Consumers Power
POWERING MICHIGAN'S PROGRESS
Palisades Nuclear Plant: 27780 Blue Star Memorial Highway, Covert, MI 49043

G B Slade
General Manager

August 31, 1990

Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555

DOCKET 50-255 - LICENSE DPR-20 - PALISADES PLANT -
UPPER SHELF ENERGY IN REACTOR BELTLINE

Consumers Power Company's July 16, 1990 response to NRC letter dated May 14, 1990 concerning upper shelf energy (USE) qualification of the Palisades reactor beltline material stated that recent analysis had resulted in the preliminary conclusion that the beltline material would be qualified (USE no less than 50 ft-lbs) until 2032. Thus, there would be no reason for Consumers Power Company (CPC) to qualify the material in accordance with Section V.C. of 10CFR50 Appendix G.

CPC's July 16, 1990 letter further states that the final results of our recent analysis would be submitted before September 1, 1990. The attachment to this letter is our recent analysis which concludes that the Palisades reactor beltline material USE will remain at greater than 50ft-lbs until the year 2032 - well beyond the scheduled end-of-plant life in the year 2011.

Gerald B Slade
General Manager

CC Administrator, Region III, USNRC
NRC Resident Inspector-Palisades

Attachment

OC-0890-0402-NL02

A001 1/1

ATTACHMENT

Consumers Power Company
Palisades Plant
Docket 50-255

LOW UPPER SHELF ENERGY MATERIAL IN REACTOR VESSEL BELTLINE (PLATE MATERIAL IN TRANSVERSE DIRECTION) (FINAL)

August 31, 1990

33 Pages

OC-0890-0402-NL02

Consumers Power
POWERING MICHIGAN'S PROGRESS

PALISADES NUCLEAR PLANT
ENGINEERING ANALYSIS WORK SHEET

EA - P-PTS-90-011R

Title: Low USE (upper Shelf Energy) material in Reactor Vessel Beltlines (Plate Material in Transverse Direction) (Final)

INITIATION AND REVIEW

Rev #	Description	Initiated By	Initiated Date	Initiator Appd By	Review Method Check (✓) Alt Calc	Det Rvw	Qual Test	Technically Reviewed By	Technically Reviewed Date	Reviewer Appd By
0	Original Issue	OP Jolly	7/30/90	[signature]	—	✓		[signature]	8/24/90	[signature]

Reference/Comment

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8.2	NOD 3110 Forms & checklist forms.	—
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Form 3619 6-89

	Reference/Comment
1.0 OBJECTIVE This EA is being developed in response to NRC's concern Ref. 3.4, to show that upper shelf energy (USE) remains above 50 ft-lbs during the Palisades operating E-O-L date of 2011.	Ref. 3.3 & 3.6
2.0 SUMMARY For the Palisades Reactor Vessel, USE of SA302 Grade B, plate material in the transverse direction remain above 50 ft-lbs until year 2032, which is beyond the nominal operating E-O-L date of 2011. This analysis is based upon the fact that the fluence rate will remain the same or lower from Cycle 9 onwards. Initial USE's of the plate material are the same as documented in Ref. 3.8 for NRC submittal.	

Reference/Comment

3.0 REFERENCES

3.1 EA-P-PTS-90-011
"Low USE (Upper Shelf Energy) Material in Reactor Vessel Beltlines (Plate Material in Transverse Direction) (PRELIMINARY)".

3.2 Letter RW Smedley to NRC (May 17, 1990) "Docket 50-255 - License DPR-20-Palisades Plant - Compliance with Pressurized Thermal Shock Regulation 10 CFR 50.61 and Regulatory Guide 1.99 Revision 2 (Tack NO. 59970).

3.3 Action Item Record NO. A-NL-90-93 "Low Upper Shelf Energy Material in Reactor Vessel Beltline per Appendix G of 10 CFR 50".

