

**Perry Buckberg - Pilgrim Amendment 17 of 5/17/2007**

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**From:** Perry Buckberg  
**To:** Pilgrim Staff  
**Date:** 5/18/2007 7:02:29 AM  
**Subject:** Pilgrim Amendment 17 of 5/17/2007

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Gentlemen,

The attached letter was e-mailed last night. It's revised **Open Item 4.2** response supercedes that of the last amendment, it revises **Commitment 45** and it revises line items in **tables 3.1.1 and 3.2.1** related to reduction of fracture toughness.

Thanks,  
Perry Buckberg  
Project Manager - Division of License Renewal  
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[phb1@nrc.gov](mailto:phb1@nrc.gov)

**Mail Envelope Properties** (464D87C5.966 : 9 : 8248)**Subject:** Pilgrim Amendment 17 of 5/17/2007**Creation Date** 5/18/2007 7:02:29 AM**From:** Perry Buckberg**Created By:** PHB1@nrc.gov

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Pilgrim LRA Amendment 17  
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Entergy Nuclear Operations, Inc.  
Pilgrim Nuclear Power Station  
600 Rocky Hill Road  
Plymouth, MA 02360

May 17, 2007

Stephen J. Bethay  
Director, Nuclear Assessment

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

SUBJECT: Entergy Nuclear Operations, Inc.  
Pilgrim Nuclear Power Station  
Docket No. 50-293 License No. DPR-35  
License Renewal Application Amendment 17

REFERENCES: 1. Entergy Letter, License Renewal Application, dated  
January 25, 2006 (TAC MC9669)  
2. NRC Request for additional information for review of the Pilgrim  
License Renewal Application, dated March 26, 2007  
3. NRC Safety Evaluation Report with Open Items Related to the  
Pilgrim License Renewal Application, dated March 2007  
4. Entergy Letter, License Renewal Application Amendment 16,  
dated May 1, 2007

LETTER NUMBER: 2.07.029

Dear Sir or Madam:

In Reference 1, Entergy Nuclear Operations, Inc. applied for renewal of the Pilgrim Nuclear Power Station operating license.

Attachment A provides a revised listing of regulatory commitments. Attachments B and C provide additional information associated with the application. Attachments D and E provide a revised response to the request for additional information (RAI) in Reference 2 associated with Open Item 4.2 in the draft NRC safety evaluation report related to the Pilgrim license renewal application (LRA) (Reference 3). The revised RAI response supersedes the response to Open Item 4.2 in Reference 4.

Commitments made by this letter are contained in Attachment A.

Please contact Mr. Bryan Ford, (508) 830-8403, if you have questions regarding this subject.

I declare under penalty of perjury that the foregoing is true and correct. Executed on May 17, 2007.

Sincerely,

  
Stephen J. Bethay  
Director Nuclear Safety Assessment

ERS/dl

Attachments: A: Revised List of Regulatory Commitments  
B: Revision to Commitment 45  
C: LRA Amendments to Revise LRA Tables 3.1.1-55 and 3.2.1-3  
D: Revised Response to the NRC Request for Additional Information  
Related to Open Item 4.2  
E: Structural Integrity Associates Fluence Evaluation for PNPS

cc: with Attachments

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NRC Resident Inspector  
Pilgrim Nuclear Power Station

**ATTACHMENT A to Letter 2.07.029**  
(8 pages)

Revised List of Regulatory Commitments

### Revised List of Regulatory Commitments

The following table identifies those actions committed to by Entergy in this document. Any other statements in this submittal are provided for information purposes and are not considered to be regulatory commitments.

#	COMMITMENT	IMPLEMENTATION SCHEDULE	SOURCE	Related LRA Section No./ Comments
1	Implement the Buried Piping and Tanks Inspection Program as described in LRA Section B.1.2.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.2 / Audit Item 320
2	Enhance the implementing procedure for ASME Section XI inservice inspection and testing to specify that the guidelines in Generic Letter 88-01 or approved BWRVIP-75 shall be considered in determining sample expansion if indications are found in Generic Letter 88-01 welds.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.6 / Audit Item 320
3	Inspect fifteen (15) percent of the top guide locations using enhanced visual inspection technique, EVT-1, within the first 18 years of the period of extended operation, with at least one-third of the inspections to be completed within the first six (6) years and at least two-thirds within the first 12 years of the period of extended operations. Locations selected for examination will be areas that have exceeded the neutron fluence threshold.	As stated in the commitment.	Letters 2.06.003 and 2.06.057 and 2.06.064 and 2.06.081	B.1.8 / Audit Items 155, 320
4	Enhance the Diesel Fuel Monitoring Program to include quarterly sampling of the security diesel generator fuel storage tank. Particulates (filterable solids), water and sediment checks will be performed on the samples. Filterable solids acceptance criteria will be = 10 mg/l. Water and sediment acceptance criteria will be = 0.05%.	June 8, 2012	Letters 2.06.003 and 2.06.057 and 2.06.089	B.1.10 / Audit Items 320, 566
5	Enhance the Diesel Fuel Monitoring Program to install instrumentation to monitor for leakage between the two walls of the security diesel generator fuel storage tank to ensure that significant degradation is not occurring.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.10 / Audit Items 155, 320
6	Enhance the Diesel Fuel Monitoring Program to specify acceptance criterion for UT measurements of emergency diesel generator fuel storage tanks (T-126A&B).	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.10 / Audit Items 165, 320



#	COMMITMENT	IMPLEMENTATION SCHEDULE	SOURCE	Related LRA Section No./ Comments
7	Enhance Fire Protection Program procedures to state that the diesel engine sub-systems (including the fuel supply line) shall be observed while the pump is running. Acceptance criteria will be enhanced to verify that the diesel engine did not exhibit signs of degradation while it was running; such as fuel oil, lube oil, coolant, or exhaust gas leakage. Also, enhance procedures to clarify that the diesel-driven fire pump engine is inspected for evidence of corrosion in the intake air, turbocharger, and jacket water system components as well as lube oil cooler. The jacket water heat exchanger is inspected for evidence of corrosion or buildup to manage loss of material and fouling on the tubes. Also, the engine exhaust piping and silencer are inspected for evidence of internal corrosion or cracking.	June 8, 2012	Letters 2.06.003 and 2.06.057 and 2.06.064	B.1.13.1 / Audit Items 320, 378
8	Enhance the Fire Protection Program procedure for Halon system functional testing to state that the Halon 1301 flex hoses shall be replaced if leakage occurs during the system functional test.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.13.1 / Audit Item 320
9	Enhance Fire Water System Program procedures to include inspection of hose reels for corrosion. Acceptance criteria will be enhanced to verify no significant corrosion.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.13.2 / Audit Item 320
10	Enhance the Fire Water System Program to state that a sample of sprinkler heads will be inspected using guidance of NFPA 25 (2002 Edition) Section 5.3.1.1.1. NFPA 25 also contains guidance to repeat this sampling every 10 years after initial field service testing.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.13.2 / Audit Item 320
11	Enhance the Fire Water System Program to state that wall thickness evaluations of fire protection piping will be performed on system components using non-intrusive techniques (e.g., volumetric testing) to identify evidence of loss of material due to corrosion. These inspections will be performed before the end of the current operating term and at intervals thereafter during the period of extended operation. Results of the initial evaluations will be used to determine the appropriate inspection interval to ensure aging effects are identified prior to loss of intended function.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.13.2 / Audit Item 320
12	Implement the Heat Exchanger Monitoring Program as described in LRA Section B.1.15.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.15 / Audit Item 320

#	COMMITMENT	IMPLEMENTATION SCHEDULE	SOURCE	Related LRA Section No./ Comments
13	Enhance the Instrument Air Quality Program to include a sample point in the standby gas treatment and torus vacuum breaker instrument air subsystem in addition to the instrument air header sample points.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.17 / Audit Item 320
14	Implement the Metal-Enclosed Bus Inspection Program as described in LRA Section B.1.18.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.18 / Audit Item 320
15	Implement the Non-EQ Inaccessible Medium-Voltage Cable Program as described in LRA Section B.1.19. Include developing a formal procedure to inspect manholes for in-scope medium voltage cable.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.19 / Audit items 311, 320
16	Implement the Non-EQ Instrumentation Circuits Test Review Program as described in LRA Section B.1.20.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.20 / Audit Item 320
17	Implement the Non-EQ Insulated Cables and Connections Program as described in LRA Section B.1.21.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.21 / Audit Item 320
18	Enhance the Oil Analysis Program to periodically change CRD pump lubricating oil. A particle count and check for water will be performed on the drained oil to detect evidence of abnormal wear rates, contamination by moisture, or excessive corrosion.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.22 / Audit Item 320
19	Enhance Oil Analysis Program procedures for security diesel and reactor water cleanup pump oil changes to obtain oil samples from the drained oil. Procedures for lubricating oil analysis will be enhanced to specify that a particle count and check for water are performed on oil samples from the fire water pump diesel, security diesel, and reactor water cleanup pumps.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.22 / Audit Item 320
20	Implement the One-Time Inspection Program as described in LRA Section B.1.23.	June 8, 2012	Letters 2.06.003 and 2.06.057 and 2.07.023	B.1.23 / Audit Items 219, 320
21	Enhance the Periodic Surveillance and Preventive Maintenance Program as necessary to assure that the effects of aging will be managed as described in LRA Section B.1.24.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.24 / Audit Item 320

#	COMMITMENT	IMPLEMENTATION SCHEDULE	SOURCE	Related LRA Section No./ Comments
22	Enhance the Reactor Vessel Surveillance Program to proceduralize the data analysis, acceptance criteria, and corrective actions described in LRA Section B.1.26.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.26 / Audit Item 320
23	Implement the Selective Leaching Program in accordance with the program as described in LRA Section B.1.27.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.27 / Audit Item 320
24	Enhance the Service Water Integrity Program procedure to clarify that heat transfer test results are trended.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.28 / Audit Item 320
25	Enhance the Structures Monitoring Program procedure to clarify that the discharge structure, security diesel generator building, trenches, valve pits, manholes, duct banks, underground fuel oil tank foundations, manway seals and gaskets, hatch seals and gaskets, underwater concrete in the intake structure, and crane rails and girders are included in the program. In addition, the Structures Monitoring Program will be revised to require opportunistic inspections of inaccessible concrete areas when they become accessible.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.29.2 / Audit Items 238, 320
26	Enhance Structures Monitoring Program guidance for performing structural examinations of elastomers (seals, gaskets, seismic joint filler, and roof elastomers) to identify cracking and change in material properties.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.29.2 / Audit Item 320
27	Enhance the Water Control Structures Monitoring Program scope to include the east breakwater, jetties, and onshore revetments in addition to the main breakwater.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.29.3 / Audit Item 320
28	Enhance System Walkdown Program guidance documents to perform periodic system engineer inspections of systems in scope and subject to aging management review for license renewal in accordance with 10 CFR 54.4(a)(1) and (a)(3). Inspections shall include areas surrounding the subject systems to identify hazards to those systems. Inspections of nearby systems that could impact the subject systems will include SSCs that are in scope and subject to aging management review for license renewal in accordance with 10 CFR 54.4(a)(2).	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.30 / Audit Items 320, 327

#	COMMITMENT	IMPLEMENTATION SCHEDULE	SOURCE	Related LRA Section No./ Comments
29	Implement the Thermal Aging and Neutron Irradiation Embrittlement of Cast Austenitic Stainless Steel (CASS) Program as described in LRA Section B.1.31.	June 8, 2012	Letters 2.06.003 and 2.06.057	B.1.31 / Audit Items 257, 320
30	Perform a code repair of the CRD return line nozzle to cap weld if the installed weld repair is not approved via accepted code cases, revised codes, or an approved relief request for subsequent inspection intervals.	June 30, 2015	Letter 2.06.057	B.1.3 / Audit Items 141, 320
31	<p>At least 2 years prior to entering the period of extended operation, for the locations identified in NUREG/CR-6260 for BWRs of the PNPS vintage, PNPS will implement one or more of the following:</p> <p>(1) Refine the fatigue analyses to determine valid CUFs less than 1 when accounting for the effects of reactor water environment. This includes applying the appropriate Fen factors to valid CUFs determined in accordance with one of the following:</p> <ol style="list-style-type: none"> <li>1. For locations, including NUREG/CR-6260 locations, with existing fatigue analysis valid for the period of extended operation, use the existing CUF to determine the environmentally adjusted CUF.</li> <li>2. More limiting PNPS-specific locations with a valid CUF may be added in addition to the NUREG/CR-6260 locations.</li> <li>3. Representative CUF values from other plants, adjusted to or enveloping the PNPS plant specific external loads may be used if demonstrated applicable to PNPS.</li> <li>4. An analysis using an NRC-approved version of the ASME code of NRC-approved alternative (e.g., NRC-approved code case) may be performed to determine a valid CUF.</li> </ol> <p>The determination of Fen will account for operating times with both hydrogen water chemistry and normal water chemistry.</p> <p>(2) Manage the effects of aging due to fatigue at the affected locations by an inspection program that has been reviewed and approved by the NRC (e.g., periodic non-destructive examination of the affected locations at inspection intervals to be determined by a method acceptable to the NRC).</p> <p>(3) Repair or replace the affected locations before exceeding a CUF of 1.0.</p> <p>Should PNPS select the option to manage the aging effects due to environmental-assisted fatigue during the period of extended operation, details of the aging management program such as scope, qualification, method; and frequency will be submitted to the NRC at least 2 years prior to the period of extended operation.</p>	<p>June 8, 2012</p> <p>June 8, 2010 for submitting the aging management program if PNPS selects the option of managing the affects of aging due to environmentally assisted fatigue.</p>	<p>Letters 2.06.057 and 2.06.064 and 2.06.081 and 2.07.005</p>	<p>4.3.3 / Audit Items 302, 346</p>

