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Constellation Energy Group

Nine Mile Point
Nuclear Station

March 22, 2004
NMP1L 1823

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

SUBJECT: Nine Mile Point Unit 1
Docket No. 50-220
License No. DPR-63

Evaluation of Upper Shelf Fracture Toughness of the Nine Mile Point Unit 1 Reactor Vessel per 10CFR50, Appendix G

Gentlemen:

By letters dated December 17, 1992, and February 26, 1993, (NMP1L 0723 and NMP1L 0739, respectively) Niagara Mohawk Power Corporation (NMPC) submitted reports entitled, "Elastic-Plastic Fracture Mechanics Assessment of Nine Mile Point Unit 1 Beltline Plates for Service Level A and B Loadings" and "Elastic-Plastic Fracture Mechanics Assessment of Nine Mile Point Unit 1 Beltline Plates for Service Level C and D Loadings," for NRC staff review and approval. These reports were intended to demonstrate through fracture mechanics analysis that there exist margins of safety against fracture equivalent to those required by Appendix G of American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME) Code, Section III, for beltline plates having upper-shelf energy (USE) values below the 50 ft-lb screening criterion.

By letter dated April 20, 1994 (TAC No. M86107) the NRC transmitted the conclusion, based upon staff review of the cited reports, that the Nine Mile Point Nuclear Station Unit No. 1 (NMP1) reactor pressure vessel plates have adequate margins of safety against fracture until a projected end-of-life (25 Effective Full Power Years (EFPY)) for all Level conditions (A, B, C, and D) and meet the criteria in ASME Section XI Code Case N-512. The NRC further concluded that the NMP1 reactor pressure vessel plates and weld material satisfy the requirements of 10 CFR Part 50, Appendix G, Section IV.A.1, in that the USE values for these plates and welds will provide margins of safety against fracture equivalent to those required by Appendix G of Section III of the ASME Code and are, therefore, acceptable. An accompanying Safety Evaluation supported these conclusions.

Current projections indicate that 25 EFPY will be reached in March 2007, more than two years before the current Operating License expiration date of August 22, 2009 for Nine Mile Point Unit 1.

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The enclosed report, CNS-04-01-01, Revision 1, "Evaluation of Upper Shelf Fracture Toughness of the Nine Mile Point Unit 1 Reactor Vessel to the End of the Period of Extended Operation," is forwarded for your review and approval in accordance with 10CFR50, Appendix G, Paragraph IV.1.c. This report supplements the cited prior submittals for Nine Mile Point Unit 1 and adopts the methodology of NRC approved BWRVIP-74-A, "BWR Vessel and Internals Project, BWR Reactor Pressure Vessel Inspection and Flaw Evaluation Guidelines for License Renewal," for elastic-plastic fracture mechanics analysis. The report, developed in conjunction with ongoing license renewal efforts, demonstrates adequate margins of safety and compliance with the requirements cited in TAC No. M86107 through the end of the current License period and a twenty year extension period provided by license renewal.

Approval of the enclosed report for use beyond the currently approved 25 EFPY is needed by March 2007 to permit plant operation until the end of the current Operating License period.

Very truly yours,

William C. Holston
Manager, Engineering Services

WCH/JRH/bjh

Enclosure

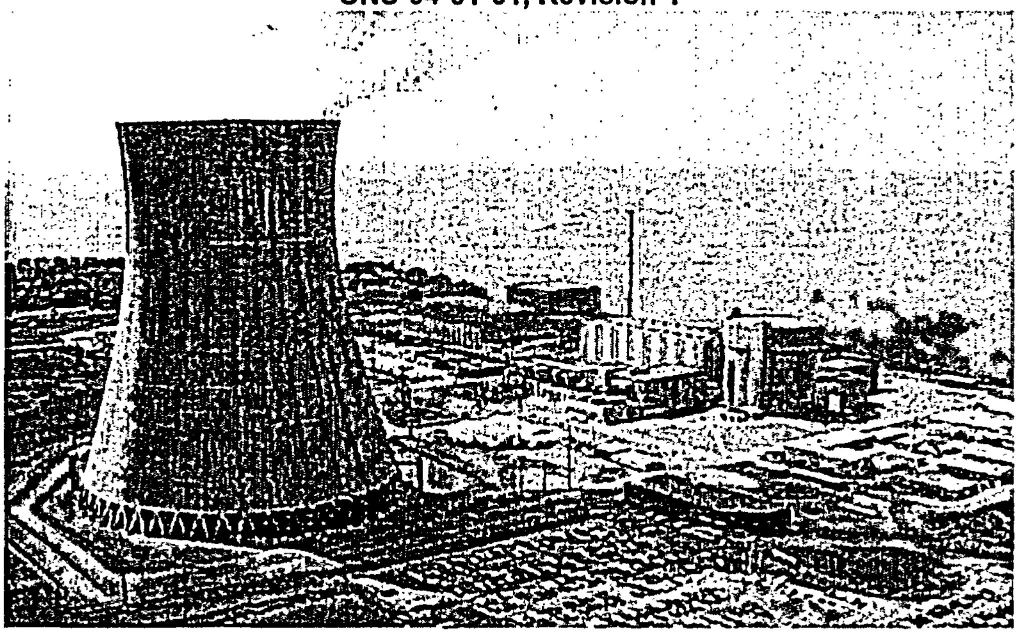
cc: Mr. H. J. Miller, NRC Regional Administrator, Region I
Mr. G. K. Hunegs, NRC Senior Resident Inspector
Mr. P. S. Tam, Senior Project Manager, NRR (2 copies)

