CALCULATION RA-0044, REVISION 1

DOSE RATE AT THE KPS SITE BOUNDARY FOLLOWING A COMPLETE DRAINDOWN OF THE SPENT FUEL POOL

Instructions: To update the Table of Contents page numbers, click within the Table of Contents to select the table, then select "**Print Preview**," (Click the **Office Button** at the upper left of the computer screen; then select "**Print**," and then "**Print Preview**") close "**Print Preview**." The page numbers should update.

Table of Contents

1. Record of Revision and Addenda

Revision 0 is the original issue of the calculation to determine the dose at the KPS site boundary from a complete draindown of the KPS SFP.

Revision 1 - The shine dose to the Exclusion Area Boundary (EAB) [defined as a 1200 meter circle located inside the site boundary] at Kewaunee from a SFP draindown event is being revised to utilize a single industry accepted method (MicroSkyShine) to calculate the dose rate at the EAB. This dose rate will be applied against the EPA Protective Action Guidelines (PAG) of 1 Rem Total Effective Dose Equivalent (TEDE) for a GENERAL EMERGENCY classification and 10 mRem TEDE for an ALERT classification to determine the duration when action would be required before exceeding the PAG criteria. For this event, the gamma shine Deep Dose Equivalent (DDE) from the exposed spent fuel is being used to represent the TEDE dose rate at the EAB.

2. Cumulative Effects Review (Required for Revisions and Addenda)

All active calculation components were identified and reviewed above in Section 1 – Record of Revision and Addenda.

The purpose of the calculation is to determine the dose at the KPS site boundary from a complete draindown of the KPS SFP. This revision utilizes a single industry accepted method to calculate this dose. This revision also calculates the duration when action would be required before exceeding the PAG criteria of 1 Rem TEDE for a GENERAL EMERGENCY and 10 mRem for ALERT classifications.

3. References

1) Kewaunee Technical Specifications thru Amendment 209.
2) Kewaunee Procedure RE-24, Rev. 25, "Special Nuclear Materials Control," Performed on May 14, 2013.
3) Drawing M-235, Rev. N, Sheet 1, "General Arrangement Spent Fuel Pool & New Fuel Storage."
4) MicroSkyShine User's Manual Version 2, Grove Software, Inc., July 2006.
5) Calculation CN-WFE-02-54, Rev. 0, "Kewaunee Spent Fuel Pool Criticality Analysis with Westinghouse 422V+ 14 x 14 Fuel Assemblies," Jan. 17, 2005.
6) Drawing S-708, Rev. D, Sheet 1, "Spent Fuel Pool Arrangement and Support Frame Assembly."
7) C11905, Rev. 0, "Kewaunee, Cycle 30 Design Report Data," October 2009.
8) ETE-NAF-2011-0029, Rev. 0, "Kewaunee Cycle 31 Nuclear Design Report," March 2011.
9) ETE-NAF-2012-0054, Rev. 0, "Kewaunee Cycle 32 Nuclear Design Report," April 2012.
10) Westinghouse Drawing 6680E93, Rev. 2, "WPBR 14 x 14 422V+ Reconstitutable Fuel Assembly Outline."
11) Westinghouse Drawing 4184C90, Rev. 1, "WPBR 14 x 14 V+ Fuel Rod Assembly Outline."

12) Calculation SFPGAMMA-04006R3, Rev. 0, Millstone 3 Gamma Heating Analysis," April 4, 2003.

4. Computer Codes Used

1) SCALE 6.1.1
2) MicroSkyShine Version 2

5. Identification of Computer Inputs and Outputs

SCALE 6.1.1 Input file: KPS.inp (date/time: 6/6/2013 1:42 PM)
SCALE 6.1.1 Output file: KPS.out (date/time: 6/6/2013 1:42 PM)
MicroSkyShine Input file: KPS SFP Draindown.sky2 (date/time: 7/29/2013 4:10 PM)
MicroSkyShine Output file: KPS SFP DRAINDOWN MICROSKYSHINE OUTPUT.doc (date/time: 7/29/2013 4:09 PM)

6. Purpose

The purpose of this calculation is to determine the dose rate at the KPS site boundary from a spent fuel pool draindown event. This revision also calculates the duration when action would be required before exceeding the PAG criteria of 1 Rem TEDE for a GENERAL EMERGENCY and 10 mRem for ALERT classifications.

