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REVIEW AND CERTIFICATION LOG

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REVISION 5					
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SUMMARY OF REVISIONS

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1.0 INTRODUCTION

This report documents analyses performed in support of American Electric Power (AEP) personnel responding to a USNRC Request for Additional Information (RAI) on the thermal-hydraulic analysis of the Cook Nuclear Plant spent fuel pool (SFP) [1]. This report addresses the use of the Unit 2 uprated reactor power in decay heat calculations.

Sections 2.0 through 5.0 each contain the response to an individual NRC or AEP question. Where appropriate, references to and comparisons with the result of the previous analyses [1] are performed. Not all of these four sections contain analyses.

2.0 AEP REQUEST - DESCRIPTION OF ANALYSIS METHODS

2.1 Decay Heat Analysis Method

All decay heat calculations are performed using implementations of the ORIGEN2 [2] computer code developed at Oak Ridge National Laboratory. This program has a long history of use in the commercial nuclear power industry for both isotope production and thermal power calculations. The ORIGEN2 code is a rigorous isotope generation and depletion code which accurately predicts the products and by-products of fission and the resulting heat generation rates.

The decay heat generation rate in the pool consists of two components: the decay heat generated by previously discharged fuel assemblies and the decay heat generated by freshly (recently) discharged assemblies. The decay heat contribution of previously discharged fuel assemblies changes very little over short periods of time, and is therefore held constant in the analyses. Because of the nature of exponential decay, this simplification is conservative. The Holtec QA Validated LONGOR [3] computer program, which incorporates the ORIGEN2 code, is used to calculate this decay heat component.

The decay heat contribution of the freshly discharged fuel assemblies changes substantially over even very short periods of time. This decay heat contribution is therefore evaluated as time-varying. The Holtec QA Validated BULKTEM [4] computer program, which incorporates the ORIGEN2 code, is used to calculate this decay heat component.

2.2 Bulk SFP Temperature Analysis Method

Due to the time-varying decay heat component, the total decay heat is also time-varying. The bulk SFP temperature is therefore calculated as a function of time. The following energy balance is solved to obtain the temperature at each instant in time:

$$C \times \frac{\partial T}{\partial \tau} = Q_{GEN}(\tau) - Q_{HX}(T) - Q_{EVAP}(T)$$

where:

- C is the SFP thermal capacity, Btu/°F
- T is the bulk SFP temperature, °F
- τ is the time after reactor shutdown, hr
- $Q_{GEN}(\tau)$ is the decay heat generation, Btu/hr
- $Q_{HX}(T)$ is the SFPCS heat rejection, Btu/hr
- $Q_{EVAP}(T)$ is the evaporative heat loss, Btu/hr

The evaporative heat loss term includes both evaporative and sensible heat transfer from the surface of the SFP. The implementation of this term has been benchmarked against actual in-plant test data [5]. The solution of this first-order ordinary differential equation is performed using the BULKTEM program [4].

2.3 Time-to-Boil Analysis Method

Following a loss of forced cooling, the continuing decay heat load in the SFP will cause the bulk SFP temperature to rise. The equation energy balance which defines this transient phenomena is similar to the ODE presented in Section 2.2, but does not include the Q_{HX} term and does include a time varying SFP thermal capacity, to account for the evaporative water losses. The time available for corrective action before bulk SFP boiling occurs is determined using the Holtec QA Validated TBOIL computer program [6].

The decay heat generation and evaporative heat loss terms in this formulation are identical to those defined in Section 2.2, except for the following two differences:

- The decay heat is calculated using the correlations of USNRC Branch Technical Position ASB 9-2 [7] instead of ORIGEN2.

- No incremental credit is given for evaporative heat loss at SFP bulk temperatures greater than 170°F.

2.4 Local Temperatures Analysis Method

The decay heat generated by the fuel assemblies stored in the SFP induced a buoyancy driven flow field upward through the fuel rack cells. Cooler water is supplied to the bottom of the racks cells through the rack-to-wall gaps and rack-to-floor plenum.

