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

Donald C. Cook Nuclear Plant Unit 2
AMERICAN SOCIETY OF MECHANICAL ENGINEERS CODE,
SECTION XI REPAIR REQUIREMENTS
PREEMPTIVE WELD OVERLAY – STRESS SUMMARIES (TAC NO. MC9305)

Reference:
1. Letter from Daniel P. Fadel, Indiana Michigan Power Company (I&M), to U. S. Nuclear Regulatory Commission (NRC) Document Control Desk, "Donald C. Cook Nuclear Plant Unit 2, Proposed Alternative to the American Society of Mechanical Engineers Code, Section XI Repair Requirements," AEP:NRC:5055-13, Accession Number ML053570112, dated December 21, 2005.
2. "Cook Unit 2: Draft Request for Additional Information on Relief Request, Re: Preemptive Weld Overlay (TAC MC9305)," Accession Number ML060340609, dated February 15, 2006.
3. Letter from Joseph N. Jensen, I&M, to NRC Document Control Desk, "Donald C. Cook Nuclear Plant Unit 2, Proposed Alternative to the American Society of Mechanical Engineers Code, Section XI Repair Requirements," AEP:NRC:6055, Accession Number ML060620063, dated March 1, 2006.

By Reference 1, I&M proposed an alternative to the American Society of Mechanical Engineers Code, Section XI (ASME Section XI) repair requirements. I&M proposed the use of preemptive weld overlays (PWOLs) using Code Cases N-504-2 and N-638-1, with modifications, to address dissimilar metal weld concerns for piping connected to the Unit 2 pressurizer. Reference 2 documented an NRC request for additional information regarding the proposed alternative. Reference 3 provided I&M's response to the additional information requested by the NRC. Reference 3 included a commitment by I&M to provide stress analysis summaries for the piping that is to be repaired using PWOLs, i.e., the pressurizer safety/relief lines, spray line, and surge line. Additionally, the NRC has requested a summary of the PWOL fatigue crack growth analysis for the piping.

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Attachment 1 to this letter provides the stress analysis summary. Attachment 2 provides the fatigue crack growth analysis summary.

This letter contains no new commitments. Should you have any questions, please contact Mr. Michael K. Scarpello, Regulatory Affairs Supervisor, at (269) 466-2649.

Sincerely

Joseph N. Jensen
Site Vice President

RV/dmb

Attachments:
1. D. C. Cook Pressurizer – Safety/Relief, Spray, and Surge Nozzles Weld Overlay Stress Analysis Summary – ASME Section III Criteria
2. D. C. Cook Pressurizer – Safety/Relief, Spray, and Surge Nozzles Weld Overlay Fatigue Crack Growth Analysis Summary

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D. C. Cook Pressurizer-
Safety/Relief, Spray and Surge Nozzles
Weld Overlay Stress Analysis Summary –
ASME Section III Criteria

Abbreviations Used in this Attachment

ASME	American Society of Mechanical Engineers
B&PV	Boiler and Pressure Vessel Code
ksi	thousand pounds per square inch
OBE	operating basis earthquake

D.C. COOK PRESSURIZER- SAFETY/RELIEF, SPRAY, & SURGE NOZZLES WELD OVERLAY STRESS ANALYSIS SUMMARY – ASME SECTION III CRITERIA

1 Introduction

ASME B&PV Code Section III stress analyses were performed for D.C. Cook Unit 2 pressurizer nozzles repaired with weld overlays (Safety/Relief, Spray, and Surge nozzles) in compliance with ASME Code Case N-504-2, Paragraph (g)(1). 3-D ANSYS finite element models for the three nozzles with weld overlays were developed, and detailed finite element analyses (thermal and structural) were conducted. The purpose of these calculations is to qualify the weld overlay design to the requirements of the 1998 ASME B&PV Code, Section III criteria. The weld overlay size (thickness and length) was calculated per ASME B&PV Code, Section XI, Division I, and ASME Code Case N-504-2.

Thermal stresses were determined for the appropriate design transients and a fatigue analysis was performed. The design conditions, as well as the thermal transients, were investigated with the finite element models. The results of the thermal analysis were reviewed by examining the magnitude of the temperature difference between critical locations in the models at all time points of interest (i.e., when the maximum thermal stresses may develop). The stresses due to the nozzle external loads were conservatively calculated and added to the stresses resulting from internal pressure and thermal gradients. The applicable criteria of the 1998 ASME B&PV Code, Section III requirements were met.

It should be noted that the results of the weld overlay stress analysis summarized below are based on conservative inputs. The external loads are derived from allowable stresses and the operating design transients were developed on conservative basis.

2. Results

2.1 Primary Stress Intensity Criteria for Design Conditions and All Service Level Loadings

The weld overlay applied on the outside surface relieves the nozzle primary stress burden resulting from the applied internal pressure and external loads. Therefore, ASME B&PV Code Section III primary stress requirements for design conditions and all service level loadings as specified in NB-3221, NB-3222, NB-3223, NB-3224, and NB-3225 have been satisfied for the nozzles, welds with overlays, safe ends, and piping elbows under investigation. Therefore, the primary stress intensity criteria for design conditions and all service level loadings are bounded by the original design.

