TURKEY POINT UNITS 3 AND 4, EVALUATION OF THE FLUX REDUCTION FACTOR USING PART-LENGTH BURNABLE ABSORBER ASSEMBLIES TO MEET THE NRC PRESSURIZED THERMAL SHOCK CRITERIA

Introduction

The staff identified several plants in need of flux reduction in order for them to be able to operate for 32 Effective Full Power Years (EFPY) without violating the NRC Pressurized Thermal Shock (PTS) screening criteria. (1, 2). For Turkey Point - 3 and 4 the staff estimated (for the end of 1982) that the required flux reduction needed for either unit to operate for 40 calendar years (at a load factor of .8) was 4.5. Florida Power and Light (FP&L) the licensee has implemented a fluence reduction program consisting of low leakage fuel loading patterns coupled with part-length burnable absorbers, located so as to reduce the neutron flux to the pressure vessel circumferential weld from high importance core locations.

Based on power and exposure distributions supplied by FP&L (3-7), the Core Performance Branch performed an evaluation of the fluxes (and fluences) associated with the first nine cycles of operation of Unit 4 and the first 10 cycles of operation of Unit 3. The review and evaluation included independent audit calculations carried out by staff consultants at BNL.

Evaluation

Fast neutron flux ($E > 1.0$ MeV) calculations at the inner surface of the Pressure Vessel (PV) on the lower core belt circumferential weld were based on the flux synthesis methodology (8).

This approach consists of the following steps:

a. Determine the contributions to the flux above 1.0 MeV near 0° (the peak azimuthal flux location) on the inner surface of the PV from individual assemblies in the reactor core based on calculations in (r,θ) geometry.

b. Determine the contributions to the fast flux at the lower-to-intermediate shell circumferential weld from discrete 12 in. high axial segments for the two outermost rows of assemblies based on calcualtions in (r,z) geometry.

c. Combine the results from (1) and (2) with the three-dimensional core power (neutron source) distributions to obtain the desired flux and fluence values.

The same approach was also used for H. B. Robinson and the (r,θ) geometrical results have been used here as well. These results were generated with the DOT-3.5 (9) discrete ordinates transport code in the fixed-source mode with an S_8-P_3 angular approximation. Region dependent, 16 neutron group cross sections were based on the DLC-37/EPR (ENDF/B-IV) library (10). HBR-2 has virtually identical core/internals/vessel dimensions and materials to those of the Turkey Point units; therefore, the only modification to the HBR-2 results was a slight increase in the flux values to account for the higher temperature of the bypass water for the Turkey Point units. The results of these calculations provided the flux above 1.0 MeV at the inner surface of the PV near the core major axis due to unit sources located in assemblies 6, 7, 8, 13, 14, 15, 19, 20 and 24, Figure 1.

Calculations were also performed in the (r,z) geometry with the reactor axial configuration as shown in Figure 2. This configuration was modelled with 91 axial and 78 radial intervals with the DOT-4.3 (11) discrete ordinates transport code.

The 16-group, P_3 cross sections were the same as those used for the (r,θ) calculations. Note that a single set of cross sections was used for the core, i.e. axially zoned burnable absorbers were not accounted for. Fixed source calculations were performed in the adjoint mode with an S_8 symmetric quadrature. The fixed source was located at the inner surface of the vessel at the elevation of the limiting circumferential weld (Figure 2) and the importance of 12 in. high axial segments in the first and second outermost rows of assemblies to the fast flux at the weld were determined. Finally the (r,θ) and (r,z) geometry results were combined with the core power distributions to obtain the flux above 1.0 MeV at the limiting circumferential weld near the core major axis. A further refinement was included i.e. an exposure correction based on the analysis of Reference 12.

Power and exposure distribution data were provided by FP&L for the determination of the sources to be used in the evaluation of present and projected EOL fluences. While the information that was provided was relatively complete for Unit-3, not all the necessary assembly exposure data were available for all cycles of Unit 4. Consequently, reasonable estimates were made for the average exposure associated with the peripheral assemblies for cycles for which this data had not been provided. The only other area where approximations for the source were made for both units was related to the axial power distributions since data were not provided for all assemblies required in the flux synthesis scheme.