A computational method for modeling this phenomena is given by Singh, et al. [8]. The method presented in the reference has been incorporated into the Holtec QA Validated computer program THERPOOL [9], this is used to perform this analysis.

3.0 NRC REQUEST 1

> "With regard to the spent fuel pool (SFP) cooling analyses for the normal refueling scenarios, Case 1A and 2 as presented in February 1, 1996 submittal are based on the spent fuel assemblies discharged from Unit 1 during Cycle 25A. Since Unit 2 will be operating at a higher power level than Unit 1 (3588 MWt vs 3250 MWt), the analyses for Case 1A and 2 should be revised based on the spent fuel assemblies discharged from the Unit 2 reactor during Cycle 20B. Also, Tables 3, 4 and 5, and Figures 1, 3, 6 and 8 should be revised to include the results from the above revised analyses."

In addition to the difference in reactor thermal power between Unit 1 and Unit 2, there are differences in the maximum burnup, initial U_{235} enrichment and fuel assembly uranium weight. These differences are summarized in the Table 1. All of the values in Table 1 are extracted from Reference 1.

As requested, the cases designated as 1A and 2 are re-evaluated using the Unit 2 values for the four parameters presented in Table 1. All input values are taken from Reference 1, and all inputs except those presented in Table 1 are identical to those used in the reference work. Unlike the original calculations, however, the thermal transient evaluations performed in this report utilize version 3.0 of the BULKTEM program [11]. This newer version of the BULKTEM code contains modification to the evaporative loss correlations [12], which are slightly more accurate than the original correlations. The effects of this modification on the results of the analysis are minimal.

The results of the maximum SFP bulk temperature analyses are presented in Table 2, where they are also compared with the previously reported values [1]. Temperature profiles for each case are presented in Figures 1 and 2. Net decay heat load and evaporative heat loss profiles for each case are presented in Figures 3 and 4. As expected, the maximum bulk SFP temperatures are marginally higher than previously reported.

The results of the bulk temperature analysis are propagated through to the time-to-boil and local temperature analyses, the results of which are presented and compared with the corresponding previously reported values [1] in Tables 3 and 4, respectively. As expected, the minimum time-to-boil is slightly less than previously reported, and the maximum evaporation rate and local temperatures are slightly higher than previously reported.

4.0 NRC REQUEST 2

> "In the analyses for the scenario of back-to-back full core discharge with two SFP cooling trains (Case 3), spent fuel assemblies from Unit 2 are assumed to be discharged in three groups each with a different burnup value. Provide curves to show the decay heat rates as a function of time generated in the SFP from each of these groups."

Figure 5 presents the decay heat profiles for each of the three groups of the full core discharge batch for Case 3. As expected, the decay heat generation rate and the reactor exposure are directly proportional.

5.0 NRC REQUEST 3

"In the response (A 4) to the staff's RAI presented in February 1, 1996 submittal, decay heat generation rates for spent fuel assemblies from each previous discharge cycle are provided. Decay heat generation rates from these previously discharged spent fuel assemblies are also provided in the Attachments 2 and 3 to the letter dated August 1, 1996. However, decay heat generation rates presented in August 1, 1996 submittal deviate significantly from that presented in February 1, 1996 submittal. Provide clarification and justification for this discrepancy."

The February 1, 1996 submittal is in response to an NRC RAI on Holtec Report HI-941183. The August 1, 1996 submittal is in response to an NRC RAI on Holtec Report HI-951389. A discussion of these differences between these decay heat generation rates has previously been provided in response 1.C of the August 1, 1996 submittal [10].

6.0 REFERENCES

[1] "Updated Thermal-Hydraulic Analysis of Spent Nuclear Fuel Pool - Donald C. Cook Nuclear Plant" Holtec Report HI-951389, Revision 1.

[2] A.G. Croff, "ORNL Isotope Generation and Depletion, A User's Manual for the ORIGEN2 Computer Code," ORNL/TM-7175, RSIC/CCC-371, Oak Ridge National Laboratory, July 1980.

[3] "QA Documentation for LONGOR v1.0," Holtec Report HI-951390, Revision 0.