2.2 Minimum Required Pressure Thickness and Reinforcement Area Criteria

Adding weld overlay will increase the nozzle wall thickness. As a result, the ASME B&PV Code Section III requirements contained in NB-3324 and NB-3330 are satisfied.

2.3 Primary + Secondary Stress Intensity (NB-3222.2)

The final stress intensity range is obtained by conservatively adding the maximum membrane plus bending stress intensity (SI) range during transients to that due to the applied external loads (thermal + OBE). Although the final SI range at most locations under investigation is below the $3S_m$ limit, there are several locations where the limit is exceeded. The highest SI range in each nozzle is listed as follows:

Safety/Relief Nozzle = 55.1 ksi > $3S_m$= 48.0 ksi
Spray Nozzle = 70.9 ksi > $3S_m$= 51.6 ksi
Surge Nozzle = 129.4 ksi > $3S_m$= 48.4 ksi

Per NB-3228.5 of the ASME B&PV Code Section III, the $3S_m$ limit on the primary plus secondary SI range may be exceeded provided that the following six requirements are met.

2.3.1 1st Requirement (NB-3228.5(a)):

Primary plus secondary membrane plus bending SI range, excluding thermal bending stresses, shall be less than $3S_m$.

Safety/Relief and Spray Nozzles: the requirement has been satisfied for all the locations where the SI range is above the $3S_m$ limit.

Surge Nozzle: the $3S_m$ limit is still exceeded at two locations (79.9 ksi, 82.6 ksi > $3S_m$ = 56.1 ksi). Therefore the ASME code requirement is not met at these locations and as a result a detailed evaluation based on the elastic-plastic approach for the Heat-up Cool-down (HUCD) transients with insurges of 320°F ΔT was performed.

Elastic – Plastic Analysis of the Surge Nozzle Weld Overlay for HUCD Transients: the elastic-plastic analysis was performed in accordance with NB-3228.4-Shakedown analysis. The ASME Code criteria NB-3228.4 are met.

2.3.2 2nd – 6th Requirements (NB-3228.5(b-f)):

These requirements are met for the Safety/Relief and Spray Nozzles at all locations where the $3S_m$ limit is exceeded.

2.4 Fatigue Analysis

The fatigue usage factor of the three nozzles is conservatively calculated for 60 years of operation (40 design life plus 20 years life extension). Below is a summary:

Safety/Relief Nozzle: the highest cumulative fatigue usage factor = 0.157 < 1.0 (ASME Criteria)
Spray Nozzle: the highest cumulative fatigue usage factor = 0.738 < 1.0 (ASME Criteria)
Surge Nozzle: the highest cumulative fatigue usage factor = 0.9 < 1.0 (ASME Criteria)

3. Conclusion

Based on the above results, the requirements of Paragraph (g)(1) of ASME Code Case N-504-2 are met, and the repair has been shown to be acceptable for the remaining service life of D.C. Cook Unit 2.

D. C. Cook Pressurizer – Safety/Relief, Spray, and Surge Nozzles Weld Overlay Fatigue Crack Growth Analysis Summary

Abbreviations Used in this Attachment

ASME	American Society of Mechanical Engineers
FCG	flaw crack growth
in.	inches
psi	pounds per square inch
WOL	Weld overlay

DC COOK PRESSURIZER - SAFETY/RELIEF, SPRAY, & SURGE NOZZLES WELD OVERLAY FATIGUE CRACK GROWTH ANALYSIS SUMMARY

1. Introduction

Due to the susceptibility of Alloy 600 and its associated weldments Alloy 82/182 to primary water stress corrosion cracking (PWSCC), American Electric Power (AEP) plans to install full structural weld overlays at the safety, relief, spray and surge nozzles of the pressurizer at DC Cook Unit 2 (CNP-2). A repair procedure has been developed where the dissimilar metal (DM) Alloy 82/182 weld and butter and stainless steel (SS) safe end and weld, and a portion of both the nozzle and attached pipe are overlaid with PWSCC resistant Alloy 52 material.

The overlays were analyzed for potential growth of a worst case flaw in the nozzle/pipe welds. It was postulated that a 360° circumferential flaw would propagate by PWSCC through the thickness of the Alloy 82/182 weld and butter, to the interface with the Alloy 52 overlay material. Although PWSCC would not continue to occur in the Alloy 52 overlay, it was further conservatively postulated that a small fatigue initiated flaw forms in the Alloy 52 overlay and combines with the PWSCC crack in the Alloy 82/182 weld to form a large part through-wall full circumferential flaw that would propagate into the Alloy 52 overlay by fatigue crack growth under cyclic loading conditions.

Fracture mechanics analyses were performed to evaluate this worst case flaw in the repair configuration in compliance with ASME Code Case N-504-2, Paragraph (g)(2). These evaluations considered welding residual, steady state and normal/upset condition transient stresses with the associated number of transient cycles to predict the final flaw size at the end of license extension at DC Cook Unit, which equates to a 32 year service life. These evaluations demonstrated that the postulated circumferential flaw met the 1989 ASME Code Section XI, Appendix C acceptance criteria. An additional check was made on the primary membrane stresses in the remaining ligament under normal operating conditions. These analyses were performed for both the Alloy 82/182 weld as well as the stainless steel weld joining the safe end to the piping.

