2807 West County Road 75
Monticello, MN 55362

June 10, 2024

L-MT-24-019
10 CFR 50.55a(b)(2)(xliii)

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Monticello Nuclear Generating Plant
Docket No. 50-263
Renewed Facility Operating License No. DPR-22

Submittal of ASME Section XI, Section IWB-3720 Analytical Evaluation in Accordance with 10 CFR 50.55a(b)(2)(xliii)

Reference: 1) NSPM letter to NRC, “Monticello Nuclear Generating Plant Licensee Event Report 2024-001-00,” dated April 25, 024 (ADAMS Accession No. ML24116A117)

On February 28, 2024, the Monticello Nuclear Generating Plant (MNGP) experienced a plant trip during which the reactor pressure vessel bottom head exceeded the Technical Specification cooldown rate specified within the Pressure and Temperature Limit Report (Reference 1). Following the 2019 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, Section IWB-3720, “Unanticipated Operating Events,” an analytical evaluation was performed to determine the effects of this condition. In accordance with 10 CFR 50.55a(b)(2)(xliii), “Section XI condition: Regulatory Submittal Requirements,” the Northern States Power Company, a Minnesota corporation, doing business as Xcel Energy (hereafter "NSPM"), is providing the enclosed evaluation, performed by Structural Integrity Associates, Inc., for U.S. Nuclear Regulatory Commission review and approval.

Please contact Mr. Richard Loeffler at 612-539-3370 or Richard.A.Loeffler@xcelenergy.com if there are any questions or if further information is needed.

Summary of Commitments

This letter makes no new commitments and no revisions to existing commitments.

Gregory D. Brown
Plant Manager, Monticello Nuclear Generating Plant
Northern States Power Company – Minnesota

Enclosure

cc: Administrator, Region III, USNRC
Project Manager, Monticello, USNRC
Resident Inspector, Monticello, USNRC
State of Minnesota

ENCLOSURE

STRUCTURAL INTEGRITY ASSOCIATES, INC.

OPERABILITY ASSESSMENT FOR THE MNGP REACTOR PRESSURE VESSEL BOTTOM HEAD

DATED MAY 31, 2024

(9 Pages Follow)

ddenis@structint.com
11515 Vanstory Drive, Suite 125, Huntersville, NC 28078 | 570-561-5097

May 31, 2024
REPORT NO. 2400420.402
REVISION: 1
PROJECT NO. 2400420.00

Quality Program: ☒ Nuclear ☐ Commercial

Russell Lidberg
Xcel Energy
Monticello Nuclear Generating Plant
2807 West County Road 75
Monticello, MN 55362

Subject: Operability Assessment for the MNGP Reactor Pressure Vessel Bottom Head

Dear Russell,

Per discussion, this letter report provides results of an investigation of margin associated with the material components of the Monticello Nuclear Generating Plant (MNGP) reactor pressure vessel (RPV) bottom head for a cooldown event that occurred on February 28, 2024. The current review included initial investigation of ASME Code approaches for margins for the bottom head within the calculation for the pressure-temperature (P-T) limit curves performed for MNGP relative to the bounding curves.

Xcel requested assistance from Structural Integrity Associates, Inc. (SI) to evaluate the surveillance data, and assess whether the potential ramp rate issue remains bounded by ASME Code limits throughout the event. The purpose of this letter report is to summarize SI's review of the associated data and document the evaluation that was performed to verify Code compliance.

Background

The current MNGP operational pressure-temperature limits curves were developed for 54 effective full power years (EFPY) by SI [2]. These curves provide guidance to bound the operation of the power plant, specifically for the protection of the reactor pressure vessel (RPV) from brittle fracture. These curves are defined by the ASME Boiler & Pressure Vessel Code (BPVC) in Section XI Appendix G and further governed by regulations in 10 CFR 50 Appendix G. As such, these curves are based on linear elastic fracture mechanics (LEFM) to ensure that plants are operated in a manner that protects the vessel from rapid propagation of a crack and failure. The flaw evaluation methodology is based on an assumed flaw of one-quarter of the thickness (1/4T) of the reactor pressure vessel.

In this approach, a stress intensity factor (K_I) must remain below the static fracture toughness (K_{IC}), a material property of base metal and weld materials. The available fracture toughness is defined by the initial RT_{NDT}, a test-based property defined by NB-2300 of ASME BPVC Section III (for Design of Nuclear Power Plants). The fracture toughness can be reduced over the lifetime of a reactor's operation by neutron irradiation, which defines a new value, the Adjusted Reference Temperature (ART) for the vessel material, and this defines a value for K_{IC} that decreases with increasing neutron irradiation. For the purposes of the current discussion of the bottom head, the material of the bottom head does not receive sufficient neutron irradiation to affect the material property for K_{IC}, therefore, the initial RT_{NDT} is also the same as the end-of-life ART.