#	COMMITMENT	IMPLEMENTATION SCHEDULE	SOURCE	Related LRA Section No./ Comments
32	Implement the enhanced Bolting Integrity Program described in Attachment C of Pilgrim License Renewal Application Amendment 5 (Letter 2.06.064).	June 8, 2012	Letters 2.06.057 and 2.06.064 and 2.06.081	Audit items 364, 373, 389, 390, 432, 443, 470
33	PNPS will inspect the inaccessible jet pump thermal sleeve and core spray thermal sleeve welds if and when the necessary technique and equipment become available and the technique is demonstrated by the vendor, including delivery system.	As stated in the commitment.	Letter 2.06.057	Audit Items 320, 488
34	Within the first 6 years of the period of extended operation and every 12 years thereafter, PNPS will inspect the access hole covers with UT methods. Alternatively, PNPS will inspect the access hole covers in accordance with BWRVIP guidelines should such guidance become available.	June 8, 2018	Letters 2.06.057 and 2.06.089	Audit Items 320, 461
35	<p>At least 2 years prior to entering the period of extended operation, for reactor vessel components, including the feedwater nozzles, PNPS will implement one or more of the following:</p> <ul style="list-style-type: none"> <li>(1) Refine the fatigue analyses to determine valid CUFs less than 1. Determine valid CUFs based on numbers of transient cycles projected to be valid for the period of extended operation. Determine CUFs in accordance with an NRC-approved version of the ASME code or NRC-approved alternative (e.g., NRC-approved code case).</li> <li>(2) Manage the effects of aging due to fatigue at the affected locations by an inspection program that has been reviewed and approved by the NRC (e.g., periodic non-destructive examination of the affected locations at inspection intervals to be determined by a method acceptable to the NRC).</li> <li>(3) Repair or replace the affected locations before exceeding a CUF of 1.0.</li> </ul> <p>Should PNPS select the option to manage the aging effects due to fatigue during the period of extended operation, details of the aging management program such as scope, qualification, method, and frequency will be submitted to the NRC at least 2 years prior to the period of extended operation.</p>	<p>June 8, 2012</p> <p>June 8, 2010 for submitting the aging management program if PNPS selects the option of managing the affects of aging.</p>	Letters 2.06.057 and 2.06.064 and 2.06.081	Audit Item 345

#	COMMITMENT	IMPLEMENTATION SCHEDULE	SOURCE	Related LRA Section No./ Comments
36	To ensure that significant degradation on the bottom of the condensate storage tank is not occurring, a one-time ultrasonic thickness examination in accessible areas of the bottom of the condensate storage tank will be performed. Standard examination and sampling techniques will be utilized.	June 8, 2012	Letter 2.06.057	Audit Items 320, 363
37	The BWR Vessel Internals Program includes inspections of the steam dryer. Inspections of the steam dryer will follow the guidelines of BWRVIP-139 and General Electric SIL 644 Rev. 1.	June 8, 2012	Letter 2.06.089	A.2.1.8 / Conference call on September 25, 2006
38	Enhance the Diesel Fuel Monitoring Program to include periodic ultrasonic thickness measurement of the bottom surface of the diesel fire pump day tank. The first ultrasonic inspection of the bottom surface of the diesel fire pump day tank will occur prior to the period of extended operation, following engineering analysis to determine acceptance criteria and test locations. Subsequent test intervals will be determined based on the first inspection results.	June 8, 2012	Letter 2.06.089	B.1.10 / Audit Item 565
39	Perform a one-time inspection of the Main Stack foundation prior to the period of extended operation.	June 8, 2012	Letter 2.06.094	B.1.23 / Audit Item 581
40	Enhance the Oil Analysis Program by documenting program elements 1 through 7 in controlled documents. The program elements will include enhancements identified in the PNPS license renewal application and subsequent amendments to the application. The program will include periodic sampling for the parameters specified under the Parameters Monitored/Inspected attribute of NUREG-1801 Section XI.M39, Lubricating Oil Analysis. The controlled documents will specify appropriate acceptance criteria and corrective actions in the event acceptance criteria are not met. The basis for acceptance criteria will be defined.	June 8, 2012	Letter 2.06.094	B.1.22 / Audit Items 553 and 589
41	Enhance the Containment Inservice Inspection (CII) Program to require augmented inspection in accordance with ASME Section XI IWE-1240, of the drywell shell adjacent to the sand cushion following indications of water leakage into the annulus air gap.	June 8, 2012	Letter 2.06.094	A.2.1.17 and B.1.16.1
42	Implement the Bolted Cable Connections Program, described in Attachment C of Pilgrim License Renewal Application 11 (Letter 2.07.003), prior to the period of extended operation.	June 8, 2012	Letter 2.07.003	A.2.1.40 and B.1.34

#	COMMITMENT	IMPLEMENTATION SCHEDULE	SOURCE	Related LRA Section No./ Comments
43	Include within the Structures Monitoring Program provisions to ensure groundwater samples are evaluated periodically to assess the aggressiveness of groundwater to concrete, as described in Attachment E of LRA Amendment 12 (Letter 2.07.005), prior to the period of extended operation.	June 8, 2012	Letter 2.07.005	A.2.1.32 and B.1.29.2
44	Perform another set of the UT measurements just above and adjacent to the sand cushion region prior to the period of extended operation and once within the first 10 years of the period of extended operation.	As stated in the commitment.	Letter 2.07.010	A.2.1.17 and B.1.16.1
45	If groundwater continues to collect on the torus room floor, obtain samples and test such water to determine its pH and verify the water is non-aggressive as defined in NUREG-1801 Section III.A1 item III.A.1-4 once prior to the period of extended operation and once every five years during the period of extended operation.	As stated in the commitment.	Letters 2.07.010 and 2.07.027 and 2.07.029	A.2.1.32 and B.1.29.2
46	Inspect the condition of a sample of the torus hold-down bolts and associated grout and determine appropriate actions based on the findings prior to the period of extended operation.	June 8, 2012	Letter 2.07.027	A.2.1.32 and B.1.29.2
47	Submit to the NRC an action plan to improve benchmarking data to support approval of new P-T curves for Pilgrim.	Sept.15, 2007	Letter 2.07.027	4.2.2, A.2.2.1.1, and A.2.2.1.2
48	On or before June 8, 2010, Entergy will submit to the NRC calculations consistent with Regulatory Guide 1.190 that will demonstrate limiting fluence values will not be reached during the period of extended operation.	June 8, 2010	Letter 2.07.027	4.2, 4.7.1, A.1.1 and A.2.2.1

**ATTACHMENT B to Letter 2.07.029**

(1 page)

Revision to Commitment 45



Revision to Commitment 45

Entergy letter dated March 13, 2007 added Commitment 45. Entergy letter dated May 1, 2007 revised Commitment 45 as part of the response to Open Item 3.0.3.3.2. Commitment 45 is revised to require performance once every five years during the period of extended operation in addition to once prior to the period of extended operation. This revised commitment is listed in Attachment A to this letter and reads as follows:

45	If groundwater continues to collect on the torus room floor, obtain samples and test such water to determine its pH and verify the water is non-aggressive as defined in NUREG-1801 Section III.A1 item III.A.1-4 once prior to the period of extended operation and once every five years during the period of extended operation.
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**ATTACHMENT C to Letter 2.07.029**  
(1 page)

LRA Amendments to Revise LRA Tables 3.1.1-55 and 3.1.2-3

**LRA Amendments to Revise LRA Tables 3.1.1-55 and 3.1.2-3**

LRA Table 3.1.1-55 on Page 3.1-30 includes a line item for Cast austenitic stainless steel Class 1 pump casings, and valve bodies and bonnets exposed to reactor coolant >250°C (>482°F). For this line item, the discussion column is modified to read as follows.

The Inservice Inspection Program or the One-Time Inspection Program manage the reduction of fracture toughness in cast austenitic stainless steel components of the reactor coolant pressure boundary.

LRA Table 3.1.2-3 on Page 3.1-72 includes a line item for valve bodies < 4" NPS, with CASS material and with the aging effect reduction of fracture toughness. For this line item, the aging management program column is modified to add Inservice Inspection to One-Time Inspection. All other entries for this line item remain unchanged.

**ATTACHMENT D to Letter 2.07.029**

(12 pages)

Revised Response to the NRC Request for Additional Information  
Related to Open Item 4.2

**OI 4.2: (SER Sections: 3.0.3.2.15 - Reactor Vessel Surveillance Program, 4.2 - Reactor Vessel Neutron Embrittlement, 4.7.1 - Reflood Thermal Shock of the Reactor Vessel Internals, 4.7.2.1 BWRVIP-05, Reactor Vessel Circumferential Welds)**

Due to the lack of benchmarking data in support of the plant-specific RAMA fluence calculations, the staff finds neutron fluence values unacceptable for use in the reactor vessel neutron embrittlement TLAAs.

**OI 4.2 Response**

OI 4.2 was clarified by the NRC in a request for additional information (RAI) transmitted in a letter dated March 26, 2007. The RAI and response is provided below.

**RAI# 4.2**

1. Fluence was calculated for the Pilgrim reactor vessel (RV) for the extended 60-year licensed operating period (54 effective full power years (EFPY) of facility operation), using the Radiation Analysis Modeling Application (RAMA) fluence methodology. The RAMA fluence methodology was previously approved by the NRC staff, and the results are acceptable for licensing actions provided that: (1) the RAMA application follows the guidance in Regulatory Guide 1.190 and (2) RV fluence calculations have at least one credible plant-specific surveillance capsule for benchmarking.

The applicant provided 54 EFPY fluence values for the Pilgrim RV beltline materials in Section 4.2.1 of the License Renewal Application (LRA). These fluence values were used throughout Section 4.2 of the LRA for the RV neutron embrittlement time limited aging analyses (TLAAs). However, due to the lack of a credible plant-specific benchmark, the staff finds the 54 EFPY fluence values provided in LRA Section 4.2.1 unacceptable for use in the RV neutron embrittlement TLAAs. Therefore, the staff requests that the applicant revise Section 4.2.1 of the LRA to provide an acceptable neutron fluence evaluation or an alternative proposal for closing this TLAA topic in the LRA review.

2. Due to the lack of benchmarking data in support of the plant-specific RAMA fluence calculations, the staff cannot complete its review of the TLAAs in LRA Sections 4.2.2, 4.2.3, 4.2.4, 4.2.5, 4.2.6 and 4.7.1, as well as the aging management program (AMP) on the RV material surveillance program, using the current fluence values for the Pilgrim RV that were provided in LRA Section 4.2.1. Therefore, the staff requests that the applicant revise LRA Sections 4.2.2, 4.2.3, 4.2.4, 4.2.5, 4.2.6, 4.7.1, and the AMP on the RV material surveillance program to provide an acceptable evaluation of these topics or an alternative proposal for closing these topics in the LRA review.

**Response**

The benchmarking validation of the RAMA fluence calculation is ongoing for the Pilgrim reactor vessel and internals. The RAMA calculated fluence is approximately 56% of the benchmark fluence calculated from the available surveillance capsule dosimetry. Uncertainties between the calculated and measured results from the dosimetry are still being examined to determine a possible cause for the discrepancy. To ensure resolution of this issue, Commitment 47, which reads as follows, was added by Entergy letter dated May 1, 2007.

47	On or before September 15, 2007 submit to the NRC an action plan to improve benchmarking data to support approval of new P-T curves for Pilgrim.
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To address this issue, an alternative analysis is provided as a means to close this TLAA topic in the LRA review. To address fluence-related TLAAs for the period of extended operation, Entergy has evaluated the affected TLAAs to determine the limiting fluence value. The evaluation included information presented in LRA sections 4.2.1, 4.2.2, 4.2.3, 4.2.4, 4.2.5, 4.2.6, 4.7.1, and the AMP on the RV material surveillance program. From this evaluation the limiting fluence was determined.

The alternative analysis to determine the limiting fluence value is included as Attachment E. This analysis assumes increasing fluence levels until an ASME Code or regulatory limit is reached based on the projected changes in material properties. Changes in the vessel (ferritic) steel material properties are measured by an increase in adjusted reference temperature or a decrease in Charpy upper shelf energy. The effects of increasing fluence on the austenitic stainless steel core shroud and internals was also considered. By assuming increasing fluence levels, the analysis identifies the maximum fluence that can be experienced while meeting the Code and regulatory criteria. This analysis also shows that there is a large margin available to this limiting fluence at the end of the period of extended operation.