3.4 Letter from NRC to K.W. Berry, Dated May 14, 1990. "Low Upper Shelf Energy Material in Reactor Vessel Beltlines".

3.5 Regulatory Guide 1.99 Revision 2, "Radiation Embrittlement of Reactor Vessel Materials, May 1988".

3.6 Letter from RW Smedley to NRC, Dated July 16, 1990. "Docket 50-255- License DPR-20 - Palisades Plant - Upper Shelf Energy of Material in

Reference/Comment

Reactor Beltline".

3.7 C-E Report P-NLM-019, April 1, 1971 "Summary Report on Manufacture of Test Specimens and Assembly of Capsules For Irradiation Surveillance of Palisades Reactor Vessel Materials".

3.8 Letter from D. P. Hoffman to D.L. Zieman NRC (Dated May 23, 1978) "Docket 50-255- License DPR-20 - Palisades Plant - Reactor Vessel Material Surveillance". (DCC 2512-1658).

3.9 Meterial Certification Reports, Combustion Engineering Inc., Metallurgical Research and Development Dept.

September 27, 1966 D-3803-1, D-3803-2, D-3803-3

January 11, 1967 D-3804-1, D-3804-2, D-3804-3

3.10 NUREG-0800 (Rev. 1, July 1981) "US NRC Standard Review Plan 5.3.2 Pressure-Temperature Limits." Branch Technical Position MTEB 5-2 "Fracture Toughness Requirements", para 1.2.

	Reference/Comment

3.11 Battelle Report (August 25, 1977) "Final Report on Palisades Pressure Vessel Inirradiated Mechanical Properties to Consumers Power".

3.12 Battelle Report (BCL-585-12, March 13, 1979), "Final Report on Palisades Nuclear Plant Reactor pressure vessel Surveillance Program: Capsule A-240 to Consumers Power Company".

3.13 Westinghouse Report (WCAP-10637 September 1984) "Analysis of Capsules T-330 and W-290 from the Consumers Power Company Palisades Reactor Vessel Radiation Surveillance Program".

3.14 EA-P-PTS-90-001 "Flux Calculations for Cycles 1 thru 5, Benchmarking with W-290 Capsule Data".

3.15 EPRI REPORT NO. NP-2428 (June 1982) "Irradiated Nuclear Pressure Vessel Steel Data Base"

3.16 EPRI REPORT NO. NP-4797 (September 1986) "Nuclear Plant Irradiated Steel Handbook".

3.17 EA-A-NL-89-69-01 "Palisades Reactor Vessel Fracture Toughness 50 foot pounds upper shelf Energy".

	Reference/Comment
4.0 ANALYSIS INPUT	
4.1 Fluence rate for Cycle 9 (proposed core design) and accumulated fluence by EOC8, 9/1990 for base metal are:	
Accumulated fluence for EOC 8 (9/1990) — 1.488×10^{19} n/cm²	Ref 3-2 Table 4-3
Fluence Rate for Base Metal — 0.100×10^{19} $\frac{n/cm^2}{EFPY}$	
4.2 USE data for un-irradiated base metal	
USE data for longitudinal base metal plates was given in Reference 3.7, Table II. USE data for transverse direction was submitted to NRC (Ref. 3.8).	
These values have been re-calculated, using a slightly different method, eg. U.S.E is calculated using a number of data points more than 3 if it is applicable ie % shear is 100% for the data.	
Attachment 8.3 provides the justification of the datapoints used and U.S.E in transverse direction.	

Reference/Comment

Summary of USE in Transverse Direction

Plate Code Number	Shell Course	USE (ft-lbs) from Att 8-3
D-3803-1	Intermediate	89.7
D-3803-2	"	86.5
D-3803-3	"	91.2
D-3804-1	Lower	71.8 ←
D-3804-2	"	75.8
D-3804-3	"	73.3

Plate D-3804-1 lower shell course has the lowest USE out of all six plates used for the fabrication of Intermediate and lower shell courses of the vessel.

71.8 ft-lbs as the minimum USE will be used for analysis.