Results for the fast flux at the limiting circumferential weld near the core major axis are presented in Table 1 for Turkey Point Units 3 and 4. Results are for Cycles 1-7 (based on single exposure weighted source and exposure distributions) and for Cycle 8, and 9, and for Unit-4, Cycle 10, explicitly. Two sets of results are given for each cycle, one assuming a uniform nominal exposure of 6,000 MWD/MTU for all assemblies, and one where the assembly-wise neutron sources were corrected for the specific exposures associated with each assembly.

The results in Table 1 account for the neglect of pin-wise source distribution effects on the (r,θ) DOT calculation by an approximate factor based on a generic study of this effect (12). The percent increase in the fast flux due to the exposure correction, and fast flux reduction factors for cycles greater than Cycle 7, relative to the results for the averaged Cycle 1-7, are also given.

The associated estimates for the accumulated fluence after each cycle and at EOL (assumed to be 32 (EFPY) are given in Table 2. These values are based on the exposure corrected fast flux values of Table 1. The results indicate that a significant reduction in the fast flux (~ 62%) can be achieved at the critical weld by a combination of an "extreme" low leakage fuel loading pattern coupled with appropriately located part-length absorbers (in assemblies 8 and 15 of Figure 1). The reduction in projected EOL fluence, however, is less (~50%) relative to the value obtained by assuming that the averaged Cycle 1-7 power distribution is applicable through life.

A reduction of the fast flux by 62% is equivalent to a factor of 2.63. If the flux reduction which was implemented for Cycle 8 in Unit 3 and Cycle 9 in Unit 4, were maintained both units would reach the screening criterion in 1989. (assuming an 80% load factor) (13). According to the August 2, 1983 licensee presentation to the staff, progressively higher flux reduction factors were planned for both units. A flux reduction factor of 2.2 will extend the date to 1994, while a factor of 3.3 will extend it to 2007. However, our estimate of the flux reduction based on the FP&L data is 2.63 which corresponds to 1999.

Summary and Conclusion

An audit calculation was performed by BNL on behalf of the staff to evaluate the performance of the proposed part-length burnable absorber assemblies with respect to fast neutron flux reduction to the pressure vessel. The methodolgy employed by BNL was based on three dimensional flux synthesis. Based on data supplied by Florida Power and Light it was estimated that the maximum flux reduction was by a factor of 2.63. Assuming an 80% load factor this would enable both units to meet the PTS screening criteria until 1999.

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TABLE 1

ϕ (>1.0 MeV) At Inner Surface of RPV on Major Axis at Elevation of Critical Weld

Turkey Point Unit-3

	No Exposure Correction	Exposure Corrected	% Increase	Flux Reduction (1)	Flux Reduction (2)
Cycles 1-7	5.695 + 10	5.770 + 10	1.3		
Cycle 8	4.579 + 10	4.739 + 10	3.5	1.2	1.2
Cycle 9	2.023 + 10	2.226 + 10	10.0	2.8	2.6

Turkey Point Unit-4

	No Exposure Correction	Exposure Corrected	% Increase	Flux Reduction (1)	Flux Reduction (2)
Cycles 1-7	5.912 + 10	6.018 + 10	1.8		
Cycle 8	4.957 + 10	5.291 + 10	6.7	1.2	1.1
Cycle 9	2.765 + 10	3.099 + 10	12.1	2.1	1.9
Cycle 10	2.107 + 10	2.312 + 10	9.7	2.8	2.6

(1), (2) flux reduction relative to results from Cycles 1-7 without (with) exposure corrections, respectively.

TABLE 2

Accumulated Fluence ϕ (>1.0 MeV) At Inner Surface of RPV on Major Axis at Elevation of Critical Weld

Turkey Point Unit-3

	Accumulated Fluence [x 10^{18} n/cm^2]	Accumulated Exposure [Effective Full PowerYears]
Cycles 1-7	10.32	5.67
Cycle 8	12.35	7.03
Cycle 9	13.06	8.04
EOL (No Fluence Reduction)*	58.23	32
EOL (Present Fluence Reduction)	29.17	32

Turkey Point Unit-4

Cycles 1-7	10.93	5.76
Cycle 8	12.12	6.47
Cycle 9	12.75	7.12
EOL (No Fluence Reduction)*	60.73	32
EOL (Present Fluence Reduction)	30.89	32

* Assumes Cycles 1-7 fast flux throughout life.