The analysis determined that the limiting fluence value was set by the maximum mean  $RT_{NDT}$  value for the vessel axial welds of 114°F to remain below a calculated reactor vessel failure frequency of  $5 \times 10^{-6}$  per reactor-year. The corresponding maximum allowable ID fluence for the axial welds was determined to be  $3.37E+18$  n/cm<sup>2</sup>.

If fluence remains below this limiting value during the period of extended operation, the fluence will yield acceptable results for all fluence-related TLAAs. To confirm that the limiting fluence will not be reached during the period of extended operation and consequently that all of the fluence-related TLAAs remain valid, Commitment 48, which reads as follows, was added by Entergy letter dated May 1, 2007.

48	On or before June 8, 2010, Entergy will submit to the NRC calculations consistent with Regulatory Guide 1.190 that will demonstrate limiting fluence values will not be reached during the period of extended operation.
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Entergy would find it acceptable if this commitment became a license condition.

It should be noted that at the ACRS meeting on April 4, 2007, reference was made to EPRI research that investigated the irradiated behavior of stainless steel components in order to predict service life. Further review has shown that the predictions of service life related to fluence are not directly relevant in this case. The core shroud and the top guide are components that are susceptible to aging effects. However, a review of the analyses related to the core shroud found that the only time-limited aging analysis (TLAA) involves the fatigue analysis and calculation of cumulative usage factors (CUFs) for the shroud repair. The core shroud does not affect the operating P-T limit curves and there is no criterion on fluence that would further limit the operation of the core shroud structure. Similarly, the top guide does not affect the operating P-T limit curves, and there is no criterion on fluence that would further limit the operation of the top guide structure.

PNPS has re-evaluated the neutron embrittlement issues of Sections 4.2 and 4.7.1 and prepared revised LRA sections below. The Reactor Vessel Material Surveillance Program, with the changes to the fluence extrapolation, is correct as written, and no changes to Appendix B, Section B.1.26 are necessary.

#### LRA Amendment

### **4.2 REACTOR VESSEL NEUTRON EMBRITTLEMENT**

The regulations governing reactor vessel integrity are in 10 CFR 50. Section 50.60 requires that all light-water reactors meet the fracture toughness, pressure-temperature limits, and material surveillance program requirements for the reactor coolant pressure boundary as set forth in 10 CFR 50 Appendices G and H.

The PNPS current licensing basis analyses evaluating reduction of fracture toughness of the PNPS reactor vessel for 40 years are TLAA. The reactor vessel neutron embrittlement TLAA has been projected to the end of the period of extended operation in accordance with 10 CFR 54.21(c)(1)(ii) as summarized below. Fifty-four effective full-power years (EFPY) are projected for the end of the period of extended operation (60 years) assuming an average capacity factor of 90% for 60 years.

#### **4.2.1 Reactor Vessel Fluence**

Calculated fluence is based on a time-limited assumption defined by the operating term. As such, fluence is the time-limited assumption for the time-limited aging analyses that evaluate reactor vessel neutron embrittlement.

Fluence values were calculated using the RAMA fluence methodology. The RAMA fluence methodology was developed for the Electric Power Research Institute, Inc. and the boiling water reactor vessel and internals project (BWRVIP) for the purpose of calculating neutron fluence in boiling water reactor components. This methodology has been approved by the NRC (Reference 4.2-20) for application in accordance with Regulatory Guide (RG) 1.190; assuming the results are appropriately benchmarked.

The benchmarking validation of the RAMA fluence calculation is ongoing for the Pilgrim reactor vessel. The RAMA calculated fluence is approximately 56% of the benchmark fluence calculated from the available surveillance capsule dosimetry. Uncertainties between the calculated and measured results from the dosimetry are still being examined to determine a possible cause for the discrepancy. Commitment 47 requires a plan for resolving this discrepancy to be developed and submitted for review by September 2007.

An alternative analysis to determine the limiting fluence value has been performed. This analysis assumes increasing fluence levels until an ASME Code or regulatory limit is reached based on the projected changes in material properties. Changes in the vessel (ferritic) steel material properties are measured by an increase in adjusted reference temperature or a decrease in Charpy upper shelf energy. The effects of increasing fluence on the austenitic stainless steel core shroud and internals was also considered. By assuming increasing fluence levels, the analysis identifies the maximum fluence that can be experienced while meeting the Code and regulatory criteria.

The analysis determined that the limiting fluence value is set by the maximum mean  $RT_{NDT}$  value for the vessel axial welds of 114°F to remain below a calculated reactor vessel failure

frequency of  $5 \times 10^{-6}$  per reactor-year. The corresponding maximum allowable ID fluence for the axial welds was determined to be  $3.37 \times 10^{18}$  n/cm<sup>2</sup>. This fluence level was the limiting fluence value identified.

If fluence remains below this limiting value during the period of extended operation, the fluence will yield acceptable results for all fluence-related TLAA's. Commitment 48 is to confirm that the limiting fluence will not be reached during the period of extended operation and consequently that all of the fluence-related TLAA's will be valid to the end of the period of extended operation.

At PNPS, the limiting beltline material for 40 years consists of 6 plates and their connecting welds, all adjacent to the active fuel zone. No nozzles are included in the limiting beltline materials for the current term of operation (Reference 4.2-2).

The beltline will be re-evaluated for 60 years. An evaluation of the RTNDT for nozzle forgings and welds is expected to show that their adjusted reference temperature at 54 EFPY will be well below the adjusted reference temperatures used in determining the P-T limits. Thus, the nozzle forgings and welds are not expected to be the limiting items for the period of extended operation.

#### **4.2.2 Pressure-Temperature Limits**

Appendix G of 10 CFR 50 requires that reactor vessel boltup, hydrotest, pressure tests, normal operation, and anticipated operational occurrences be accomplished within established pressure-temperature (P-T) limits. These limits are established by calculations that utilize the materials and fluence data obtained through the Reactor Vessel Surveillance Program.

Pilgrim received License Amendment 227 dated March 29, 2007 that extended the existing P-T limit curves for Pilgrim through Cycle 18.

The P-T limit curves will continue to be updated, as required by Appendix G of 10 CFR Part 50 or as operational needs dictate. This updating will assure that the operational limits remain valid through the period of extended operation. Maintaining the P-T limit curves in accordance with Appendix G of 10 CFR 50 assures that the effects of aging on the intended function(s) will be adequately managed for the period of extended operation consistent with 10 CFR 54.21(c)(1)(iii).

#### **4.2.3 Charpy Upper-Shelf Energy**

Appendix G of 10 CFR 50 requires that reactor vessel beltline materials "have Charpy upper-shelf energy ... of no less than 75 ft-lb initially and must maintain Charpy upper-shelf energy throughout the life of the vessel of no less than 50 ft-lb...." The initial (unirradiated) values of upper-shelf energy (CvUSE) for PNPS beltline welds were provided to the NRC in correspondence responding to Generic Letter 92-01 (References 4.2-9, 4.2-10).

Regulatory Guide 1.99, *Radiation Embrittlement of Reactor Vessel Materials*, Revision 2, provides two methods for determining Charpy upper-shelf energy (CvUSE). Position 1 applies for material that does not have surveillance data and Position 2 applies for material with surveillance data. Position 2 requires a minimum of two sets of credible material surveillance data. Since PNRS has data from only one material surveillance capsule, Position 2 does not apply. For Position 1, the percent drop in CvUSE for a stated copper content and neutron fluence is determined by reference to Figure 2 of Regulatory Guide 1.99, Revision 2. This percentage drop is applied to the initial CvUSE to obtain the adjusted CvUSE.



The predictions for percent drop in CvUSE at 54 EFPY must be based on chemistry data, the maximum 1/4T fluence values, and unirradiated CVUSE data submitted to the NRC in the PNPS response to GL 92-01. The predicted CvUSE values for 54 EFPY will utilize Regulatory Guide 1.99 Position 1. The predictions will use Regulatory Guide 1.99, Position 1, and Figure 2; specifically, the formula for the lines will be used to calculate the percent drop in CvUSE (Reference 4.2-14).

PNPS will use chemistry data from previous licensing submittals, the PNPS response to GL 92-01 (References 4.2-9, 4.2-10, 4.2-14), and the 1/4T fluence values to be determined to perform linear interpolation on the CvUSE percent drop values in RG 1.99, Revision 2, Figure 2.

The license renewal SER for BWRVIP-74 (Reference 4.2-11), Action Item #10, states that each license renewal applicant shall demonstrate that the percent reduction in Charpy USE for their beltline materials is less than that specified for the limiting BWR/3-6 plates and the non-Linde 80 submerged arc welds given in BWRVIP-74. This action item is not applicable to PNPS if the PNPS projected CvUSE remains above the 50 ft-lb limit, even for the period of extended operation.

An analysis determined that the limiting fluence value is set by the maximum mean  $RT_{NDT}$  value for the vessel axial welds of 114°F to remain below a calculated reactor vessel failure frequency of  $5 \times 10^{-6}$  per reactor-year. The corresponding maximum allowable ID fluence for the axial welds was determined to be  $3.37E+18$  n/cm<sup>2</sup>. This fluence is the limiting fluence value identified.

If fluence remains below this limiting value during the period of extended operation, the fluence will yield acceptable results for the reactor vessel Charpy upper shelf energy TLAA. To confirm that the limiting fluence will not be reached during the period of extended operation and consequently that this TLAA will be valid to the end of the period of extended operation, Commitment 48 is added.

#### 4.2.4 Adjusted Reference Temperature

Irradiation by high-energy neutrons raises the value of  $RT_{NDT}$  for the reactor vessel.  $RT_{NDT}$  is the reference temperature for nil-ductility transition as defined in Section NB-2320 of the ASME Code. The initial  $RT_{NDT}$  is determined through testing of unirradiated material specimens. The shift in reference temperature,  $\Delta RT_{NDT}$ , is the difference in the 30 ft-lb index temperatures from the average Charpy curves measured before and after irradiation. The adjusted reference temperature (ART) is defined as initial  $RT_{NDT} + \Delta RT_{NDT} + \text{margin}$ . The margin is defined in RG 1.99, Revision 2. The P-T curves are developed from the ART value for the vessel materials. RG 1.99 Revision 2 defines the calculation methods for  $RT_{NDT}$  and ART.

The PNPS reactor vessel was evaluated for an assumed exposure of less than  $10^{19}$  nvt of neutrons with energies exceeding 1 MeV (Reference 4.2-1). After approximately 4.17 EFPY, the first surveillance capsule was withdrawn from the vessel and tested. The capsule test report concludes that the shift in  $RT_{NDT}$  and upper-shelf energy over 32 EFPY will be within 10 CFR 50 guidelines.

PNPS will project values for  $\Delta RT_{NDT}$  and ART at 54 EFPY using the methodology of RG 1.99. These values will be calculated using the chemistry data, margin values, initial  $RT_{NDT}$  values, and chemistry factors (CFs) contained in the PNPS response to GL 92-01 (References 4.2-3, 4.2-9, 4.2-10, 4.2-13). Initial  $RT_{NDT}$  values are from report SIR-00-082, which was submitted in 2001 as part of the PNPS P-T limit change request (Reference 4.2-5). The 1/4T fluence values discussed in Section 4.2.1 will be used. New fluence factors (FFs) will be calculated using the expression in RG 1.99, Revision 2, Equation 2, where the fluence factor is given by

$$FF = f^{(0.28-0.10*\log f)}$$

In this equation,  $f$  is the 1/4T fluence value. The new  $\Delta RT_{\text{NDT}}$  values will be calculated by multiplying the CF and the FF for each plate and weld. Calculated margins and the initial  $RT_{\text{NDT}}$  will then be added to the calculated  $\Delta RT_{\text{NDT}}$  in order to arrive at the new value of ART.

An analysis determined that the limiting fluence value is set by the maximum mean  $RT_{\text{NDT}}$  value for the vessel axial welds of 114°F to remain below a calculated reactor vessel failure frequency of  $5 \times 10^{-6}$  per reactor-year. The corresponding maximum allowable ID fluence for the axial welds was determined to be  $3.37\text{E}+18$  n/cm<sup>2</sup>. This fluence is the limiting fluence value identified.

If fluence remains below this limiting value during the period of extended operation, the fluence will yield acceptable results for the reactor vessel adjusted reference temperature TLAA. To confirm that the limiting fluence will not be reached during the period of extended operation and consequently that this TLAA will be valid to the end of the period of extended operation, Commitment 48 is added.

#### **4.2.5 Reactor Vessel Circumferential Weld Inspection Relief**

Relief from reactor vessel circumferential weld examination requirements under Generic Letter 98-05 is based on an analysis indicating acceptable probability of failure per reactor operating year. The analysis is based on reactor vessel metallurgical conditions as well as flaw indication sizes and frequencies of occurrence that are expected at the end of a licensed operating period.