	Reference/Comment
4.3 SURVEILLANCE PROGRAM DATA	
4.3.1 Un-irradiated Case (Transverse)	
Palisades Surveillance program has base metal from the plate no. D-3803-1.	Ref. 3.7
Impact energy corresponding to 100% shear (similar to Att 8-3 treatment) will be considered. There are 5 impact energy data points:	
114.0, 107.0, 92.0, 102.0, 93.0 ft-lbs.	
Arithmetic mean of these values is:	
$(114+107+92+102+93)/5 = \underline{\underline{101.6}}$ ft-lbs	
This is the same value as reported in Ref. 3.13, Table 5-18, $\underline{\underline{102}}$ - ft-lbs (after rounding-off).	
This value is somewhat different than the value quoted in Ref. 3.11, Table 7 and Ref. 3.12, Table 13,	
105 ft-lb.	

Reference/Comment

4.3.2 Charpy V-notch data from A-240 Capsule

Ref 3-12, Table 10 provides the impact energy (for 100 % shear):

68.0 ft - lbs
69.0 "
67.9 "

Arithmetic mean of these 3 values is

$$(68.0+69.0+67.9)/3 = \underline{68.3} \text{ ft-lbs}$$

This is the same value as presented in Table 13, Ref 3.13, 68 ft-lb (after rounding-off).

Corresponding measured fluence value was $\underline{4.4 \times 10^{19}}$ n/cm².

	Reference/Comment
4.3.3 Charpy V-notch data from W-290 capsule	
Ref. 3.13, Table 5-18 provides the Intermediate Shell Plate D-3803-1 (transverse orientation) as 84 ft lbs which is the arithmetic mean at 100 % shear data of Ref. 3.13, Table 5-10 eg.	
$(78+84+88+85)/4 = 83.75 = \underline{84.0}$ (ft-lbs) (after rounding off)	
Corresponding measured fluence in Reference 3.13, Table 6-8 is 1.09×10^{19} n/cm². This value was corrected due to corrections in time history data and EFPY discrepancy.	Ref 3.14
Measured capsule flux 6.73×10^{10} n/cm²-sec	p. 43
Effective-full power secs 0.16417×10^{9}	p. 42
Accumulated fluence seen by Charpy specimen $6.73 \times 10^{10} \times 0.16417 \times 10^{9} = \underline{1.105 \times 10^{19}}$ n/cm²	

	Reference/Comment
4.3.4 Indian Point3 data for Charpy V-Notch	
Indian Point 3 plant has the same base-metal as of Palisades, SA 302B.	
Note: Data for Indian Point 3 are for comparison only.	
un-irradiate Transverse Orientation Data for base-metal	
Ref 3.15, p 3-163, Heat type AA Orientation TL which corresponds to transverse direction There are 9 data points with 100 % shear for impact energy. Arithmetic mean is	
$(65+66+59+62+70+65+70+68+70)/9$	Ref. 3.15 see also p 3-159
= 66.1 FT-LBS.	
Irradiated data from capsule T for Fluence of 0.2920×10^{19} n/cm²-sec	Ref. 3.15 p 3-157
There are only 2 data points for the impact energy for 100 % shear and mean value can be consider as $(56+58)/2 = 57.0$ ft-lbs	Ref. 3.15 p. 3-163 & p. 3-159

	Reference/Comment
Irradiated data from capsule Y	Ref 3.16 p20.15 p20.2

Fluence 0.805×10^{19} n/cm², Heat A0512

Heat type AA of Ref 3.15 is the same as Heat A0512 of Ref 3.16. Remaining data (irradiated and unirradiated) of p. 20.15 Ref 3.16 is the same as in Ref 3.15 p 3-159.

No details of impact energy are available, hence direct reading of p. 20.15 of Ref 3.16 has been used to find the impact energy data for fluence 0.805×10^{19} n/cm². The impact energy is

56.0 ft-lbs.