Constellation
Nuclear Services

A Member of the Constellation Energy Group

Evaluation of Upper Shelf Fracture Toughness Of the Nine Mile Point Unit 1 Reactor Vessel to the End of the Period of Extended Operation

CNS-04-01-01, Revision 1



March 17, 2004

Prepared by: Wayne Pavinich
Reviewed by: J. C. Poehler
R. O. Hardies

RECORD OF REVISIONS

Revision No.	Summary of Revision
0	Initial Issue, March 2004
1	Changed neutron fluence references and write-up in Section 4.1 to reflect the recent fluence benchmarking, March 17, 2004.

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Evaluation of Upper Shelf Fracture Toughness of the NMP1 Reactor Vessel to the End of the Period of Extended Operation.

1.0 Purpose

The purpose of this evaluation is to predict the upper shelf energy (USE) for the NMP1 reactor pressure vessel (RPV) beltline materials through the end of the period of extended operation and compare these predictions to an equivalent margin analysis in accordance with ASME Code Case N-512 if 10CFR50, Appendix G requirements are not met.

2.0 Background

The NMP1 reactor pressure vessel (RPV) was built prior to the issuance of 10CFR 50 Appendix G, "Fracture Toughness Requirements". Appendix G requires all pressure retaining materials maintain a USE (determined by Charpy impact tests) of 50 ft-lbs or greater. Appendix G also requires a reactor vessel surveillance program (RVSP) in accordance with 10CFR 50 Appendix H that incorporates by reference ASTM E 185 [1]. ASTM E 185 requires the Charpy impact specimens to be oriented transverse to the rolling direction for plates. The RVSPs of many older plants such as NMP1 did not meet the ASTM E 185 requirements. The determination of the initial USE for NMP1 RPV beltline materials were made using longitudinal specimens (long axis of specimen parallel to rolling direction). The NRC addressed this problem by issuing Branch Technical Position MTEB 5-2 [2], that requires the USE measured using longitudinal specimens (with respect to the rolling direction) to be multiplied by 0.65 to obtain the USE for transversely oriented (with respect to the rolling direction) specimens. Applying the conversion factor the limiting plates for the NMP1 RPV resulted in low initial USE values. The predicted USE for the limiting plate (using Regulatory Guide 1.99, Rev 2) falls below 50 ft-lbs before the end of the current license. The predicted USE will continue to fall during the period of extended operation as well.

If the USE falls below 50 ft-lbs any time during operation of the plant, it must be demonstrated that the RPV has margins of safety against fracture equivalent to those required by Appendix G of Section XI of the ASME Code. An equivalent margins analysis (EMA), in accordance with ASME Code Case N-512 [3], was performed for the NMP1 RPV using elastic-plastic fracture mechanics techniques to demonstrate adequate resistance to fracture for service level A and B loadings [4]. According to this analysis, the flaw stability criterion was met for a J-R curve corresponding to a USE of 23 ft-lbs or higher for the 1/4T axial flaw. The stability criterion was easily met because the projected USE for the end of the current license is 40.0 ft-lbs and 42.6 ft-lbs for plates G-307-4 and G-8-1 respectively using the RG 1.99 Rev. 2 method. An equivalent margins analysis for level C and D loadings was developed using similar methods and submitted to NRC [5].

The NRC issued a Request for Additional Information (RAI) regarding the NMP1 EMA submittals based on an Oak Ridge National Laboratory (ORNL) Technical Evaluation Report (TER) [6]. A conclusion of the TER is that the J-R curves used in developing the EMA did not conservatively correlate with USE values for crack extensions greater than 0.1 inch. An independent Code Case N-512 analysis performed by ORNL indicated that the NMP1 plates satisfied Level A and B loading criteria, but with less margin than indicated in reference [4] and concluded that Level C and D loading were not controlling.

The NRC issued a Safety Evaluation Report (SER) of the two EMA submittals [7] indicating that the USE correlating with an acceptable value of $J_{0.1MAT}$ is 40 ft-lbs. It was concluded in the SER therefore that the NMP1 reactor vessel plates have adequate margins of safety against fracture up to 25 EFPY. A new EMA submittal is needed prior to the end of the current license period to support operation beyond 25 EFPY and operation during the period of extended operation.

