Attachment to March 16, 1992 PTS Submittal

DUQUESNE LIGHT COMPANY
BEAVER VALLEY POWER STATION
NUCLEAR ENGINEERING DEPARTMENT

FLUX REDUCTION PROGRAM FOR UNIT 1 REACTOR PRESSURE VESSEL

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INTRODUCTION

The U. S. Nuclear Regulatory Commission has amended the rule for Pressurized Thermal Shock effective June 14, 1991. Westinghouse Electric Corp., NATD, was contracted to provide the projected values of RT_{PTS} for the reactor vessel beltline materials as required in 10CFR50.61. The bounding requirement for the calculated values stated that plant specific information shall be considered which includes credible surveillance capsule data as defined in Regulatory Guide 1.99 Revision 2. The Unit 1 reactor vessel capsules meet these requirements and, therefore, the test data was used for the first time in determining the RT_{PTS} values. The resulting RT_{PTS} value at end of license life for the Unit 1 controlling material exceeds the PTS screening criteria for plate by $1^{0}F$.

In accordance with 10CFR50.61, "For each pressurized water nuclear power reactor for which the value of the RT_{PTS} for any material in the beltline is projected to exceed the PTS screening criteria before the expiration date of the operating license, ...the licensee shall submit... an analysis and schedule for implementation of such flux reduction programs as are reasonably practicable to avoid exceeding the screening criteria... "

ANALYSIS

The analysis for the required flux reduction is contained in the attached WCAP-13208, "EVALUATION OF FLUX REDUCTION OPTIONS FOR BEAVER VALLEY UNIT 1 FOR REACTOR VESSEL LIFE ATTAINMENT". The evaluation is based on the results of the assessment submitted to the NRC December 16, 1991[1], as required by 10CFR50.61.

The analysis identifies three basic operational issues affected by radiation embrittlement; heatup and cooldown pressure-temperature limits, upper shelf energy, and pressurized thermal shock. The pressure- temperature limits contained in the Technical Specifications were addressed in the November, 1988, response to Generic Letter 88-11, as were the PTS values prior to the mandatory inclusion of surveillance capsule results. The pressure-temperature limits contain adequate margin for operation and will be periodically updated based on fluence projections and results of surveillance capsule data .

The upper shelf energy was determined to be acceptable at the projected end of life, compared to the 50 ft-lb minimum, using paragraph 2.2 of RG 1.99 Rev. 2.

The PTS values for the reactor vessel materials at Beaver Valley Unit 1 were previously presented in WCAP-13106 [2] as part of the 10CFR50.61 December 1991 submittal. Updated flux information, available as a result of the vessel specific evaluation for cycle 10, was recently used to calculate fluence accumulated through cycle 9 (8.6 EFPY in March, 1993), and revised RT_{PTS} values for the beltline materials are presented in Table 3 of WCAP-13208. All the RT_{PTS} values remain below the NRC screening values using projected fluences for both the end-of-life, 32 EFPY, and 48 EFPY, except the lower shell plate B6903-1, the most limiting material in the vessel beltline region. This result necessitates implementation of flux reduction for the Unit 1 vessel.

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Flux Reduction Program

In order to reach the end-of-design life, a flux reduction on the order of 1.07 to 1.15, depending on time of implementation, is needed to limit the fluence to 3.76 x 10^{19} n/cm^2 and maintain the RT_{PTS} value for B6903-1 below 270^{o}F. The upper shelf energy at that fluence is projected to be 50.9 ft-lbs using RG 1.99 Rev 2. The analysis goes beyond the license life by projecting the limiting fluence to 48 EFPY in order to maintain the option to consider extended life goals. The goal of the flux reduction program, in any case, must be to stay below the limiting fluence requirement.

OPTIONS

WCAP-13208 presents an integrated approach to flux reduction including fuel management and internals modifications. These options are described generically with the more effective flux reduction methods requiring more extensive evaluations for plant specific application.

IMPLEMENTATION

The program for implementation of flux reduction measures is a coordinated approach involving the integrity of the reactor vessel, the effect on plant operating criteria, outage scheduling, and fuels management and vessel modifications.

The results of the November PTS evaluation [2] were assessed and the decision was immediately made to implement a fuels management based flux reduction option. At that time, the core design for cycle 10 was being developed and maximum benefit could be achieved with no scheduling delay to the refueling outage in February, 1993, with the implementation of a loading pattern modification. The cycle 10 core loading design will incorporate the L^{4}P low-low leakage loading pattern. The fast neutron exposure calculations for the L^{4}P loading pattern were specific to Unit 1 in WCAP-13208 using the information available with the detailed core design for cycle 10. The results of the fluence projections calculated for this option confirm that the Unit 1 vessel will meet the regulations in the PTS rule at 32 EFPY.

FUTURE ACTIONS

Further flux reduction will require additional vessel specific evaluations to implement the most effective flux reduction options. The actions to be taken are:

- Flux reduction goals will be determined based on the desired vessel life and the potential for code and regulatory issues to affect the attainment of that desired life.
- A vessel specific evaluation will be performed to determine the modifications necessary to meet the flux reduction goals and identify the possible implementation times.
- A schedule for implementation will be prepared based on the vessel specific evaluations, the complexity of the modifications, and future outage activity.

