Appendix 10 Spent Fuel Heatup Time During Adiabatic Conditions

In the preliminary study, we used a conservative calculation to determine the minimum amount of time available to take unplanned emergency offsite evacuation actions. We calculated the time to heat a single fuel rod from 30 °C to 900 °C at various times following permanent shutdown without considering any heat losses. This is a very conservative, nonrealistic calculation because some cooling would occur through conduction, convection, or radiation and increase the time to heatup. However, it provides a measure of time that is a bounding value for all heatup scenarios, including scenarios such as having a flat material fall on top of an assembly. This information was not used in determining interim criteria.

The time available before a release is useful because the likelihood that personnel actions or offsite actions could be taken could affect the consequences of the event. Figures A10-1 and A10-2 show how much time is required to heat a fuel pin from 30 °C to 900 °C, as the time after shutdown increases, assuming that all the heat is maintained in the fuel pin. For the calculations, the staff used a decay heat per assembly and divided it equally among the pins. It assumed a 9X9 assembly for the PWRs and a 17x17 assembly for the BWRs. The design assumptions values are provided in Table A10-1. The values for the progression of the calculation are provided in Tables A10-2 to A10-4. Decay heats were computed by extrapolating from the decay power tables in NUREG/CR-5625 [Ref. 1]. The decay heat in NUREG/CR-5625 is based on ORIGEN calculations. The tables for the decay heat extend to burnups of 50 GWD/MTU for PWRs and 45 GWD/MTU for BWRs. The staff recognizes that the decay heat is only valid for values up to the maximum values in the tables, but the functional dependence of the decay power with respect to burnup for values in the table indicate that extrapolation may provide a reasonable estimate of the decay heat for burnup values beyond the limits of the tables. The BWR decay heat was calculated using a specific power of 26.178 MW/MTU. The PWR decay heat was calculated using a specific power of 37.482 MW/MTU. Both the PWR and BWR decay heats were calculated for a burnup of 60 GWD/MTU and include an uncertainty factor of 6 percent.

Reference:

1. Hermann, et.al., "Technical Support for a Proposed Decay Heat Guide Using SAS2H/ORIGEN-S Data", NUREG/CR-5625, September 1994.

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PWR Adiabatic Heatup

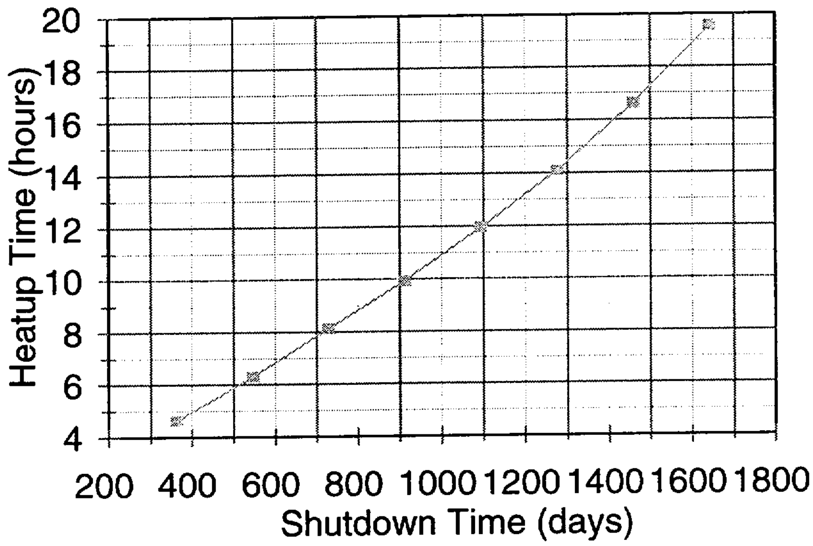

Figure A10-1 Adiabatic Heatup Time vs. Shutdown Time for a PWR

BWR Adiabatic Heatup

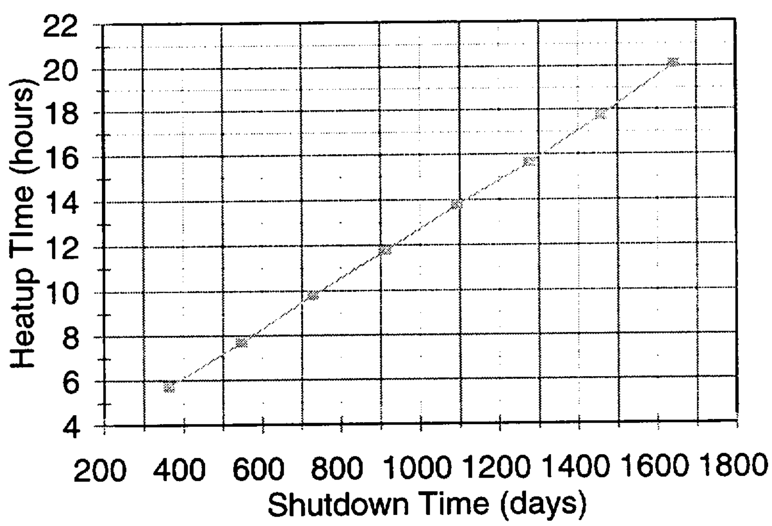

Figure A10-2 Adiabatic Heatup Time vs. Shutdown Time for a BWR

Table A10-1 Values Assumed for Calculation

	PWR	BWR
burnup/assembly (MWD/MTU)	60000	60000
MTU/assembly	0.47	0.17
MWt/core	3400	3400
assemblies/core	193	764
MW/assembly	17.6	4.5
rods/assembly	(17x17) 264	(9x9) 72
pellet diameter (m)	0.0081916	0.00906
inside clad diameter (m)	0.0083276	0.00925
outside clad diameter (m)	0.0094996	0.01077
fuel length (m)	3.65	3.8
rod peaking factor	1.166	1.166
axial peaking factor	1.2	1.2
fraction theoretical UO2	0.95	0.95

Table A10-2 Decay Power in Kw/MTU

Years	PWR Decay Power	BWR Decay Power
1	15.5561572	12.544759
1.5	11.416337106	9.3360165
2	8.85047	7.3451549
2.5	7.252431291	6.1212766
3	6.0268945746	5.2179396
3.5	5.1149641086	4.601295
4	4.341018	4.0575242
4.5	3.6841778116	3.578015

Table A10-3 Decay Power in Watts for One Assembly

(kW/MTU)*MTU*1000
Decay Power*0.47*E3 Decay Power*0.17*E3

Shutdown days	PWR Decay Power(W)	BWR Decay Power(W)
365	7311.393884	2132.609
547.5	5365.6784396	587.1228
730	4159.7209	1248.6763
912.5	3408.6427068	1040.617
1095	2832.6404501	887.04973
1277.5	2404.0331311	782.22016
1460	2040.27846	689.77911
1642.5	1731.5635715	608.26254

Table A10-4 Calculated Adiabatic Heatup Time from 30°C to 900°C in Hours for One Fuel Rod

Shutdown Days	PWR Heatup time (hrs)	BWR Heatup time (hrs)
365	4.64	5.73
547.5	6.32	7.7
730	8.15	9.79
912.5	9.94	11.75
1095	11.96	13.78
1277.5	14.1	15.64
1460	16.62	17.72
1642.5	19.57	20.11