Besides the RT_{NDT} (or ART as appropriate), the K_{IC} value of a material is affected by the current operating temperature of a material, such that increasing temperature increases the value of K_{IC} for a given value of RT_{NDT} (or ART). The applied K_I is affected both by the pressure in the vessel (increasing pressure increases the pressure contribution to K_I) and by the thermal ramp rate (higher rate increases the thermal contribution to K_I).

In overall summary, the vessel must be sufficiently warmed before pressurization for startup and also, during a shutdown, the pressure must be reduced before the vessel is allowed to cool. The specific parameters of these heatup and cooldown cycles are defined by pressure-temperature limit curves, which provide guidance and boundaries to retain structural stability and not have occurrence of rapidly propagating failure due to unstable brittle crack extension.

The pressure-temperature limit curves (also called P-T curves) are defined by two applicability criteria. One is a time-based criterion for plant age (generally defined in EFPY) that is a proxy for the accumulated embrittlement and shift in the K_{IC} value for various materials in the reactor vessel. The other criterion is the temperature ramp rate, which provides a maximum thermal stress effect on the vessel. If either the limitation of the plant age or the temperature ramp rate of the curves is exceeded, an evaluation for the specific reactor conditions and transients must be made to establish if a risk to the structural stability of the reactor occurred. Typically, the temperature ramp rate for the components in the RPV are limited to 100°F/hr (although other ramp rates can be utilized if appropriate analysis is performed). For P-T Limit Curve generation, curves are generated for various components in the RPV, and the limiting curve provides the overall composite curve that defines operational limitations for the unit.

In winter 2024, MNGP had a scram event that continued to shutdown and during a portion of the operational event, a ramp rate of approximately 129°F/hr was experienced by the bottom head of the RPV as measured by RPV106 (Vessel Bottom Head) and a ramp rate of approximately 229°F/hr as measured by RPV103 (Vessel Bottom Head Drain Line) during the first hour following the scram event. In accordance with the 2019 ASME BPVC, Section IWB-3720, "Unanticipated Operating Events", this ramp rate excursion is evaluated herein.

Within the MNGP PTLR [1], the limitation for the temperature ramp rate of the bottom head of the RPV is 100°F/hr. Although that ramp rate was exceeded for a portion of the event, there is margin within the material to tolerate a higher ramp rate for operation. The purpose of this evaluation is to define a higher ramp rate curve for the bottom head of the MNGP RPV that envelopes the rates experienced during the scram event and subsequently provide confirmation that the component was not at-risk for brittle failure.

Approach

Structural Integrity Associates has previously prepared pressure-temperature limit curves in support of MNGP [2]. The calculation employed the methodology of an NRC-approved topical report for generation of boiling water reactor (BWR) pressure-temperature limits [3]. The current approach will be to take the data for MNGP and utilize the approved methodology approach for the pressure-temperature limit curves [3] for the bottom head component, but instead of a ramp rate of 100°F/hr (provided in the current PTLR curves), a bounding ramp rate of 230°F/hr will be utilized.

In accordance with the 2019 ASME BPVC, Section IWB-3720, "Unanticipated Operating Events", this ramp rate excursion is evaluated herein.

The newly developed curve will show acceptability of the ramp rate exceedance event. Although the higher ramp rate will increase the thermal stress contribution to the applied stress intensity factor, the bottom head material retains sufficient margin in its K_{IC} value not to be negatively affected by the increased ramp rate for brittle crack stability.

The RT_{NDT} (and equivalent ART) for the bottom head is 26.0°F [2], and because of the low neutron irradiation levels below 1 x 10^{17} n/cm^2 (E > 1.0 MeV), the RT_{NDT} value remains valid for utilization of pressure-temperature limit curves in a time-independent (not dependent on limiting EFPY of the plant) manner.

Figure 1 shows the extended beltline for the MNGP RPV associated with a PTLR license amendment request (LAR) under NRC review to be applicable through the subsequent license renewal period, with the green zone showing the axial area around the core mid-plane with fluence greater than 1 x 10^{17} n/cm^2 (E > 1.0 MeV) for 72 EFPY (assumed EFPY for 80 years of plant operation) [4]. The TransWare fluence evaluation [4] provides confirmation that no embrittlement shift from neutron irradiation is required for evaluation in the bottom head, which is well below the extended beltline region.