REFERENCES

[1] " Beaver Valley Power Station, Unit No. 1; Docket No. 50-334, License No. DPR-66; 10 CFR 50.61 (b) (1) RT-PTS Submittal"

[2] WCAP-13106, "Evaluation of Pressurized Thermal Shock for Beaver Valley Unit 1", J.M. Chicots and N.K. Ray, November, 1991.

WCAP-13208

EVALUATION OF FLUX REDUCTION OPTIONS FOR BEAVER VALLEY UNIT 1 FOR REACTOR VESSEL LIFE ATTAINMENT

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1. INTRODUCTION

The U. S. Nuclear Regulatory Commission has amended the Pressurized Thermal Shock (PTS) Rule effective from June 14, 1991 [1]. Westinghouse evaluated pressurized thermal shock for the Beaver Valley Unit 1 reactor vessel using this revised PTS rule. This evaluation showed that the vessel would exceed the PTS screening criteria prior to 32 EFPY. The PTS Rule requires that any utility expected to exceed the screening criteria prior to license expiration submit an analysis and schedule for the implementation of a flux reduction program to avoid exceeding the PTS screening criteria. This report will describe the methodology for developing a flux reduction program and examine potential benefits of flux reduction to demonstrate reactor vessel integrity for different time spans for the Beaver Valley Unit 1 reactor vessel.

2. GENERIC NEUTRON FLUX REDUCTION PROGRAM

Industry studies have indicated that the reactor pressure vessel may be the limiting component with respect to attaining the desired life and life extension for many nuclear power plants. The primary reactor vessel life attainment issue is concerned with the prevention of non-ductile failure of the reactor vessel , which is subject to neutron radiation embrittlement effects. For those vessels where this concern exists during its anticipated operational life, the implementation of neutron flux reduction programs can play a significant role in attaining its desired life.

There are three basic operational issues affected by radiation embrittlement of the reactor vessel: pressurized thermal shock (PTS), low upper shelf energy, and heatup and cooldown pressure-temperature limits. Since a neutron flux reduction program can effect these issues differently and since there is a range of neutron flux reduction methods available, an integrated approach is required, as suggested in Figure 1.

