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Memo Note

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Decay Heat Calculations for the Dalhousie University SLOWPOKE-2 Reactor (DUSR)

This memo summarizes the decay heat calculations of the DUSR spent fuel core at different cooling periods and can be used to demonstrate that after 48 hours of cooling it is within the F-257 flask thermal limit of 1 Watt [1]. Supplementary information found in Appendix A also supports this conclusion.

Details of the calculation methodology and assumptions can be found in the DUSR radiation physics report [2]. In general, the irradiation history of the reactor was simulated each year for a fixed period of operation and downtime using ORIGEN-S [3]. ORIGEN-S is used extensively in industry for a wide range of reactor types and fuel enrichments and is applicable to the DUSR. No research experiments have been performed in the DUSR since December 16, 2008 and therefore a decay of 2 years was credited prior to the safety tests performed before dismantling the DUSR. The safety tests were assumed to occur at 1% FP (i.e., 0.2 kW) for a duration of 4 and 8 hours. This will result in a range of thermal values that cover the uncertainty in the time duration for the safety tests.

The decay heat as a function of time following the last use of the reactor for experimental purposes is shown in Figure 1 and the decay heat values are listed in Table 1. The decay heat increases at 2 years due to the safety tests performed on the reactor. In reality the curve would have mulitiple spikes as the reactor is operated briefly (~15 to 30 minutes) every week at low power to confirm the functionality of the remote shutdown system. This will not impact the decay heat values presented here.

Decommissioning of the DUSR is planned to start in 2011 January. By that time, the core would have been shut down for 2 years. Before the safety test, the decay heat of the DUSR fuel core is at 0.57 Watt. Immediately after the safety test, the total core decay power would be ~16.7 Watt at 4 hours irradiation and ~17 Watt for an 8 hour safety test duration.

However because of the short operation period, the short-lived fission products decay quickly; one day after the safety test the decay heat is approximately 0.63 Watt for a safety test duration of 4 hours and 0.68 Watt for an 8 hour duration. Additional cooling beyond one day will result in a decrease to ~0.59 Watt and 0.62 Watt for a 4 hour and 8 hour safety test duration, respectively. Therefore by the time the DUSR fuel core will be packaged in the F-257 flask, the 1 Watt thermal limit of the F-257 flask will be met.

The decay heat calculations presented in this memo should be considered a conservative estimate and the information found in Appendix A further supports this conclusion. However, given the fact that the University of Toronto SLOWPOKE-2 reactor reached a similar cumulative burnup prior to decommissioning and the spent fuel core had decayed by a similar amount of time during flasking, it is expected that the DUSR decay power will be under 1 Watt.

1. REFERENCES

[1] IAEA Certificate of Competent Authority for a Type B(U)F Fissile Radioactive Materials Package Design Certificate USA/0561/B(U)F, Revision 0. "Revalidation of Canadian Competent Authority Certificate CDN/2048/B(U)F", June 2000.

[2] Smith, P. "Radiation Physics Analysis in Support of the Dalhousie University SLOWPOKE-2 Decommissioning", SLWPK2-03320-AR-001, Rev. 1, February 2010.

[3] O.W. Hermann, R.M. Westfall, NUREG/CR-0200, Rev. 6, Vol. 2, Sec. F7, ORNL/NUREG/CSD-2/V2/R6, "ORIGEN-S: SCALE System Module to Calculate Fuel Depletion, Actinide Transmutation, Fission-Product Build-up and Decay, and Associated Radiation Source Terms", September 1998.

[4] ANSI/ANS-.5.1-2005, "American National Standard Decay Heat Power in Light Water Reactors", April 2005.

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Table 1 DUSR Decay Heat for Irradiation at 10%FP for 4 Hours and 8 Hours

	Decay Heat (W)	
Time (days)	10% @ 4 hours	10% @ 8 hours
0	4.32E+02	4.33E+02
1	2.18E+01	2.18E+01
2	1.65E+01	1.65E+01
5	1.14E+01	1.14E+01
10	8.08E+00	8.08E+00
60	2.18E+00	2.18E+00
120	1.35E+00	1.35E+00
180	1.03E+00	1.03E+00
240	8.55E-01	8.55E-01
365	6.92E-01	6.92E-01
730	5.74E-01	5.74E-01
Safety Test	Decay Heat (W)	
Time (minutes)	10% @ 4 hours	10% @ 8 hours
0	1.67E+01	1.71E+01
10	4.22E+00	4.63E+00
1440	6.32E-01	6.78E-01
2880	5.97E-01	6.17E-01

* The total includes the value at 730 days from the previous irradiation.

