SASR 89-59

DRF 137-0010

October 1989

IMPLEMENTATION OF REGULATORY GUIDE 1.99 REVISION 2 FOR CLINTON POWER STATION UNIT 1

Prepared by: T. A. Caine

T. A. Caine, Senior Engineer
Materials Monitoring &
Structural Analysis Services

Verified by: T. Nguyen

T. M. Nguyen, Engineer
Materials Monitoring &
Structural Analysis Services

Reviewed by: S. Ranganath

S. Ranganath, Manager
Materials Monitoring &
Structural Analysis Services

GE Nuclear Energy

IMPORTANT NOTICE REGARDING
CONTENTS OF THIS REPORT
PLEASE READ CAREFULLY

This report was prepared by General Electric solely for the use of Illinois Power Company. The information contained in this report is believed by General Electric to be an accurate and true representation of the facts known, obtained or provided to General Electric at the time this report was prepared.

The only undertakings of the General Electric Company respecting information in this document are contained in the contract governing Illinois Power Company Purchase Order No. 513496, and nothing contained in this document shall be construed as changing said contract. The use of this information except as defined by said contract, or for any purpose other than that for which it is intended, is not authorized; and with respect to any such unauthorized use, neither General Electric Company nor any of the contributors to this document makes any representation or warranty (express or implied) as to the completeness, accuracy or usefulness of the information contained in this document or that such use of such information may not infringe privately owned rights; nor do they assume any responsibility for liability or damage of any kind which may result from such use of such information.

TABLE OF CONTENTS

APPENDICES

1.0 BACKGROUND

The pressure-temperature (P-T) curves in the Technical Specifications are established to the requirements of 10CFR50, Appendix G [1] to assure that brittle fracture of the reactor vessel is prevented. Part of the analysis involved in developing the P-T curves is to account for irradiation embrittlement effects in the core region, or beltline. In the past, Regulatory Guide 1.99, Revision 1 [2] has been used to predict the shift in nil-ductility reference temperature (RT_{NDT}) as a function of fluence in the beltline region. Regulatory Guide 1.99, Revision 1 (Rev 1) was developed assuming that copper (Cu) and phosphorus (P) were the key chemical elements influencing embrittlement.

Regulatory Guide 1.99, Revision 2 [3] (Rev 2) was issued in May 1983. Rev 2 represents the results of statistical evaluation of commercial reactor surveillance test data accumulated through about 1984. The basic elements of the regulatory guide, a chemistry factor and a fluence factor remained the same from Rev 1 to Rev 2. However, each factor is significantly different. The chemistry factor (CF) has been changed from an equation based on Cu and P in Rev 1 to tables of CF values based on Cu and nickel (Ni), with separate tables for plates and for welds. The fluence factor has been modified in Rev 2 to a somewhat more complex form. The overall effect of the changes from Rev 1 to Rev 2 has generally been to increase RT_{NDT} shift predictions for relatively low fluences (below 10^{19} n/cm²) and to decrease RT_{NDT} shift predictions for higher fluences.

A GE-prepared response [4] to Generic Letter 88-11 [5], which presented an evaluation of the impact of Rev 2 on existing P-T curves for Clinton Power Station Unit 1 (CPS) was submitted to Illinois Power (IP) in October 1988. In that response, the recommendation was made to implement Rev 2 after testing the first cycle flux wire dosimeter. This report provides the results of that dosimetry test, documents the impact results from [4], accounting for revised fluence values based on the flux wire test, updates the P-T curves based on Rev 2 shifts, and provides recommended USAR and Tech Spec revisions.

2.0 FLUX WIRE TEST

2.1 INTRODUCTION

In January 1989, CPS completed its first fuel cycle. During the outage that followed, the flux wire dosimeter attached to the surveillance capsule at the vessel 3° azimuth was removed. The dosimeter was shipped to the General Electric Vallecitos Nuclear Center (VNC) in Pleasanton, CA for testing. The test results and the associated determination of peak vessel flux and fluence are presented in this section.

The surveillance program for CPS consists of three surveillance capsules and one separate flux wire dosimeter. Each surveillance capsule contains Charpy specimens of the beltline base, weld and HAZ materials, and a set of flux wires used to determine the fluence experienced by the capsule. The surveillance capsules are scheduled to be withdrawn periodically during plant life (the current schedule required by ASTM E185-82 is a capsule at 6, 15, and 32 effective full power years). In addition to the flux wires in the surveillance capsules, a flux wire dosimeter is attached to the capsule at 3°, as shown in Figure 2-1, for removal after the first fuel cycle. Since the vessel fluence is proportional to thermal power produced, the results of the flux wire dosimeter test are used to provide a calibration point of vessel fluence versus accumulated thermal power. A linear extrapolation provides an estimate of the fluence at 32 effective full power years (EFPY). It should be noted that the flux wires that will be removed later with the surveillance capsules will have an irradiation history more typical of normal operation, and will be useful for re-calibrating the 32 EFPY fluence estimate.

2.2 ANALYSIS

The determination of the peak 32 EFPY fluence is basically a two-step process. First, the flux wires are analyzed to determine the flux and fluence at the dosimeter location. Then, lead factors are calculated which relate the flux magnitude at the dosimeter location to that at the location of peak flux.

The flux wire dosimeter was disassembled at VNC and the iron flux wires were cleaned and weighed. Gamma spectrometry was used to determine the rate of disintegrations. The daily power history of the first fuel cycle was used, along with cross-section data developed for BWRs to transform the disintegration data into rates of irradiation, or flux (n/cm^2-s). The detailed procedure used in evaluating the flux wires is contained in the test report in Appendix A.

The determination of lead factors was done for a generic 218 inch diameter vessel with 624 fuel bundles. This matches the CPS configuration. The lead factors are essentially geometry dependent. Plant-specific characteristics of the flux are accounted for in the results of the flux wire test. Furthermore, the generic lead factors were calculated assuming an equilibrium fuel cycle, which is representative of a typical normal operation core power distribution. Therefore, the generic lead factors provide the best available means of predicting peak 32 EFPY fluence from the flux wire data.

Determination of the lead factors for the RPV peak location at the inside wall and 1/4 T depth was done using a combination of two-dimensional finite difference computer analyses. One two-dimensional analysis established the relative fluence in the azimuthal direction at the vessel surface and 1/4 T depth. The other two-dimensional analysis was done to determine the core height of the axial flux peak and its relationship to the surveillance capsule height. The combination of azimuthal and axial distribution results provides the lead factor between the dosimeter location and the peak flux location.

The two-dimensional DOT computer program was used to solve the Boltzman transport equation using the discrete ordinate method on an (R,θ) geometry, assuming a fixed source. One quarter core symmetry was used with periodic boundary conditions at 0° and 90°. Neutron cross sections were determined for 26 energy groups, with angular scattering approximated by a third-order Legendre expansion. A total of 99 radial intervals and 90 azimuthal intervals were used. The

model consists of an inner and outer core region, the shroud, water regions inside and outside the shroud, the vessel wall, and an air region representing the drywell. Flux as a function of azimuth was calculated, establishing the azimuth of the peak flux and its magnitude relative to the flux at the dosimeter location of 3°. This factor, the azimuthal component of the lead factor, is shown in Figure 2-2.

