the pressurizer (i.e., a steam or nitrogen bubble is maintained with the reactor vessel head on); the B&W plant design is not likely to exceed Appendix G limits due to LTOP.

In the B&W design, mass can be injected into the system through:

1. the four HPI nozzles (one or two of which also serve as normal makeup);
2. the core flood nozzles through which the core flood tank system, decay heat removal system, and low pressure injection system (LPI) can provide added inventory; and
3. the pressurizer spray nozzle via HPI, LPI, or the nitrogen addition system.

Energy can be added to the RCS via:

1. failure of the decay heat removal system;
2. actuation of the pressurizer heaters; and
3. reactor coolant pumps.

As a result, the following transients were postulated and evaluated for their potential to increase reactor vessel pressure:

1. Erroneous actuation of the High Pressure Injection (HPI) system
2. Erroneous opening of the core flood tank discharge valve
3. Erroneous addition of nitrogen to the pressurizer
4. Makeup control valve (makeup to the RCS) fails full open
5. All pressurizer heaters erroneously energized
6. Temporary loss of the Decay Heat Removal System's (DHRS) capability to remove decay heat from the RCS
7. Thermal expansion of the RCS after starting an RC pump due to stored thermal energy in the steam generator

Consequences of LTOP Events

The postulated LTOP events were analyzed to determine the rate of RCS pressure increase and/or the total amount of pressure increase that the system would experience. A stand-alone thermal-hydraulic model of the pressurizer was used for these predictions. Capabilities to model RCS inventory increases (e.g., makeup, HPI), inventory decreases (e.g., letdown), RCS expansion, and pressurizer heaters were included. A range of initial pressures and pressurizer levels were applied so that the pressurization rates could be applied to different initial P-T operating conditions. A brief summary of each transient response is provided below.

1. Erroneous actuation of the High Pressure Injection (HPI) system - this event would be the most limiting LTOP transient. However, HPI actuation results in a very rapid pressurization of the RCS and precludes achieving the necessary 10 minutes for operator action. Thus, this event is prevented below the LTOP enable temperature through plant procedures.

2. Erroneous opening of the core flood tank discharge valve - this event is precluded by closing and locking out the breakers of the motor operated block valves before the RCS pressure decreases below the CFT pressure (600 psig). This will occur prior to cooling below the LTOP enable temperature.

3. Erroneous addition of nitrogen to the pressurizer - this event cannot over-pressurize the RCS because of plant equipment that regulates the nitrogen pressure to 150 psig (i.e., pressure regulator and relief valves).

4. Makeup control valve (makeup to the RCS) fails full open - this event results in a pressurization rate of 20 to 30 psi/minute and is the most limiting of the remaining LTOP events.

5. All pressurizer heaters erroneously energized - this event is a slow transient (9 to 12 psi/minute) and is bounded by the failed makeup control valve event.

6. Temporary loss of the Decay Heat Removal System's (DHRS) capability to remove decay heat from the RCS - this event is a slow transient (7 psi/minute) and is bounded by the failed makeup control valve event.
7. Thermal expansion of the RCS after starting an RC pump due to stored thermal energy in the steam generator - this event results in a finite increase in pressure that is less than the margin between the Appendix G and LTOP limits. Because of the presence of a pressurizer bubble, this event is much less severe than at other PWRs.

In summary, the most limiting, credible event is the failed open makeup control valve. Because of system design differences, the plant response is sensitive to the makeup pump head-capacity curve and system resistance. This requires each plant to evaluate a plant specific response.

Definition of Methods to Protect the Reactor Vessel Pressure Limit

In general, each plant is equipped with either: (1) a dual setpoint pilot operated relief valve that is set below the LTOP limit, or (2) an additional relief valve (e.g., decay heat removal system relief valve) that is also set below the LTOP limit. In the event of relief valve failure, plant operation is limited (i.e., combination of operating pressure, pressurizer level) such that, in the event of the most limiting LTOP event, failed open makeup control valve, either: (1) ten minutes are available between the time the pressure-temperature operating limits are exceeded and the LTOP limits are violated, thus, providing adequate time for the operator to terminate the event, or (2) the available makeup tank volume would be exceeded and thus terminate the event before the LTOP limit is violated.

2.3 LTOP Events-Operating Experience

Low temperature pressurization events became an issue for the operating plants in early 1976 when the NRC conducted a review of reported pressure transients that had occurred. For each of the 30 events identified at the time, the Technical Specification pressure-temperature limits were exceeded. These overpressurization events, which occurred mostly during startup and shutdown operations when the RCS was in a water solid condition, were caused either by equipment malfunction, procedural deficiencies, or incorrect operator action. (Reference 10)

For the B&W-designed plants, there has been only one instance of exceeding the Technical Specification pressure limit. This single event, identified as one of the 30 events by the NRC review, occurred at Oconee Unit 1 in 1972, five months before initial criticality. This event was not a transient, but was a planned operation as part of the zero power physics testing procedure. B&W-designed plants have a much lower potential for startup and cooldown overpressure transients than other PWR's and a disproportionately lower frequency of occurrence for such events.

From 1979 through 1987 there have been 61 LTOP events that have occurred in Westinghouse plants. The LTOP event type contributions are discussed in EPRI Report TR-103084-T2 and a summary of each of these LTOP events is provided in Appendix A of the report (Reference 11).

An informal review of the INPO operating experience (OE) database for LTOP events that occurred between 1995 to the present date revealed at least 9 additional LTOP events that occurred at Combustion Engineering and Westinghouse designed plants.

3.0 REFERENCES

1. License Amendment Request Update the Reactor Coolant System Pressure and Temperature and the Low Temperature Overpressure Protection System Limits, Arkansas Nuclear One, Unit 1, Adams Accession Numbers ML14330A246, ML14330A249, ML14330A250, November 21, 2014
2. Responses to Request for Additional Information Update the Reactor Coolant System Pressure and Temperature and the Low Temperature Overpressure Protection System Limits, Adams Accession Number ML15041A073, February 6, 2015
3. Responses to Request for Additional Information Update the Reactor Coolant System Pressure and Temperature and the Low Temperature Overpressure Protection System Limits Arkansas Nuclear One, Adams Accession Number 15071A054, March 10, 2015
4. E-mail from NRC Singal, Balwant to Bob Clark, March 20, 2015, 11:57 a.m., FW: Arkansas Nuclear One, Unit No. 1, Request for Additional Information (Second Round) - License Amendment Request (TAC MF5292)
5. [ ]
6. [ ]
7. [ ]
8. Not used

9. WCAP-14040-A, Revision 4,Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves, May 2004, Adams Accession Number ML050120209

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11. EPRI Report TR-103084-T2, System Aspects of Reactor Pressure Vessel Integrity, Final Report, November 1993

12. Duke Energy Carolinas, LLC Oconee Nuclear Station (ONS), Units 1, 2, and 3, Docket Numbers 50-269, 50-270, and 50-287, License Amendment Request to Update Pressure-Temperature Limit Curves, License Amendment Request (LAR) No. 2012-10, Adams Accession Number ML13058A059, Enclosure 2, ANP-3127

13. NRC SER, OCONEE NUCLEAR STATION, UNITS 1, 2, AND 3, ISSUANCE OF AMENDMENTS REGARDING REVISED PRESSURE-TEMPERATURE LIMITS (TAC NOS. MF0763, MF0764, AND MF0765), ADAM Accession Number ML14041A093 , February 27, 2014

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