Reference/Comment

Summary of Input Data

Following set of data will be used for transverse orientation of base metal

	Fluence $\times 10^{19}$ n/cm2	UpperShelf Energy ft-lbs	% Reduction	Reference/Comment
	Initial	101.6	—	Palisades Surveillance Program Data Sec. 4.3.1
1)	1.105	84.0	17.3	Sec. 4.3.3
2)	4.4	68.3	32.8	Sec. 4.3.2
	Initial	66.1	—	Indian Point Data Sec 4.3.4
3)	0.2920	57.0	13.8	
4)	0.8050	56.0	15.3	

% Reduction is calculated as $\frac{(USE)_{INITIAL} - (USE)_{fluence}}{(USE)_{INITIAL}} \times 100$

Four (4) fluence vs. decrease in upper shelf energy data have been plotted in Figure 4.1. Various curves in this Figure are adopted from Ref 3.5, Figure 2.

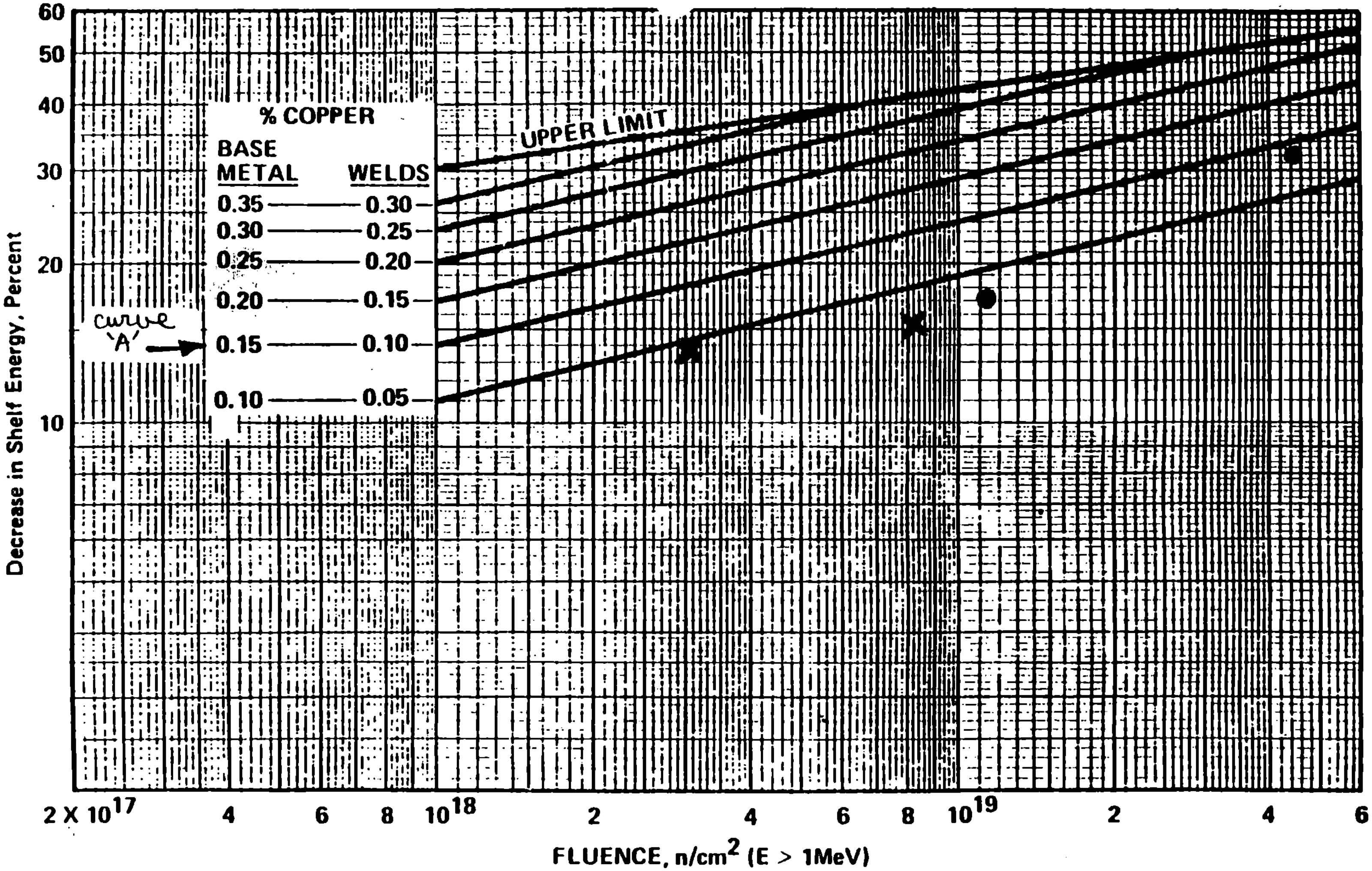

Figure 2 Predicted Decrease in Shelf Energy as a Function of Copper Content and Fluence. (Ref. 3.5)

● (Transverse) Base Metal Data from Palisades Surveillance Program for A-240 & W-290 capsules

✗ (Transverse) Base Metal Data from Indian Point 3 Plant

Figure 4.1

Reference/Comment

	Reference/Comment
Figure 4.1 demonstrates that all the four (4) USE data points fall below the bounding curve of 0.15% (curve 'A' of Figure 4.1) for the base-metal	
Actually, Palisades reactor vessel plates have 0.25% copper.	Ref 3.2 Table 33.
Thus, the bounding curve 'A' for 0.15% Cu (Ref. 3.5) can be used in determining the limiting value corresponding to USE ≥ 71.8 ft-lbs (for the base metal in transverse direction).	Section 4.2

Reference/Comment

5.0 ASSUMPTIONS

5.1 It is assumed that the Palisades plant will remain operational at 75% capacity factor from BOC 9 to EOL date of 2011.
EOC8 will occur on 9/1990

5.2 Fluence rate for Palisades reactor vessel will be the same or lower than the core design of Cycle 9.