[4] "QA Documentation for BULKTEM v2.0," Holtec Report HI-951391, Revision 0.

[5] Wang, Yu, "Heat Loss to the Ambient from Spent Fuel Pool: Correlation of Theory with Experiments," Holtec Report HI-90477.

[6] "QA Documentation for TBOIL v1.6," Holtec Report HI-92832, Revision 2.

[7] USNRC Branch Technical Position ASB 9-2, "Residual Decay Energy for Light Water Reactors for Long Term Cooling," Revision 2, July 1981.

[8] Singh, K.P. et. al., "Method for Computing the Maximum Water Temperature in a Fuel Pool Containing Spent Nuclear Fuel", Heat Transfer Engineering, Volume 7, Number 1-2, pp. 72-82, 1986.

[9] "QA Validation for THERPOOL v 1.2", Holtec Report HI-87120, Revision 2.

[10] Letter from E.E. Fitzpatrick (AEP) to USNRC, Docket Numbers 50-315 and 50-316, Document ID AEP:NRC:1202B, Attachment 1, Response 1.C.

[11] "QA Documentation for BULKTEM v3.0", Holtec Report HI-951391, Revision 1.

[12] "An Improved Correlation for Evaporation from Spent Fuel Pools," Holtec Report HI-971664, Revision 0.

TABLE 1

DIFFERENCES BETWEEN UNIT 1 AND UNIT 2 NORMAL DISCHARGES

Parameter	Unit 1 Value	Unit 2 Value
Reactor Thermal Power (MWt)	3,250	3,588
Maximum Average Burnup (MWd/MTU)	52,200	68,400
Initial U_{235} Enrichment (%)	3.50	4.00
Assembly Uranium Weight (kg)	461	410

TABLE 2

RESULTS OF MAXIMUM BULK SFP TEMPERATURE ANALYSES

Parameter	Current Results (Unit 2)	Previous Results (Unit 1)
Case 1A		
Maximum SFP Temperature	156.56°F	154.37°F
Coincident Time After Shutdown	138.0 hrs	138.0 hrs
Coincident Net Heat Load to HXs	28.50×10^6 Btu/hr	27.19×10^6 Btu/hr
Coincident Evaporative Heat Loss	2.79×10^6 Btu/hr	2.35×10^6 Btu/hr
Case 2		
Maximum SFP Temperature	129.84°F	128.68°F
Coincident Time After Shutdown	130.0 hrs	131.0 hrs
Coincident Net Heat Load to HXs	30.75×10^6 Btu/hr	29.32×10^6 Btu/hr
Coincident Evaporative Heat Loss	0.99×10^6 Btu/hr	0.57×10^6 Btu/hr

TABLE 3

RESULTS OF BOILING TIMES ANALYSES

Parameter	Current Results (Unit 2)	Previous Results (Unit 1)
Case 1A		
Time to Start of Boiling	8.53 hrs	9.45 hrs
Maximum Evaporation Rate	66.83 gpm	63.35 gpm
Case 2		
Time to Start of Boiling	12.11 hrs	13.37 hrs
Maximum Evaporation Rate	67.30 gpm	63.64 gpm

TABLE 4

RESULTS OF MAXIMUM LOCAL TEMPERATURES ANALYSIS
(Case IA Only)

Parameter	Current Results (Unit 2)	Previous Results (Unit 1)
No Blockage		
Maximum Local Water Temperature	166.0°F	163.6°F
Maximum Fuel Clad Temperature	216.3°F	214.5°F
50% Blockage		
Maximum Local Water Temperature	226.7°F	223.5°F
Maximum Fuel Clad Temperature	256.8°F	254.3°F

FIGURE 1: Spent Fuel Pool Bulk Water Temperature Profiles
Case 1A, Normal Discharge, 1 Cooling Train