The other two-dimensional computer code (SN2D) was used to calculate flux distribution for the (R,Z) geometry at the peak azimuth angle. The elevation of the peak flux was determined, as well as its magnitude relative to the flux at the dosimeter elevation. This factor, shown graphically in Figure 2-3, is the axial component of the lead factor. The total lead factor between the peak and dosimeter locations was calculated as the minimum azimuthal component times the minimum axial component.

2.3 RESULTS

The flux wire dosimeter test results are presented in detail in Appendix A. A summary of the >1 MeV flux and fluence values for the dosimeter are presented in Table 2-1. As discussed in the test report, there is an uncertainty of ±25% on the >1 MeV flux and fluence. Table 2-1 shows the upper bound values with the nominal values.

The lead factors for the peak location inside surface and 1/4 T depth are presented in Table 2-1 with the dosimeter test results. The lead factors are used to predict the peak fluence according to the following equation:

Peak Fluence = (Dosimeter Flux)*(Full Power Seconds)/Lead Factor

The first fuel cycle for CPS consisted of 545 days of operation with an average capacity factor of 0.665. This is equivalent to 362.0 days at full power, or 0.99 EFPY. These values are used to calculate the fluence values at the end of cycle one (EOC1) and at 32 EFPY, as shown in Table 2-1.

The fluences at the peak location I.D. and 1/4 T are plotted as a function of EFPY in Figure 2-4.

The error range of ±25% is based on the following uncertainties:

- the cross section values ....(23%)
- the disintegrations per second per nucleus ..(10%) related to uncertainties in wire mass, disintegration count and power history

The square root of the sum of the squares of these uncertainties are combined to get ±25%.

2.4 CONCLUSIONS

The flux wire test results summarized in Table 2-1 show a nominal peak fluence on the vessel ID at 32 EFPY of 6.9×10^{18} n/cm^2. The fluence determined by dosimetry is somewhat lower than the calculated design fluence value of 8.5×10^{18} n/cm^2. This lower trend is consistent with the results of dosimetry tests at other plants.

The 32 EFPY fluence value determined from the flux wire testing results is used to modify the Rev 2 impact analysis in Section 3 and the pressure-temperature curves in Section 4. The dosimetry test and revised fluence are reflected in text changes in the USAR described in Section 5.

Table 2-1

FLUENCE DETERMINATION FOR THE PEAK LOCATION
IN THE CLINTON VESSEL

Time at Power:

EOC1	0.99 EFPY = 3.13×10^7 seconds
32 EFPY	32 EFPY = 1.01×10^9 seconds

Lead Factors:

I.D.	0.67
1/4 T	0.89

Dosimeter Flux (n/cm^2-s) 4.6×10^9 (nominal) 5.75×10^9 (upper bound)

FLUENCE (n/cm^2):

	NOMINAL	UPPER BOUND
EOC1 Peak I.D.	2.1×10^{17}	2.7×10^{17}
32 EFPY Peak I.D.	6.9×10^{18}	8.7×10^{18}
32 EFPY Peak 1/4 T	5.2×10^{18}	6.5×10^{18}