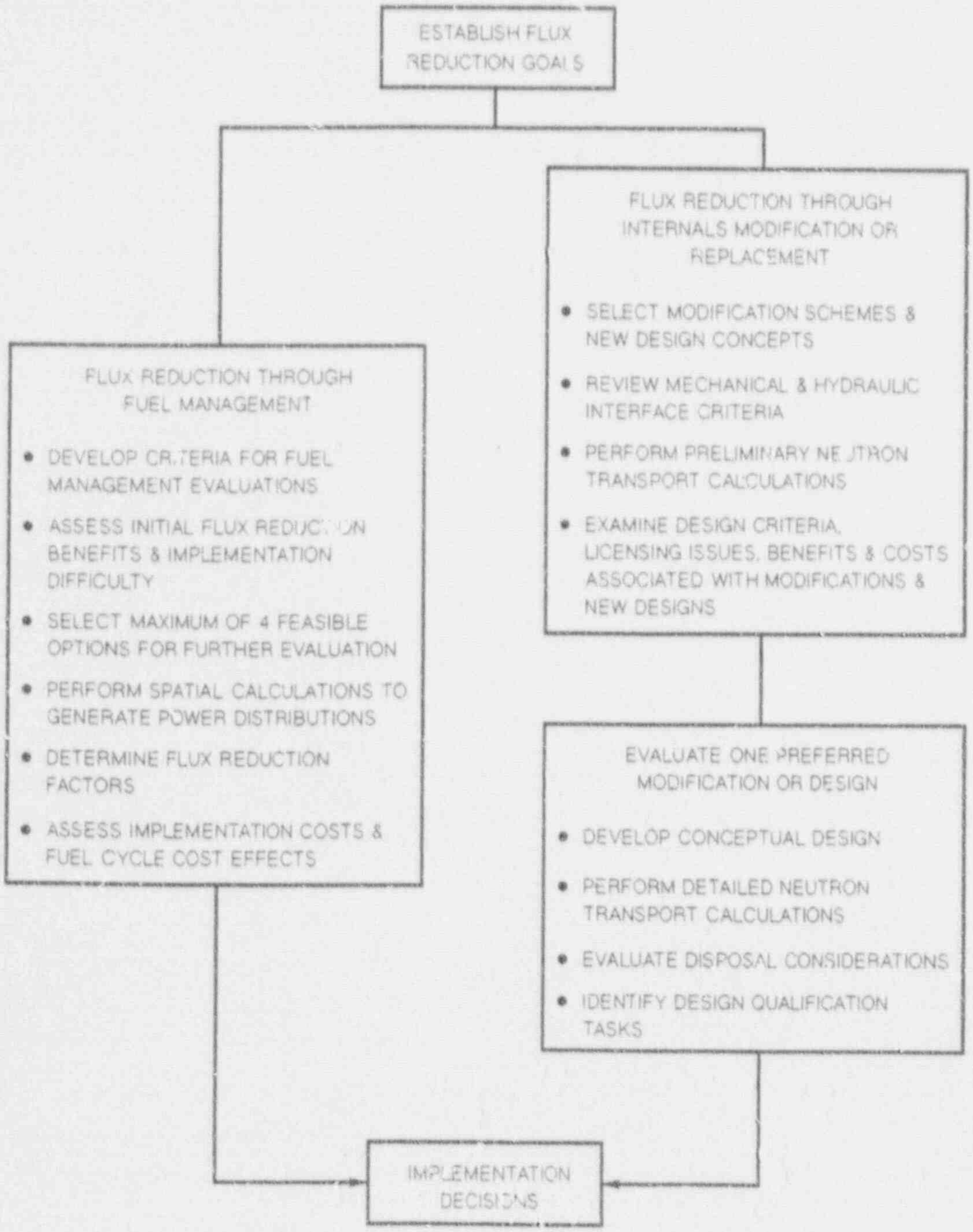

FIGURE 1. AN INTEGRATED APPROACH TO NEUTRON FLUX REDUCTION

3. GENERIC NEUTRON FLUX REDUCTION GOALS

The first step in developing a flux reduction program is to assess the need for flux reduction and to set a flux reduction goal. In order to set flux reduction goals, a target end-of-life fluence must first be established. In setting the target end-of-life fluence, a variety of key issues may be taken into consideration to ensure setting the correct target. The first issue that is considered is PTS. PTS is assessed using the latest radiation embrittlement prediction methods specified by the U. S. Nuclear Regulatory Commission in the PTS Rule [1]. The upper shelf fracture toughness of the critical plates and welds is addressed next. Finally, the end-of-life heatup and cooldown curves are evaluated to ensure operability within the limits that are imposed by technical and administrative requirements.

Neutron fluence limits are established for end-of-licensed life, end-of-design life, and life extension. These neutron fluence limits are used to calculate required flux reduction factors that, in turn, are used to establish the neutron flux reduction goals for the critical material in the reactor vessel. These flux reduction factors are calculated for the matrix of issues under consideration for each of the critical materials.

In order to determine the required flux reduction factors, assumptions must be made relative to when the neutron flux reduction measures will be implemented and what neutron flux rate is used for neutron fluence projections. The following equations are then used to calculate the required flux reduction factors:

$$\text{Remaining Fluence} = \text{Limiting Fluence} - \text{Fluence at Implementation}$$

$$\text{Required Flux} = \frac{\text{Remaining Fluence}}{\text{Remaining Time}}$$

$$\text{Required Flux Reduction Factor} = \frac{\text{Current Flux}}{\text{Required Flux}}$$

A required flux reduction factor is determined for each critical vessel material and the governing neutron embrittlement issues. Ranges of flux reduction goals are then established for each critical vessel location relative to the fluence limits and required flux reduction factors. These goals represent the required reduction in neutron flux to achieve a desired vessel life relative to the current in-place fuel loading patterns. The flux reduction goals provide guidance for fuel management and reactor vessel internals localized shielding designs. Separate goals are defined for each of these mitigative actions to address the license life, design life and plant life extension considerations.

To further support the definition of flux reduction goals for the reactor vessel, flux reduction factor versus time of implementation curves are developed for the most limiting material, as exemplified on a generic basis in Figure 2.