Justification of 230°F/hr Ramp Rate Versus 100°F/hr Ramp Rate

The pressure-temperature limits curves are defined at a particular ramp rate. The ramp rate relates to a thermal contribution to the overall applied stress intensity factor. The pressure-temperature limits for BWRs are generally defined by the more limiting cooldown event that induces stress on the 1/4T location (versus the 3/4T location for the heatup event).

The below equation defines the thermal contribution to the stress intensity factor from Appendix G of the ASME Code, Section XI [5]:

$$K_{It} = 0.953 \cdot 10^{-3} \cdot CR \cdot t^{2.5}$$

Where:

K_{It} = Thermal contribution to stress intensity factor,
CR = Cooling rate in °F/hr, and
t = thickness of the material in inches.

Thermal contribution to stress intensity factor, K_{It}, for 100°F/hr is 8.19 ksi√inch while the value for 230°F/hr is 18.8 ksi√inch. A newly defined bottom head curve augments the existing 100°F/hr Curve B for operating events to contain heatup or cooldown rates for the bottom head up to 230°F/hr. The pressure contribution to stress intensity factor is dependent on the pressure of the water inventory within the vessel and is independent of the thermal ramp rate.

The 230°F/hr bottom head curve (shown in Figure 2) shifts the existing curve up and to the left on the graph and captures additional design margin, while being more restrictive in operating space relative to the 100°F/hr bottom head curve. The combined applied stress intensity factor (from pressure and thermal contributions) is compared to the margin within a component of the K_{IC} (for a given operating temperature).

Figure 2 shows the dotted line 230°F/hr pressure-temperature limit curve plotted with the existing 54 EFPY Curve B (and bottom head curve) currently within the MNGP PTLR. The data from the scram event have also been plotted. Thermocouples RPV 101, 103, and 106 have been plotted (but RPV 101 remains well above the temperature range of the plot). Thermocouple locations RPV 103 and 106 are shown in Figure 3.

The new 230°F/hr line is positioned above the Curve B bottom head curve, showing a more limiting curve than the 100°F/hr Curve B (applicable to the bottom head). The new curve provides margin to the existing Curve B for Core Not Critical operation. Tabular data for the 230°F/hr curves are contained within Table 1. Furthermore, all data associated with the ramp rate event [6] are positioned to the upper left of the 230°F/hr limit curve, providing assurance of protection from brittle fracture.

Conclusion

Based on the evaluation, the bottom head components that experienced greater than 100°F/hr temperature ramp rates (approximately 229°F/hr in worst case scenario) have no risk of brittle fracture and satisfy the pressure-temperature limit curve defined for a 230°F/hr temperature ramp rate. The 230°F/hr curve captures additional margin available for the component to experience higher temperature ramp rates. The applied ramp rate did not apply any degradation to the components or impairment to their safe and reliable operation.

References:

1. Xcel Energy Document for Monticello Nuclear Generating Plant, PTLR, Revision 1, “Monticello Nuclear Generating Plant”, Pressure and Temperature Limits Report (PTLR) up to 54 Effective Full-Power Years (EFPY)”, Approved August 5, 2014.
2. Structural Integrity Calculation, 1000847.303, Revision 2, “Revised P-T Curves Calculation”.
3. Licensing Topical Report (LTR), SIR-05-044-A, Revision 0, “Pressure-Temperature Limits Report Methodology for Boiling Water Reactors,” August 2007, ADAMS Accession No. ML072340283.
4. TransWare Enterprises Report, MNT-FLU-001-R-002, Revision 0, “Monticello Nuclear Generating Plant Reactor Pressure Vessel Fluence Evaluation - End of Cycle 30”, June 2022. SI File Number 2100300.201.
5. ASME Boiler & Pressure Vessel Code, Section XI, Division 1, “Rules for Inspection and Testing of Components of Light-Water Cooled Plants”, 2019 Edition.
6. E-mail from Russell Lidberg to Dan Denis, March 12, 2024, “RPV Temp and Pressure data.xsl”. SI File Number 2400420.201.
7. Xcel Energy Drawing, NF-36790, Revision 77, “Reactor Pressure Vessel Thermocouple Locations & Extension Lead Routing. SI File Number 2400420.201.