PNPS received NRC approval for this relief for the remainder of the original 40-year license term. The basis for this relief request is an analysis that satisfied the limiting conditional failure probability for the circumferential welds at the expiration of the current license, based on BWRVIP-05 and the extent of neutron embrittlement (References 4.2-16, 4.2-17). The anticipated changes in metallurgical conditions expected over the extended operating period require additional analysis to extend this relief request.

The NRC evaluation of BWRVIP-05 utilized the FAVOR code to perform a probabilistic fracture mechanics (PFM) analysis to estimate the reactor pressure vessel (RPV) shell weld failure probabilities. Three key inputs to the PFM analysis are (1) the estimated end-of-life mean neutron fluence, (2) the mean chemistry values based on vessel types, and (3) the assumption of potential for beyond-design-basis events.

PNPS will compare the reactor vessel limiting circumferential weld parameters to those used in the NRC analysis for the first two key assumptions. The data will be from the NRC SER for PNPS Relief Request 28 (Reference 4.2-17), and from the data in Table 2.6.4 of the NRC SER for BWRVIP-05 (Reference 4.2-18). (For comparison, the EOL mean  $RT_{\text{NDT}}$  will be calculated without margin and hence will be lower than the Section 4.2.2  $RT_{\text{NDT}}$  value.)

The procedures and training used to limit cold over-pressure events will be the same as those approved by the NRC when PNPS requested approval of the BWRVIP-05 technical alternative for the current license term.

An analysis determined that the limiting fluence value is set by the maximum mean  $RT_{\text{NDT}}$  value for the vessel axial welds of 114°F to remain below a calculated reactor vessel failure frequency of  $5 \times 10^{-6}$  per reactor-year. The corresponding maximum allowable ID fluence for the axial welds was determined to be  $3.37\text{E}+18$  n/cm<sup>2</sup>. This fluence is the limiting fluence value identified.

If fluence remains below this limiting value during the period of extended operation, the fluence will yield acceptable results for the reactor vessel circumferential weld failure probability TLAA. To confirm that the limiting fluence will not be reached during the period of extended operation and consequently that this TLAA will be valid to the end of the period of extended operation, Commitment 48 is added.

#### **4.2.6 Reactor Vessel Axial Weld Failure Probability**

The BWRVIP recommendations for inspection of reactor vessel shell welds (BWRVIP-05) are based on generic analyses supporting an NRC SER conclusion that the generic-plant axial weld failure rate is no more than  $5 \times 10^{-6}$  per reactor year (Reference 4.2-18). BWRVIP-05 showed that this axial weld failure rate is orders of magnitude greater than the 40-year end-of-life circumferential weld failure probability, and used this analysis to justify relief from inspection of the circumferential welds as described above.

PNPS received relief from the circumferential weld inspections for the remainder of the original 40-year operating term (Reference 4.2-17). The basis for this relief request was a plant-specific analysis that showed the limiting conditional failure probability for the PNPS circumferential welds at the end of the original operating term was less than the values calculated in the BWRVIP-05 SER (Reference 4.2-18). The BWRVIP-05 SER concluded that the reactor vessel failure frequency due to failure of the limiting axial welds in the BWR fleet at the end of 40 years of operation is less than  $5 \times 10^{-6}$  per reactor year. This failure frequency is dependent upon given assumptions of flaw density, distribution, and location. The failure frequency also assumes that "essentially 100%" of the reactor vessel axial welds will be inspected. The PNPS relief request requires additional relief request if less than 90% coverage is achieved.

Applicant Action Item 12 from the NRC SER for BWRVIP-74 specified that applicants should monitor axial beltline weld embrittlement. One acceptable method was to determine that the mean  $RT_{NDT}$  of the limiting axial beltline weld at the end of the period of extended operation is less than the values specified in Table 1 of the FSER for BWRVIP-74. The limiting mean  $RT_{NDT}$  value of 114°F for the axial welds was determined to be equivalent to a failure frequency of less than  $5 \times 10^{-6}$  per reactor-year.

An analysis determined that the ID fluence value that yields a mean  $RT_{NDT}$  value for the vessel axial welds of 114°F is  $3.37E+18$  n/cm<sup>2</sup>. This fluence is the limiting fluence value identified.

If fluence remains below this limiting value during the period of extended operation, the fluence will result in acceptable results for the reactor vessel axial weld failure probability TLAA. To confirm that the limiting fluence will not be reached during the period of extended operation and consequently that this TLAA will be valid to the end of the period of extended operation, Commitment 48 is added.

#### **4.7.1 Reflood Thermal Shock of the Reactor Vessel Internals**

UFSAR Section 3.3.6.8 addresses reflood thermal shock of the reactor vessel internals (core shroud). This evaluation of thermal shock was considered a TLAA as it is potentially based on shroud material properties that are affected by neutron fluence.

The shroud material is Type 304 stainless steel, which is not significantly affected by irradiation.

An analysis determined that the limiting fluence value is set by the maximum mean  $RT_{NDT}$  value for the vessel axial welds of 114°F to remain below a calculated reactor vessel failure frequency of  $5 \times 10^{-6}$  per reactor-year. The corresponding maximum allowable ID fluence for the axial welds was determined to be  $3.37E+18$  n/cm<sup>2</sup>. This fluence level is the limiting fluence value identified.

If fluence remains below this limiting value during the period of extended operation, the fluence will yield acceptable results for the reflood thermal shock TLAA. To confirm that the limiting fluence will not be reached during the period of extended operation and consequently that this TLAA will be valid to the end of the period of extended operation, Commitment 48 is added.

Changes to existing UFSAR Section 3.3.6.8 information presented in Section A.1.1 of the LRA (page A-3) are revised as follows:

### 3. Shroud inner surfaces at highest irradiation zone

~~The most irradiated point on the inner surface of the shroud is subjected to a total integrated neutron flux of  $2.7 \times 10^{20}$  nvt (> 1 MeV) by the end of station life. The peak thermal shock stress is 155,700 psi, corresponding to a peak strain of 0.57 percent. The shroud material is Type 304 stainless steel, which is not significantly affected by irradiation. The material does experience a loss in reduction of area. Because reduction of area is the property which determines tolerable local strain, irradiation effects can be neglected. The peak strain resulting from thermal shock at the inside of the shroud represents no loss of integrity of the reactor vessel inner volume. The service limit of Type 304 stainless steel is approached at a fluence of  $8 \times 10^{21}$  n/cm<sup>2</sup> (BWRVIP-35). As the PNPS shroud will remain below that fluence level for the period of extended operation, the shroud will remain serviceable.~~

UFSAR Supplement Sections are revised to read as follows:

#### A.2.2.1.1 Reactor Vessel Fluence

Calculated fluence is based on a time-limited assumption defined by the operating term. As such, fluence is the time-limited assumption for the time-limited aging analyses that evaluate reactor vessel embrittlement. Fluence values were calculated using the RAMA fluence calculation method. The RAMA fluence method was developed for the Electric Power Research Institute, Inc. and the Boiling Water Reactor Vessel and Internals Project (BWRVIP) for the purpose of calculating neutron fluence in boiling water reactor components. This method has been approved by the NRC (Reference A.2-9) for application in accordance with Regulatory Guide 1.190 provided the fluence calculations for the reactor are appropriately benchmarked.

The benchmarking validation of the RAMA fluence calculation is ongoing for the PNPS reactor vessel. The RAMA calculated fluence is approximately 56% of the benchmark fluence calculated from the available surveillance capsule dosimetry. Uncertainties between the calculated and measured results from the dosimetry are still being examined to determine a possible cause for the discrepancy. An action plan to improve benchmarking data to support approval of new P-T curves will be developed and submitted for NRC review.

An alternative analysis to determine the limiting fluence value has been performed (Reference A.2-12). This analysis assumes increasing fluence levels until an ASME Code or regulatory limit is reached based on the projected changes in material properties. Changes in the vessel (ferritic) steel material properties are measured by an increase in adjusted reference temperature or a decrease in Charpy upper shelf energy. The effects of increasing fluence on the austenitic stainless steel core shroud and internals was also considered. By assuming increasing fluence levels, the analysis identifies the maximum fluence that can be experienced while meeting the Code and regulatory criteria.

The analysis determined that the limiting fluence value is set by the maximum mean  $RT_{NDT}$  value for the vessel axial welds of 114°F to remain below a calculated reactor vessel failure frequency of  $5 \times 10^{-6}$  per reactor-year. The corresponding maximum allowable ID fluence for the axial welds was determined to be  $3.37E+18$  n/cm<sup>2</sup>. This fluence level is the limiting fluence value identified.

On or before June 8, 2010, Entergy will submit to the NRC calculations consistent with Regulatory Guide 1.190 that will demonstrate limiting fluence values will not be reached during the period of extended operation.

#### A.2.2.1.2 Pressure-Temperature Limits

Appendix G of 10 CFR 50 requires that reactor vessel bolt-up, hydrostatic tests, pressure tests, normal operation, and anticipated operational occurrences be accomplished within established pressure-temperature (P-T) limits. These limits are established by calculations that utilize the materials and fluence data obtained through the Reactor Vessel Surveillance Program.

Pilgrim received License Amendment 227 dated March 29, 2007 that extended the existing P-T limit curves for Pilgrim through Cycle 18.

The P-T limit curves will continue to be updated, as required by Appendix G of 10 CFR Part 50 or as operational needs dictate. This updating will assure that the operational limits remain valid through the period of extended operation. Maintaining the P-T limit curves in accordance with Appendix G of 10 CFR 50 assures that the effects of aging on the intended function(s) will be adequately managed for the period of extended operation consistent with 10 CFR 54.21(c)(1)(iii).

#### A.2.2.1.3 Charpy Upper-Shelf Energy

Appendix G of 10 CFR 50 requires that reactor vessel beltline materials "have Charpy upper-shelf energy ... of no less than 75 ft-lb initially and must maintain Charpy upper-shelf energy throughout the life of the vessel of no less than 50 ft-lb...." The initial (unirradiated) values of upper-shelf energy (CvUSE) for PNPS beltline welds were provided to the NRC in correspondence responding to Generic Letter 92-01.

Regulatory Guide 1.99, *Radiation Embrittlement of Reactor Vessel Materials*, Revision 2, provides two methods for determining Charpy upper-shelf energy (CvUSE). Position 1 applies for material that does not have surveillance data and Position 2 applies for material with surveillance data. Position 2 requires a minimum of two sets of credible material surveillance data. Since PNPS has data from only one material surveillance capsule, Position 2 does not apply. For Position 1, the percent drop in CvUSE for a stated copper content and neutron fluence is determined by reference to Figure 2 of Regulatory Guide 1.99, Revision 2. This percentage drop is applied to the initial CvUSE to obtain the adjusted CvUSE.

The predictions for percent drop in CvUSE at 54 EFPY must be based on chemistry data, the maximum 1/4T fluence values, and unirradiated CvUSE data submitted to the NRC in the PNPS response to GL 92-01. The predicted CvUSE values for 54 EFPY will utilize Regulatory Guide 1.99 Position 1. The predictions will use Regulatory Guide 1.99, Position 1, Figure 2; specifically, the formula for the lines will be used to calculate the percent drop in CvUSE.

PNPS will use chemistry data from previous licensing submittals, the PNPS response to GL 92-01, and the 1/4T fluence values to be determined to perform linear interpolation on the CvUSE percent drop values in RG 1.99, Revision 2, Figure 2.

The license renewal SER for BWRVIP-74, Action Item #10, states that each license renewal applicant shall demonstrate that the percent reduction in Charpy USE for their beltline materials is less than that specified for the limiting BWR/3-6 plates and the non-Linde 80 submerged arc welds given in BWRVIP-74. This action item is not applicable to PNPS if the PNPS projected CvUSE remains above the 50 ft-lb limit, even for the period of extended operation.

An analysis determined that the limiting fluence value is set by the maximum mean  $RT_{NDT}$  value for the vessel axial welds of 114°F to remain below a calculated reactor vessel failure frequency of  $5 \times 10^{-6}$  per reactor-year. The corresponding maximum allowable ID fluence for the axial welds was determined to be  $3.37E+18$  n/cm<sup>2</sup>. This fluence is the limiting fluence value identified.

If fluence remains below this limiting value during the period of extended operation, the fluence will yield acceptable results for the reactor vessel Charpy upper shelf energy TLAA. To confirm that this TLAA will be valid to the end of the period of extended operation, Entergy will submit to the NRC on or before June 8, 2010 calculations consistent with Regulatory Guide 1.190 that will demonstrate limiting fluence values will not be reached during the period of extended operation.

#### A.2.2.1.4 Adjusted Reference Temperature

Irradiation by high-energy neutrons raises the value of  $RT_{NDT}$  for the reactor vessel.  $RT_{NDT}$  is the reference temperature for nil-ductility transition as defined in Section NB-2320 of the ASME Code. The initial  $RT_{NDT}$  is determined through testing of unirradiated material specimens. The shift in reference temperature,  $\Delta RT_{NDT}$ , is the difference in the 30 ft-lb index temperatures from the average Charpy curves measured before and after irradiation. The adjusted reference temperature (ART) is defined as initial  $RT_{NDT} + \Delta RT_{NDT} + \text{margin}$ . The margin is defined in RG 1.99, Revision 2. The P-T curves are developed from the ART value for the vessel materials. RG 1.99 Revision 2 defines the calculation methods for  $RT_{NDT}$  and ART.