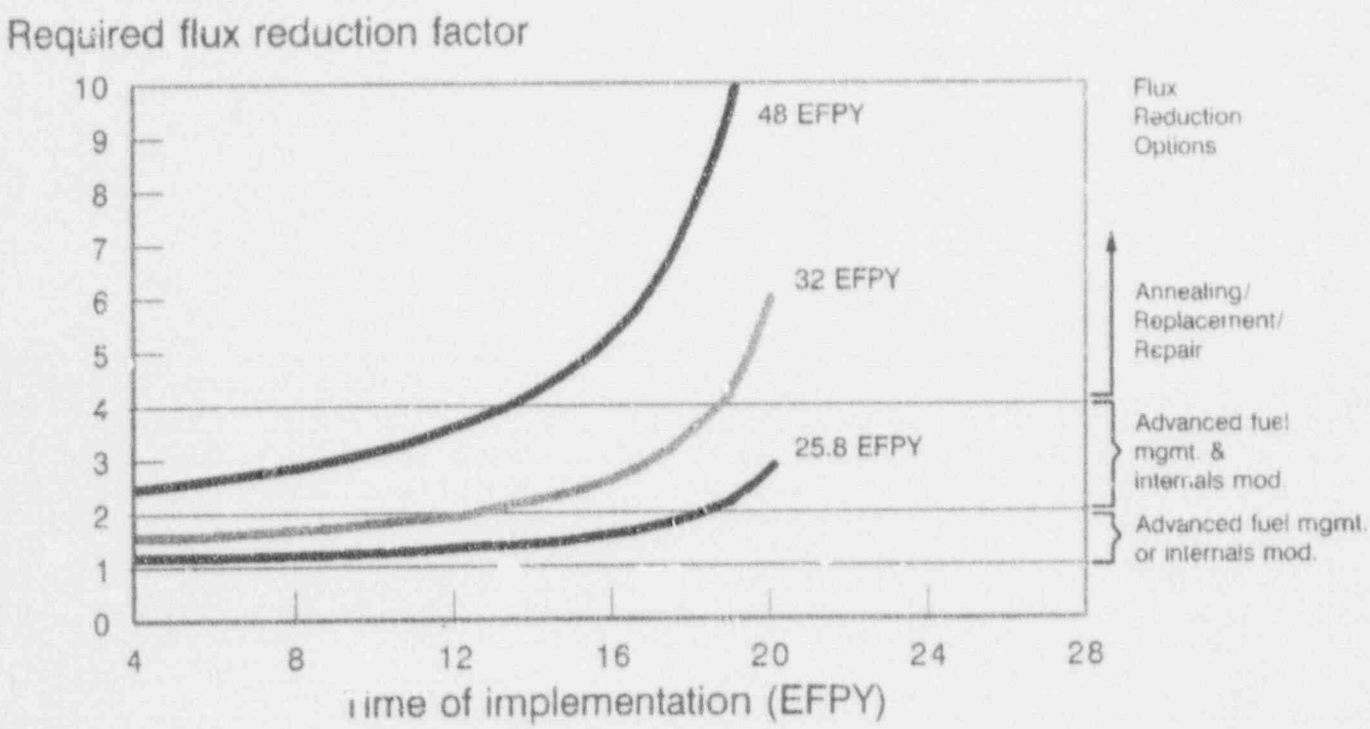

FIGURE 2. REQUIRED FLUX REDUCTION FACTORS

4. GENERIC NEUTRON FLUX REDUCTION OPTIONS

There is a range of alternative flux reduction methods available via fuel management and localized vessel shielding. The amount of flux reduction required or desired and the limiting vessel material location will determine the options which can be considered. Table 1 shows the estimated flux reduction factors which may be achieved by the implementation of alternative flux reduction methods based on available generic information. It is important to note that these are generic estimates and the actual amount of flux reduction that can be achieved will vary from plant to plant.

TABLE 1

ESTIMATED FLUX REDUCTION FACTORS FOR ALTERNATIVE FLUX REDUCTION METHODS

OPTION	POTENTIAL FLUX REDUCTION FACTOR
FUEL MANAGEMENT	
L^4P	1.0 - 1.5
L^4P + Poisons	1.3 - 2.2
L^4P + Poisons + Modified Assembly	1.5 - 3.0
SHIELDING	
Replacement of Thermal Shield with Neutron Pads (Stainless Steel)	1.0 - 3.0
Replacement of Thermal Shield with Neutron Pads (Heavy Metal)	1.5 - 3.0
Replacement of Reactor Vessel Internals	3.0 - 5.0

4.1 Flux Reduction Through Fuel Management

There are two basic concerns, technical and economic, that must be addressed when making decisions regarding which flux reduction alternative to implement. This reports considers only the technical concerns. The goal of a flux reduction program is to achieve a desired plant life and, therefore, reactor vessel life. Not all flux reduction actions achieve this goal. There are many fuel management options which may be implemented to reduce the neutron flux in the reactor vessel, however, not all may be feasible for implementation in all plants. Furthermore, the amount of flux reduction achieved from each option is plant specific. In performing a plant specific evaluation, a set of criteria that can be used by core designers to estimate the flux reduction factors which can be achieved with each of the fuel management options is first developed. These criteria may include restrictions on peripheral assembly powers consistent with the desired flux reductions. Next, the flux reduction benefits and implementation cost of fuel management options are examined. The options are grouped into categories for convenience. These options are presented in Table 2.

4.2 Flux Reduction Through Vessel Shielding

There may be a number of internals modification schemes and design concepts identified for each of the following categories to reduce the neutron flux at the limiting areas of the vessel beltline region via vessel shielding:

1) Modify existing thermal shield
2) Replace thermal shield with neutron pads
3) Modify baffle-barrel region to include neutron reflector
4) Reactor internals replacement

Mechanical and hydraulic interface and design criteria between the reactor vessel and internals are reviewed relative to each of the modifications/designs defined above. One-dimensional neutron transport calculations are performed to estimate the neutron flux reduction benefit of each option.

TABLE 2

FUEL MANAGEMENT FLUX REDUCTION OPTIONS

GROUP	OPTIONS
1) Loading Pattern Modifications	a) Annual fuel cycles b) Low leakage loading Pattern (L^3P) c) Multi-enrichment regions d) High discharge burnup e) Low-low leakage loading pattern (L^4P)
2) Poisons in Guide Tubes	a) Peripheral poisons b) Peripheral burnable poisons
3) Modified Assembly Designs	a) Radial blanket rods b) Variable enrichment assemblies c) Stainless steel rods or cells
4) Radial Assembly Designs	a) Dummy assemblies b) Radial half assemblies c) Peripheral burnable poisons with large water holes
5) Other	a) Reconstitutable assembly

As indicated in Table 1, on a generic basis the largest flux reduction factors are found to be achievable with changes to the existing reactor internals and more so with new designs of replacement reactor internals. The process for implementation of an internals modification/replacement program is complex. After selecting a preferred modification option and preferred replacement concept, an assessment of the potential to meet design criteria on the reactor vessel internals for each option, as well as the licensability and cost/benefit analysis is performed.