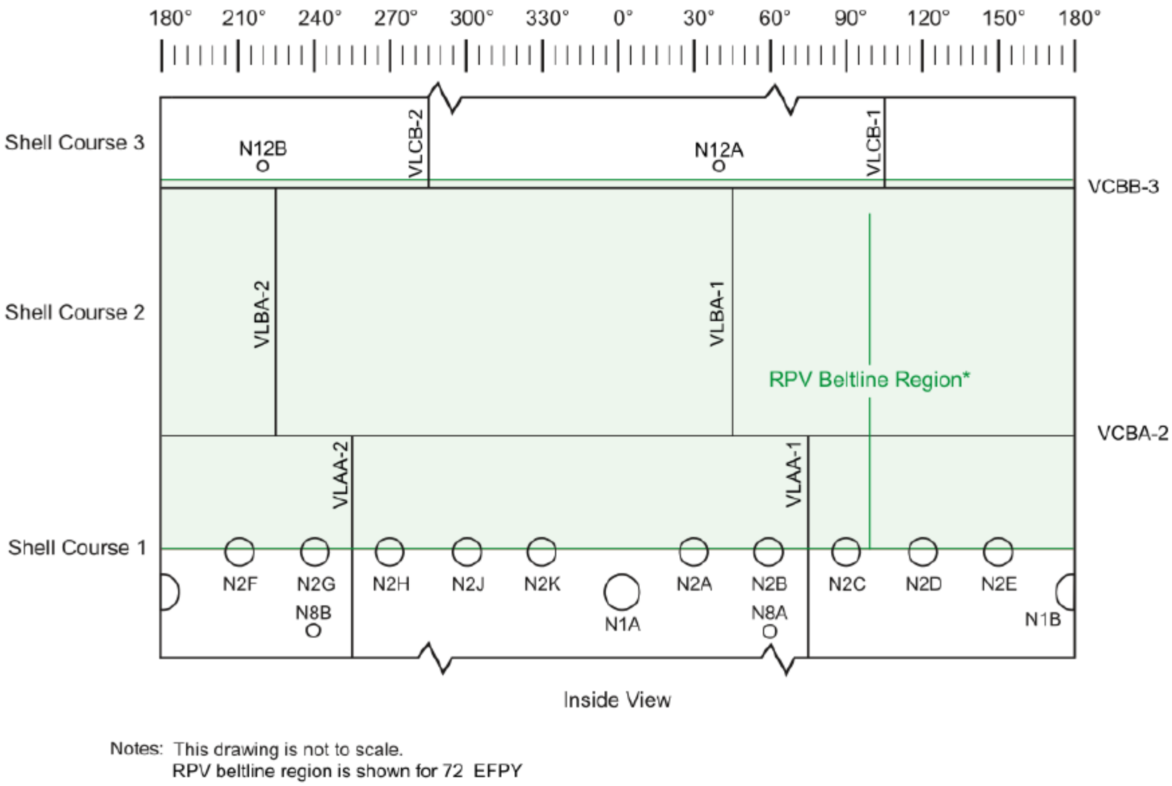

Figure 1: Extended Beltline Zone for 72 EFPY for MNGP [4]