The PNPS reactor vessel was evaluated for an assumed exposure of less than  $10^{19}$  nvt of neutrons with energies exceeding 1 MeV. After approximately 4.17 EFPY, the first surveillance capsule was withdrawn from the vessel and tested. The capsule test report concludes that the shift in  $RT_{NDT}$  and upper-shelf energy over 32 EFPY will be within 10 CFR 50 guidelines.

PNPS will project values for  $\Delta RT_{NDT}$  and ART at 54 EFPY using the methodology of RG 1.99. These values will be calculated using the chemistry data, margin values, initial  $RT_{NDT}$  values, and chemistry factors (CFs) contained in the PNPS response to GL 92-01. Initial  $RT_{NDT}$  values are from report SIR-00-082, which was submitted in 2001 as part of the PNPS P-T limit change request. The 1/4T fluence values discussed in Section 4.2.1 will be used. New fluence factors (FFs) will be calculated using the expression in RG 1.99, Revision 2, and Equation 2, where the fluence factor is given by

$$FF = f^{(0.28 - 0.10 \cdot \log f)}$$

In this equation,  $f$  is the 1/4T fluence value. The new  $\Delta RT_{NDT}$  values will be calculated by multiplying the CF and the FF for each plate and weld. Calculated margins and the initial  $RT_{NDT}$  will then be added to the calculated  $\Delta RT_{NDT}$  in order to arrive at the new value of ART.

An analysis determined that the limiting fluence value is set by the maximum mean  $RT_{NDT}$  value for the vessel axial welds of 114°F to remain below a calculated reactor vessel failure frequency of  $5 \times 10^{-6}$  per reactor-year. The corresponding maximum allowable ID fluence for the axial welds was determined to be  $3.37E+18$  n/cm<sup>2</sup>. This fluence is the limiting fluence value identified.

If fluence remains below this limiting value during the period of extended operation, the fluence will result in acceptable results for the reactor vessel adjusted reference temperature TLAA. To confirm that this TLAA will be valid to the end of the period of extended operation, Entergy will submit to the NRC on or before June 8, 2010 calculations consistent with Regulatory Guide 1.190 that will demonstrate limiting fluence values will not be reached during the period of extended operation.

#### A.2.2.1.5 Reactor Vessel Circumferential Weld Inspection Relief

Relief from reactor vessel circumferential weld examination requirements under Generic Letter 98-05 is based on an analysis indicating acceptable probability of failure per reactor operating year. The analysis is based on reactor vessel metallurgical conditions as well as flaw indication sizes and frequencies of occurrence that are expected at the end of a licensed operating period.

PNPS received NRC approval for this relief for the remainder of the original 40-year license term. The basis for this relief request is an analysis that satisfied the limiting conditional failure probability for the circumferential welds at the expiration of the current license, based on BWRVIP-05 and the extent of neutron embrittlement. The anticipated changes in metallurgical conditions expected over the extended operating period require additional analysis to extend this relief request.

The NRC evaluation of BWRVIP-05 utilized the FAVOR code to perform a probabilistic fracture mechanics (PFM) analysis to estimate the reactor pressure vessel (RPV) shell weld failure probabilities. Three key inputs to the PFM analysis are (1) the estimated end-of-life mean neutron fluence, (2) the mean chemistry values based on vessel types, and (3) the assumption of potential for beyond-design-basis events.

PNPS will compare the reactor vessel limiting circumferential weld parameters to those used in the NRC analysis for the first two key assumptions. The data will be from the NRC SER for PNPS Relief Request 28, and from the data in Table 2.6.4 of the NRC SER for BWRVIP-05. (For comparison, the EOL mean  $RT_{NDT}$  will be calculated without margin and hence will be lower than the Section 4.2.2  $RT_{NDT}$  value.)

The procedures and training used to limit cold over-pressure events will be the same as those approved by the NRC when PNPS requested approval of the BWRVIP-05 technical alternative for the current license term.

An analysis determined that the limiting fluence value is set by the maximum mean  $RT_{NDT}$  value for the vessel axial welds of 114°F to remain below a calculated reactor vessel failure frequency of  $5 \times 10^{-6}$  per reactor-year. The corresponding maximum allowable ID fluence for the axial welds was determined to be  $3.37E+18$  n/cm<sup>2</sup>. This fluence is the limiting fluence value identified.

If fluence remains below this limiting value during the period of extended operation, the fluence will yield acceptable results for the reactor vessel circumferential weld failure probability TLAA. To confirm that this TLAA will be valid to the end of the period of extended operation, Entergy will submit to the NRC on or before June 8, 2010 calculations consistent with Regulatory Guide 1.190 that will demonstrate limiting fluence values will not be reached during the period of extended operation.

#### A.2.2.1.6 Reactor Vessel Axial Weld Failure Probability

The BWRVIP recommendations for inspection of reactor vessel shell welds (BWRVIP-05) are based on generic analyses supporting an NRC SER conclusion that the generic-plant axial weld failure rate is no more than  $5 \times 10^{-6}$  per reactor year. BWRVIP-05 showed that this axial weld failure rate is orders of magnitude greater than the 40-year end-of-life circumferential weld failure probability, and used this analysis to justify relief from inspection of the circumferential welds as described above.

PNPS received relief from the circumferential weld inspections for the remainder of the original 40-year operating term. The basis for this relief request was a plant-specific analysis that showed the limiting conditional failure probability for the PNPS circumferential welds at the end of the original operating term was less than the values calculated in the BWRVIP-05 SER. The BWRVIP-05 SER concluded that the reactor vessel failure frequency due to failure of the limiting axial welds in the BWR fleet at the end of 40 years of operation is less than  $5 \times 10^{-6}$  per reactor year. This failure frequency is dependent upon given assumptions of flaw density, distribution, and location. The failure frequency also assumes that "essentially 100%" of the reactor vessel axial welds will be inspected. The PNPS relief request requires additional relief request if less than 90% coverage is achieved.

Applicant Action Item 12 from the NRC SER for BWRVIP-74 specified that applicants should monitor axial beltline weld embrittlement. One acceptable method was to determine that the mean  $RT_{NDT}$  of the limiting axial beltline weld at the end of the period of extended operation is less than the values specified in Table 1 of the FSER for BWRVIP-74. The limiting mean  $RT_{NDT}$  value of  $114^{\circ}\text{F}$  for the axial welds was determined to be equivalent to a failure frequency of less than  $5 \times 10^{-6}$  per reactor-year.

An analysis determined that the ID fluence value that yields a mean  $RT_{NDT}$  value for the vessel axial welds of  $114^{\circ}\text{F}$  is  $3.37\text{E}+18$  n/cm<sup>2</sup>. This fluence is the limiting fluence value identified.

If fluence remains below this limiting value during the period of extended operation, the fluence will yield acceptable results for the reactor vessel axial weld failure probability TLAA. To confirm that this TLAA will be valid to the end of the period of extended operation, Entergy will submit to the NRC on or before June 8, 2010 calculations consistent with Regulatory Guide 1.190 that will demonstrate limiting fluence values will not be reached during the period of extended operation.

The following reference is added to UFSAR Supplement Section A.2.3.

A.2-12 Bethay, Stephen J. (Entergy), to Document Control Desk (NRC), "License Renewal Application Amendment 17," letter 2.07.029 dated May 17, 2007, Attachment E, Structural Integrity Associates Fluence Evaluation for PNPS.



**ATTACHMENT E to Letter 2.07.029**

(22 pages)

Structural Integrity Associates Fluence Evaluation for PNPS



**Structural Integrity Associates, Inc.**

File No.: PNPS-27Q-301

**CALCULATION PACKAGE**

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**Contains References to Proprietary Information**

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## **1.0 INTRODUCTION**

The recent fluence re-evaluation for the Pilgrim Nuclear Power Station (PNPS) reactor pressure vessel (RPV) using the EPRI RAMA code required an increased fluence bias correction factor (CF) of 1.78 to adjust for the benchmarking discrepancy with the cycle 4 surveillance capsule dosimetry results [1]. A rigorous technical explanation for this bias has not been determined. As a result, the NRC will not accept the PNPS fluence calculations for application to future plant operation without further justification. In response to this, Entergy Nuclear Northeast (ENN) has requested SI to perform an additional evaluation to demonstrate adequate vessel life prediction through the extended 60-year operating period with respect to the fluence projections.

Increasing fluence has an effect on the toughness of the RPV materials. This is measured by an increase in the adjusted reference temperature (ART) and a decrease in the upper shelf energy (USE) of the RPV beltline materials. The PNPS FSAR identifies the vessel as being controlling for all reactor pressure boundary carbon steel components [17]. The ASME Code [2] and 10CFR50, Appendix G [3] give criteria for maintaining pressure boundary integrity including the effects of materials degradation due to irradiation damage. Additional evaluations for equivalent margins have been submitted to the Nuclear Regulatory Commission (NRC) and approved for use by boiling water reactors (BWRs) for Charpy USE drop. These equivalent margin analyses for USE are published in BWRVIP-74-A [4]. In addition, BWRVIP-05 [5] provides a technical basis for alternative inspection requirements of the RPV shell welds to eliminate inspections of circumferential welds. BWRVIP-05 and the Supplemental SER [18] provide the basis for acceptable limits for BWR reactor vessel axial welds. The methods and criteria in these documents form the basis for demonstrating vessel integrity margins, including the effects of plant aging due to fluence.

ENN performed an integrated plant assessment (IPE) to extend the operating license of PNPS. This included a review of the time-limited aging analyses (TLAA) and exemptions to 10CFR50 for the period of extended operation [6]. Increasing fluence is one aspect considered in the TLAAs. The calculated fluence in the vessel using the method from Reference [1] is projected through 54 effective full power years (EFPY) without a bias correction factor. The results of that study are now being reevaluated using assumed fluences greater than the previously calculated results. This analysis for PNPS uses the established methods and criteria for evaluating embrittlement for fluence levels exceeding the previously projected end-of-license fluence in the vessel.

## **2.0 TECHNICAL APPROACH**

The shift in the ART and a decrease in the USE for ferritic materials are predicted by Regulatory Guide 1.99, Revision 2 [7]. The embrittlement trend curves are a function of



copper (Cu) content, nickel (Ni) content, and fluence; different trend curves apply for welds and base metals. The materials in the RPV that must be monitored for irradiation effects are the regions where significant fluence levels are projected ( $> 1 \times 10^{17}$  n/cm<sup>2</sup>,  $E > 1$  MeV), and those materials are characterized as beltline materials. Analyses of all of the beltline materials for the PNPS vessel determine the weld or plate that is the limiting RPV beltline material. The properties of that limiting beltline material are then used to calculate the operating heatup, cooldown, and pressure test curves. Those calculations were performed previously for the PNPS RPV for a fluence up to 54 EFPY using fluence projections with and without the 1.78 bias correction factor [8, 9]. The calculations show that there is no RPV integrity concern for 54 EFPY even with the bias corrected fluence.

To further demonstrate that the fluence uncertainty issue for PNPS is not a concern, additional analyses are being performed in this calculation assuming even greater fluence levels in the RPV beyond the 54 EFPY predicted fluence values with the 1.78 bias correction factor. The fluence levels are assumed to increase until a criterion for operability can no longer be maintained. When that limit is determined, the calculated factor on fluence is an indication of the conservatism against brittle fracture of the RPV (or some other criteria) in order to accommodate the observed uncertainty in the fluence calculations.

### 3.0 ASSUMPTIONS / DESIGN INPUTS

1. The pressure for the pressure test is normal operating pressure (1,035 psig) from Reference [10].
2. The maximum test temperature for the hydrotest is 212°F per the PNPS Technical Specifications [11]. (Note that this is an operational limit, not a brittle fracture limit.)

### 4.0 CALCULATIONS

#### 4.1 Maximum Fluence to Perform Hydrotest

Irradiation by high energy neutrons raises the  $RT_{NDT}$  of the reactor vessel materials. The ART is defined as  $RT_{NDT} + \Delta RT_{NDT} + \text{Margin}$  in accordance with Regulatory Guide 1.99, Rev. 2 [7]. The pressure-temperature (P-T) curves are developed from the ART value for the vessel material. The calculated hydrotest pressure vs. temperature curve (Curve A) results for 54 EFPY are shown in Table 1 and in Figure 1 [8]. The PNPS projected values for  $\Delta RT_{NDT}$  and ART at 54 EFPY were calculated with the 1.78 bias correction factor on fluence [9]. The projected values of ART are shown in Table 2. The hydrotest pressure is the normal operating pressure, which is 1,035 psig [10]. The system hydrostatic test temperature is calculated to meet the requirements of ASME Section XI, Appendix G, Article G-2400 [2]. The system hydrostatic test should be performed at a temperature not lower than the highest required temperature for any component in the system. For PNPS, the limiting component is the beltline

material with the highest ART value at the quarter-thickness (1/4t) location. From Table 2, the limiting materials are the lower intermediate shell longitudinal welds #1 and #3.