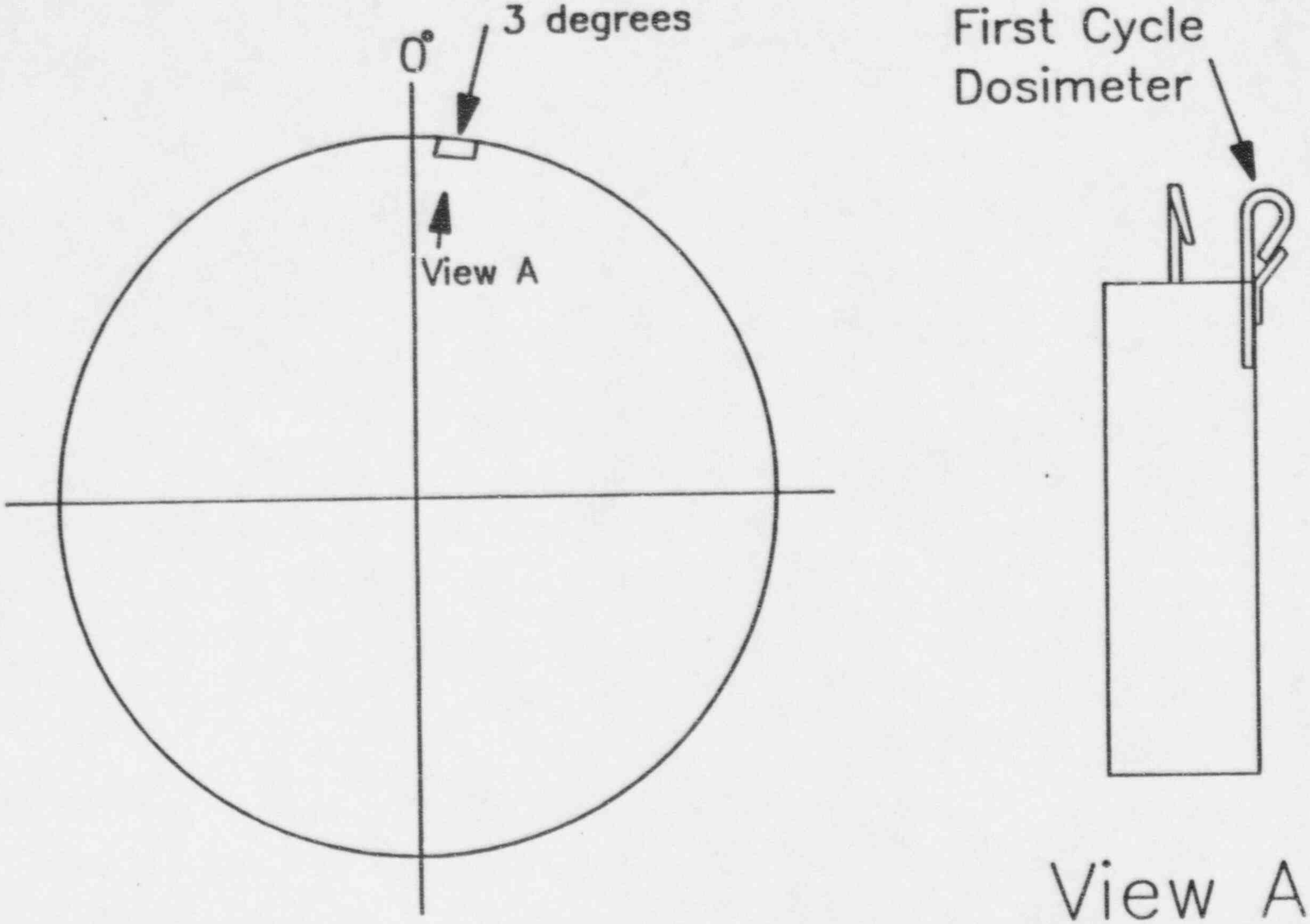


Figure 2-1. Schematic of Dosimeter Position in Vessel

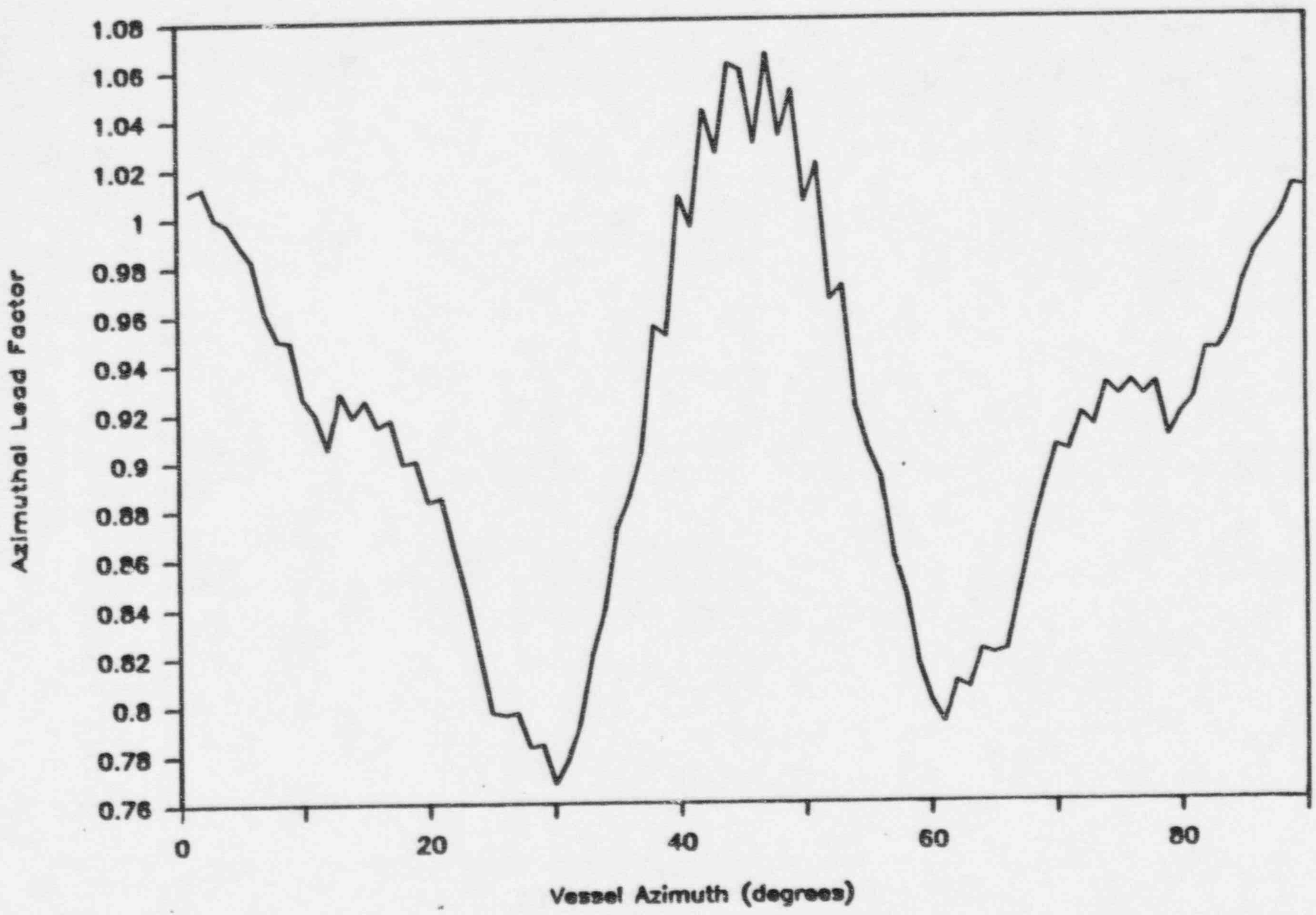


Figure 2-2. Azimuthal Lead Factor for a 218 Inch BWR with 624 Fuel Bundles

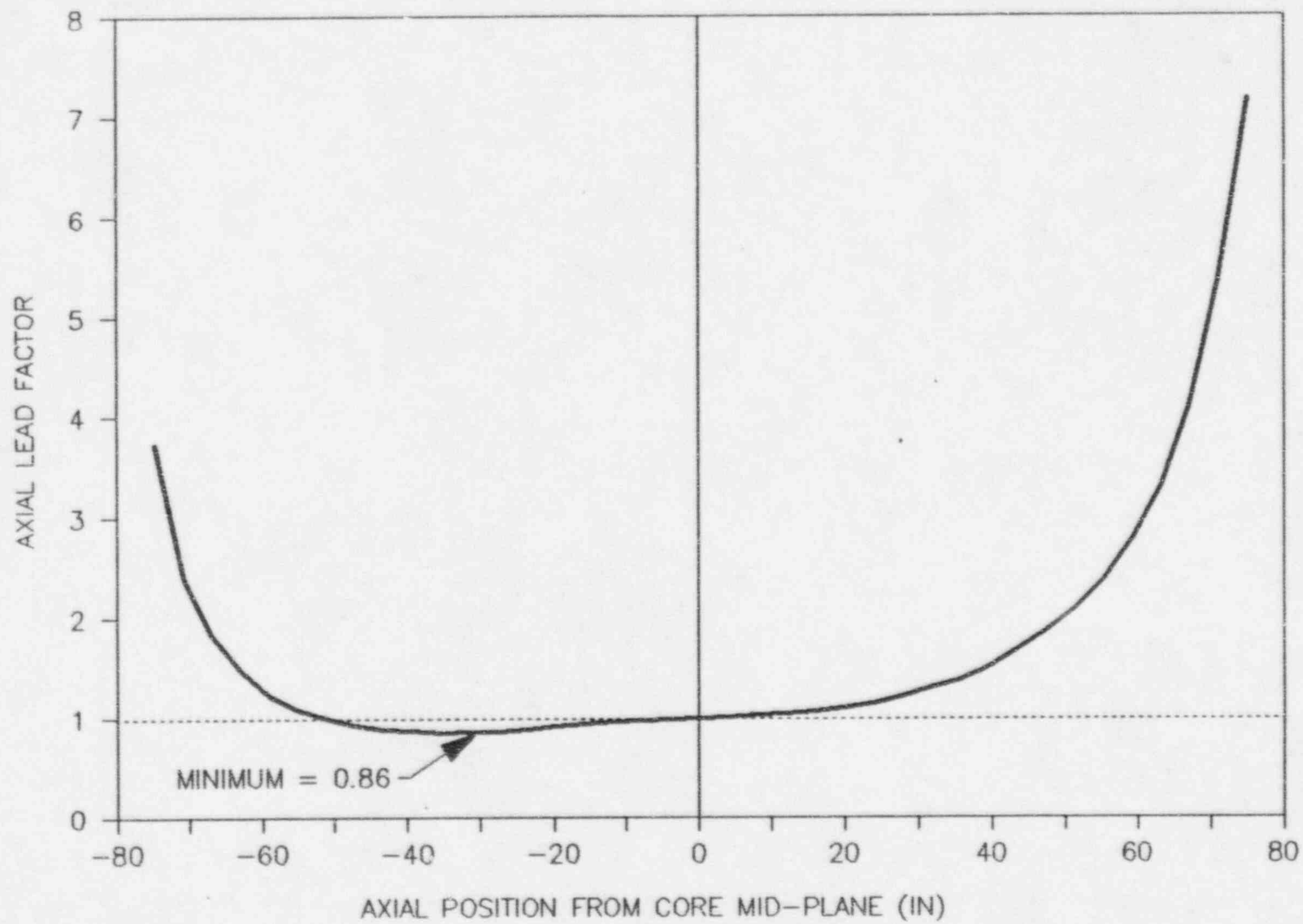


Figure 2-3. Axial Lead Factor for a 218 Inch BWR with 624 Fuel Bundles

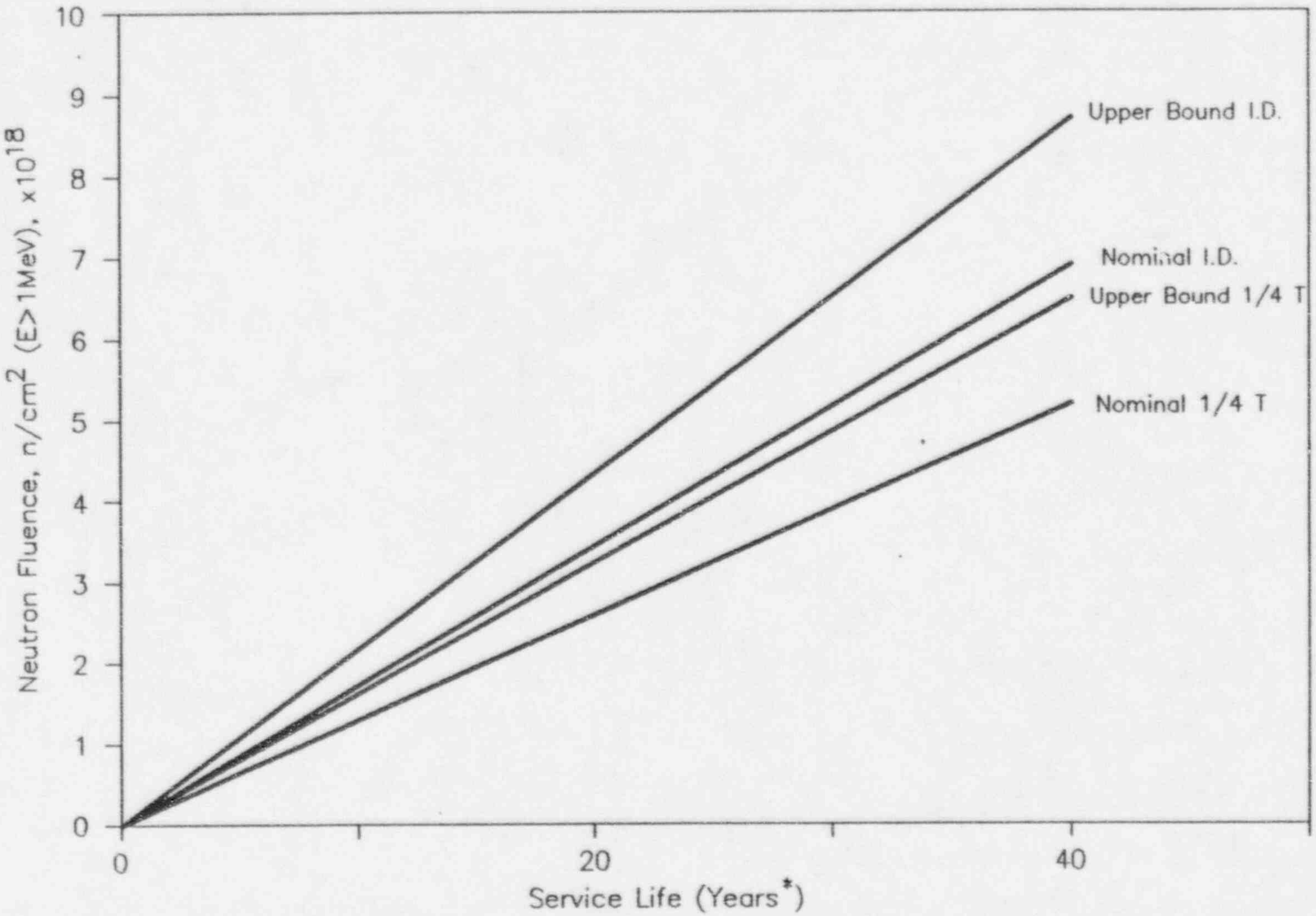


Figure 2-4. Predicted Vessel Fluence During Service Life

*At 90% RATED THERMAL POWER and 90% availability

3.0 GENERIC LETTER 88-11 EVALUATION

The beltline region in the CPS vessel consists of three No. 2 shell ring plates and their associated welds. The two plates in shell course No. 1, because of their exposure to a peak End-of-Life (EOL) fluence in excess of 1×10^{17} n/cm^2 ($E > 1MeV$), are also considered. Since weld metal heats are not traceable to specific welds, all metal heats were considered in the USAR and in this analysis. However, only the five most limiting weld heats are documented. Appendix B shows the details of the impact evaluation for CPS. The process followed for each beltline material is described below. In addition to the information provided previously in [4], discussions are provided justifying the use of $\sigma_I = 0°F$ in the Rev 2 Margin term for the CPS beltline materials. Furthermore, the results in [4] are modified to account for the use of the flux wire test results.

3.1 CHEMISTRY

The chemistry data for the No. 2 shell ring plates and all beltline weld filler material shown in Appendix B were taken from Figure 5.3-6 of the Clinton USAR [6]. The chemistry data for the shell course No. 1 plates was taken from both Figure 5.3-7 of [6] and the GE design record file material that supports it.

3.2 INITIAL RT_{NDT}