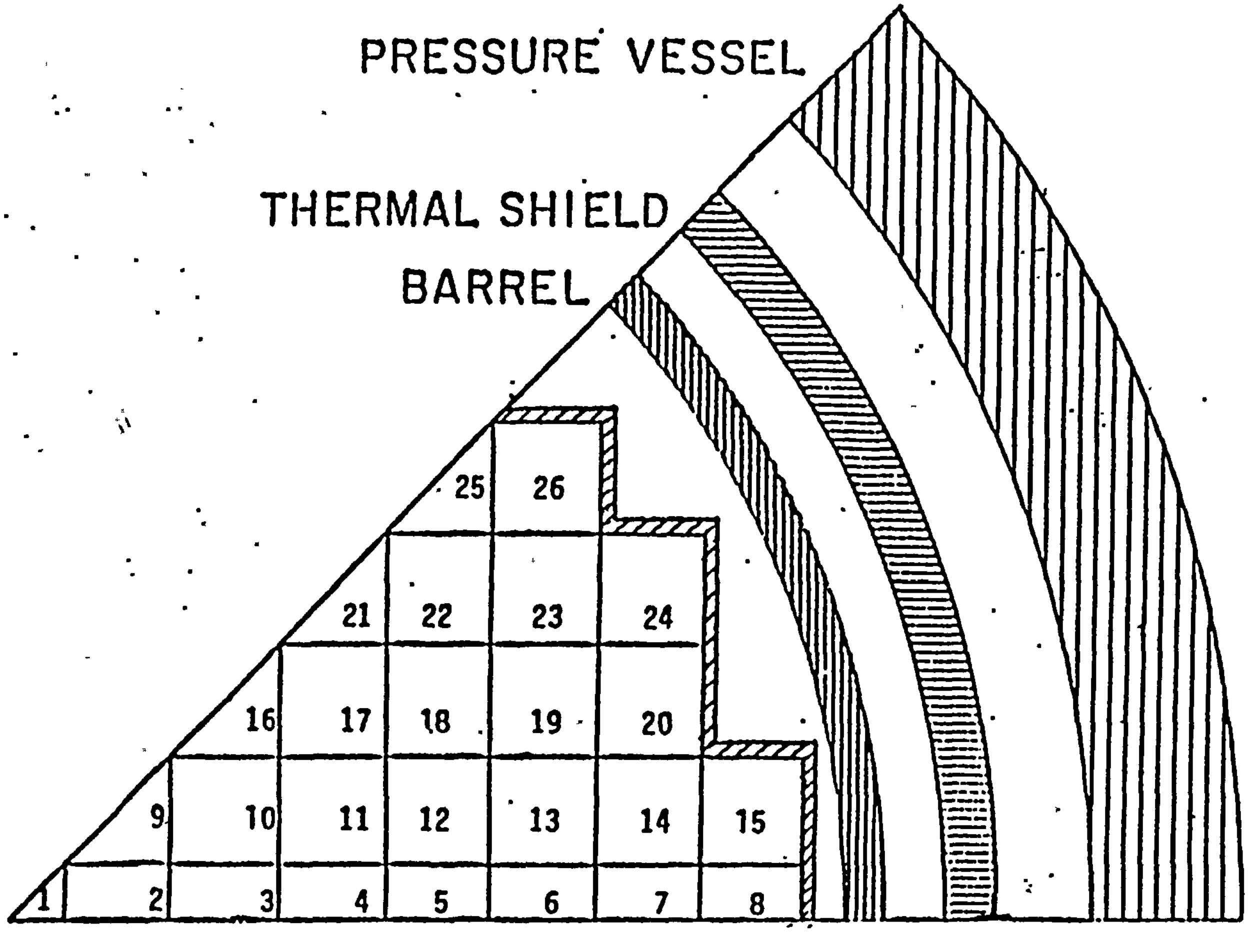

Figure 1 - Turkey Point Geometry Configuration and