The costs for modification of the existing internals or for replacement of reactor internals, in attempting to maximize plant life by significantly reducing neutron flux, are estimated to approach an order of magnitude beyond the costs of implementing advanced fuel management schemes, depending on the extent of the changes.

4.3 Implementation Decisions

Additional flux reduction versus time of implementation curves can be generated to assist in the decisions that will have to be made relative to the implementation of a flux reduction measures via advanced fuel management or localized vessel shielding. These curves show the effect of implementing the flux reduction program. An example is shown in Figure 3. These curves are best estimates of the flux reduction which can be achieved on a generic basis through the selected method.

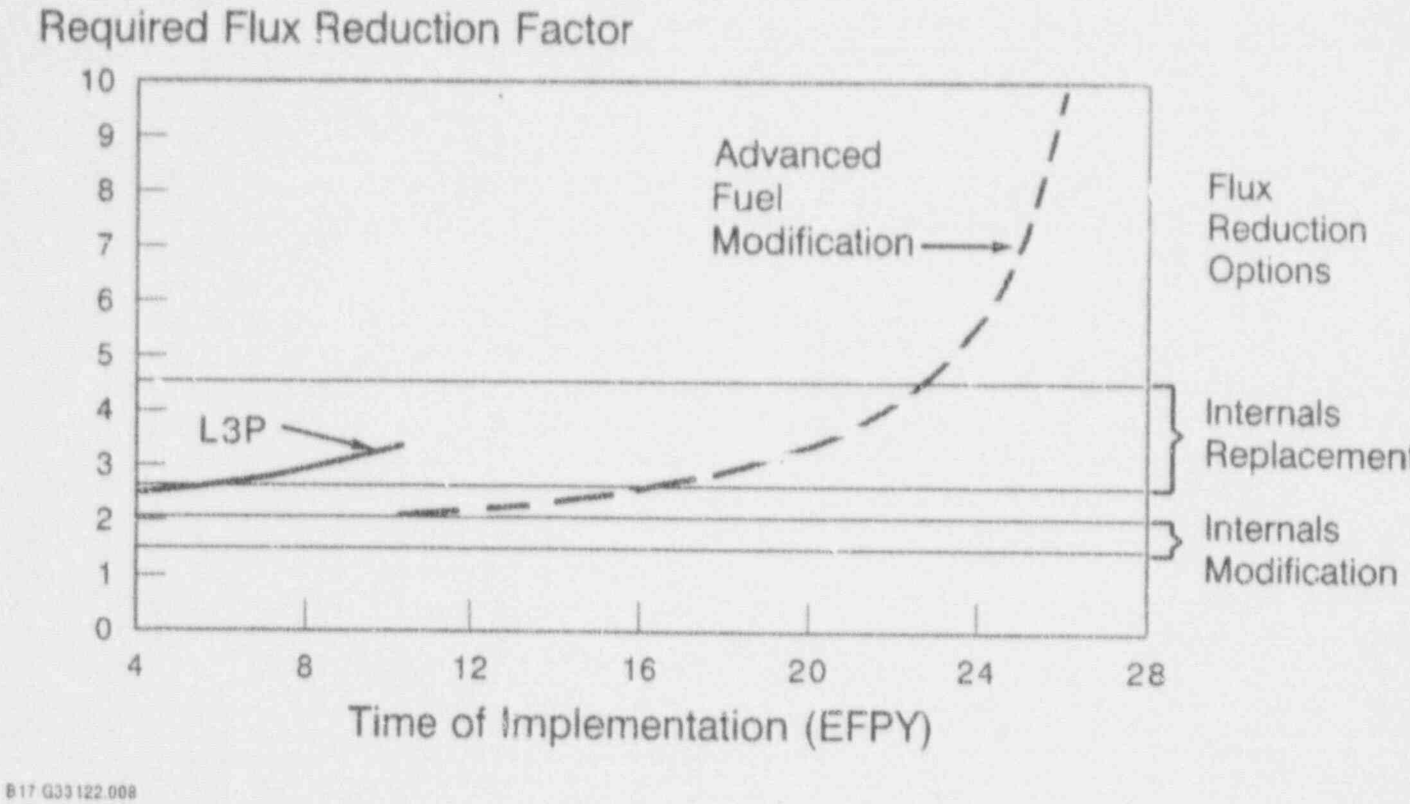

FIGURE 3. EFFECTS OF IMPLEMENTING A FLUX REDUCTION PROGRAM

5. BEAVER VALLEY UNIT 1 FLUX REDUCTION EVALUATION

A preliminary assessment of the flux reduction requirements was performed for the Duquesne Light Company Beaver Valley Unit 1 reactor vessel. Flux reduction goals for the Beaver Valley Unit 1 reactor vessel were established for license life (defined for this evaluation to be 32 EFPY) as well as for extended life (48 EFPY) for the key issues related to neutron embrittlement, i.e. pressurized thermal shock, low upper shelf energy, and heatup and cooldown pressure temperature limits. The goals were determined by establishing fluence limits and flux reduction factors required to keep the reactor vessel in compliance with regulatory limits (primarily PTS) through the desired time periods. The current condition of the reactor vessel was taken into account in this evaluation.