5.3 Ref. 3-4 has identified that the base plate material SA302 Grade B as the limiting case for USE in the transverse direction. In this analysis only this case will be used for the computation of End-of-life based upon USE data.

5.4 Ref. 3.17 (P. 7 of 17) shows that the other belt line materials: heat-affected zone, axial and circumferential welds have higher initial U.S.E. compare to base metal in the transverse direction. In this reference, it was also determine That the base metal (in transverse direction) is the limiting case for the U.S.E.

	Reference/Comment
6.0 ANALYSIS	
6.1 Methodology	
6.1.1. Reg. Guide 1.99 Rev. 2, eq. 3 will be used for the calculation of fluence attenuation through the vessel wall.	Ref. 3.5
6.1.2. Input data from section 4.0 will be utilized to determine which curve of Ref. 3.5 Figure 2 would be applicable to determine the decrease in upper shelf energy.	
6.1.3 Accumulated fluence @ EOC8 and fluence rate for proposed Cycle 9 loading scheme (E > 1 MeV) will be used. This is the same data which have been transmitted to NRC.	Ref. 3.2

Reference/Comment

6.2 Results

Allowed decrease in USE from 50 ft-lbs for base metal in transverse direction is

$$\frac{71.8 - 50}{71.8} \times 100 = 31.3\ \%.$$

Using Figure 4.1, curve 'A' for 0.15% Cu, fluence @ 1/4 T ($T = 8\frac{1}{2}$") is

$$2.8 \times 10^{19}\ n/cm^2.$$

$$f_{T/4} = f_{surf}\left(e^{-0.24 \times \frac{8.5}{4}}\right)$$ Eq. 3, Ref. 3.5

or $$f_{surf} = f_{T/4} \Big/ e^{-0.24 \times \frac{8.5}{4}}$$

$$= 1.665\ f_{T/4} = 1.665 \times 2.8 \times 10^{19}$$

$$= 4.6 \times 10^{19}\ n/cm^2$$

Fluence @ EOC8 (9/1990) $= 1.488 \times 10^{19}\ n/cm^2$ Sec 4.1

EFPY to reach $4.6 \times 10^{19}\ n/cm^2$ @ the rate of $0.100 \times 10^{19}\ (n/cm^2)/EFPY$ is

$$\frac{(4.6 - 1.488) \times 10^{19}\ (n/cm^2)}{0.100 \times 10^{19}\ (n/cm^2)/EFPY}$$