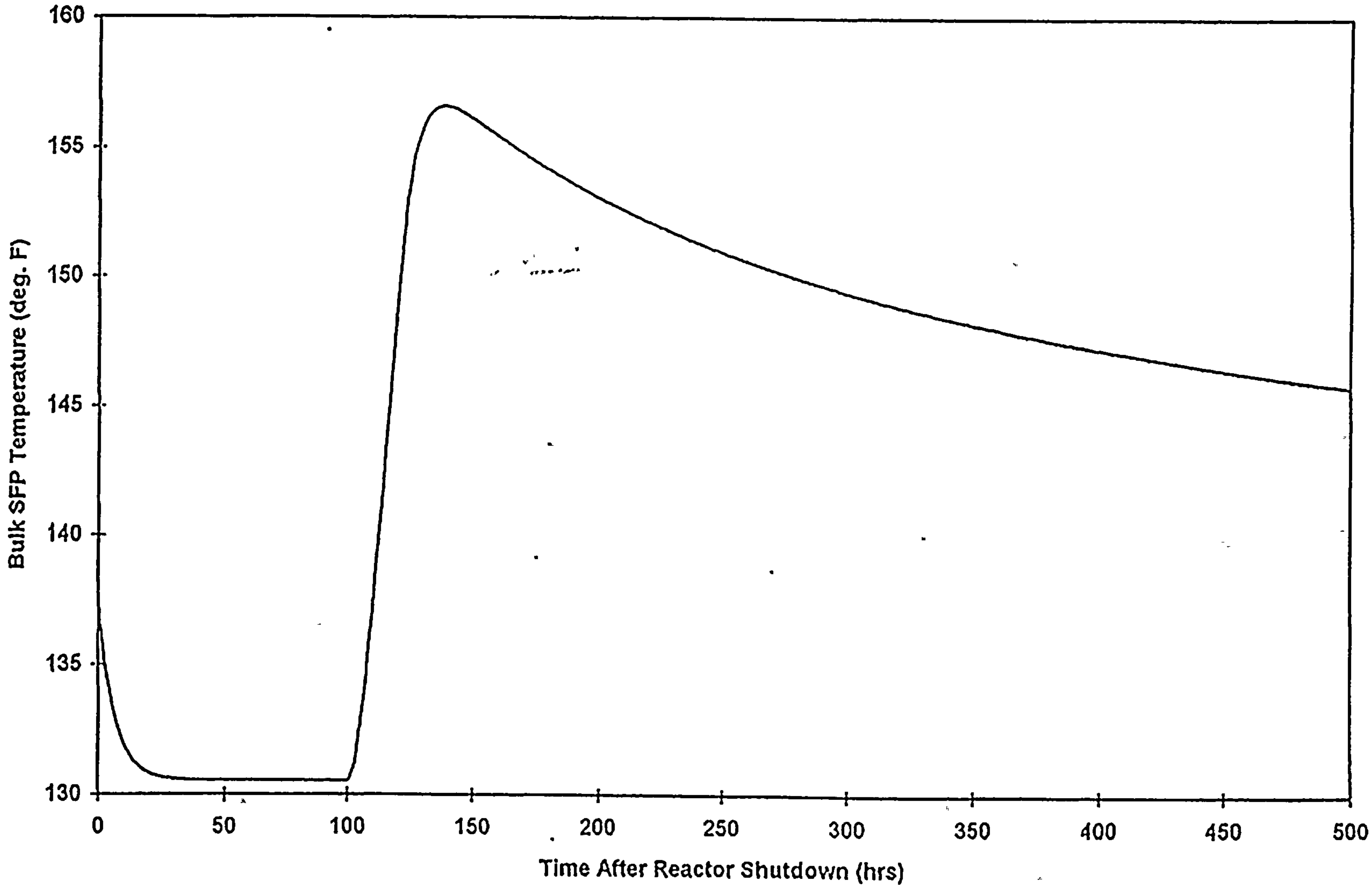


FIGURE 2: Spent Fuel Pool Bulk Water Temperature Profiles
Case 2, Normal Discharge, 2 Cooling Trains