In 1993, the BWR Owners Group (BWROG) submitted a generic EMA that applies to all BWR RPVs. The NRC approved the generic EMA [19] through issuance of an SER [8]. The generic EMA demonstrates that a USE of 35 ft-lbs in the T-L direction is sufficient to meet Code Case N-512 flaw stability requirements for circumferential flaws in A302B beltline plates in BWR-2 plants. BWRVIP-74-A contains a screening criterion for applicability of the generic EMA for plants that will renew their licenses [9]. To confirm plant specific applicability, surveillance capsule USE data is compared with the drop in USE predicted by RG 1.99 Rev. 2. If the surveillance material USE decreases by an amount less than or equal to the predicted decrease from RG 1.99 Rev. 2, the predicted drop in USE for the limiting material at 54 EFPY is determined using RG 1.99 Rev. 2, Figure 2, while if the surveillance material USE decrease exceeds that predicted for Figure 2, Position 2.2 of the regulatory guide is used to predict the USE decrease at 54 EFPY for the limiting material. For BWR/2 plates the EMA is bounded if the percent decrease in USE is less than or equal to 29.5%.

3.0 Comparison of the Current MPM Technologies Plant Specific EMA to the Methods of BWRVIP-74-A

ASME Code Case N-512 has four requirements to determine the minimum upper shelf energy of RV beltline materials while maintaining margins equivalent to those of 10CFR50, Appendix G.

1) Postulate flaws
2) Determine loadings for ASME Levels A, B, C, D
3) Define materials properties including Young's modulus, yield strength, and the J-integral resistance curve
4) Evaluate the postulated flaws using the criteria of Code Case N-512, Section 2000

To reconcile the present EMA [7] that allows operation of the NMP1 RV to 25 EFPY, to the BWR Owners' Group EMA [8], the methods that both EMAs address the above requirements are compared. In general, this comparison is only made for beltline plates G-8-1 and G-307-4 because they are the only RV material projected to fall below 50 ft-lbs and ASME service loading conditions A and B because these conditions are limiting.

3.1 Beltline Geometry

The dimensions used in the BWR Owners' Group analysis are as follows.

Inner Radius	=	106.7 inch
Wall Thickness	=	7.13 inch
Cladding Thickness	=	0.22 inch

The dimensions used in the MPM analysis are as follows.

Inner Radius	=	106.5 inch
Wall Thickness	=	7.281 inch
Cladding Thickness	=	0.1563 inch

There are minor differences in the dimensions between the two analyses. The effect of this difference and other differences identified later in this report is evaluated in Section 3.6.

3.2 Comparison of Material Properties

3.2.1 Tensile Properties

3.2.1.1 BWR Owners' Group

Tensile properties that were used for all loading conditions for the BWR Owners' Group analysis are as follows [8].
Yield Strength = 69 Ksi
Young's Modulus = 27,700 Ksi
Poisson's Ratio = 0.3

3.2.1.2 MPM Technologies

The tensile properties that were use in the MPM analyses are based on a temperature of 500°F for Loading Conditions A and B [7]. The ASME Code Table I-6.0 was used to calculate Young's modulus.

$E = 26.4 \times 10^6$ psi, at T = 500°F

Poisson's Ratio = 0.33

The yield strengths used for this analysis are room temperature values for unirradiated material taken from reactor vessel surveillance program test results adjusted by approximately 8 Ksi to account for the decrease in yield strength from room temperature to 500°F. The resultant values of yield strength are 61 Ksi and 58 Ksi for plates G-307-4 and G-8-1 respectively [4].

There are differences in the tensile properties used the two analyses. The effect of these differences and other differences identified later in this report is evaluated in Section 3.6.

3.2.2 Initial USE values

3.2.2.1 BWR Owners' Group

There were no plate specimens of the transverse orientation in RVSPs for BWR /2 reactor vessels. USE values were therefore determined by multiplying USE values obtained from longitudinal specimens by 0.65 as required by MTEB 5-2. Since there are too few USE values available for BWR/2 reactor vessel plates to provide a statistically determined lower bound for unirradiated material, the bounding upper shelf value for
BWR /2 plates in the transverse orientation was determined to be the lowest available data point of 49 ft-lbs. USE values for irradiated material were determined using Reg. Guide 1.99, Rev 2.

3.2.2.2 MPM Technologies

USE values for NMP1 RV beltline plates were determined using plant-specific RVSP data. USE for the transverse orientation was determined by multiplying the longitudinal USE data by 0.65. The resultant values of transverse USE are 52.0 ft-lbs and 53.3 ft-lbs for plates G-307-4 and G-8-1 respectively. USE values for irradiated material were determined using Reg. Guide 1.99, Rev 2.