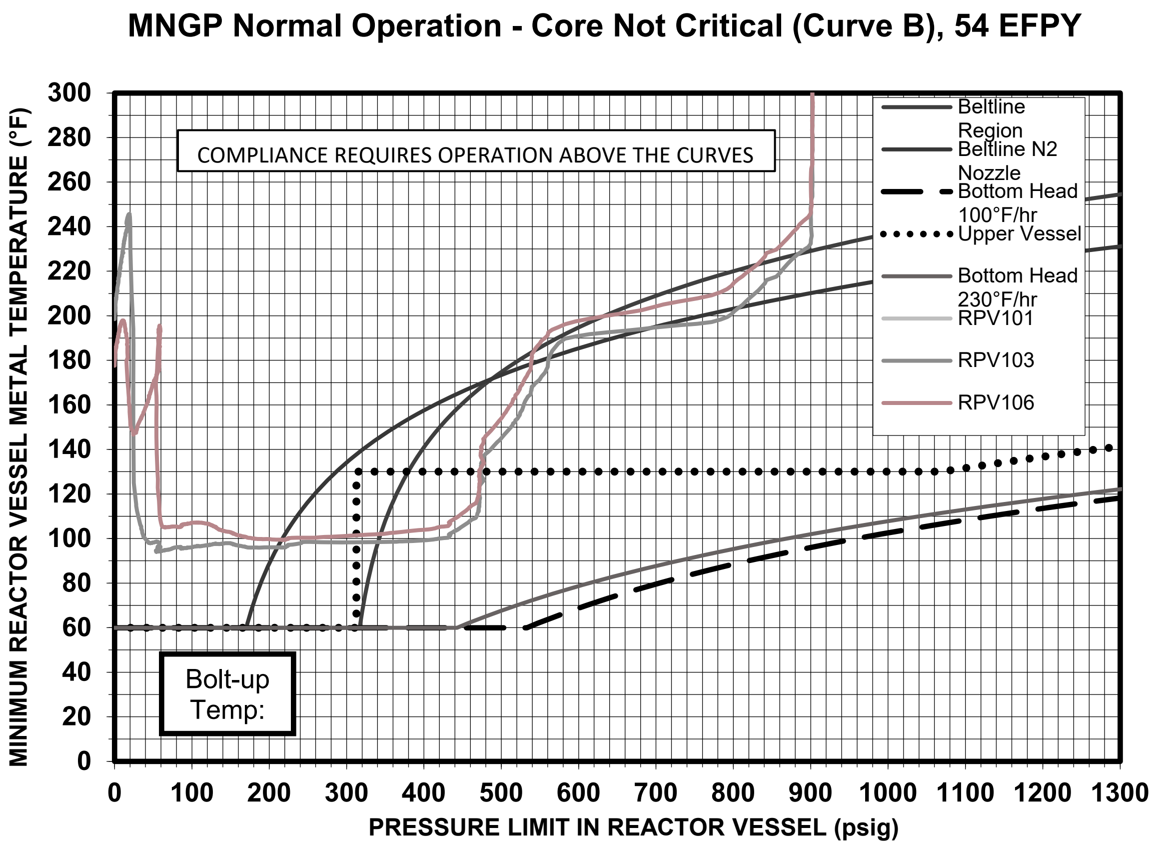

Figure 2: Pressure-Temperature Limit Curve of Bottom Head with 230°F/hr Ramp Rate with 54 EFPY Curve B and Plotted Temperature Data

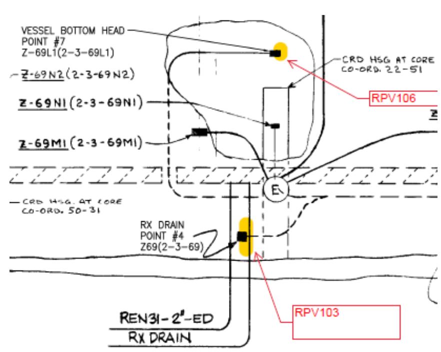

Figure 3: Thermocouple Locations for Bottom Head Temperatures [7]

Table 1: Bottom Head Tabular Values for 230°F/hr Ramp Rate Curve (K_{It} of 18.8 ksi√inch)

Gauge Fluid Temperature (°F)	**K_{Ic} (ksi*inch$^{1/2}$)**	**K_{Im} (ksi*inch$^{1/2}$)**	**Temperature for P-T Curve (°F)**	**Adjusted Pressure for P-T Curve (psig)**
60	74.13	27.65	60	0
60	74.13	27.65	60	443
62	75.80	28.48	62	457
64	77.54	29.35	64	472
66	79.34	30.26	66	487
68	81.23	31.20	68	503
70	83.19	32.18	70	520
72	85.23	33.20	72	537
74	87.35	34.26	74	555
76	89.56	35.37	76	574
78	91.86	36.52	78	593
80	94.25	37.71	80	614
82	96.75	38.96	82	635
84	99.34	40.26	84	657
86	102.04	41.61	86	680
88	104.85	43.01	88	704
90	107.77	44.47	90	729
92	110.82	45.99	92	755
94	113.98	47.58	94	781
96	117.28	49.23	96	810
98	120.71	50.94	98	839
100	124.28	52.73	100	869
102	128.00	54.59	102	901
104	131.87	56.52	104	934
106	135.90	58.53	106	968
108	140.09	60.63	108	1003
110	144.45	62.81	110	1040
112	148.99	65.08	112	1079
114	153.72	67.44	114	1119
116	158.63	69.90	116	1161
118	163.75	72.46	118	1205
120	169.08	75.13	120	1250
122	174.63	77.90	122	1297
124	180.40	80.78	124	1346

126	186.40	83.79	126	1397
128	192.66	86.91	128	1450
130	199.16	90.17	130	1506
132	205.94	93.55	132	1563
134	212.99	97.08	134	1626

Authored by:

Daniel B. Denis, PE
Manager

5/31/2024
Date

Reviewed by:

Jianxin Wang
Senior Consultant

5/31/2024
Date

Approved by:

Daniel B. Patten
Director

5/31/2024
Date

Supporting Files:

Document Name	**Description**
2400420.402.R1 P-T Curves 54EFPY.xlsx	Excel spreadsheet that documents the generation of a 230°F/hr curve for the bottom head region of the MNGP RPV.