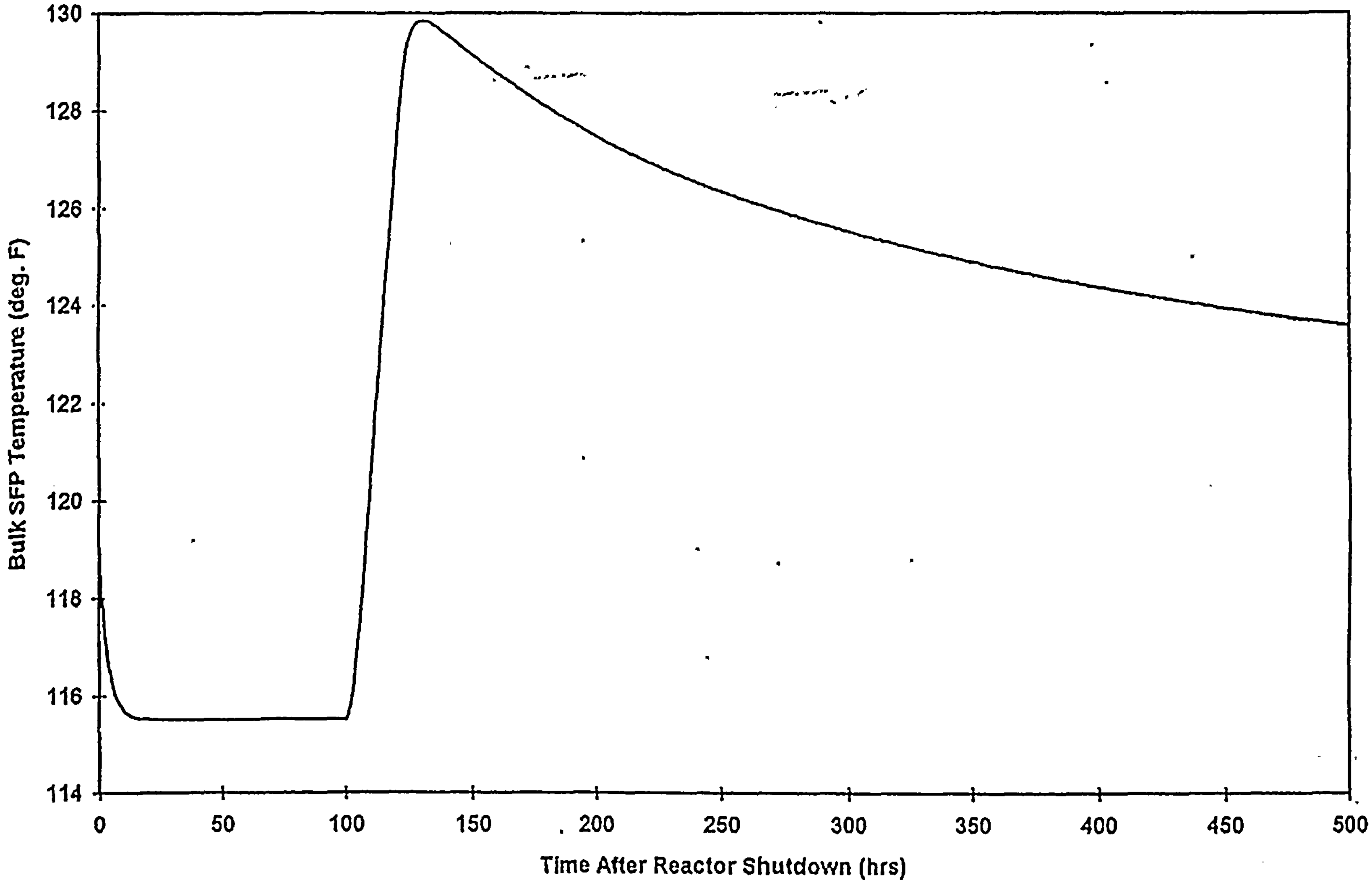


FIGURE 3: Spent Fuel Pool Decay Heat Load and Loss Profiles
Case 1A, Normal Discharge, 1 Cooling Train