The values of initial RT_{NDT} shown in Appendix B were taken frbm the Clinton 1 USAR [6]. These values were based on 50 ft-lb impact energy verification testing, with transverse Charpy specimens used for plate, as required by ASME Code, paragraph NB-2300.

For beltline materials, the methods of calculating adjusted RT_{NDT} in Rev 2 include a Margin term to be added to the calculated value ΔRT_{NDT}. The Margin term includes a component for uncertainty in initial RT_{NDT}, σ_I. Rev 2 discusses determination of σ_I for two categories of initial RT_{NDT}, measured values and generic mean values. For generic mean values, σ_I is simply the standard deviation calculated for the data set used to compute the mean. For measured values, requirements for determination of σ_I are somewhat vague.

Rev 2 states, "If a measured value of initial RT_{NDT} for the material in question is available, σ_I is to be estimated from the precision of the test method."[a] GE's position for RT_{NDT} values derived from measured data, as is the case for the CPS beltline materials, is that σ_I is zero, as explained below.

The Charpy curves fit to surveillance data, which ultimately provided the ΔRT_{NDT} data for development of Rev 2, were best-estimate fits. An idealized example is provided as curve #1 in Figure 3-1. However, the ASME Code approach to determining RT_{NDT} is based on the lowest value of three specimens exceeding the required limits of impact energy and lateral expansion. A visualization of a Charpy curve drawn on the basis of the Code RT_{NDT} approach is shown as curve #2 in Figure 3-1. In comparing curves #1 and #2, it is clear that curve #2, which is based on the lowest value rather than the mean value, provides a conservative estimate of initial RT_{NDT}. Therefore, the ASME Code method of determining RT_{NDT} from measured data is conservative, and $\sigma_I = 0°F$ is appropriate.