The difference in initial USE values between the two analyses affects the projection of USE for irradiated material with the BWROG analysis giving the more conservative result.

3.3 J-R Curve Model

3.3.1 BWR Owners' Group

For A, B, and C loading conditions a conservative estimate of the J-R curve is taken to be the mean curve minus two standard deviations. For D loading conditions the J-R curve is taken to be the mean curve. To determine the J-R curves for SA302B plate, such as those in the beltline of the NMP1 RV, J-integral values were tied to J_{IC} values. The data generated by Hiser [21] was used to develop a correlation between J_{IC} and USE. It was assumed that J-R curves for SA 302B plates flattened out at J-integral values 30% above J_{IC}. Therefore the maximum J-integral value is 1.3 x J_{IC}.

3.3.2 MPM Technologies

This analysis is also based on a USE-J_{IC} correlation similar to that of the of the BWR Owners' Group. After the initial plateau of the J-R curve is achieved, the J-R curve is assumed to be flat. However, the correlation was based on weld data, plate data in the L-T and T-L orientations from unirradiated and irradiated specimens, whereas the BWR Owners' Group correlation used only SA 302B data.

3.3.3 Comparison of the MPM and BWROG USE-J_{IC} Correlations

The difference between MPM and BWROG USE-J_{IC} correlations led to different J-R curves. The NRC concluded the MPM $J_{0.1}$ values were non-conservative [7]. For example, $J_{0.1}$ values that correspond to a USE value of 40 ft-lbs are 298 and 222 in-lb/in^2 for the MPM and BWROG analyses respectively (See Table 1 of reference [7]). The BWROG J-R curves bound the MPM J-R curves.

3.4 Stress Calculations

3.4.1 Bounding Transients for Levels A and B

Both the BWROG and the MPM analyses use a cooldown rate of 100°F/hr to calculate thermal stress. Stresses due to pressure were calculated using a pressure of 1.1 x design pressure with a safety factor of 1.15 as prescribed by ASME Code Case N-512.

Therefore, the stress calculations are not factors for any difference in the MPM and BWR Owners' Group EMA results for Service Levels A and B.

3.4.2 Bounding Transients for Levels C and D

3.4.2.1 Bounding Transient for Level C (BWROG)

The BWROG analysis [8] used the information in reference [13] to define the bounding transient for Service Level C loading. Although reference [13] is for BWR/6 design, reference [8] indicates that reference [13] bounds the transients of all BWR designs. For BWR/2 design (applicable to NMP1), the most limiting transient for the beltline region for Level C is automatic blowdown. Finite element calculations were performed to determine stresses caused by this transient using a convective heat transfer coefficient of 10,000 Btu/hr-ft^2-°F. In the fracture mechanics analysis, the flaw depth was postulated to be 1/10 of the base metal thickness plus the clad thickness, the stress intensity was calculated using the Raju-Newman method, stress distribution was characterized using a third order polynomial, and included stress intensity due to discontinuity stress induced by the differential thermal expansion of the plate-clad interface.

3.4.2.2 Bounding Transient for Level C (MPM)

The MPM analysis [6] determined blowdown as the limiting transient for Level C conditions. The input values for the transient were similar to that of the BWROG except that the maximum flaw depth was taken to be 1/10 of the vessel wall thickness. Wall thickness in the MPM analysis was defined as base metal thickness plus clad thickness. As a result, the maximum flaw depth in this case was smaller than for the BWROG case leading to smaller maximum stress intensities. However, as pointed out by reference [7], Level C and D conditions are not limiting and will not define the minimum allowable USE for NMP1 RV beltline materials.

3.4.2.3 Bounding Transient for Level D (BWROG)

The BWROG analysis selected the Loss of Coolant Accident as the most limiting Level D loading event [8]. The temperature drops 259°F in 15 seconds while pressure drops to 20 psig. The convective heat transfer coefficient was conservatively assumed to be 10,000 Btu/hr-ft^2-°F. The peak stress was determined to be 76,550 psi at 125 seconds after the initiation of the event.

3.4.2.4 Bounding Transient for Level D (MPM)

The MPM analysis [6] indicates that the limiting transient for Level D is a steam line break where temperature drops approximately 320°F in 300 seconds as pressure falls to 0 psig. The convective heat transfer coefficient was assumed to be 10,000 Btu/hr-ft^2-°F. As with the Level C analysis, the maximum flaw depth was taken to be 1/10 of the vessel wall thickness. The peak stress was determined to be 78,400 psi at 240 seconds after the initiation of the event. Although the MPM analysis predicts slightly higher peak stresses (approximately 2000 psi higher) for Level D conditions, this analysis is not limiting and therefore the difference in analysis has no effect on the minimum allowable USE for NMP1 RV beltline materials.