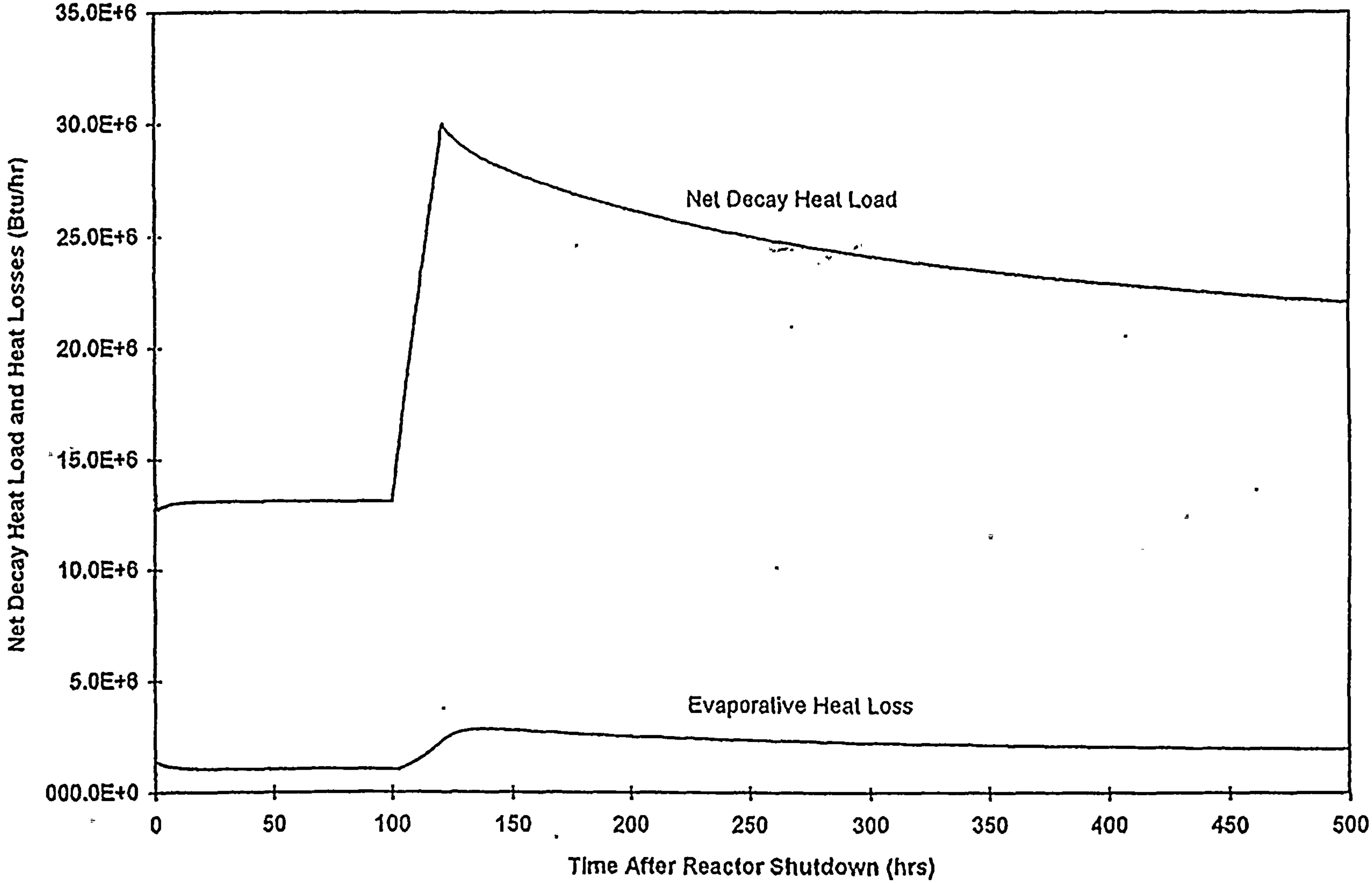


FIGURE 4: Spent Fuel Pool Decay Heat Load and Loss Profiles
Case 2, Normal Discharge, 2 Cooling Trains