3.3 FLUENCE

The values of fluence for 32 effective full power years (EFPY) are based on best estimate dosimetry results, described in Section 2.

The dosimeter test results present calculated values of 32 EFPY fluence at the 1/4 thickness depth (1/4 T) and at the inside surface. The 1/4 T value was used in Appendix B for the Rev 1 shift calculations. The inside surface fluence was used in the Rev 2 shift calculations, as described on the next page.

---

[a] In the Rev 2 draft which was circulated <u>after</u> editing to incorporate public comments, the text stated, "σ_I, the standard deviation for the initial RT_{NDT}, may be taken as zero if a measured value of initial RT_{NDT} for the material in question is available."

The Rev 2 method of calculating shift requires that the fluence at the vessel inside surface, f_{surf}, be calculated and then attenuated to the depth x according to the relationship:

$$f_x = f_{surf} (e^{-0.24x}).$$

This method results in a lower fluence at the 1/4 T location than was calculated in Section 2 with the lead factors.

3.4 SURVEILLANCE TEST CORRECTION FACTOR

Rev 1 allows for consideration of credible surveillance data when it becomes available. Rev 2 requires that two sets of credible data be developed before considering their use. However, no surveillance testing has been performed yet, so surveillance test correction factors do not apply for either Rev 1 or Rev 2 calculations, and are set to 1.0 in Appendix B.

3.5 SHIFT AND ADJUSTED REFERENCE TEMPERATURE (ART)

The RT_{NDT} shift calculations in Appendix B are based on the procedures in Rev 1 and Rev 2. For Rev 1, the equation for SHIFT is:

$$SHIFT = (STF)*[40 + 1000(\%Cu - .08) + 5000(\%P - .008)]*(f)^{0.5}$$

where STF = surveillance test correction factor

f = fluence for the given EFPY / 10^{19}

For Rev 2, the SHIFT equation consists of two terms:

$$SHIFT = \Delta RT_{NDT} + Margin$$

where $\Delta RT_{NDT} = [CF]*f^{(0.28 - 0.10 \log f)}$

$Margin = 2(\sigma_I^2 + \sigma_\Delta^2)^{.5}$

Chemistry factors (CF) are tabulated for welds and plates in Tables 1 and 2, respectively, of Rev 2. The margin term σ_Δ has set values in Rev 2 of 17°F for plate and 28°F for weld. However, σ_Δ need not be greater than $0.5*\Delta RT_{NDT}$.

The values of ART in Appendix B are computed by adding the SHIFT terms to the values of initial RT_{NDT}. ART versus EFPY is plotted for the most limiting beltline conditions in Figure 3-2.

3.6 RESULTS OF IMPACT EVALUATION

The impact of implementing Rev 2 can best be determined by comparing the ART values based on Rev 1 and Rev 2. Table 3-1 shows the ART values at 32 EFPY for each beltline material. The following conclusions are drawn from the results in the table:

1. The Rev 2 ART values at 32 EFPY are below 200°F, which is the allowable limit in 10CFR50, Appendix G. Therefore, implementation of Rev 2 will not result in any additional requirements for analysis, testing or provisions for thermal annealing.

2. Rev 2 increased the maximum ART value by 92°F. As a result, the P-T curves A',B',C' currently in the Tech Spec are valid for only 2.7 EFPY, not 32 EFPY as they were for Rev 1.

Based on these conclusions, presented in [4], IP requested that the CPS P-T curves be updated to reflect requirements of Rev 2.

Table 3-1

COMPARISON OF REV 1 AND REV 2 ART VALUES
FOR CPS

Beltline Component	32 EFPY Rev 1 ART (°F)	32 EFPY Rev 2 ART (°F)
Plates:		
C4363-2	16.9	29.4
C4380-2	26.9	49.3
C4320-2	23.3	29.8
A2758-1	6.6	26.8
A2740-1	-10.1	12.1
Welds:		
3P4955 (Single Wire)	37.7	30.1
3P4955 (Tandem Wire)	37.7	34.6
5P6756	-31.2	82.7
76492	42.1	134.4
431T1831	6.9	25.8