Assembly Numbering

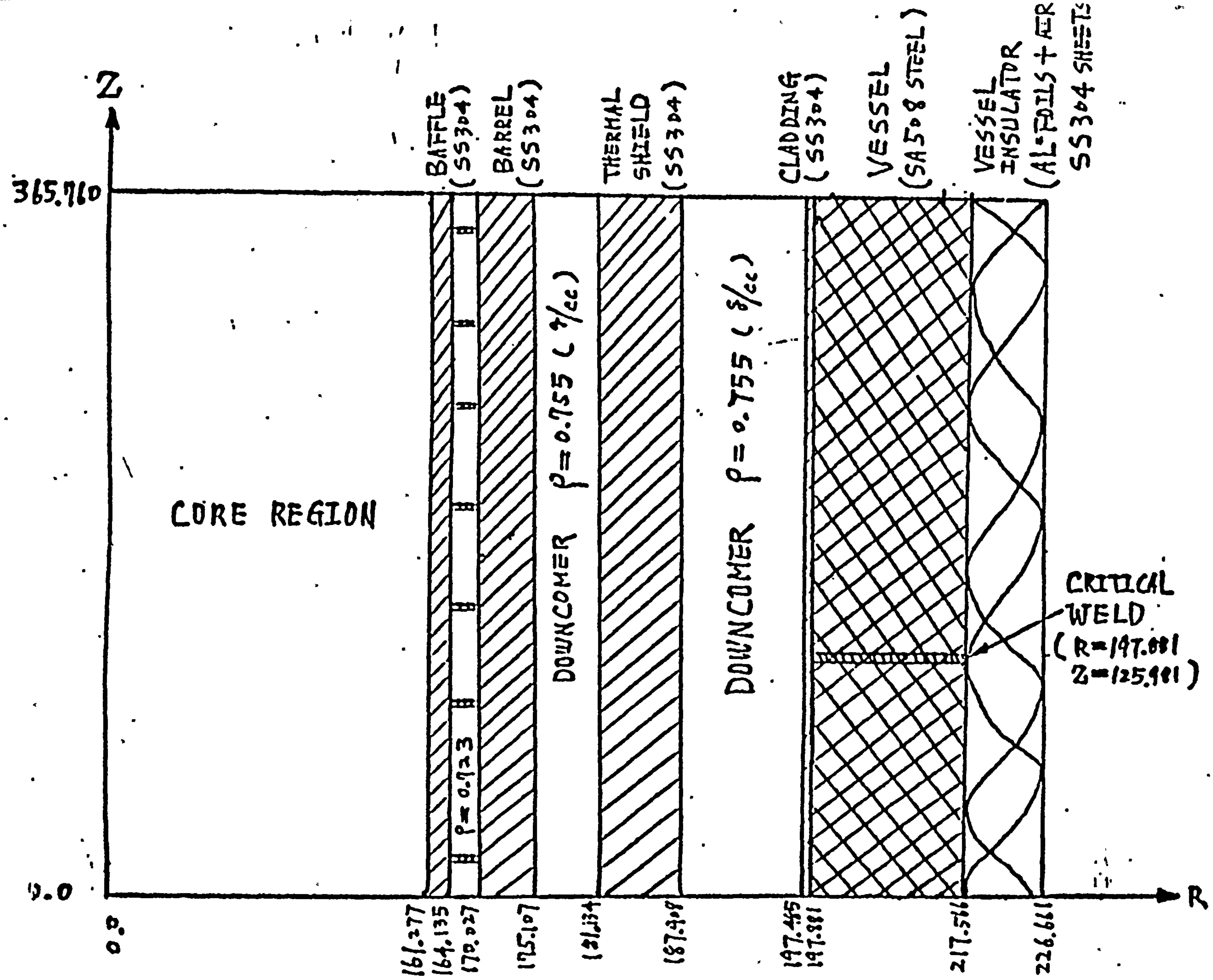

Figure 2 - Turkey Point (R,Z) Geometry