5.1 Initial Pressurized Thermal Shock Evaluation

Pressurized thermal shock evaluations (RT_{PTS} values) were performed using the PTS rule. These calculations were carried out for the entire beltline region of the Beaver Valley Unit 1 reactor vessel as a function of end-of-life (32 EFPY) and 48 EFPY fluence values. The fluence data was generated based on the average flux at the end of the last fuel cycle (Cycle 9). Table 3 provides a summary of the RT_{PTS} values for all the beltline region materials for 32 and 48 EFPY. As indicated in Table 3, the lower shell plate B6903-1 is the most limiting material yielding a RT_{PTS} value of 271°F at 32 EFPY which exceeds the applicable PTS screening criteria of 270°F. In order for Beaver Valley Unit 1 to continue to operate through the design life (32 EFPY), flux reduction measures must be implemented.

TABLE 3

RT_{PTS} VALUES FOR BEAVER VALLEY UNIT 1 FOR 32 AND 48 EFPY

MATERIAL	32 EFPY*	48 EFPY*
Intermediate Shell Plate, B6607-1	213	221
Intermediate Shell Plate, B6607-2	243	251
Lower Shell Plate, B6903-1	271	284
Lower Shell Plate, B7203-2	187	195
Circumferential Weld Seam 11-714 (Wire Ht. 90136)	190	200
Longitudinal Weld Seam 19-714A&B (Wire Ht. 305424)	185	206
Longitudinal Weld Seam 20-714A&B (Wire Ht. 305414)	202	225

* RT_{PTS} values are in degrees Fahrenheit.

5.2 Evaluation of Other Reactor Vessel Concerns

In addition to PTS, two other operational issues should be addressed; low upper shelf energy of the critical welds and plates, and the end-of-life heatup and cooldown pressure-temperature limits.

The upper shelf energy decreases as a function of fluence and copper content. The objective of the pertinent regulations is to assure that the upper shelf energy of the material at normal operating temperatures is maintained above the minimum 50 ft-lb Charpy energy value prescribed by 10 CFR 50 Appendix G [6]. The decrease in upper shelf energy for the limiting materials for Beaver Valley Unit 1 was calculated for 32 and 48 EFPY based upon the conservative methodology presented in U. S. NRC Regulatory Guide 1.99, Rev. 2 [3]. The results indicate that the upper shelf energy will drop to 50.8 at 32 EFPY, which is above the minimum 50 ft-lb limit given in 10CFR50 Appendix G [6]. Additional plant specific evaluations may result in higher values but this issue has not been addressed as part of this flux reduction evaluation.

The heatup and cooldown pressure-temperature limits are defined to prevent non-ductile fracture of the reactor vessel while at lower temperatures during reactor startup and shutdown. The objective of flux reduction in regard to heatup and cooldown pressure-temperature limits is to maintain the RT_{NDT} values at the 1/4 and 3/4 wall thickness locations to values that do not result in operating limits that could impair plant startup or shutdown. This issue was previously addressed in "Beaver Valley Unit 1 Reactor Vessel Life Attainment Plan" [4]. As a result of this evaluation it was concluded that Beaver Valley Unit 1 has acceptable margin of operation up to 48 EFPY provided i) the reactor vessel core maintains the current or lower flux level, ii) no significant change is identified for material chemistry in the beltline region, and iii) there is no significant change in the applicable regulatory requirements.

5.3 Flux Reduction Goals for Beaver Valley Unit 1

In order to set flux reduction goals, a target end-of-life fluence must first be established. The PTS issue was the primary issue considered in determining the limiting fluence for Beaver Valley Unit 1. Fluence limits were established for both end-of-design life and life extension for 20 additional calendar years of operation based upon the limiting material as calculated in the PTS evaluation. The end-of-design life was assumed to be 32 effective full power years (EFPY) and life extension was assumed to be 48 EFPY. The limiting fluence to maintain RT_{PTS} values below 270°F was calculated to be 3.76×10^{19} n/cm^2.

The required flux reduction factors were calculated using the results of the PTS evaluation [2]. The following assumptions were used in determining the required flux reduction factors:

- The average flux of Cycles 1 through 6 [5] was updated to include Cycles 7, 8 and 9. The updated flux was then used to calculate the fluence accumulated through Cycle 9 (8.6 EFPY).

A required flux reduction factor was determined for the limiting material in the Beaver Valley Unit 1 reactor vessel beltline region. To further support the definition of flux reduction goals for the Beaver Valley Unit 1 reactor vessel, flux reduction factor versus time of implementation curves were developed for 32 and 48 EFPY. These curves are shown in Figure 4.

Relative to the fluence and required flux reduction factor results that were presented in Figure 4, ranges of flux reduction may be established. These goals represent the required reduction in neutron flux relative to the current fuel loading pattern necessary for Beaver Valley Unit 1 to remain below the PTS screening criteria and obtain the desired plant life as presented in Table 4.