7. Background (Optional)

NA

8. Design Inputs

1) 1079 spent fuel assemblies in the spent fuel pool. (Ref. 2)
2) Fuel assembly weight: 1227 lbs (Ref. 10)
3) KPS Cycle 32 total MTU: 47.708 MTU (Reference 9)
4) Fuel assembly dimensions: 7.76" x 7.76" x 159.8" (Ref. 10)
5) Active fuel length: 143.25" (Ref. 11)
6) Rods per assembly: 179 (Ref. 5)
7) Clad, guide tube, and instrument tube material: Zirlo (Ref. 11)
8) Spent fuel rack cell pitch: 10.0" (Ref. 5)
9) Top of floor elevation: 649'-6" (Ref. 3)
10) Top of spent fuel rack elevation: 622.08' (Ref. 3)
11) Distance to the EAB: 1200 meters (Ref. 1)

12) Distance from SFP racks to SFP wall: no more than 12" (Ref. 6)
13) KPS Cycle 30: Discharge burnups in the mid 50 GWD/MTU (Reference 7)
14) KPS Cycle 31: 3.25 w/o U-235 fuel (lowest enrichment used typically results in highest fission product loading) (Reference 8)
15) KPS Cycle 32 power level: 1772 MW(th) (Reference 9)
16) KPS Cycle 32 fuel assemblies per core: 121 (Reference 1)

9. *Assumptions*

1) When calculating the weights of material in the spent fuel rack and fuel array source term, the weight of steel in the rack is ignored and the steel, INCONEL, ZIRLO and other elements in the fuel assembly (including the oxygen, but not the uranium in the fuel pellets) are assumed to be Zirconium metal. This is conservative as including the weight of steel in the racks increases the source density, providing more shielding and thus lowering the dose rates. Also, it is reasonable to model ZIRLO as zirconium metal as ZIRLO is composed mostly of zirconium.
2) When calculating the volume of the fuel assembly, the volume of the spent fuel rack storage cell is used. This is conservative as it increases the volume, lowering effective densities, and thus increasing dose rates.
3) Instead of calculating a source term for each cycle of fuel, it is assumed that one-half of the fuel assemblies in the SFP have been decayed 1 year and the other half 10 years. This is a conservative assumption since only 121 fuel assemblies (1 core worth) have been decayed for a year. A review of a database of the fuel stored in the pool as of 7/24/2013 indicates that the median date of last irradiation is Sept. of 1996.
4) The top nozzle is not modeled as a source in this analysis as the source term is insignificant when compared to the fuel itself. This can be seen in reference 12 when comparing the MP3 fuel assembly source term to that of the top nozzle. See Tables 5.3.2-1 and 5.3.2-2.
5) The volume that is encompassed by the top nozzle and the non-fuel part of the fuel assembly is not modeled in MicroSkyShine. Instead the fuel assembly height is the height of the active fuel and the distance to the SFP operating floor is measured as the distance from the top of the top nozzle. This is conservative as it reduces the distance from the active fuel.
6) The top of the rack elevation is assumed as the top of the fuel. This is conservative as the fuel sits inside the rack and using this assumption places the fuel closer to the SFP floor operating elevation.
7) 1 Roentgen is assumed to be equivalent to 1 Rad. This is a reasonable assumption. 1 roentgen (in air) = 0.876 rad (in air).