3.5 Fracture Mechanics Evaluation Method

3.5.1 Postulated Flaw

For Service Levels A and B, both the MPM and BWR Owners' Group analyses use a postulated semi-elliptic flaw with a 1/4T depth and a length equal to 6 times the depth. Therefore, postulated flaw size is not a factor in any difference in results of the BWROG and MPM analyses.

For Service Levels C and D, both the MPM and BWR Owners' Group analyses use a postulated semi-elliptic flaw with a length equal to 6 times the depth. As discussed in Section 3.3.2.2, the crack depths for C and D loading conditions were different.

3.5.2 Stress Intensity Factors and Applied J Calculation

Both the MPM and BWR Owners' Group analyses use the applied J and stress intensity factors as prescribe in Code Case N-512. Therefore, the applied J and stress intensity factors are not factors for any difference in the MPM and BWR Owners' Group EMA results.

3.6 Evaluation of Differences in the BWROG and MPM Fracture Mechanics Calculations Caused by Differences Input Values

To assess the impact of the slight differences in beltline dimensions and tensile properties, $J_{applied}$ was calculated using the Code Case N-512 equations for A and B loading conditions except for the F_3 equation where a more conservative equation was used as indicated in reference [8].

K_{Ip}	=	$(SF)p[1 + (R_i/t)](\pi a)^{0.5}F_1$	axial flaw, psi-in$^{1/2}$	
K_{Ip}	=	$(SF)p[1 + (R_i/2t)](\pi a)^{0.5}F_2$	circumferential flaw, psi-in$^{1/2}$	
F_1	=	$0.982 + 1.006(a/t)^2$		
F_2	=	$0.885 + 0.233(a/t) + 0.345(a/t)^2$		
K_{It}	=	$(CR)t^{2.5}F_3$		
F_3	=	$0.690 + 3.127(a/t) - 7.435(a/t)^2 + 3.532(a/t)^3$		
SF	=	Factor of safety	=	1.15 for A and B conditions
p	=	Pressure, psig		
R_i	=	Inside radius of RV at the beltline, inch		

t	=	RV wall thickness, inch	
a	=	Crack depth, inch	
CR	=	Cooldown rate, 100°F/hr	
a_e	=	$a + (1/(6\pi))[(K_{Ip} + K_{It})/\sigma_y]^2$	= effective crack depth, inch
σ_y	=	Yield Strength, psi	
$J_{applied}$	=	$(K_{Ip}' + K_{It}')^2/E'$, in-lb/in^2	
E'	=	$E/(1-v^2)$, psi	
E	=	Young's Modulus, psi	
v	=	Poisson's Ratio	

K_{Ip}' and K_{It}' are calculated by substituting a_e for crack length in the above equations.

It can be seen from the results of the calculations summarized in Table 3.1 that there are only slight differences in $J_{applied}$ caused by differences in input data. Results from both the BWROG and MPM $J_{applied}$ values are conservative because the yield strength of material irradiated to 3.39 x 10^{18} n/cm^2 will be higher than the yield strength values of the BWROG and MPM analyses where yield strength values were taken from unirradiated materials.

Table 3.1 - $J_{applied}$ Values That Apply to the NMP1 RPV Beltline Plates (Axial Orientation) [20]

Calculation	R_i (inch)	a (inch)	t (inch)	σ_y (psi)	E (psi)	v	$J_{applied}$ (in-lb/in^2)
BWROG	106.7	1.7825	7.13	69,000	2.77 x 10^7	0.30	201.2
MPM (G-8-1)	106.5	1.82025	7.281	58,000	2.64 x 10^7	0.33	210.1
MPM (G-307-4)	106.5	1.82025	7.281	61,000	2.64 x 10^7	0.33	210.0

4.0 Evaluation of the Applicability of the BWRVIP Equivalent Margin Analysis to the NMP1 RPV

4.1 Input Data

In order to predict USE using Regulatory Guide 1.99, Rev 2, at the end of the period of extended operation, several parameters must be defined or projected. These parameters are unirradiated USE, copper content of the RPV materials, and the 1/4T neutron fluence at the end of the period of extended operation. Copper, nickel, and phosphorous contents and unirradiated USE values are shown for NMP1 RPV beltline materials in Table 4-1. Transverse unirradiated USE values for NMP1 plates were calculated by multiplying the longitudinal value by 0.65.