$= 31.12$ EFPY

Reference/Comment

If we assume that the plant will be operating at 75 % capacity factor, the calendar years will be

$$\frac{31.12}{0.75} = 41.49 \text{ years}$$

or ~41 years, 6 months

Date when the USE limit will exceed is $\begin{Bmatrix} \text{Month} & \text{year} \\ 9 & - 1990 \end{Bmatrix} + \begin{Bmatrix} \text{Month} & \text{years} \\ 6 & - 41 \end{Bmatrix}$

year = 3/2032

This date is beyond the nominal end-of operating life for Palisades by year 2011.

Reference/Comment

7.0 Conclusion

This analysis has shown that the Palisades Plant base metal material (transverse direction) will have minimum upper shelf energy above 50 ft-lbs till year 2032, which is beyond the expected nominal operating life of year 2011.

Form 3693 '9-89

PALISADES NUCLEAR PLANT
ENGINEERING ANALYSIS CHECKLIST

EA-P-PTS-90-011R
Rev. 0
1 of Att 8.1

Items Affected By This EA	Affected Yes	Affected No	Revision Required	Identify*	Closeout
1. Other EAs	☒	☐	NO	EA-P-PTS-90-011	
2. Design Documents Elec E-38 through E-49	☐	☒			
3. Design Documents Mech M259, M664, M665	☐	☒			
4.0 LICENSING DOCUMENTS					
4.1 Final Safety Analysis Report (FSAR)	☐	☒			
4.2 Technical Specifications	☐	☒			
4.3 Standing Order 54	☐	☒			
5.0 PROCEDURES					
5.1 Administrative Procedures	☐	☒			
5.2 Working Procedures	☐	☒			
5.3 Tech Spec Surveillance Procedures	☐	☒			
6.0 OTHER DOCUMENTS					
6.1 Q-List	☐	☒			
6.2 Plant Drawings	☐	☒			
6.3 Equipment Data Base	☐	☒			
6.4 Spare Parts (Stock/MMS)	☐	☒			
6.5 Fire Protection Program Report (FPPR)	☐	☒			
6.6 Design Basis Documents	☐	☒			
6.7 Operating Checklists	☐	☒			
6.8 SPCC/PIPP Oil and Hazardous Material Spill Prevention Plan	☐	☒			
6.9 EEQ Documents	☐	☒			

Do any of the following documents need to be generated as a result of this EA:

	Yes	No	Reference
1. Corrective Action Document?	☐	☒	
2. Safety Evaluation?	☐	☒	
3. EEQ Evaluation Sheet?	☐	☒	
Is PRC Review of this EA Required?	☐	☒	

Completed By O. P. Jolly   Date 8/22/90

*Identify Section, No, Drawing, Document, etc.

	Reference/Comment
Att 8-2 NOD 3110 Forms & checklist forms	

Consumers Power Company

NUCLEAR OPER. .ONS DEPARTMENT
Document Review Sheet

Document Title	Document Number	Revision	Revision Number	Page
EA-P-PTS-90-011R				1 of 1

Item Number	Page and/or Section Number	Comments	Response or Resolution
1	pg 18 & 19	The nominal uncertainty factor for fluence calculations is 15%. The allowed EFPY applying this uncertainty factor is $\frac{4.6-1.488(1.15)}{0.100(1.15)} = 25.12$ 25.12/.75 = 33.49 ≈ 33 1/2 yrs year = 3/2024 which is still beyond 2011 and does not account for expected further reductions in RV flux.	I agree with 15% uncertainty in the fluence value, this further reduces the number of years from 41.49 (in this EA) to 33.5 years. The calculated date 3/2024 (by reviewer) is still beyond the E-O-L-date of 2011. No change to the EA is made.