8) 3.25 w/o U-235 fuel (based on KPS Cycle 31 data). This is conservative because lower enrichments typically result in higher fission product loading.
9) 60 GWD/MTU in 3 cycles (uniformly distributed) (conservative based on KPS Cycle 30 - 32 data)
10) For this event, the gamma shine Deep Dose Equivalent (DDE) from the exposed spent fuel is being used to represent the TEDE dose rate at the EAB. This is a reasonable assumption.

10. Methodology

The ORIGEN computer code is used to develop the source term in 1 fuel assembly decayed for 1 year and 10 years after a burnup of 60 GWD/MTU. The computer code MicroSkyShine will be used to calculate the dose rate at the site boundary from a complete draindown of the KPS spent fuel pool using the design inputs and assumptions stated previously. Since MicroSkyShine is a onetime use code, a benchmark case must be run first. The identical geometry, #11, was chosen from the MicroSkyShine User's manual (Reference 4). The result as shown in the User's Manual is 1.88E-09 mr/hr. The result of the benchmark case is 1.875E-09 mr/hr. The matching result allows MicroSkyShine to be used for this analysis. The benchmark case ran here is shown in Attachment 1.

11. Calculations

MTU/fuel assembly → 47.708 MTU/121 fuel assemblies = 0.3942 MTU/fuel assembly
MW(th)/fuel assembly → 1772 MW(th)/121 fuel assemblies = 14.644 MW(th)/fuel assembly

MicroSkyShine Model
Source Geometry
A MicroSkyShine model must be developed to calculate the dose rate from the fuel assemblies in the spent fuel pool at the EAB. Since there are 1079 fuel assemblies in the SFP, they will contain an effective source term equal to one-half containing a source term decayed 1 year and the other half with a 10 year decayed source term.

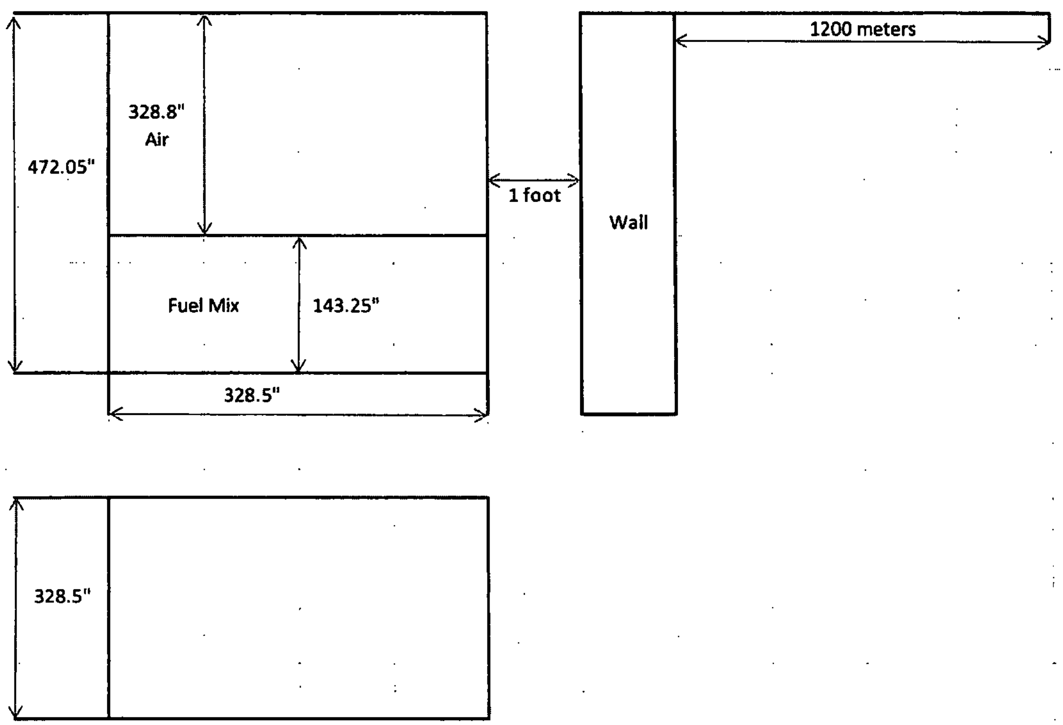
The pitch of a spent fuel rack is 10" x 10," therefore the surface area of 1079 fuel assemblies in racks is 1.080E+05 in^2 or 6.96E+05 cm^2. Assuming the spent fuel is arranged in a square pattern, each side will have a dimension of 328.5 in or 834.3 cm. To reduce the effects of self-shielding, only the active fuel length (143.25 in or 363.9 cm) will be modeled in MicroSkyShine instead of the entire length of the fuel assembly (159.8").