2. Results

2.1 Safety/Relief Nozzles

2.1.1 Flaw Growth Results

		DM WELD OVERLAY	SS WELD OVERLAY
Min WOL thickness, in.	t_{wol} =	0.4720 in.	0.2150 in.
Additional WOL thickness for FCG, in.	Δt_{wol} =	0.0070 in.	0.0030 in.
Initial flaw size, in.	a_i =	1.4150 in.	0.6450 in.
Final flaw size after 32 years, in.	a_f =	1.4201 in.	0.6470 in.
Flaw growth, in.	Δa =	0.0051 in.	0.0020 in.
Final crack depth to thickness ratio,	a/t =	0.7498	0.7498

2.1.2 Limit Load Analysis Results

At the final crack depth, the plastic collapse stress calculated according to ASME Code Section XI, Appendix C is compared to the failure bending stress in the pipe, accounting for safety factors for normal/upset and emergency/faulted conditions. At both overlaid locations (the DM and SS welds), the plastic collapse stress exceeds the failure bending stress, precluding failure by net section collapse.

Overlay at DM Weld

	Normal/Upset	Emergency/Faulted
Plastic collapse stress (psi)	30,467	30,188
Failure bending stress (psi)	8,214	9,761

Overlay at SS Weld

	Normal/Upset	Emergency/Faulted
Plastic collapse stress (psi)	26,609	25,873
Failure bending stress (psi)	19,142	22,884

2.1.3 Primary Membrane Stress Considerations

The applied primary membrane stress in the remaining ligament is less than the operating temperature yield stress.

Overlay at DM Weld	
Yield stress (psi)	27,500
Membrane stress (psi)	10,925

Overlay at SS Weld	
Yield stress (psi)	27,500
Membrane stress (psi)	21,151

2.2 Spray Nozzle

2.2.1 Flaw Growth Results

		DM WELD OVERLAY	SS WELD OVERLAY
Min WOL thickness, in.	t_{wol} =	0.3320 in.	0.1810 in.
Additional WOL thickness for FCG, in.	Δt_{wol} =	0.0010 in.	0.0130 in.
Initial flaw size, in.	a_i =	0.9950 in.	0.4050 in.
Final flaw size after 32 years, in.	a_f =	0.9952 in.	0.4171 in.
Flaw growth, in.	Δa =	0.0002 in.	0.0121 in.
Final crack depth to thickness ratio,	a/t =	0.7494	0.6963

2.2.2 Limit Load Analysis Results

At the final crack depth, the plastic collapse stress calculated according to ASME Code Section XI, Appendix C is compared to the failure bending stress in the pipe, accounting for safety factors for normal/upset and emergency/faulted conditions. At both overlaid locations (the DM and SS welds), the plastic collapse stress exceeds the failure bending stress, precluding failure by net section collapse.

Overlay at DM Weld	Normal/Upset	Emergency/Faulted
Plastic collapse stress (psi)	30,055	29,828
Failure bending stress (psi)	14,404	11,225

Overlay at SS Weld	Normal/Upset	Emergency/Faulted
Plastic collapse stress (psi)	32,581	31,963
Failure bending stress (psi)	32,133	25,413

2.2.3 Primary Membrane Stress Consideration

The applied primary membrane stress in the remaining ligament is less than the operating temperature yield stress.

Overlay at DM Weld

Yield stress (psi)	27,500
Membrane stress (psi)	11,734

Overlay at SS Weld

Yield stress (psi)	27,500
Membrane stress (psi)	17,544

2.3 Surge Nozzle

2.3.1 Flaw Growth Results

		DM WELD OVERLAY	SS WELD OVERLAY
Min WOL thickness, in.	t_{wol} =	0.5270 in.	0.5440 in.
Additional WOL thickness for FCG, in.	Δt_{wol} =	0.0790 in.	0.0040 in.
Initial flaw size, in.	a_i =	1.5800 in.	1.6310 in.
Final flaw size after 32 years, in.	a_f =	1.6389 in.	1.6338 in.
Flaw growth, in.	Δa =	0.0589 in.	0.0028 in.
Final crack depth to thickness ratio,	a/t =	0.7497	0.7498

2.3.2 Limit Load Analysis Results

At the final crack depth, the plastic collapse stress calculated according to ASME Code Section XI, Appendix C is compared to the failure bending stress in the pipe, accounting for safety factors for normal/upset and emergency/faulted conditions. At both overlaid locations (the DM and SS welds), the plastic collapse stress exceeds the failure bending stress, precluding failure by net section collapse.

Overlay at DM Weld

	Normal/Upset	Emergency/Faulted
Plastic collapse stress (psi)	27,636	27,401
Failure bending stress (psi)	19,296	19,826

Overlay at SS Weld

	Normal/Upset	Emergency/Faulted
Plastic collapse stress (psi)	27,765	27,524
Failure bending stress (psi)	19,309	20,162