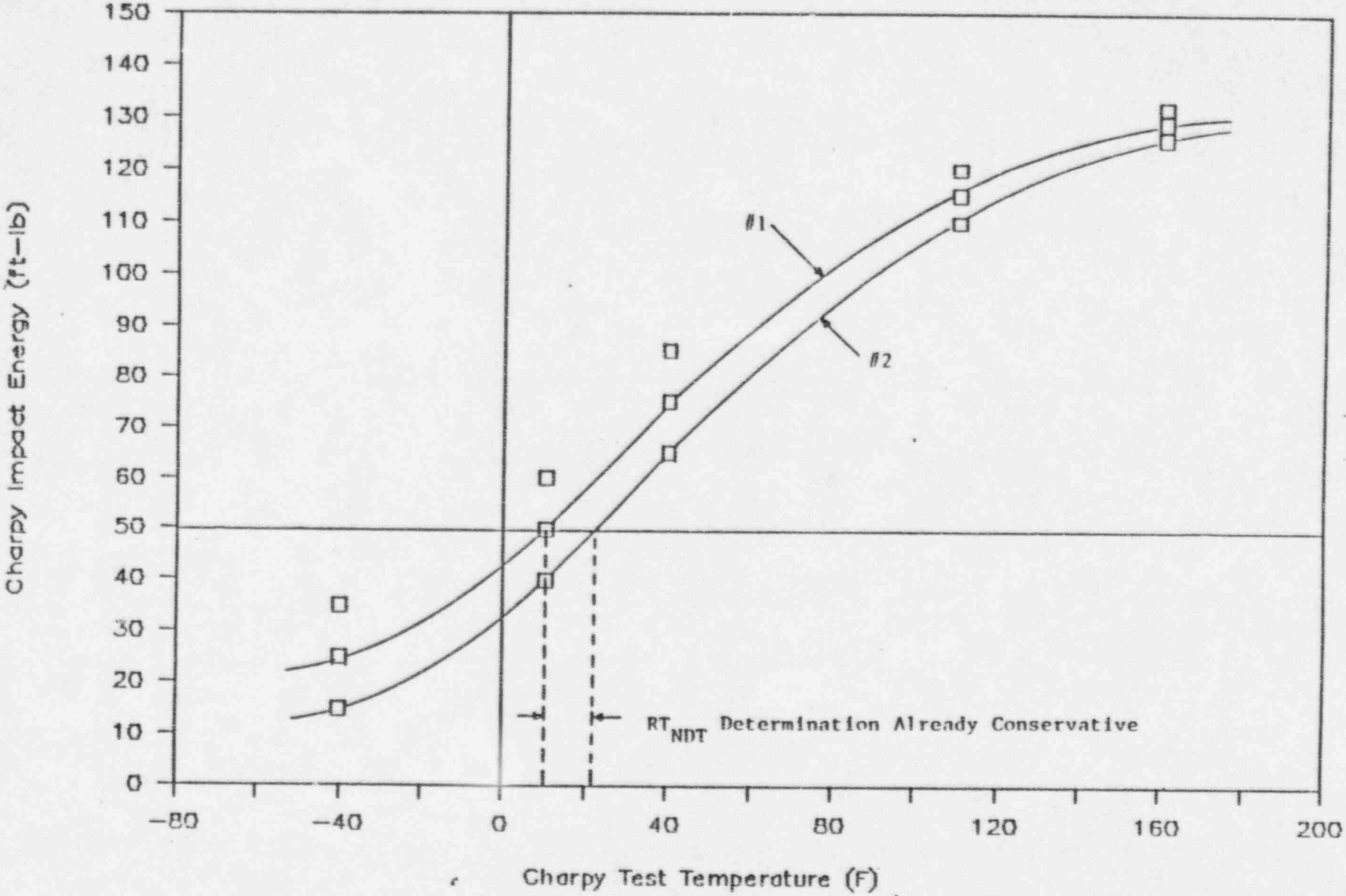


Figure 3-1. Comparison of Surveillance Data Fit and RT_{NDT} Approach

Figure 3−2. Limiting Beltline Material ART versus EFPY

4.0 PRESSURE-TEMPERATURE CURVES

4.1 BACKGROUND

Operating limits for pressure and temperature are required for three categories of operation: (a) hydrostatic pressure tests and leak tests, referred to as Curve A; (b) non-nuclear heatup/cooldown and low-level physics tests, referred to as Curve B; and (c) core critical operation, referred to as Curve C. There are three vessel regions that affect the operating limits: the closure flange region, the core beltline region, and the remainder of the vessel, or non-beltline regions. The closure flange region limits are controlling at lower pressures primarily because of 10CFR50 Appendix G [1] requirements. The non-beltline and beltline region operating limits are evaluated according to procedures in 10CFR50 Appendix G, Appendix G of the ASME Code [7] and Welding Research Council (WRC) Bulletin 175 [8], with the beltline region minimum temperature limits adjusted to account for vessel irradiation.

Figure 4-1 has curves applicable per Rev 2 for 32 EFPY of operation, for use in the USAR. Figure 4-2 has curves applicable per Rev 2 for 12 EFPY of operation, for use in the Tech Spec. The requirements for each vessel region influencing the P-T curves are discussed below.

4.2 NON-BELTLINE REGIONS

Non-beltline regions are those locations that receive too little fluence to cause any RT_{NDT} increase. Non-beltline components include the nozzles, the closure flanges, some shell plates, top and bottom head plates and the control rod drive (CRD) penetrations. Detailed stress analyses, specifically for the purpose of fracture toughness analysis, of the non-beltline components were performed for the BWR/6. The analyses took into account all mechanical loadings and thermal transients anticipated. Detailed stresses were used according to [8] to develop plots of allowable pressure (P) versus temperature relative to the reference temperature ($T - RT_{NDT}$). Plots were developed for the two most limiting regions; the feedwater nozzle and the CRD

penetration regions. All other non-beltline regions are categorized under one of these two regions.

The generic BWR/6 non-beltline region results were applied to CPS by adding the highest RT_{NDT} for the non-beltline discontinuities to the appropriate P versus $(T - RT_{NDT})$ curves for the BWR/6 CRD penetration or feedwater nozzle. The limiting RT_{NDT} values are 10°F for the CRD penetration limits and -20°F for the feedwater nozzle limits.

4.3 CORE BELTLINE REGION

The pressure-temperature (P-T) limits for the beltline region are determined according to the methods in ASME Code Appendix G [7]. As the beltline fluence increases during operation, these curves shift by an amount discussed in Section 2. Typically, the beltline curves shift to become more limiting than the non-beltline curves at some point during operating life. Using Rev 2 for CPS, this occurs after only 2.7 EFPY of operation. The curves resulting from shifting the beltline limits are shown in Figures 4-1 as A', B' and C' for 32 EFPY of operation. The beltline limits also affect the higher pressure portion of the curves in Figure 4-2.

The stress intensity factors (K_I), calculated for the beltline region according to ASME Appendix G procedures, were based on a combination of pressure and thermal stresses for a 1/4 T flaw in a flat plate. The pressure stresses were calculated using thin-walled cylinder equations. Thermal stresses were calculated assuming the through-wall temperature distribution of a flat plate subjected to a 100°F/hr thermal gradient. A 32 EFPY ART of 134°F and a 12 EFPY ART of 100°F were used to adjust the $(T - RT_{NDT})$ values from Figure G-2210-1 of [7].

4.3.1 Bottom Head Monitoring During Pressure Tests

While the beltline curves are limiting for pressure test conditions, the non-beltline limits can still be applied to the bottom head region. It is likely that, during leak and hydrostatic pressure testing, the bottom head temperature may be significantly cooler than the higher elevations of the vessel. This condition can occur when the recirculation pumps are operating at low speed, or are off, and injection through the control rod drives is used to pressurize the vessel.

Monitoring the bottom head separately from the beltline region may reduce the required pressure test temperature by 10°F to 20°F. Some hypothetical temperatures demonstrating the potential benefit of separate bottom head monitoring are shown in Figure 4-3. The Technical Specifications currently require that <u>all</u> vessel temperatures be above the limiting conditions on the P-T curve. That would mean that, for a leak test, the bottom head would have to be heated above 183°F at 12 EFPY, as shown in case (a) of Figure 4-3. The bottom head temperature reading would likely be the limiting reading on the vessel during the test. If, by using the bottom head curve, the required temperature for the bottom head were only 131°F, the limiting reading would probably be near the beltline, as shown in case (b), and the actual vessel temperatures could be lowered compared to case (a).

One condition on monitoring the bottom head separately is that it must be demonstrated that the vessel beltline temperature can be monitored during pressure testing. An experiment has been conducted at a BWR-4 which showed that thermocouples on the vessel near the feedwater nozzles, or temperature measurements of recirculation pump inlet water provide good estimates of the beltline temperature during pressure testing. IP may need to confirm this before implementing separate monitoring of the bottom head.

4.4 CLOSURE FLANGE REGION

10CFR50 Appendix G sets several minimum requirements for pressure and temperature, in addition to those outlined in the ASME Code, based on the closure flange region RT_{NDT}. In some cases, the results of analysis for other regions exceed these requirements and they do not affect the shape of the P-T curves. However, some closure flange requirements do impact the curves. In addition, General Electric recommends 60°F margin on the required bolt preload temperature.

As stated in Paragraph G-2222(c) of [7], for application of full bolt preload and reactor pressure up to 20% of hydrostatic test pressure, the RPV metal temperature must be at RT_{NDT} or greater. The GE practice is to require (RT_{NDT} + 60°F) for bolt preload, for two reasons:

a. The original ASME Code of construction required (RT_{NDT} + 60°F), and

b. The highest stressed region during boltup is the closure flange region, and the flaw size assumed in that region (0.24 inches) is less than 1/4 T. This flaw size is detectable using ultrasonic testing (UT) techniques. In fact, CB&I studies report that a flaw in the closure flange region of 0.09 inch can be reliably detected using UT.

For CPS, the closure flange and attached shell values of (RT_{NDT} + 60°F) = 70°F, are consistent with the allowable lowest service temperature for the bolting material.

10CFR50 Appendix G, paragraph IV.A.2, sets minimum temperature requirements for pressure above 20% hydrotest pressure based on the RT_{NDT} of the closure region. Curve A temperature must be no less than (RT_{NDT} + 90°F) and Curve B temperature no less than (RT_{NDT} + 120°F). These requirements cause the steps in the curves at 20% hydrotest pressure (312 psig) shown in Figures 4-1 and 4-2.