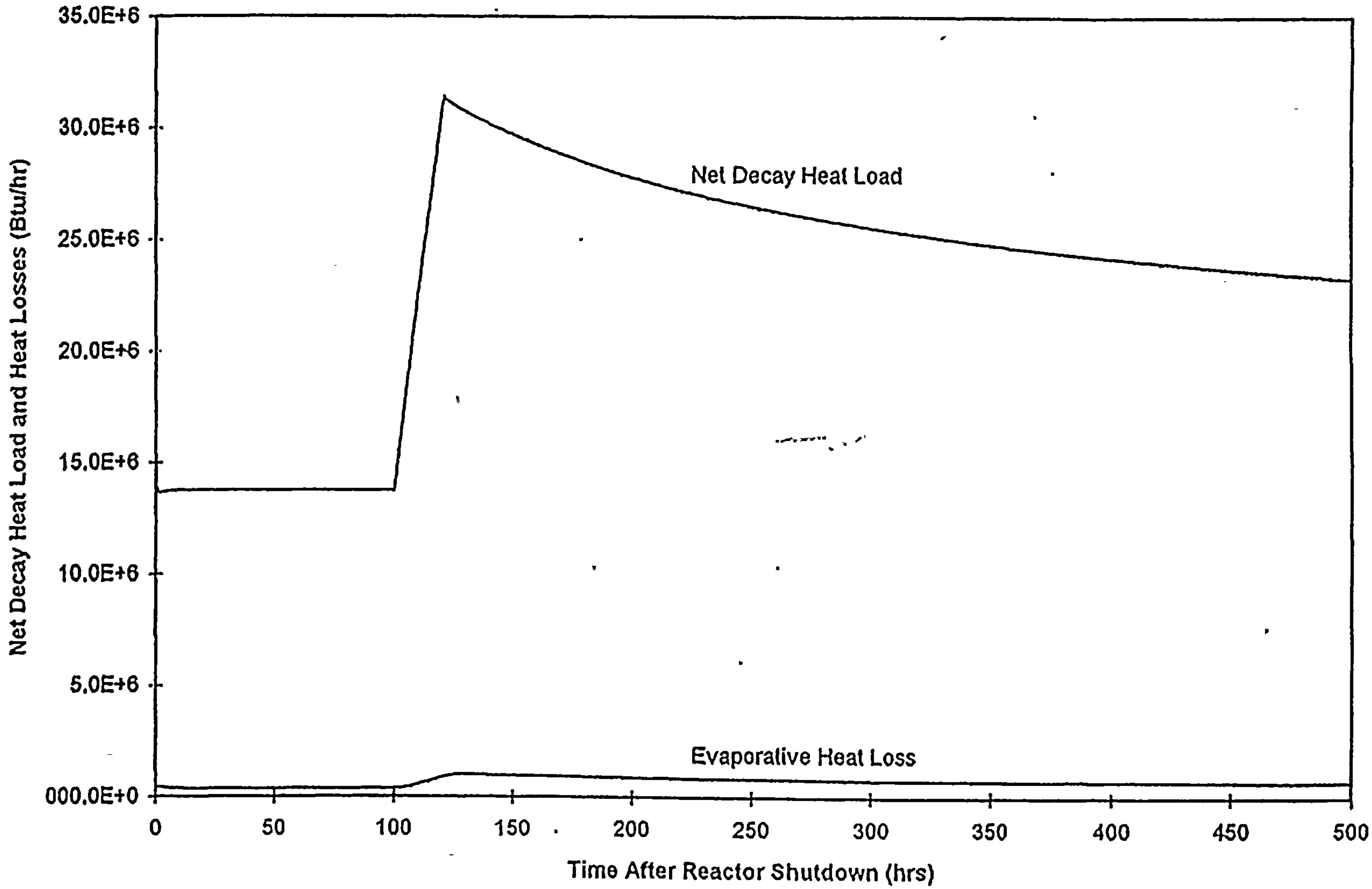
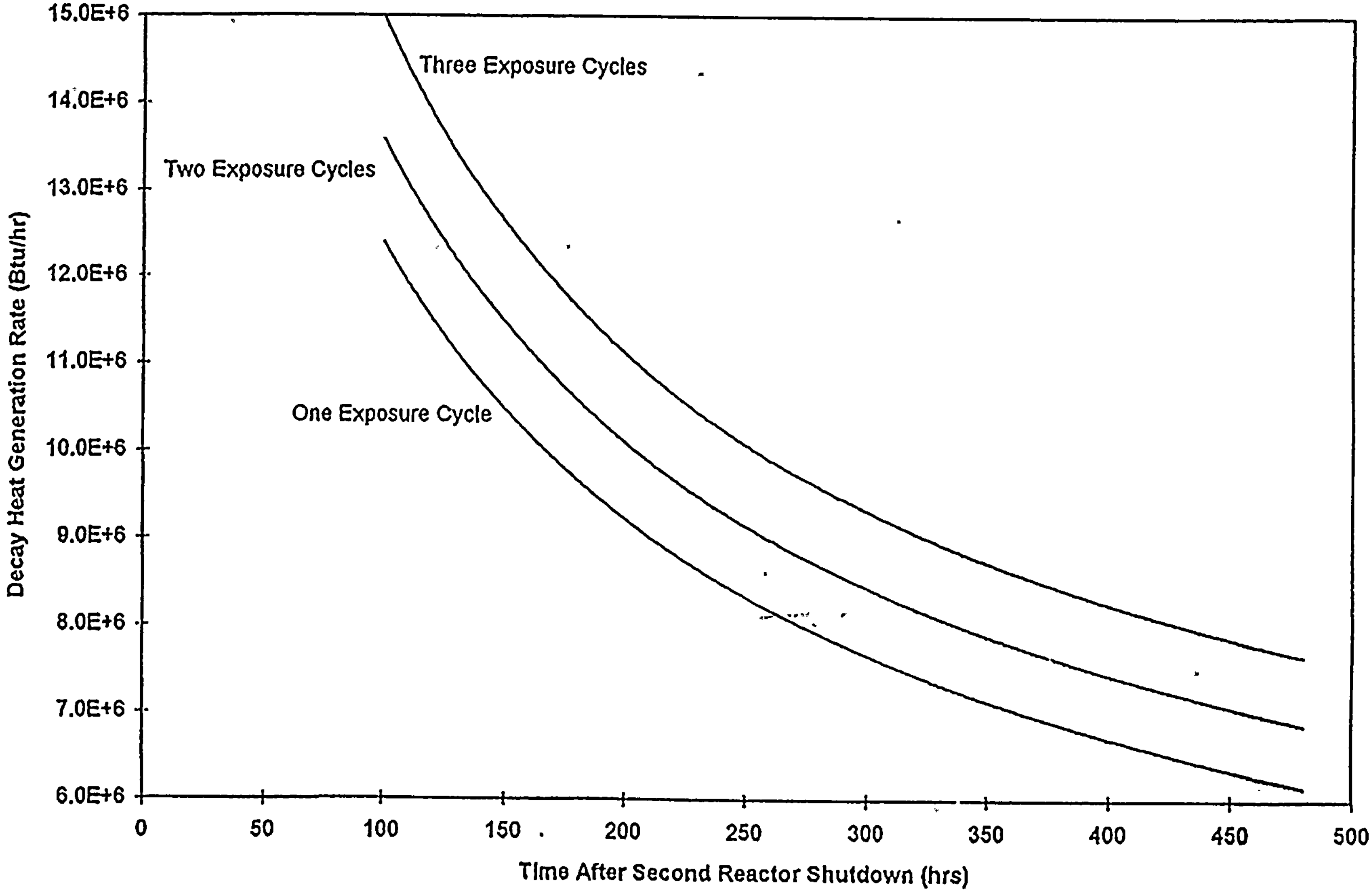


FIGURE 5: Decay Heat Generation Rate for Each Discharge Batch in the Full Core Back-to-Back Discharge Case 3



ATTACHMENT 2 TO AEP:NRC:1202D

RESPONSE TO QUESTION 4
REQUEST FOR ADDITIONAL INFORMATION
REGARDING REFUELING OPERATIONS DECAY TIME

NRC Question 4.0

"Is full-core offload a current practice during normal refueling?"

Response to Question 4.0

Current practice is to perform full core offloads.