The flux reduction goals, having been established for the limiting location in the beltline region of the Beaver Valley reactor vessel, provides guidance for the selection of mitigative actions to enable Beaver Valley to operate to 32 or 48 EFPY and remain below the PTS screening criteria.

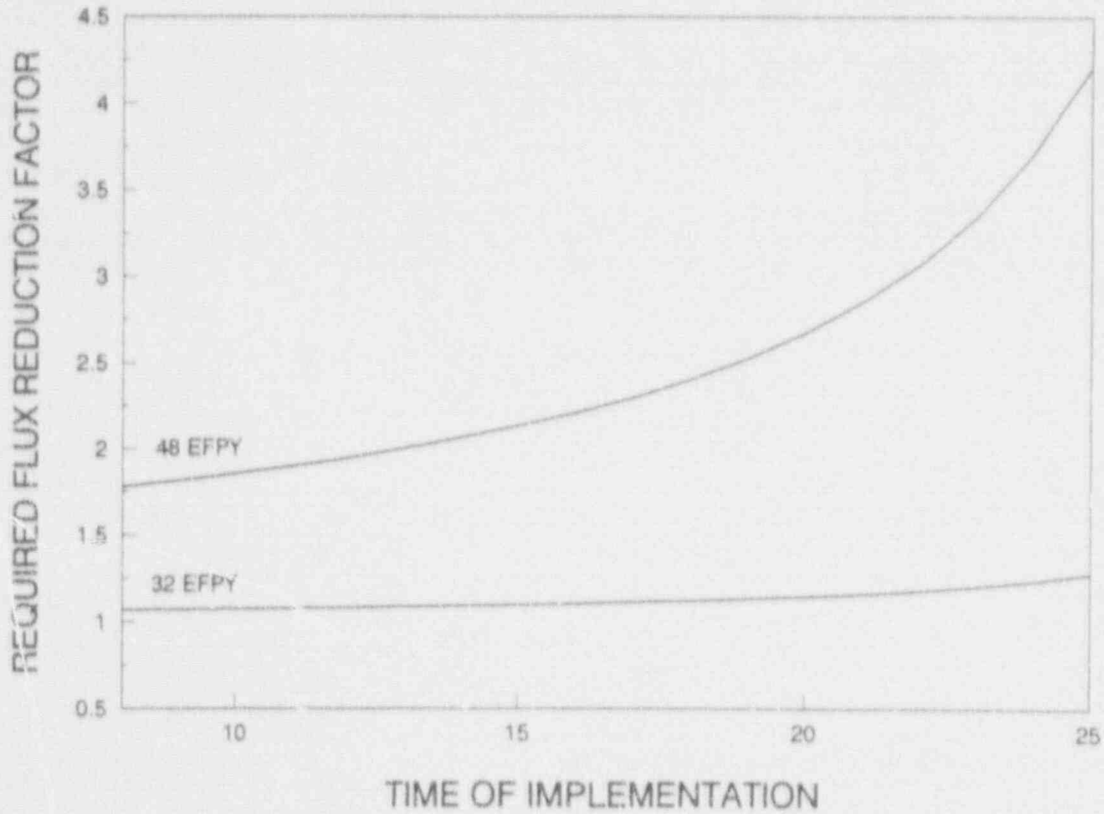

FIGURE 4. REQUIRED FLUX REDUCTION FACTORS FOR BEAVER VALLEY UNIT 1 FOR 32 AND 48 EFPY

TABLE 4
RANGE OF REQUIRED FLUX REDUCTION FACTORS
FOR BEAVER VALLEY UNIT 1

EFPY	Flux Reduction Factor*
32	1.07 ---> 1.15
48	1.82 ---> 2.67

* Range based on implementation at 9 --> 20 EFPY

There is a range of neutron flux reduction options available via fuel management and localized vessel shielding. As shown in Figure 4, the need for action is readily apparent considering; 1) Beaver Valley Unit 1 has been in operation for about 10 EFPY, 2) the potential flux reduction factors that can be attained via fuel management and/or vessel shielding measures, and 3) the desired plant lifetimes. The amount of flux reduction required or desired and the limiting vessel location will determine the options which can be considered. Table 1 shows the potential flux reduction factor which may be achieved based on prior generic information from some of the various methods of flux reduction.

The following two flux reduction alternatives were selected by Duquesne Light Company for evaluation for use in the Beaver Valley Unit 1 reactor vessel:

1. Low-low leakage loading pattern (L^4P).

2. L^4P utilizing non-burnable neutron poisons in guide tubes of peripheral fuel assemblies (L^4P + Hafnium).

Flux reduction factors were estimated for each option. The method used to estimate the neutron flux rate for each option are detailed in the following sections.

5.4 Neutron Flux Estimates for L^4P Fuel Loading Pattern

The fast neutron exposure calculations for Beaver Valley Unit 1 were based on a series of adjoint discrete ordinates transport calculations relating the fast neutron flux (E > 1.0 MeV) at several azimuthal locations on the pressure vessel inner radius to neutron source distributions in the reactor core. The importance functions generated from these adjoint analyses, when combined with cycle specific neutron source distributions, provided absolute predictions of neutron exposure at the locations of interest. It is important to note that the cycle specific source distributions utilized in these analyses included not only spatial variations of fission rates within the reactor core; but, also accounted for the effects of varying neutron yield per fission and fission spectrum introduced by the build-in of plutonium as the burnup of individual

fuel assemblies increased.