The maximum calculated ART value for these welds at 54 EFPY is 122.7°F. This corresponds to a 1/4t fluence value of  $1.46 \times 10^{18}$  n/cm<sup>2</sup>, including the 1.78 bias correction factor. The hydrotest temperature at this fluence is 152.5°F. This hydrotest temperature is interpolated linearly from the values from Table 1 as follows:

Hydrotest Temperature (°F)	Hydrotest Pressure (psig)
150	1,007
<b>152.5</b>	<b>1,035</b>
155	1,063

The temperature difference between the 1/4t ART value and the hydrotest temperature is calculated to be 29.8°F. This temperature difference is assumed to be constant for increasing fluence and ART values, so the maximum fluence to conduct the hydrotest can be calculated from the maximum achievable temperature to perform the hydrotest, which is 212°F for PNPS [11]. The 1/4t fluence and corresponding 1/4t ART for the limiting welds are increased until the hydrotest temperature of 212°F is reached. From the table below it is noted that the maximum 1/4t fluence of  $4.12 \times 10^{18}$  n/cm<sup>2</sup> corresponds to a 1/4t ART value of 182.2°F for a hydrotest temperature of 212°F, the maximum temperature to perform the hydrotest at PNPS.

**Calculation of Hydrotest Maximum Temperature and Fluence**

1/4t Fluence (n/cm <sup>2</sup> )	1/4t ART (°F)	Hydrotest Temp. (°F)	Temp. Difference (°F)	Fluence Ratio	
1.46E+18	122.7	152.5	29.8	1.00	
2.00E+18	139.6	169.4	29.8	1.37	
3.00E+18	162.9	192.7	29.8	2.05	
4.00E+18	180.4	210.2	29.8	2.74	
<b>4.12E+18</b>	<b>182.2</b>	<b>212</b>	<b>29.8</b>	<b>2.82</b>	maximum fluence to conduct hydrotest < 212°F
4.50E+18	187.8	217.6	29.8	3.08	
5.00E+18	194.4	224.2	29.8	3.42	

The calculated hydrotest temperature and 1/4t ART values versus fluence are shown in Figure 2. A fluence ratio of 2.82 is the ratio of the maximum 1/4t fluence at the limiting vessel beltline welds compared to the 54 EFPY fluence with the 1.78 bias correction factor. In other words, the fluence with the 1.78 bias correction factor would have to be increased by an additional factor of 2.82 before the limiting hydrotest temperature of 212°F is reached.



#### 4.2 Maximum Fluence to Maintain Charpy Upper Shelf Energy

Appendix G of 10CFR50 requires that reactor vessel beltline materials “have Charpy upper shelf energy...of no less than 75 ft-lb initially and must maintain Charpy upper shelf energy throughout the life of the vessel of no less than 50 ft-lb.” Regulatory Guide 1.99, Rev. 2, *Radiation Embrittlement of Reactor Vessel Materials*, defines the method for predicting upper shelf energy drop in terms of a percentage from the unirradiated value. Figure 3 shows the predicted Charpy upper shelf energy for welds and base metals as a function of copper content and fluence.

The predicted Charpy upper shelf energy ( $C_v$ USE) values for PNPS at 54 EFPY were determined previously for the PNPS license renewal project [6]. The predicted  $C_v$ USE values based on the Regulatory Guide 1.99 Position 1 method are shown in Table 3. The predicted values for  $C_v$ USE using the 54 EFPY fluences with the 1.78 bias correction factor are shown in Table 4. It is noted that all projected USE values are above 50 ft-lbs, even with the 1.78 bias correction factor on fluence. The USE limit shows a minimum fluence ratio of 4.9 for the projected fluence to reach 50 ft-lbs for the lower intermediate shell axial welds, as shown in Table 5. Because the USE values are always greater than 50 ft-lbs., the equivalent margin method of BWRVIP-74-A is not required.

#### 4.3 Maximum Fluence Bounded by the Reactor Vessel Weld Failure Probability

The BWRVIP recommendations for inspection of reactor vessel shell welds in BWRVIP-05 [5] are based on generic analyses supporting a Safety Evaluation Review (SER) conclusion that the generic plant axial weld failure rate is no greater than  $5 \times 10^{-6}$  per reactor year [12] at the end of 40 years. BWRVIP-05 showed that this axial weld failure rate is orders of magnitude greater than the 40-year end-of-life circumferential weld failure probability, and used this analysis to justify relief from inspection of the circumferential welds as described above.

PNPS received relief from the circumferential weld inspections for the remainder of the original 40-year operating term [13]. The basis for this relief request was a plant specific analysis that showed the limiting conditional failure probability for the PNPS circumferential welds at the end of the original operating term were less than the values calculated in the BWRVIP-05 SER [12].

Table 6 contains a comparison of the PNPS reactor vessel limiting axial weld parameters to those used in the NRC analysis. The data in column two is from the NRC Supplemental SER on the BWRVIP-05 Report, and it is the basis for evaluating axial welds in BWRs [18]. The data in the third column (PNPS) is the projected 54 EFPY data for PNPS without the 1.78 bias correction factor on fluence [6]. (For consistency with the NRC evaluation, the  $RT_{NDT}$  is calculated without the margin term.) The data in column four (PNPS with Bias CF) is the projected 54 EFPY data for PNPS with the 1.78 bias correction factor on fluence. Column



five (PNPS Limit) shows the maximum fluence and  $RT_{NDT}$  to assure that the limiting axial weld remains bounded by the mean value of  $RT_{NDT} < 114^{\circ}F$  from the NRC Supplemental SER [18]. The mean  $RT_{NDT}$  limit of  $114^{\circ}F$  was chosen to represent a vessel failure frequency due to failure of the axial welds of less than  $5 \times 10^{-6}$  per reactor-year. Although this analysis was performed for the initial 40-year license period, it was considered to be applicable for the license renewal period per the guidance in the Supplemental SER. The maximum ID fluence of  $3.37 \times 10^{18}$  n/cm<sup>2</sup> gives a fluence ratio of 1.66 compared to the 54 EFPY fluence with the 1.78 bias correction factor.

Table 7 contains a comparison of the PNPS reactor vessel limiting circumferential weld parameters to those used in the NRC analysis. The data in column two (CE) is from Table 2.6-5 of the NRC SER for BWRVIP-05 [12]. The data in the third column (PNPS) is the projected 54 EFPY data for the PNPS circumferential weld without the 1.78 bias correction factor on fluence [6]. The data in column four (PNPS with Bias CF) is the projected 54 EFPY data for the PNPS circumferential weld with the 1.78 bias correction factor on fluence. Column five (PNPS Limit) shows the maximum fluence and  $RT_{NDT}$  to assure that the PNPS circumferential weld remains bounded by the value of  $128.5^{\circ}F$  determined from the CEOG and accepted in the SER [12]. The maximum ID fluence of  $1.14 \times 10^{19}$  n/cm<sup>2</sup> gives a fluence ratio of 7.35 compared to the 54 EFPY fluence with the 1.78 bias correction factor.

PNPS obtained relief from the examination of RPV circumferential welds related to the augmented shell weld examination requirements contained in 10CFR50.55a(g)(6)(ii)(A)(5). The reduction in scope of these inspections from essentially 100 percent of all RPV shell welds to examination of essentially 100 percent of the axial welds and essentially zero percent of the circumferential welds was based on the NRC staff determination that the conditional probability of failure for these welds was within the acceptable limits at the expiration of the current operating license [13]. The results in Tables 6 and 7 show that the bounding reactor vessel weld conditional failure probabilities can be maintained well beyond the 54 EFPY projected fluences and ART values for the PNPS vessel. The large calculated fluence ratio shown in Table 7 indicates that the criteria for circumferential vessel welds will not be the limiting factor for fluence margin in the PNPS RPV. However, the fluence ratio of 1.66 shown in Table 6 to assure that the limiting axial weld  $RT_{NDT}$  (and equivalent failure frequency) is acceptable makes the axial welds in the PNPS vessel the limiting concern with respect to fluence.

#### 4.4 Effect of Fluence on Evaluation of N2 Nozzles

The fluence levels in the N2 nozzles are relatively low compared to the peak fluence in the beltline. These fluences shown in the table below were obtained from the RAMA code fluence calculation [9, 14].



	54 EFPY Fluence @ 1/4t (w/o 1.78 bias CF) (n/cm <sup>2</sup> )	54 EFPY Fluence @ 1/4t (with 1.78 bias CF) (n/cm <sup>2</sup> )
Recirc. inlet (N2) nozzles	2.02E+17	3.60E+17
Limiting Axial Welds	8.18E+17	1.46E+18

The effect of the increasing fluence on the calculated ART values for the limiting weld and the N2 nozzles is shown below. The ART values for the A508-2 nozzle forgings was estimated using upper bound Cu = 0.35, Ni = 0.85, and an initial RT<sub>NDT</sub> of 0°F [14].

	54 EFPY ART @ 1/4t (w/o 1.78 bias CF) (°F)	54 EFPY ART @ 1/4t (with 1.78 bias CF) (°F)
Recirc. inlet (N2) nozzles	77.0	94.7
Limiting Axial Welds	95.3	122.7*

Structural Integrity Associates recently performed an evaluation of the recirc. inlet nozzles using best estimate copper and nickel chemistry values of Cu = 0.15 wt%, Ni = 0.85 wt% [14]. Using these best estimate values, the calculated ART values for the nozzles are as follows:

	54 EFPY ART @ 1/4t (w/o 1.78 bias CF) (°F)	54 EFPY ART @ 1/4t (with 1.78 bias CF) (°F)
Recirc. inlet (N2) nozzles	39.9	56.4
Limiting Axial Welds	95.3	122.7*

From the comparison of the ART values for the recirc. inlet nozzles and the limiting axial welds, the recirc. inlet nozzle embrittlement levels are well below the projected ART values for the limiting axial welds. This is mainly because of significantly lower fluences at the height of the nozzles compared to the active core region. Thus, there is no impact of fluence uncertainty for this evaluation, and it is determined that the nozzles will not become the limiting beltline materials for P-T limits or hydrotest conditions as fluence levels are increased.

\* Note: The limiting axial weld values for ART = RT<sub>NDT</sub> + ΔRT<sub>NDT</sub> + Margin Term (see Table 2); these values are different than the calculated mean RT<sub>NDT</sub> values for the limiting axial welds shown in Table 6 that do not include the Margin Term.

#### 4.5 Effect of Fluence on RPV Internals

##### 4.5.1 Top Guide

BWRVIP-26 calculated the minimum top guide fluence for 32 EFPY (40 years) as  $4 \times 10^{21}$  n/cm<sup>2</sup> [15]. The threshold for IASCC is  $5 \times 10^{20}$  n/cm<sup>2</sup>, and the PNPS top guide fluence will exceed this threshold [6]. Therefore, PNPS must manage IASCC of the top guide assembly. PNPS has implemented the inspection recommendation in BWRVIP-26 through the BWR Vessel Internals Program [16]. The BWR Vessel Internals Program will adequately manage the effects of aging on the top guide for the period of extended operation. The top guide does not affect the operating P-T limit curves, and there is no criterion on fluence that would further limit the operation of the top guide structure.

##### 4.5.2 Core Shroud

The core shroud is a BWR component that is known to be susceptible to aging effects. Section 3.8.12 of the PNPS License Renewal Project, TLAA and Exemption Evaluations [6] addresses the time limited aging analyses of the core shroud. A review of the analyses related to the core shroud found that the only TLAA involves the fatigue analysis and calculation of cumulative usage factors (CUFs) for the shroud repair. The core shroud does not affect the operating P-T limit curves, and there is no criterion on fluence that would further limit the operation of the core shroud structure.

### 5.0 RESULTS OF ANALYSIS

The effects of increased fluence beyond the projected 54 EFPY fluence calculations for the PNPS RPV are summarized below for each of the potential aging effects. The results are compared to determine the minimum acceptable fluence ratio. This is the fluence multiplier that could be achieved compared to the 54 EFPY fluence with the 1.78 bias correction factor, and is the measure of tolerance on fluence before a limit is reached that would exceed a Code limit, regulatory criterion, or service limit.

Effect of Fluence on	Acceptable Fluence Ratio
Hydrotest Temperature	2.82
Charpy Upper Shelf Energy	4.86
RPV Axial Weld Failure Probability	1.66*
RPV Circ. Weld Failure Probability	7.35
Evaluation of N2 Nozzles	Bounded by bellline

\* minimum acceptable fluence ratio = 1.66



## 6.0 CONCLUSIONS AND DISCUSSIONS

Fluence contributes to changes in the vessel beltline material properties. These changes are measured by the shift in  $RT_{NDT}$  or the drop in USE of the ferritic materials (i.e., welds, plates, and forgings). The analyses using projected fluence values for license renewal (54 EFPY) for PNPS show no limitations due to embrittlement concerns for the vessel. Considering increasing fluence levels, the RPV analyses demonstrate that the Code and regulatory criteria can be met for operation well beyond this maximum fluence level by a factor of 1.66 (or greater) on the 54 EFPY fluence including a bias correction factor of 1.78.