The distance between the top of the spent fuel rack, instead of the top of the active fuel or fuel assembly, to the operating floor elevation represents the minimum air gap above the fuel. The top of the spent fuel rack

elevation is 622.1 feet. The refuel floor elevation is 649.5 feet resulting in a distance of 27.4 feet or 328.8 inches. The receptor point is also assumed to be at the same elevation as the refuel floor.

The MicroSkyShine model is depicted below.

Figure 1



Material Specification and Density

Next the effective densities of the materials in the fuel assembly must be determined. The volume of a fuel assembly in a rack is 10" x 10" x 159.8" = 1.60E+04 in3 or 2.62E+05 cc. The weight of uranium is 3.94E+05 gms (47.708 MTU / 121 assemblies * 1E6 gms/MT) resulting in an effective density of the fuel of 1.50 gms/cc.

The remaining weight of the assembly will be conservatively assumed to be zirconium. Therefore:

Total assembly weight: 1227 lbs x 453.592 gms/lb = 5.57E+05 gms

Weight of zirconium = 5.57E+05 gms – 3.94E+05 gms U = 1.63E+05 gms

Effective density of Zr = 1.63E+05 gms / 2.62E+05 cc = 0.622 gms/cc

Source Spectrum

The default W14x14 ORIGEN-ARP library (a generic library for Westinghouse 14 x 14 fuel, part of SCALE 6.1.1) was used for the calculations and developed the source term for 1 KPS fuel assembly with 1 year decay and 10 year decay with a standard Scale 5 18 energy group structure. Table 1 below depicts those results and then multiplies each of the decayed values by half of the number of spent fuel assemblies in the SFP (1079/2). The last column represents the source input into MicroSkyShine, which is the sum of half of the 1 year and 10 year decayed fuel.

Table 1: OrigenS Source Gamma Spectra (gamma/sec) for Westinghouse 14 x 14 Fuel (60 GWD/MTU Burnup in 3 Cycles, 3.25% U235, 0.3942 MTU, 1772 MWt)

	1 Year Decay		10 Year Decay		Microshield
Energy Group (MeV)	1 FA	(1079/2) FA	1 FA	(1079/2) FA	Input
1.00E-02 - 5.00E-02	1.04E+16	5.60E+18	9.65E+14	5.21E+17	6.12E+18
5.00E-02 - 1.00E-01	3.44E+15	1.86E+18	2.59E+14	1.40E+17	2.00E+18
1.00E-01 - 2.00E-01	3.29E+15	1.78E+18	1.95E+14	1.05E+17	1.88E+18
2.00E-01 - 3.00E-01	8.79E+14	4.74E+17	5.65E+13	3.05E+16	5.05E+17
3.00E-01 - 4.00E-01	6.83E+14	3.68E+17	3.54E+13	1.91E+16	3.87E+17
4.00E-01 - 6.00E-01	5.60E+15	3.02E+18	2.09E+14	1.13E+17	3.13E+18
6.00E-01 - 8.00E-01	8.52E+15	4.60E+18	1.98E+15	1.07E+18	5.67E+18
8.00E-01 - 1.00E+00	1.91E+15	1.03E+18	1.13E+14	6.10E+16	1.09E+18
1.00E+00 - 1.33E+00	4.47E+14	2.41E+17	5.80E+13	3.13E+16	2.72E+17
1.33E+00 - 1.66E+00	2.01E+14	1.09E+17	8.43E+12	4.55E+15	1.13E+17
1.66E+00 - 2.00E+00	2.28E+13	1.23E+16	1.28E+11	6.93E+13	1.24E+16
2.00E+00 - 2.50E+00	6.41E+13	3.46E+16	4.83E+10	2.60E+13	3.46E+16
2.50E+00 - 3.00E+00	1.63E+12	8.82E+14	3.81E+09	2.05E+12	8.84E+14
3.00E+00 - 4.00E+00	1.50E+11	8.07E+13	4.24E+08	2.29E+11	8.09E+13
4.00E+00 - 5.00E+00	4.99E+07	2.69E+10	3.38E+07	1.83E+10	4.52E+10
5.00E+00 - 6.50E+00	2.00E+07	1.08E+10	1.36E+07	7.33E+09	1.81E+10
6.50E+00 - 8.00E+00	3.93E+06	2.12E+09	2.66E+06	1.44E+09	3.56E+09
8.00E+00 - 1.00E+01	8.35E+05	4.50E+08	5.66E+05	3.05E+08	7.55E+08