The transport calculations were carried out in R,θ geometry using the DOT two-dimensional discrete ordinates code and the SAILOR cross-section library. The SAILOR library is a 47 group ENDFB-IV based data set produced specifically for light water reactor applications. In these analyses, anisotropic scattering was treated with a P_3 expansion of the cross-sections and the angular discretization was modeled with an S_8 order of angular quadrature.

In the case of the L_4 with hafnium absorbers, specific transport calculations were not carried due to the lack of a detailed core design. Instead, estimates of the flux reduction over that observed with L_4P alone were based on measured comparisons from cavity dosimetry deployed at a plant utilizing the L_4P with hafnium approach.

5.5 Revised Pressurized Thermal Shock Evaluation

RT_{PTS} values were calculated for each of the components in the beltline region of the Beaver Valley Unit 1 reactor vessel using the fluence projections calculated for the two flux reduction options evaluated. The results are presented in Tables 5 and 6.

TABLE 5

RT_{PTS} VALUES FOR BEAVER VALLEY UNIT 1 FOR 32 AND 48 EFPY BASED UPON IMPLEMENTATION OF L^4P**

MATERIAL	32 EFPY*	48 EFPY*
Intermediate Shell Plate, B6607-1	210	218
Intermediate Shell Plate, B6607-2	240	248
Lower Shell Plate, B6903-1	266	280
Lower Shell Plate, B7203-2	185	192
Circumferential Weld Seam 11-714 (Wire Ht. 90136)	186	197
Longitudinal Weld Seam 19-714A&B (Wire Ht. 305424)	188	210
Longitudinal Weld Seam 20-714A&B (Wire Ht. 305414)	206	230

* RT_{PTS} values are in degrees Fahrenheit.

** Based upon implementation at Cycle 10.

TABLE 6

RT_{PTS} VALUES FOR BEAVER VALLEY UNIT 1 FOR 32 AND 48 EFPY
BASED UPON IMPLEMENTATION OF L^4P + HAFNIUM**

MATERIAL	32 EFPY*	48 EFPY*
Intermediate Shell Plate, B6607-1	206	214
Intermediate Shell Plate, B6607-2	236	244
Lower Shell Plate, B6903-1	259	272
Lower Shell Plate, B7203-2	181	188
Circumferential Weld Seam 11-714 (Wire Ht. 90136)	180	191
Longitudinal Weld Seam 19-714A&B (Wire Ht. 305424)	188	210
Longitudinal Weld Seam 20-714A&B (Wire Ht. 305414)	206	230

* RT_{PTS} values are in degrees Fahrenheit.

** Based upon implementation of L^4P fuel loading pattern at Cycle 10 and L^4P+Hafnium at Cycle 11.

6. CONCLUSIONS

Flux reduction provides a viable means to improve or resolve reactor vessel integrity issues associated with radiation embrittlement of reactor vessel materials. In order for the Beaver Valley Unit 1 reactor vessel RT_{PTS} values to remain below 270°F through 32 EFPY, a flux reduction program must be implemented to address PTS concerns. Either of the two flux reduction methods evaluated in this report if implemented at the next fuel cycle (Cycle 10) are estimated to enable the Beaver Valley Unit 1 vessel to meet the regulations set forth in the PTS rule at 32 EFPY. These advanced fuel management schemes should be technically and economically considered for implementation via more

detailed plant specific evaluation as soon as possible in order to maximize their benefit or provide sufficient time to consider other mitigative actions for achieving 32 EFPY or plant life extension (48 EFPY). A lead time of up to four years is needed for implementation of vessel shielding designs. These more extensive actions should be performed during a planned, extended outage for other plant operations (e.g., 10 year in-service inspection) to be cost-effective.

7. REFERENCES

[1] 10 CFR Part 50, "Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events", U. S. Nuclear Regulatory Commission, Washighton D. C. Federal Register, Vol. 56, No. 94, May 15, 1991.

[2] WCAP-13106, "Evaluation of Pressurized Thermal Shock for Beaver Valley Unit 1", J. M. Chicots and N. K. Ray, November 1991.

[3] Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials", U. S. Nuclear Regulatory Commission, May 1988.

[4] FDRT-SMART-124(90), "Duquesne Light Company Beaver Valley Unit 1 Reactor Vessel Life Attainment Plan", N. K. Ray and J. M. Chicots, February 1990.

[5] WCAP-12005, "Analysis of Capsule W from the Duquesne Light Company Beaver Valley Unit 1 Reactor Vessel Radiation Surveillance Program", S. E. Yanichko, et al., November 1988.

[6] Code of Federal Regulations, 10CFR50, Appendix G, "Fracture Toughness Requirements", U. S. Nuclear Regulatory Commission, Washighton D. C. Federal Register, Vol. 48, No. 104, May 27, 1983.