4.5 CORE CRITICAL OPERATION REQUIREMENTS OF 10CFR50, APPENDIX G

Curves C and C', the core critical operation curves shown in Figures 4-1 and 4-2, are generated from the requirements of 10CFR50 Appendix G, paragraph IV.A.3. Essentially paragraph IV.A.3 requires that core critical P-T limits be 40°F above any Curve A or B limits. Curve B is more limiting than Curve A, so Curve C is Curve B plus 40°F.

Another requirement of IV.A.3, or actually an allowance for the BWR, concerns minimum temperature for initial criticality in a startup. The BWR, given that water level is normal, is allowed initial criticality at the closure flange region (RT_{NDT} + 60°F) at pressures below 312 psig. Above 312 psig, the Curve C temperature must be at least that required for the hydrostatic pressure test (Curve A or A' at 1100 psig). As a result of this requirement above 312 psig, Curve C' on Figure 4-1 has a step to the temperature corresponding to the Curve A' value at 1100 psig.

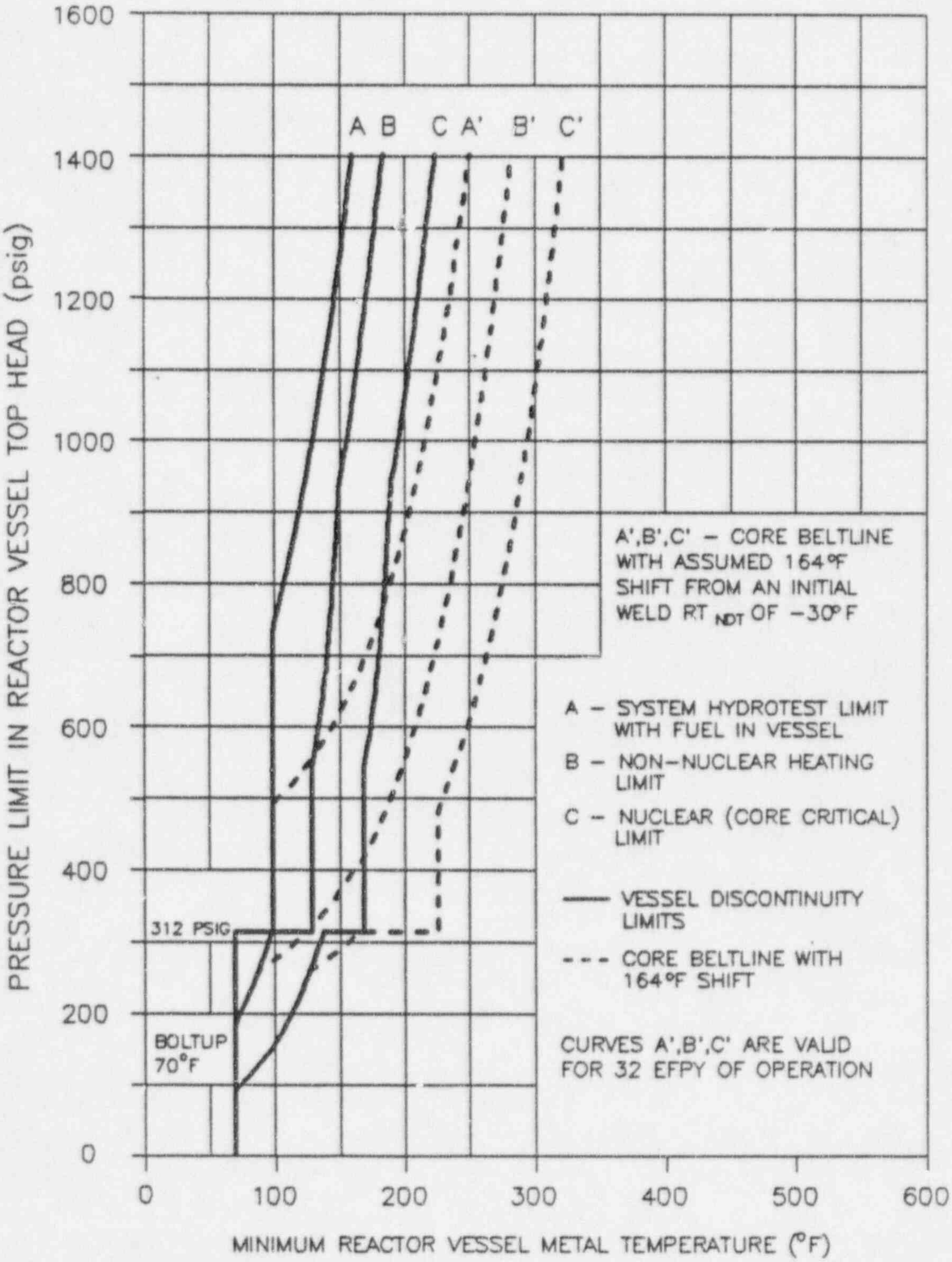


Figure 4–1. Vessel Pressure Versus Minimum Vessel Metal Temperature

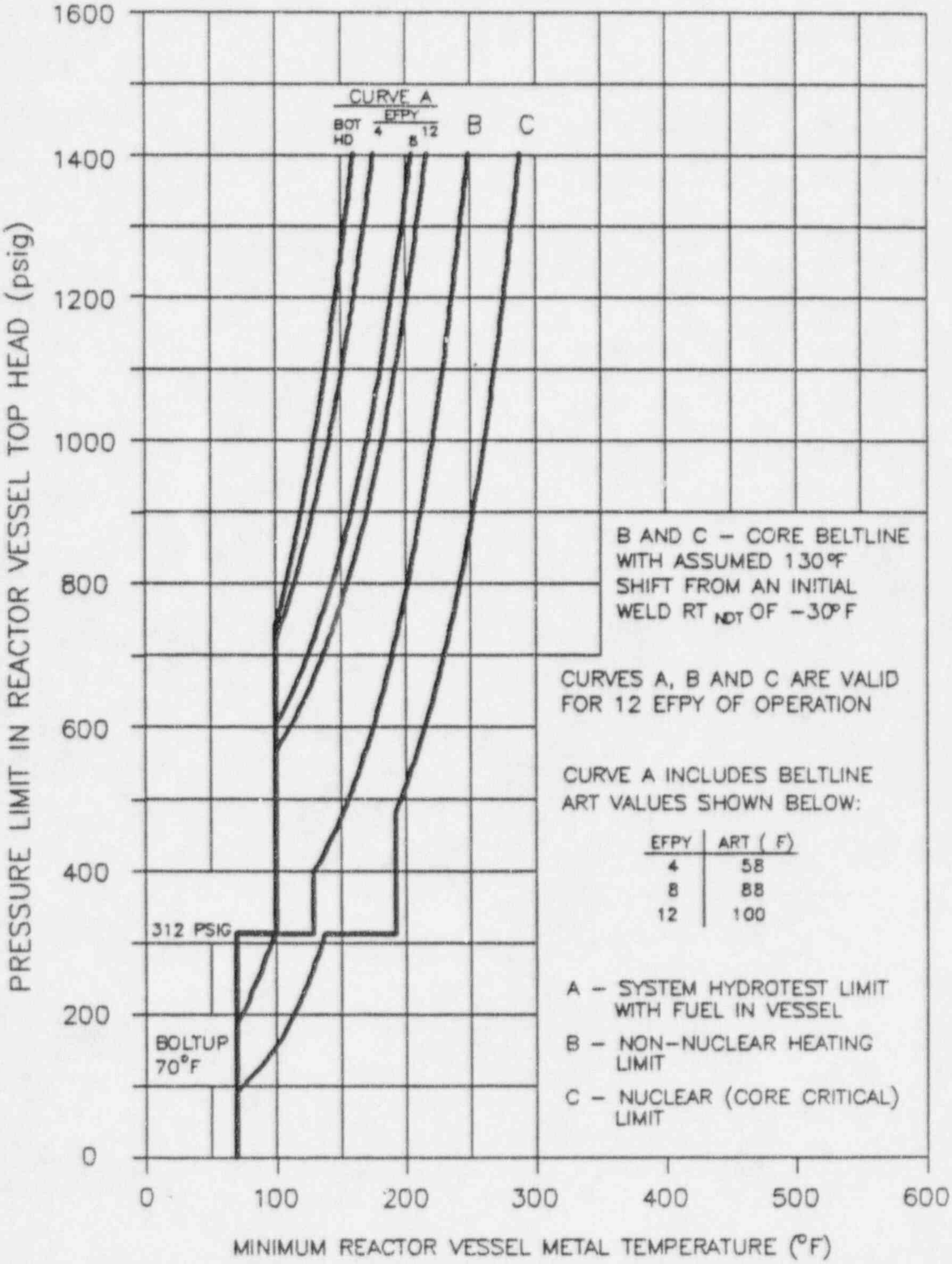
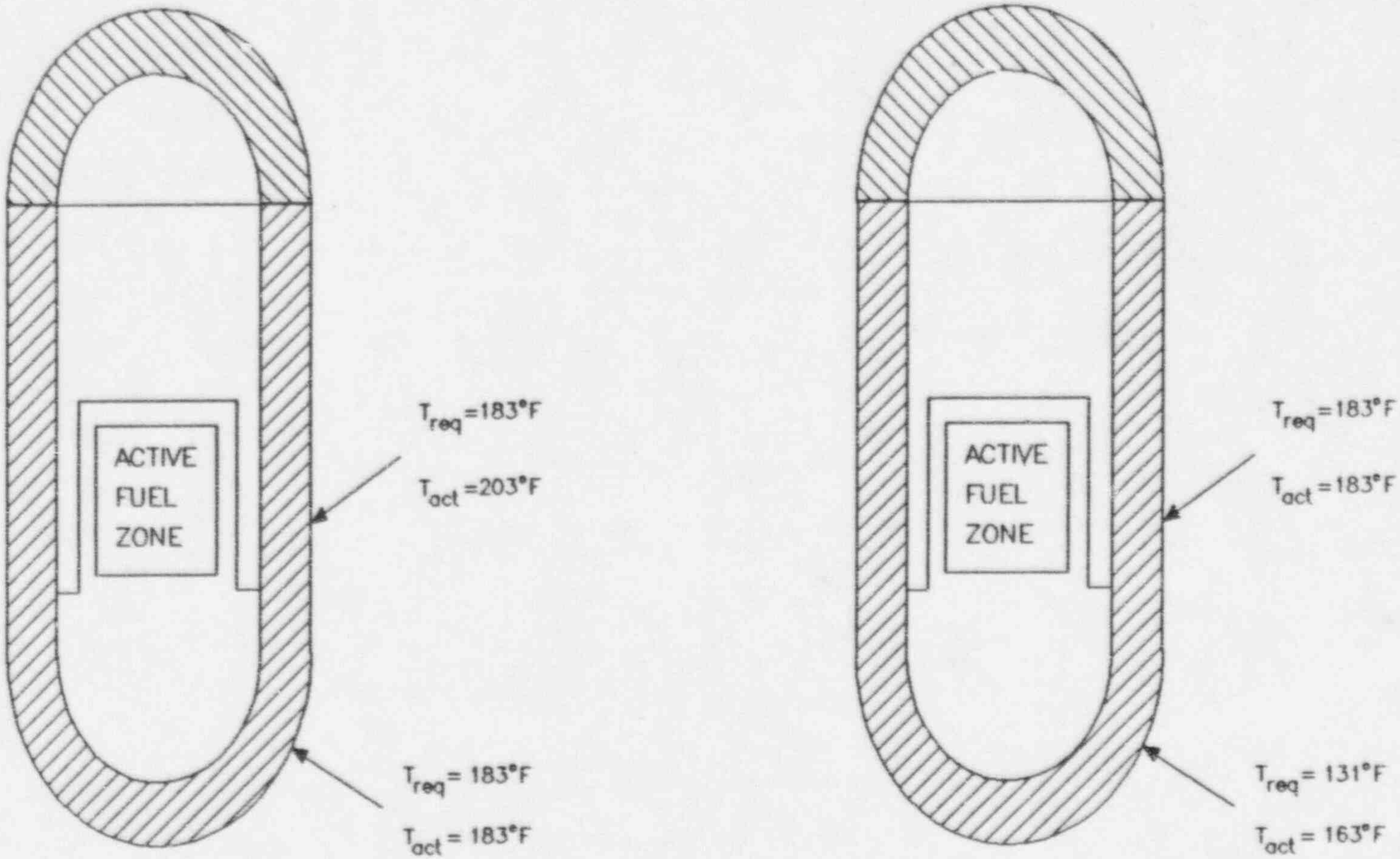


Figure 4-2. Reactor Vessel Pressure Versus Minimum Reactor Vessel Metal Temperature



a) Bottom Head Monitored with Beltline Limits