comment resolution acceptable.
G. Pratt 8/28/90

Reviewer	Organization	Date	Review Coordinator	Date	Document Sponsor	Date
Gary J. Pratt	RED	8/24/90	O. P. Jolly	8/24/90		

Consumers Power
POWERING MICHIGAN'S PROGRESS

NUCLEAR OPER. ONS DEPARTMENT
Document Review Sheet

Document Title	Document Number	Revision	Revision Number	Page 1 of 1
	EA-P-PTS-90-011R			

Item Number	Page and/or Section Number	Comments	Response or Resolution
1		Should indicate that the Indian Point data are for comparison purposes only - RG 1.99 does not allow use of other plants' surveillance data.	In Section 4.3.4 a note added
2		Some discussion is necessary here as to why only the base metal enters into the use question.	Section 5.3 was addressing this issue. See also Section 5.4.
3			

Reviewer	Organization	Date	Review Coordinator	Date	Document Sponsor	Date
[signature]	RED/NF	8/22/90	O.P. Jolly	8/22/90		

REACTOR ENGINEERING DEPARTMENT
EA REVIEW CHECKLIST

Review Step	Comments	Reviewer
1. Have the appropriate procedural requirements been satisfied?	yes	JFP
2. Was an appropriate design method used?	yes	JFP
3. Are assumptions adequately described and reasonable?	yes	JFP
4. Were the inputs correctly selected and incorporated into the design?	yes	JFP
5. Are the acceptance criteria sufficient to allow verification that design requirements have been satisfactorily accomplished?	yes	JFP
6. Is the output reasonable compared to input?	yes	JFP
7. Have the design interface requirements been satisfied?	None	JFP
8. Are the applicable codes, standards and regulations properly identified and are their requirements met?	yes	JFP
9. Are the appropriate quality assurance requirements met?	yes	JFP
10. Have appropriate certified computer programs been used?	None	JFP
11. Is an FSAR, Tech Spec, Tech Spec Basis, Design Basis Document or Procedure Revision required?	No	JFP

TECHNICAL REVIEW CHECKLIST

This checklist provides guidance for the review of engineering analyses. Answer questions Yes or NO, or N/A if they do not Apply. Document all comments on 3110 form. Satisfactory Resolution of comments and completion of this checklist is noted by Technically Reviewed Signature on the Initiation and Review record block of form 3619.

		(Y, N, N/A)
1.	Are all constants, variables and formulas correct and properly applied?	Y
2.	Are all inputs and assumptions valid and the Basis for their use documented?	Y
3.	Is Vendor Information used as inputs addressed correctly in the analysis?	Y
4.	If the analysis argument departs from Vendor Information/Recommendations, is the departure justification documented?	N/A
5.	Have the proper input codes, standards and design principles been specified?	Y
6.	Have the input codes, standards and design principles been properly applied?	Y
7.	Has the use of engineering judgement been documented and justified?	Y
8.	Has the objective of the analysis been met?	Y
9.	Are all calculated values correct?	Y
10.	Are assumptions accurately described and reasonable?	Y
11.	Have administrative requirements such as numbering and format been satisfied?	Y
12.	Have any minor (Insignificant) errors been identified? If Yes; Identify on 3110 form and justify insignificance.	N
13.	Does analysis involve welding? If Yes; verify the following information is accurately represented on analysis drawing(s).	N

le

- Type of Weld
- Size of Weld
- Material Being Joined
- Thickness of Material Being Joined
- Location of Weld(s)
- Appropriate Weld Symbology

Reference/Comment

Att. 8-3

U.S.E of Plates (six)