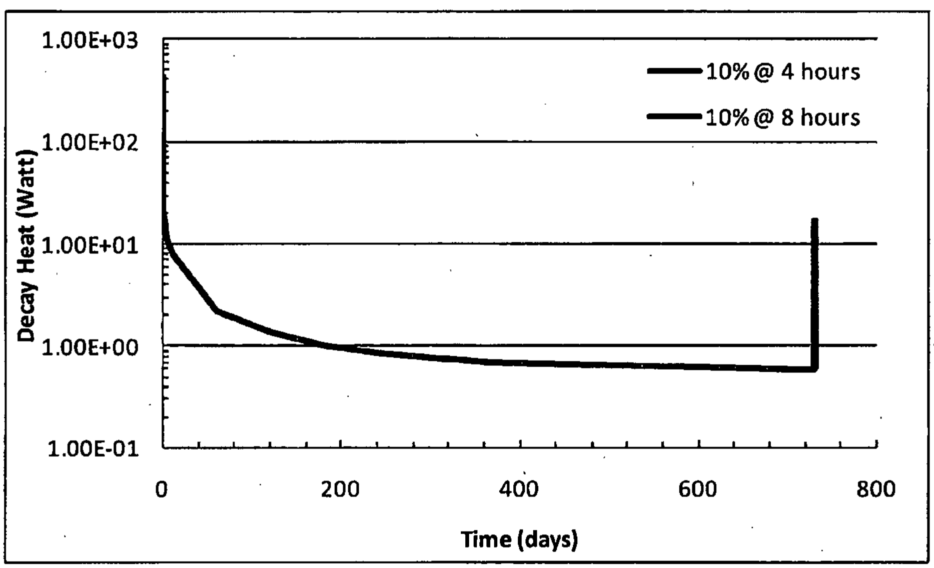

Figure 1 Decay Heat Versus Time

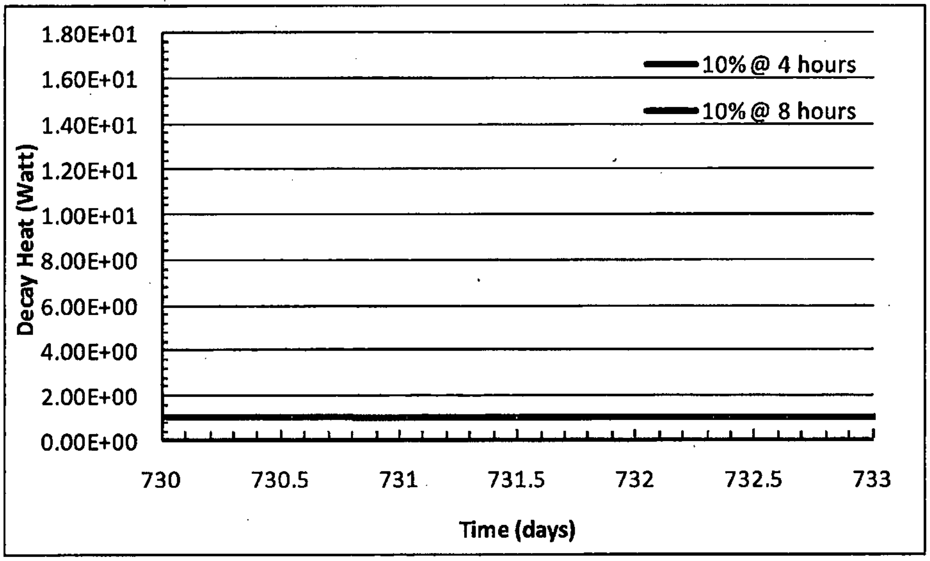

Figure 2 Decay Heat Versus Time (Safety Test)

Appendix A

Additional Information to Support the 1 W F-257 Flask Thermal Limit

The calculated decay heat power of ~0.6 W was further verified by using the ANSI/ANS-5.1 [4] decay heat standard to estimate the decay heat power. When the reactor operating history can be represented by a histogram of a number of time intervals with constant power from fissionable ^{235}U, then the decay heat power and its uncertainty may be calculated. The methodology and data used to calculate the decay heat power are found in Reference [4].

As mentioned in the main part of this memo, the kWh generated per year is known, therefore the number of days of operation is known for every year the DUSR was operating. The DUSR operates when experiments are required, therefore simulating the exact irradiation history is difficult. For simplification it was assumed the reactor operated constantly for a number of days and the rest of the year the reactor was down. This isn't a bad assumption as the decay heat at long decay times is driven by the overall burnup.

The decay heat power calculated using the ANS-5.1 decay heat standard was 0.29 W. The overall uncertainty is expected to be less than 5%. This decay power is lower than the value estimated using ORIGEN-S. Since ORIGEN-S was used in flux irradiation mode and the cross section libraries available in ORIGEN-S are meant for PWR reactors, it is estimated that the power and consequently the burnup was overestimated using ORIGEN-S. Thus, the decay heat power 2-years post shutdown is also overestimated using ORIGEN-S.