The limiting condition for the PNPS vessel due to fluence is the maximum level of embrittlement of the axial welds of 114°F to remain below a calculated reactor vessel failure frequency of  $5 \times 10^{-6}$  per reactor-year.

The next limiting condition for the vessel is the temperature required to perform the ASME Code hydrotest. The temperature to perform the hydrotest is prescribed by ASME Section XI, Article G-2400 that requires a safety factor of 1.5 on the pressure stress intensity to prevent brittle fracture of the vessel during this test. The maximum temperature limit for the hydrotest of 212°F in the PNPS Technical Specifications is an administrative limit; it may be possible to perform the test at higher temperatures which would allow for even higher fluence levels.

These analyses demonstrate that there is a considerable tolerance on the acceptable range of fluence. This is exemplified by the difference between the fluence for the maximum predicted levels of embrittlement and the limiting criteria for axial weld failure frequency, a difference large enough to accommodate the uncertainties on the calculated fluence for PNPS.

## 7.0 REFERENCES

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2. ASME Boiler and Pressure Vessel Code, Section XI, Appendix G, 1998 Edition, 2000 Addenda.
3. Code of Federal Regulations, 10 CFR, Part 50, Appendix G, Federal Register: January 2005.
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5. BWRVIP-05, "BWR Reactor Pressure Vessel Shell Weld Inspection Recommendations (BWRVIP-05)," BWR Vessel and Internals Project," **EPRI Proprietary**, EPRI TR-105697, September 1995. (SI File No. BWRVIP-01-205P).
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**Table 1: Beltline Curve A for 54 EFPY with Bias Correction Factor on Fluence [8]**

**Pressure-Temperature Curve Calculation**

*(Pressure Test = Curve A)*

*(NOTE: THE ART<sub>NDT</sub> includes a calculated bias on fluence of 1.78.)*

<b>Inputs:</b>	Plant =	<b>Pilgrim</b>	
	Component =	<b>Beltline</b>	
	Vessel thickness, t =	<b>5.5312</b>	inches, so $\sqrt{t} = 2.352$ $\sqrt{\text{inch}}$
	Vessel Radius, R =	<b>113.91</b>	inches
	ART <sub>NDT</sub> =	<b>122.7</b>	°F =====> <b>54 EFPY</b>
	Cooldown Rate, CR =	<b>0</b>	°F/hr
	K <sub>IT</sub> =	<b>0.00</b>	ksi*inch <sup>1/2</sup> (From Appendix G, for cooldown rate above)
	$\Delta T_{1/4t}$ =	<b>0.0</b>	°F (no thermal for pressure test)
	Safety Factor =	<b>1.50</b>	(for pressure test)
	M <sub>m</sub> =	<b>2.176</b>	(From Appendix G, for inside surface axial flaw)
	Temperature Adjustment =	<b>0.0</b>	°F
	Height of Water for a Full Vessel =	<b>507.5</b>	inches
	Pressure Adjustment =	<b>18.3</b>	psig (hydrostatic pressure for a full vessel at 70°F)
	Hydro Test Pressure =	<b>1,565</b>	psig
	Flange RT <sub>NDT</sub> =	<b>10.0</b>	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K <sub>IC</sub> (ksi*inch <sup>1/2</sup> )	K <sub>IP</sub> (ksi*inch <sup>1/2</sup> )	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
70.0	70.0	40.43	26.95	0	70.0	0
70.0	70.0	40.43	26.95	601	70.0	583
75.0	75.0	41.19	27.46	612	75.0	594
80.0	80.0	42.03	28.02	625	80.0	606
85.0	85.0	42.95	28.64	638	85.0	620
90.0	90.0	43.98	29.32	654	90.0	635
95.0	95.0	45.11	30.08	671	95.0	652
100.0	100.0	46.37	30.91	689	100.0	671
105.0	105.0	47.75	31.84	710	105.0	691
110.0	110.0	49.28	32.86	733	110.0	714
115.0	115.0	50.97	33.98	758	115.0	739
120.0	120.0	52.84	35.23	785	120.0	767
125.0	125.0	54.91	36.61	816	125.0	798
130.0	130.0	57.19	38.13	850	130.0	832
135.0	135.0	59.72	39.81	888	135.0	869
140.0	140.0	62.51	41.67	929	140.0	911
145.0	145.0	65.59	43.73	975	145.0	957
150.0	150.0	68.99	46.00	1026	150.0	1,007
155.0	155.0	72.76	48.51	1082	155.0	1,063
160.0	160.0	76.92	51.28	1143	160.0	1,125
165.0	165.0	81.52	54.34	1212	165.0	1,193
170.0	170.0	86.60	57.73	1287	170.0	1,269
175.0	175.0	92.21	61.48	1371	175.0	1,352
180.0	180.0	98.42	65.61	1463	180.0	1,445
185.0	185.0	105.28	70.19	1565	185.0	1,547
190.0	190.0	112.86	75.24	1678	190.0	1,659
195.0	195.0	121.24	80.83	1802	195.0	1,784

**Table 2: PNPS ART Calculations for 54 EFPY with Bias Correction Factor on Fluence [9]**
**Pilgrim RPV Material ART Calculations**
**(54 EFPY)**

 (NOTE: This table covers all RPV materials with an exposed fluence,  $E > 1 \text{ MeV}$ , of greater than  $1.0 \times 10^{17} \text{ n/cm}^2$ .)

includes 1.78 calculated bias on fluence

Description	Piece No.	Code No.	Heat No.	Estimated Initial RT <sub>NDT</sub> (°F)	Chemistry		Chemistry Factor (°F)	Adjustments For 1/4t			
					Cu (wt %)	Ni (wt %)		ΔRT <sub>NDT</sub> (°F)	Margin Terms		ART <sub>NDT</sub> (°F)
									σ <sub>A</sub> (°F)	σ <sub>1</sub> (°F)	
Lower Shell #1	337-01A	G-3109-2	C-2957-2	0	0.10	0.47	65.0	30.5	15.3	0.0	81.1
Lower Shell #2	337-01B	G-3109-1	C-2957-1	-3	0.10	0.48	65.0	30.5	15.3	0.0	58.1
Lower Shell #3	337-01C	G-3109-3	C-2973-1	-4	0.11	0.63	74.5	35.0	17.0	0.0	65.0
Lower-Int. Shell #1	337-03A	G-3108-3	C-2945-2	-12	0.10	0.66	65.6	34.3	17.0	0.0	56.3
Lower-Int. Shell #2	337-03B	G-3108-1	C-2921-2	-30	0.14	0.60	100.0	52.2	17.0	0.0	56.2
Lower-Int. Shell #3	337-03C	G-3108-2	C-2945-1	-7	0.10	0.65	65.5	34.2	17.0	0.0	61.2

Description	Seam No.	Heat No.	Flux Type & Lot No.	Estimated Initial RT <sub>NDT</sub> (°F)	Chemistry		Chemistry Factor (°F)	Adjustments For 1/4t			
					Cu (wt %)	Ni (wt %)		ΔRT <sub>NDT</sub> (°F)	Margin Terms		ART <sub>NDT</sub> (°F)
									σ <sub>A</sub> (°F)	σ <sub>1</sub> (°F)	
L. Int. Shell Long. Weld #1	1-338A	27204/12008	Linde 1092 #3774	-48	0.219	0.996	231.1	114.7	28.0	0.0	122.7
L. Int. Shell Long. Weld #2	1-338B	27204/12008	Linde 1092 #3774	-48	0.219	0.996	231.1	78.4	28.0	0.0	86.4
L. Int. Shell Long. Weld #3	1-338C	27204/12008	Linde 1092 #3774	-48	0.219	0.996	231.1	114.7	28.0	0.0	122.7
L. Int./L. Shell Girth Weld	1-344	21935	Linde 1092 #3869	-50	0.183	0.704	172.2	75.4	28.0	0.0	81.4
Lower Shell Long. Weld #1	2-338A	27204	Linde 1092 #3714	-34	0.203	1.018	226.8	83.5	28.0	0.0	105.5
Lower Shell Long. Weld #2	2-338B	27204	Linde 1092 #3714	-34	0.203	1.018	226.8	96.5	28.0	0.0	118.5
Lower Shell Long. Weld #3	2-338C	27204	Linde 1092 #3714	-34	0.203	1.018	226.8	87.8	28.0	0.0	109.8

Fluence Information (see Note 2):						
Location	Wall Thickness (inches)	Fluence at ID (n/cm <sup>2</sup> )	Attenuation, 1/4t e <sup>-0.24x</sup>	Fluence @ 1/4t (n/cm <sup>2</sup> )	Fluence Factor, FF f <sub>(0.28-0.10log f)</sub>	Calculated Fluence Bias = 1.78
	Full (t)	1/4t				
Lower Shell #1	5.531	1.383	1.80E+18	0.718	1.29E+18	0.470
Lower Shell #2	5.531	1.383	1.80E+18	0.718	1.29E+18	0.470
Lower Shell #3	5.531	1.383	1.80E+18	0.718	1.29E+18	0.470
Lower-Int. Shell #1	5.531	1.383	2.28E+18	0.718	1.63E+18	0.522
Lower-Int. Shell #2	5.531	1.383	2.28E+18	0.718	1.63E+18	0.522
Lower-Int. Shell #3	5.531	1.383	2.28E+18	0.718	1.63E+18	0.522
L. Int. Shell Long. Weld #1	5.531	1.383	2.03E+18	0.718	1.46E+18	0.496
L. Int. Shell Long. Weld #2	5.531	1.383	9.20E+17	0.718	6.60E+17	0.339
L. Int. Shell Long. Weld #3	5.531	1.383	2.03E+18	0.718	1.46E+18	0.496
L. Int./L. Shell Girth Weld	5.531	1.383	1.55E+18	0.718	1.11E+18	0.438
Lower Shell Long. Weld #1	5.531	1.383	1.08E+18	0.718	7.77E+17	0.368
Lower Shell Long. Weld #2	5.531	1.383	1.45E+18	0.718	1.04E+18	0.425
Lower Shell Long. Weld #3	5.531	1.383	1.20E+18	0.718	8.58E+17	0.387

- Notes:
1. Material information taken from SIA Report No. SIR-00-082, Revision 0, "Updated Evaluation of Reactor Pressure Vessel Materials Properties for Pilgrim Nuclear Power Station," August 2000, Tables 3-1 through 3-12.
  2. Fluence values from Transware Report No. ENT-FLU-001-R-001, Revision 0, "Pilgrim Nuclear Power Station Reactor Pressure Vessel Fluence Evaluation," Tables 7-3 and 7-4, and are multiplied by a calculated bias of 1.78.
  3. RPV minimum thickness = 5 17/32" per Section 3.3.2 of SIR-00-082, Revision 0.



**Table 3: PNPS Charpy Upper Shelf Energy Values for 54 EFPY (Without 1.78 Bias Correction Factor on Fluence) [6]**

Material Description						54 EFPY Projection		
Reactor Vessel Beltline Region Location	Matl Type	Material Identification	Heat #	%Cu	Unirradiated CvUSE	1/4 T fluence ( $10^{19}$ n/cm <sup>2</sup> )	% Drop in USE	USE (1/4 T)
Lower Intermediate Shell	A533B	G-3108-1	C-2921-2	0.14	81	0.084	12.79%	70.6
Lower Intermediate Shell	A533B	G-3108-2	C-2945-1	0.10	80	0.084	10.57%	71.5
Lower Intermediate Shell	A533B	G-3108-3	C-2945-2	0.10	81	0.084	10.57%	72.4
Lower Shell	A533B	G-3109-1	C-2957-1	0.10	76	0.061	9.79%	68.6
Lower Shell	A533B	G-3109-2	C-2957-2	0.10	79	0.061	9.79%	71.3
Lower Shell	A533B	G-3109-3	C-2973-1	0.11	72	0.061	10.31%	64.6
Lower Int/Lower Shell Circ Weld	Linde 1092	1-334	21935	0.18	75	0.057	16.39%	62.7
Lower Int Shell Axial Welds	Linde 1092	1-338A,B,C	27204-12008	0.22	75	0.076	19.52%	60.4
Lower Shell Axial Welds	Linde 1092	2-338A,B,C	27204	0.20	75	0.050	16.87%	62.3



**Table 4: PNPS Charpy Upper Shelf Energy Values for 54 EFPY (With 1.78 Bias Correction Factor on Fluence)**

Material Description						54 EFPY Projection (with 1.78 bias CF on fluence)		
Reactor Vessel Beltline Region Location	Matl Type	Matl Ident.	Heat#	%Cu	Unirr. CvUSE	1/4t fluence (10 <sup>19</sup> n/cm <sup>2</sup> )	% Drop in USE	USE @ 1/4t
Lower Intermediate Shell	A533B	G-3108-1	C-2921-2	0.14	81	0.129	14.3	69.4
Lower Intermediate Shell	A533B	G-3108-2	C-2945-1	0.10	80	0.129	11.7	70.6
Lower Intermediate Shell	A533B	G-3108-3	C-2945-2	0.10	81	0.129	11.7	71.5
Lower Shell	A533B	G-3109-1	C-2957-1	0.10	76	0.163	12.3	66.7
Lower Shell	A533B	G-3109-2	C-2957-2	0.10	79	0.163	12.3	69.3
Lower Shell	A533B	G-3109-3	C-2973-1	0.11	72	0.163	13.1	62.6
Lower Int./Lower Shell Circ. Weld	Linde 1092	1-334	21935	0.183	75	0.111	19.6	60.3
Lower In. Shell Axial Welds	Linde 1092	1-338A,B,C	27204/12008	0.219	75	0.146	23.2	57.6
Lower Shell Axial Welds	Linde 1092	2-338A,B,C	27204	0.203	75	0.104	20.5	59.6