Table 4.1 - Copper, Nickel, Phosphorus, and Unirradiated USE Values for the NMP1 Beltline Materials

Material ID	Longitudinal USE, ft-lbs	Transverse USE, ft-lbs	Copper Content, wt%	Nickel Content, wt%	Phosphorus Content, wt%
1248 (weld)	N/A	90.0 [18]	0.214 [16]	0.076 [16]	0.015 [18]
G-8-1 (plate)	82 [18]	53.3 [18]	0.236 [17]	0.503 [17]	0.021 [18]
G-307-4 (plate)	80 [18]	52.0 [18]	0.27 [17]	0.53 [17]	0.019 [18]

Neutron fluence values at the end of the period of extended operation are needed to predict the upper shelf at the end of the period of extended operation. For consistency with Reference [9], the end of the period of extended operation was defined as 54 EFPY for NMP1. The neutron fluence values of reference [11] were used to determine the projected neutron fluence values to 54 EFPY. Since the issuance of reference [11], transport calculations were carried out, in full compliance with RG 1.190, using the DORT two-dimensional discrete ordinates code and the BUGLE-96 cross section library [10, 22]. The results of reference [10] indicate that the neutron fluence values of reference [11] are conservative, where the inside radius fluence values are 2.70×10^{18} n/cm^2 [11] and 1.96×10^{18} n/cm^2 [10] at 28 EFPY. Therefore, the projections of upper shelf energy decreases in this report are conservative.

4.2 Projected NMP1 Neutron Fluence at 54 EFPY

The 1/4T fluence prediction at 54 EFPY was scaled up from a 1/4T fast neutron fluence of 1.76E+18 n/cm^2 at 28 EFPY [11] (Section 4.1). The 54 EFPY inner surface neutron fluence was similarly determined using an inner radius fluence of 2.70×10^{18} n/cm^2 at 28 EFPY. The resultant fluence projections to 54 EFPY are 5.21×10^{18} n/cm^2 and 3.39×10^{18} n/cm^2 for the inner surface and 1/4T position respectively.

4.3 Acceptance Criteria

The projected value at the end of the period of extended operation must be compared to the acceptance criteria of 10CFR50 Appendix G (50 ft-lbs) and those of Reference [10] as shown in Table 4.2.

Table 4.2 - Acceptable USE Values for BWR/2 Based on BWRVIP-74-A Analysis

Orientation	Equivalent Margin Required USE (ft-lb)	Conclusion
Longitudinal	≥ 50	Acceptable
Transverse	≥ 35	Acceptable

4.4 Projections of Upper Shelf Energy for the NMP1 RPV at 54 EFPY

Projections of USE for the NMP1 RPV was made based on percentage decreases in USE as determined by Reg. Guide 1.99, Rev 2 at 1/4T. Table 4.3 summarizes the results of the projection.

Table 4.3 - Projected USE Values for the NMP1 RPV Beltline Materials

Material ID	Cu Content, wt %	1/4T Neutron Fluence at 54 EFPY, n/cm^2	Initial USE*, ft-lbs	Percent Decrease in USE	Projected USE at 54 EFPY, ft-lbs
1248 (weld)	0.214 [16]	3.39×10^{18}	90 [18]	28.5	64.0 [20]
G-8-1 (plate)	0.236 [17]	3.39×10^{18}	53.3 [18]	24.0	40.0 [20]
G-307-4 (plate)	0.27 [17]	3.39×10^{18}	52.0 [18]	28.5	37.2 [20]

* Initial USE values for plates are for the transverse orientation converted from the longitudinal value by multiplying the longitudinal value by 0.65 in accordance with Branch Technical Position – MTEB 5-2

The NMP1 beltline weld is projected to remain above 50 ft-lbs up to 54 EFPY and therefore is projected to meet the requirements of 10CFR50, Appendix G through the period of extended operation. Both NMP1 RPV beltline plates are projected to fall below 50 ft-lbs before the end of the period of extended operation. However, the minimum allowable USE is 35 ft-lbs for plates in the transverse orientation according to the BWRVIP-74-A EMA. Table 4.3 indicates that both beltline plates will remain above 35 ft-lbs through the period of extended operation and therefore have margins equivalent to those of Appendix G.

Table 4.4 - Equivalent Margin Analysis Plant Applicability Verification Form for BWR/2 Plate (See Reference 10, Table B-3)

NMP1 PLATE G-8-1

Surveillance Plate USE:

%Cu	=	N/A
Capsule Fluence	=	N/A
Measured % Decrease	=	N/A
R.G. 1.99 Predicted % Decrease	=	N/A

Limiting Beltline Plate USE:

%Cu	=	0.236
54 EFPY Fluence	=	3.39×10^{18} n/cm^2
R.G. 1.99 Predicted % Decrease	=	24.0
Adjusted % Decrease	=	0

24.0% ≤ 29.5%, so vessel plates are bounded by equivalent margin analysis

NMP1 PLATE G-307-4

Surveillance Plate USE:

%Cu	=	N/A
Capsule Fluence	=	N/A
Measured % Decrease	=	N/A
R.G. 1.99 Predicted % Decrease	=	N/A

Limiting Beltline Plate USE:

%Cu	=	0.27	
54 EFPY Fluence	=	3.39×10^{18} n/cm^2	
R.G. 1.99 Predicted % Decrease	=	28.5	(R.G. 1.99, Figure 2)
Adjusted % Decrease	=	0	(R.G. 1.99, Position 2.2)