	Reference/Comment
Plate NO. D-3803-1, Shell Course: Intermediate	
only At 160°F Test temperature, Charpy V notch impacts energy are for 100 % shear:	Ref. 3.9
133.0, 125.0, 156.0 ft-lb (for longitudinal)	
Arithmetic Mean is $\frac{133.0 + 125.0 + 156.0}{3} = 138.0$ ft-lbs.	
USE for transverse direction = 65 % of $(USE)_{longitudinal\ direction}$	Ref. 3.10
$= 138 \times \frac{65}{100} = 89.7$ ft-lb.	
Same as in Reference 3.8 Table 2.1	

	Reference/Comment
Plate NO: D-3803-2, Shell Course: Intermediate	
There are 4 data points with 100 % shear for longitudinal case:	
+110° F 135.0 ft-lbs	Ref 3.9
+160° F 132.0 "	
+160° F 127.0 "	
+160° F 138.0 "	
(135+132+127+138)/4 =	
Arithmetic Mean is 133.0 ft-lbs.	
USE for transverse direction is:	
$133.0 \times \frac{65}{100}$	Ref 3.10
= 86.5 ft-lbs.	
Ref 3.8, Table 2.2 has used 86.0 ft-lbs	
Slight difference in the value is probably not inclusion of the data point at 110°F.	

	Reference/Comment
Plate NO. D-3803-3, Shell Course: Intermediate	
There are 3 data points with 100% shear and for longitudinal case values are:	
146.0 ft-lbs	Ref 3.9
142.0 "	
133.0 "	
Arithmetic Mean is $\frac{146+142+133}{3}$	
$= 140.3$ ft-lbs.	
USE for Transverse direction is	
$= 140.3 \times \frac{65}{100} = 91.2$ ft-lbs	Ref 3.10
This value is the same as in Ref 3.8, Table 2.3.	

	Reference/Comment

Plate No. D-3804-1, Shell Course: Lower

There are 4 data points with 100% shear and their energy values are:

@		
110°F	114.0 ft-lb	Ref 3.9
160°F	110.0 "	
160°F	108.0 "	
160°F	110.0	

Arithmetic Mean is

$$\frac{114+110+108+110}{4} = 110.5 \text{ ft lb}$$

U.S.E in transverse direction

= 65% of (USE) longitudinal direction — Ref 3.10

$= \frac{65}{100} \times 110.5 = 71.8$ ft-lb.

This value is slightly different than the 70.9 ft lb value of Ref 3.8, Table 2.4, which was probably calculated based upon 3 data points of 160°F values.

Reference/Comment

Plate No. D-3804-2, Shell Course: Lower

There are 5 data points with 100% shear and there values are: — Ref-3.9

@ 110°F	115 ft-lbs
@ 110°F	117 "
@ 160°F	119 "
@ 160°F	115 "
@ 160°F	117 "

Arithmetic Mean for longitudinal USE is

$$\frac{115+117+119+115+117}{5} = 116.6 \text{ ft-lbs.}$$

USE in transverse direction is — Ref 3.10

$$\frac{65}{100} \times 116.6 = 75.8 \text{ ft-lbs.}$$

This value is slightly different than used in Ref. 3-8, Table 2.5 i.e. 76.0 ft-lbs which seemed to be based upon only 160°F data points.

	Reference/Comment
Plate D-3804-3, Shell Course: lower	
There are 6 data points with 100% shear @ 110°F and 160°F data points, there longitudinal direction energies are:	Ref 3.9
113, 114, 119 } @ 110°F	
115, 108, 108 } @ 160°F	
Arithmetic mean of six values is:	
$(113+114+119+115+108+108)/6$	
$= 112.8$ ft-lbs.	
USE in transverse direction is	Ref 3.10
$= \frac{65}{100} \times 112.8 = 73.3$ ft-lb.	
which is slightly different than the value of 75.0 ft-lbs of Ref 3.8 Table 2.6. 75.0 ft-lbs value was based upon, probably 110°F data.	