**Table 5: PNPS Maximum Projected Fluence and USE Drop for Vessel Beltline Materials**

Material Description					Maximum Projected Fluence and USE Drop			
Reactor Vessel Beltline Region Location	Matl Type	Matl Ident.	%Cu	Unirr. CvUSE	1/4t fluence (10 <sup>19</sup> n/cm <sup>2</sup> )	Max. % Drop in USE	Min. USE @ 1/4t	Fluence Ratio
Lower Intermediate Shell	A533B	G-3108-1	0.14	81	> 6.0	38.3	50.0	> 46.5
Lower Intermediate Shell	A533B	G-3108-2	0.10	80	> 6.0	37.5	50.0	> 46.5
Lower Intermediate Shell	A533B	G-3108-3	0.10	81	> 6.0	38.3	50.0	> 46.5
Lower Shell	A533B	G-3109-1	0.10	76	> 6.0	34.2	50.0	> 36.8
Lower Shell	A533B	G-3109-2	0.10	79	> 6.0	36.7	50.0	> 36.8
Lower Shell	A533B	G-3109-3	0.11	72	> 6.0	30.6	50.0	> 36.8
Lower Int./Lower Shell Circ. Weld	Linde 1092	1-334	0.183	75	1.11	33.3	50.0	10
Lower Int. Shell Axial Welds	Linde 1092	1-338A,B,C	0.219	75	0.71	33.3	50.0	<b>4.86*</b>
Lower Shell Axial Welds	Linde 1092	2-338A,B,C	0.203	75	0.86	33.3	50.0	8.3

\* limiting fluence ratio to reach 50 ft-lbs CvUSE = (0.71E19)/(0.146E19) = 4.86

**Table 6: Effects of Irradiation on RPV Axial Weld Properties**

Limiting Axial Welds - Lower Int. Long. Welds #1 and #3

Wire Heat/Lot (27204/12008, Lot No. 3774)

Plant	PNPS Mod 2**	PNPS	PNPS with Bias CF	PNPS Limit
Parameter Description	USNRC Limiting Plant-Specific Data	Data for axial weld (no bias CF)	Data for axial weld (1.78 bias CF)	Data for axial weld (limiting fluence)
EFPY	32**	54	54	>54
Initial (unirradiated) reference temperature (RT <sub>ndt</sub> ), °F	-2**	-48	-48	-48
Neutron fluence at the end of the requested relief period (Peak Surface Fluence in the Beltline), n/cm <sup>2</sup>	---	1.14E+18	2.03E+18	3.37E+18*
FF = Fluence factor (calculated per Reg. Guide 1.99, Rev. 2)	---	0.444	0.573	0.701
Weld Copper content, wt. %	---	0.219	0.219	0.219
Weld Nickel content, wt%	---	0.996	0.996	0.996
CF = Chemistry Factor	---	231.1	231.1	231.1
Increase in reference temperature (ΔRT <sub>ndt</sub> ), °F (= FF*CF)	---	102.9	132.4	162.0
Mean adjusted reference temperature (ART), °F (= RT <sub>ndt</sub> + ΔRT <sub>ndt</sub> )	114.0**	54.9	84.4	114.0

\*Fluence ratio = (3.37E18)/(2.03E18) = 1.66

\*\* This is a variant of the PNPS limiting weld input data with initial RT<sub>NDT</sub> = -2°F to match a vessel failure frequency of the axial welds below 5x10<sup>-6</sup> per reactor-year for each BWR

**Table 7: Effects of Irradiation on RPV Circumferential Weld Properties**

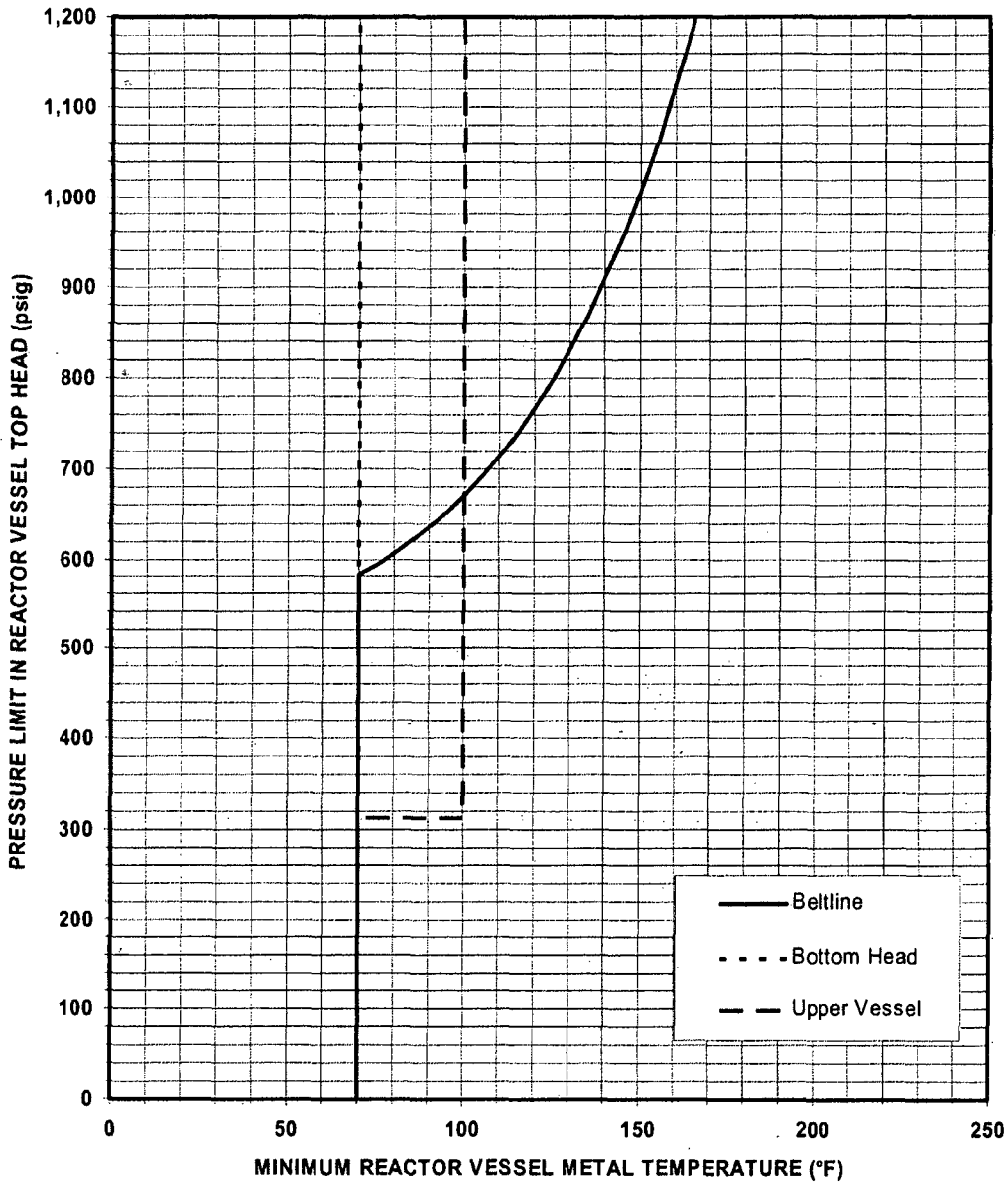
Limiting Circ. Weld – Lower Int.-to-Lower Shell Circ. Weld 1-344

Wire Heat/Lot (21935, Lot No. 3869)

Plant	CE (CEOG)	PNPS	PNPS with Bias CF	PNPS Limit
Parameter Description	USNRC Limiting Plant-Specific Data	Data for circ. weld (no bias CF)	Data for circ. weld (1.78 bias CF)	Data for circ. weld (limiting fluence)
EPFY	64	54	54	>54
Initial (unirradiated) reference temperature (RTndt), °F	0	-50	-50	-50
Neutron fluence at the end of the requested relief period (Peak Surface Fluence in the Beltline), n/cm <sup>2</sup>	4.00E+18	8.69E+17	1.55E+18	1.14E+19*
FF = Fluence factor (calculated per Reg. Guide 1.99, Rev. 2)	0.746	0.389	0.510	1.037
Weld Copper content, wt. %	0.183	0.183	0.183	0.183
Weld Nickel content, wt%	0.704	0.704	0.704	0.704
CF = Chemistry Factor	172.2	172.2	172.2	172.2
Increase in reference temperature (ΔRTndt), °F (= .FF*CF)	128.5	67.1	87.9	178.5
Mean adjusted reference temperature (ART), °F (= RTndt +ΔRTndt)	128.5	17.1	37.9	128.5

\*Fluence ratio = (1.14E19)/(1.55E18) = 7.35

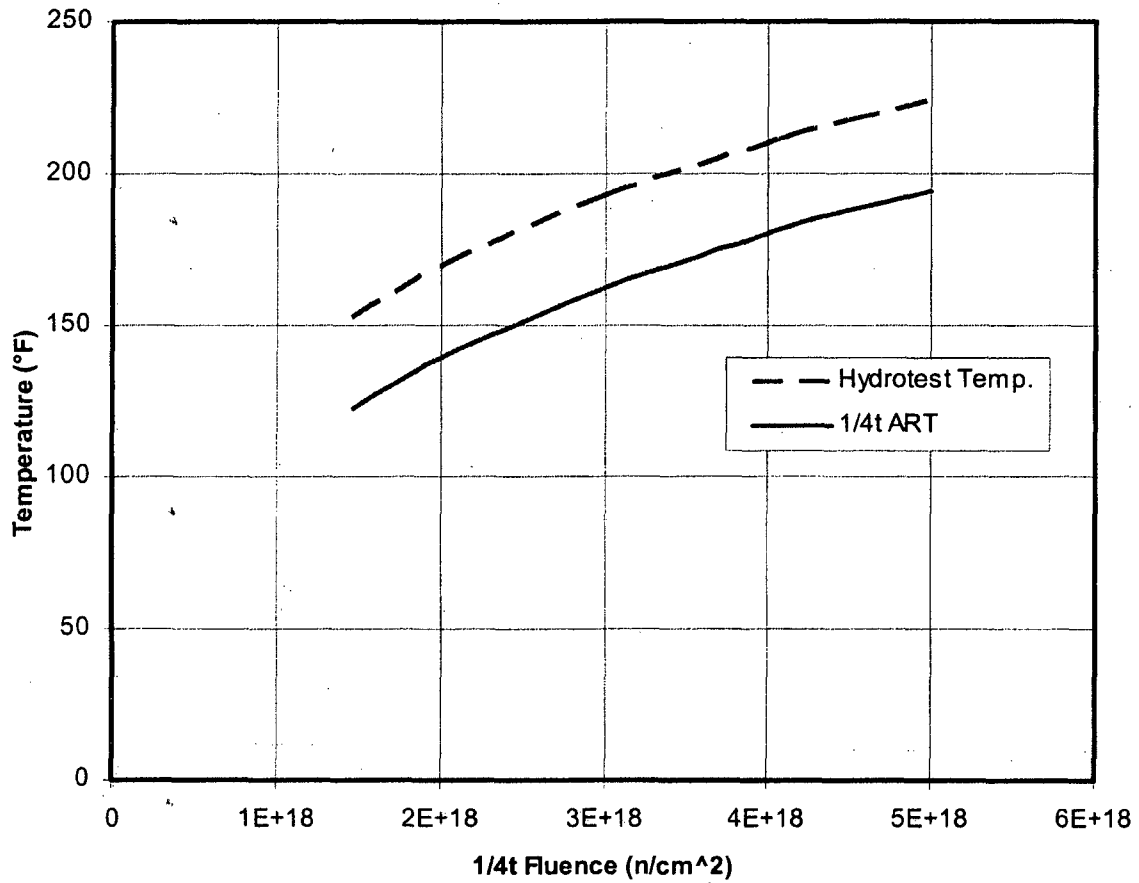
**Figure 1: Pressure Test P-T Curve (Curve A) for 54 EFPY with Bias CF on Fluence [8]**



**PNPS Pressure Test Curve (Curve A), 54 EFPY**

*(NOTE: The fluence used on the beltline curve is increased by a calculated bias on fluence of 1.78.)*

**Figure 2: Calculated Hydrotest Temperature and 1/4t ART versus Fluence**



**Figure 3: Predicted Decrease in Upper Shelf Energy as a Function of Pct. Copper and Fluence  
(from Reg. Guide 1.99, Rev. 2 [7])**