28.5% ≤ 29.5%, so vessel plates are bounded by equivalent margin analysis

5.0 Projection of NMP1 USE Values Using the NUREG/CR-6551 Upper Shelf Energy Models

Since Reg. Guide 1.99, Rev 2 were issued, many technological advancements have been made that directly affect the current and future regulatory framework for reactor vessel integrity. These advancements include new embrittlement correlations based on improved physical understanding of radiation embrittlement and an expanded data base (NUREG/CR-6551, E900-2002) potentially leading to Reg. Guide 1.99, Rev 3

As a result of these new technologies, the regulatory framework may change as a result of NRC new rulemaking, changes in the ASME Code, and changes in ASTM standards. The purpose of this section is to anticipate the potential change to the projection of USE value for RPV beltline materials and assess the impact of the changes. The recommended USE model is equation 3-2 of Reference [1].

$$USE_i = 0.0570\, USE_u^{1.456} + A - [17.5 f(Cu)(1 + 1.17 Ni^{0.8894}) + 305P](\phi t)^{0.2223}$$

Where:

USE_i	=	USE as a result of neutron irradiation
USE_u	=	Unirradiated USE
A	=	55.4 for welds
	=	61.0 for plates
	=	66.3 for forgings
(ϕt)	=	Neutron fluence x 10^{19} (E > 1.0 MeV)
Ni	=	Nickel content, wt%
P	=	Phosphorous content, wt%
$f(Cu)$	=	$0.5 + 0.5\tanh[(Cu - 0.138)/0.0846]$
Cu	=	Copper content, wt%

RPVDATA does not have values of phosphorous content and irradiation temperature. Irradiation temperatures were taken from Embrittlement Data Base [5]. Phosphorous content was set at 0.015 wt% for all materials. This simplification has little effect on the evaluation because the effect phosphorous content on USE drop is minimal.

Table 3 indicates that upper shelf values will increase at the end of the period of extended operation; an apparent inconsistency with the physical understanding of radiation embrittlement. Potential reasons for this behavior include:

1) In the data used for fitting, there were numerous measured increases in USE. In fact 113 of the 662 "drops" in USE in the fitting set were negative (increases in USE with irradiation), as noted on page 16 of CR-6551. The form of the USE function is able to go both positive and negative from the initial unirradiated USE_u because the data showed increases in USE with irradiation. Increases in USE could be caused by data scatter, but it is also possible that the measured USE actually initially increases at low neutron fluence as calculated.

2) The NMP1 beltline plates have values of USE_u that are outside the range of all the data used for the USE fit, as shown in NUREG/CR-6551, Table 5.2, page 47, therefore this calculation is an extrapolation. Typical values of USE_u (90% range) for plates in the transverse orientation ranged from 74 to 126 ft-lb, therefore starting at less than 54 ft-lb is a large extrapolation of the correlation for plates.

3) The uncertainty on the USE_i calculated from the model is given by the standard error (Se = 11.2 ft-lb). Therefore, the estimated value of USE_i (90% range) should be considered to be within scatter of the data and that there is little change in USE up to a neutron fluence of 3.4×10^{18} n/cm^2.

The NUREG/CR-6551 correlation may not be the final correlation used in a revision to Reg. Guide 1.99. However, it is evident that any new predictions of decreases in USE based on the NUREG/CR-6551 data will be small. Therefore, it is anticipated that a change in Regulatory Guide 1.99 with respect to predictions of USE values will provide favorable results for the NMP1 RPV beltline materials.

Table 5.1 – Projected Upper Shelf Energy at 54 EFPY Using NUREG/CR-6551 for NMP1 RPV Beltline Materials [20]

Material ID	1/4T Neutron Fluence at 54 EFPY, n/cm^2	Initial USE, ft-lbs	Projected USE at 54 EFPY, ft-lbs
1248 (weld)	3.39×10^{18}	90 [18]	78.5 [20]
G-8-1 (plate)	3.39×10^{18}	53.3 [18]	54.1 [20]
G-307-4 (plate)	3.39×10^{18}	52.0 [18]	52.5 [20]

6.0 Conclusions

The conclusions that can be drawn from the evaluation in this report are as follows.

- The differences in the BWROG and MPM equivalent margin analyses have minimal effect on Applied J values. Both analyses give conservative results.
- The BWROG equivalent margin analysis predicted lower R-curves than the MPM analysis. Therefore the BWROG analysis gave more conservative results.
- Based on the above two conclusions, the BWROG analysis bounds the MPM analysis.
- Nine Mile Point Unit 1 RPV beltline plates do not meet the 10CFR50, Appendix G 50 ft-lb criterion through the end of the period extended operation. Although plates G-8-1 and G-307-4 are projected to fall below 50 ft-lbs before 54 EFPY, the projected USE at 54 EFPY are above the BWROGVIP-74-A criterion of 35 ft-lbs. Therefore, the NMP1 RPV is projected to have adequate upper shelf toughness through the period of extended operation.
- It is anticipated that a change in Regulatory Guide 1.99 with respect to predictions of USE values will provide favorable results for the NMP1 RPV beltline materials.