These inputs were used in MicroSkyShine; however, the lowest energy group in MicroSkyShine is 0.1 MeV. Therefore the 0.05 and 0.1 MeV energy groups were combined to result in 8.12E+18 photons/sec. The calculated dose rate from MicroSkyShine is 0.01 mr/hr.

The duration when action would be required before exceeding the PAG criteria of 1 Rem TEDE for a GENERAL EMERGENCY is: 100,000 hours or approximately 11 years.

The duration when action would be required before exceeding the PAG criteria of 10 mRem TEDE for an ALERT is: 1,000 hours or approximately 41 days.

12. *Acceptance Criteria (Optional)*

NA

13. *Results and/or Conclusions*

The dose rate at the KPS site boundary from a SFP draindown event is 0.01 mr/hr after a 1 year decay post-shutdown.

The duration when action would be required before exceeding the PAG criteria of 1 Rem TEDE for a GENERAL EMERGENCY is: 100,000 hours or approximately 11 years.

The duration when action would be required before exceeding the PAG criteria of 10 mRem TEDE for an ALERT is: 1,000 hours or approximately 41 days.

14. *Precautions and Limitations*

NA

15. *Recommendations (Optional)*

NA

16. *Calculation Review Checklist*

See page 10.

17. *List of Attachments*

Attachment 1:
MicroSkyShine Benchmark Case #11

[This page intentionally omitted.]

Case Information	
Geometry	Rectangular Volume Source Behind a Wall
Name	Rectangular Volume Source Behind a Wall
File	C:\Jim\MicroSkyShine Benchmark KPS.sky2
Time	Tuesday, August 27, 2013 2:31:43 PM

Results				
Energy Groups			Dose Results	
Group	Energy (MeV)	Activity (Photons / sec)	Rads / Photon	mR / hr
1	5.000	5.000e+9	9.096e-26	1.875e-9
Totals:	5.000	5.000e+9	9.096e-26	1.875e-9

Geometry Parameters (Units: Meters)					
Name	Value	Name	Value	Name	Value
X	990	Y	1	Z	0
Length	2	Width	1	Height	20
Diameter	0.5	Radius One	11.5	Radius Two	13
Thickness One	0.5	Thickness Two	0		

Material Densities				
Material	Ambient Air	Cover Slab	Lower Shield	Source Volume
Air	0.00120			0.00120
Water				
Concrete		2.35000		
Iron				
Lead				
Zirconium				
Urania				

Buildup Factor and Attenuation Coefficients					
	Buildup Factor	Attenuation Mean Free Paths			
Energy	Concrete	Cover Slab	Lower Shield	Source Volume	MFP
5.0000	2.69	3.40		0.00	3.40

Integration Parameters	
Numerical Quadrature	Eight
Length Segments (M):	5
Width Segments (N):	5
Vertical Segments (C):	5