b) Bottom Head Monitored Separately

Figure 4–3. Hypothetical Case of Pressure Test Temperature Reduction from Separate Bottom Head Monitoring

5.0 REFERENCES

[1] "Fracture Toughness Requirements," Appendix G to Part 50 of Title 10 of the Code of Federal Regulations, July 1983.

[2] "Effects of Residual Elements on Predicted Radiation Damage to Reactor Vessel Materials," USNRC Regulatory Guide 1.99, Revision 1, April 1977.

[3] "Radiation Embrittlement of Reactor Vessel Materials," USNRC Regulatory Guide 1.99, Revision 2, May 1988.

[4] Papandrea, C.J., "Response to NRC Generic Letter 88-11 for Clinton Unit 1," GE DRF 137-0010, entry SASR 88-80, October 1988.

[5] "NRC Position on Radiation Embrittlement of Reactor Vessel Material and Its Impact of Plant Operations," USNRC Generic Letter 88-11, July 1988.

[6] Clinton Power Station, Unit 1 Updated Safety Analysis Report, Amendment 37, March 1986.

[7] "Protection Against Non-Ductile Failure," Appendix G to Section III of the ASME Boiler & Pressure Vessel Code, 1986 Edition with 1988 Addenda.

[8] "PVRC Recommendations on Toughness Requirements for Ferritic Materials," Welding Research Council Bulletin 175, August 1972.

APPENDIX A

FLUX WIRE DOSIMETER TEST REPORT
AT END OF CYCLE 1

FOR

CLINTON UNIT 1