7.0 References

[1] ASTM E 185 –73, -79,and –82, "Standard Practice for Conducting Surveillance Tests for Light Water Cooled Nuclear Power Reactor Vessels".

[2] Branch Technical Position – MTEB 5-2, "Fracture Toughness Requirements", part of U.S. Nuclear Regulatory Commission Standard Review Plan," Section 5.3.2, "Pressure Temperature Limits, Rev. 1 July 1981.

[3] ASME Boiler and Pressure Vessel Code Nuclear Code Cases, Code Case N-512, 1998.

[4] "Elastic-Plastic Fracture Mechanics Assessment of Nine Mile Point Unit 1 Beltline Plates for Service Level A and B Loadings," NMPC Project 03-9425, MPM-USE-129215, Final Report, December 16, 1992.

[5] "Final Report, Elastic Plastic Fracture Mechanics Assessment of Nine Mile Point Unit 1 Beltline Plates for Service Level C and D Loadings", NMPC Project 03-9425, MPM-USE-293216.

[6] Merkle, J. G., Shum, K. M., Technical Evaluation Report (TER): Review of NMPC Project 03-9425 Reports, "Elastic-Plastic Fracture Mechanics Assessment of Nine Mile Point Unit 1 Beltline Plates for Service Level A and B Loadings (MPM-USE-129215) and Service Level C and D Loadings (MPM-USE-293216)", December 21, 1993, Oak Ridge National Laboratory.

[7] Safety Evaluation by the Office Of Nuclear Reactor Regulation Related to Reports MPM-USE-129215 and MPM-USE-293216 on Upper–Shelf Energy Equivalent Margins Analysis Niagara Mohawk Power Corporation, Nine Mile Point Nuclear Station Unit No. 1, Docket No. 50-220, enclosure 1 to letter from Robert A. Capra (USNRC) to Mr. B. Ralph Sylvia (NMPC) re: "Elastic-Plastic Fracture Mechanics Assessment of Nine Mile Point Nuclear Station Unit No. 1 Reactor Vessel Beltline Plates, April 26, 1994.

[8] Safety Evaluation by the Office Of Nuclear Reactor Regulation, BWR Owner's Group Topical Report NEDO-32205, Revision 1 on Upper Shelf Energy Equivalent Margin Analysis, Materials Integrity Section , Materials and Chemical Engineering Branch, Division of Engineering" enclosure to Letter from James T. Wiggins (USNRC) to Mr. Lesley A. England, re: Acceptance for Referencing of Topical Report NEDO-32205, Revision 1, "10CFR50 Appendix G Equivalent Margins analysis for Low Upper Shelf Energy in BWR/2 through BWR/6 Vessels".

[9] BWRVIP-74-A: BWR Vessel and Internals Project, BWR Reactor Pressure Vessel Inspection and Flaw Evaluation Guidelines for License Renewal; 1008872; Final Report June 2003.

[10] MPM-703782, "Response to NRC Request for Additional Information: Nine Mile Point Unit 1 P-T Curves, MPM Technologies Inc., July 2003

[11] Manahan, M.P., Report to Niagara Mohawk Power Corporation, MPM Report Number MPM-59838 entitled, "Pressure-Temperature Operating Curves for Nine Mile Point Unit 1", dated May 1998.

[12] E. D. Eason, J. E. Wright, G. R. Odette, "Improved Correlations for Reactor Pressure Vessel Steels," NUREG CR 6551, November 1998.

[13] "Reactor Cycles – BWR/6 Standard," GE Drawing No. 795E949, Revision 0, July 1981 (GE proprietary information).

[14] Generic Letter 92-01, Revision 1, Supplement 1, Reactor Vessel Structural Integrity," Letter from Niagara Mohawk Power Corporation (NMP1L 1004) to U.S. Nuclear Regulatory Commission Dated November 20, 1995.

[15] NMP1L 1358, Letter from Richard B. Abbot to USNRC, NMP1 Docket No. 50-220 DPR-63, Subject: "Request for Additional Information Regarding Reactor Pressure Vessel Structural Integrity at Nine Mile Point Nuclear Station Unit 1 (TAC No. MA1200), September 4, 1998.

[16] MPM-703782, "Response to NRC Request for Additional Information: Nine Mile Point Unit 1 P-T Curves, MPM Technologies Inc., July 2003.

[17] NMP1L 0747, Letter from C.D. Terry to USNRC, re: NMP1 Docket No. 50-220, DPR-63, TAC No. M83486, Subject: "Generic Letter 92-01, Revision 1, Reactor Vessel Structural Integrity, Upper Shelf Energy Estimates for Beltline Welds.

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