2. To: (Receiving Organization) Distribution		3. From: (Originating Organization) Criticality and Shielding		4. Related EDT No.: 620300	
5. Proj./Prog./Dept./Div.:		6. Design Authority/ Design Agent/Cog. Engr.: S. R. Gedeon		7. Purchase Order No.: NA	
8. Originator Remarks:				9. Equip./Component No.: NA	
				10. System/Bldg./Facility:	
11. Receiver Remarks: 11A. Design Baseline Document? ☐ Yes ☒ No				12. Major Assm. Dwg. No.: NA	
				13. Permit/Permit Application No.: NA	
				14. Required Response Date:	

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Design- nator	Reason for Trans- mittal	Origin- ator Dispo- sition	Receiv- er Dispo- sition
1	HNF-SD-WM-CN-101		0	Shielding Analysis for 300 Area Light Water Reactor Spent Nuclear Fuel Within a Modified Multi-Canister Overpack Canister in a Modified Multi-Canister Overpack Transportation Cask	NA	1,2		

16. KEY					
Approval Designator (F)		Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)		1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)									
(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature (L) Date (M) MSIN
		Design Authority				1		J. S. Lan	5.5 3-26-97 H0-35
		Design Agent							
1		Cog.Eng. S. R. Gedeon		3/25/97	H0-35				
1		Cog. Mgr. J. Greenberg		4/7/97	H0-35				
		QA							
		Safety							
		Env.							

18. S. R. Gedeon Signature of EDT Originator Date 3/25/97		19. Authorized Representative Date for Receiving Organization		20. J. Greenberg Design Authority/ Cognizant Manager Date 4/7/97		21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments	
--	--	--	--	---	--	---	--

Shielding Analysis for 300 Area Light Water Reactor Spent Nuclear Fuel Within a Modified Multi-Canister Overpack Canister in a Modified Multi-Canister Overpack Cask

S. R. Gedeon

Fluor Daniel Northwest, Inc., Richland, WA 99352
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Key Words: Dose Rate, Overpack, LWR Fuel

Abstract: An estimate of gamma ray dose rate on the exterior of a transport cask loaded with spent LWR fuel.

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SHIELDING ANALYSIS FOR 300 AREA LIGHT WATER REACTOR SPENT NUCLEAR FUEL WITHIN A MODIFIED MULTI-CANISTER OVERPACK CANISTER IN A MODIFIED MULTI-CANISTER OVER-PACK TRANSPORTATION CASK

1.0 PURPOSE

Spent light water reactor fuel is to be moved out of the 324 Building. It is anticipated that intact fuel assemblies will be loaded in a modified Multi-Canister Overpack Canister, which in turn will be placed in an Overpack Transportation Cask. An estimate of gamma ray dose rates from a transportation cask is desired.

2.0 METHODOLOGY AND ASSUMPTIONS

The computer code ISOSHL D (References 1, 2, and 3) was used to calculate dose rates out the side of, and along the centerline axis above, a transportation cask. Bremsstrahlung from the β -particle emitting radionuclides was accounted for. The fluence-to-dose conversions used here are for radiation that enters a homogenized body according to ANSI/ANS-6.1.1-1997.

A cylindrical source with concentric cylindrical shield geometry was used. Each fuel assembly was modelled as a cylinder of the same cross sectional area, with an active fuel length region of 366 cm. The material composition and density of the fuel region was determined by smearing the assembly, using typical PWR dimensions from Appendix H of Reference 4. The gamma source term came from Table C.1 of Reference 5. The overpack canister was modelled as a cylinder of wall thickness 0.5 in (1.27 cm), and the transportation cask as a cylinder of wall thickness 7.31 in (18.56 cm). Each cask is envisioned as holding three fuel assemblies. Two geometries were modelled: one representing the assembly closest to the cask wall, the other representing one of the two (symmetrically placed) assemblies behind the first. The results given below in Figure 1 and Table 1 are the sum of the first case and twice the second.

Table 1. Dose Rates versus Distance at Cask Midplane (mrem/hr)

Distance	Dose Rate
Contact (2 inch)	650
1 meter	194
6 meter	25

Figure 1 Dose Rate vs Distance From Transport Cask Mid-Plane

To determine dose rates above a cask, the ISOSHL D geometry of a cylindrical source region viewed from on end, with slab shields, was used. The dose point was chosen to be 12 inches (30.5 cm) above the fuel assembly. The source region was given the same cross sectional area as three rectangular fuel assemblies. Shields, representing cask lids, of various thickness and material, were analyzed. Results are given in Tables 2 and 3.

Table 2. Dose Rates Above the Canister Lid (12 inches above the fuel assembly) for Various Thicknesses and Lid Materials (rem/hr)

Lid Thickness	Steel	Lead	Depleted Uranium	Tungsten
1 inch	640	91	15	34
2 inches	230	13	0.7	2
3 inches	78	2.3	0.04	0.14
4 inches	27	0.5	0.002	0.01
6 inches	3.1	-		
8 inches	0.4	-		

Table 3. Dose Rates Above the Canister Lid (6 inches above the fuel assembly) for Various Thicknesses of Depleted Uranium (rem/hr)

Lid Thickness	Depleted Uranium
1 inch	24.
2 inches	1.1
3 inches	0.05
4 inches	0.0025

ISOSHL D input files are given in Appendix A.

To further refine this problem, the Monte Carlo code MCNP (References 6 and 7) was used with an existing model of the transport cask and overpack cask. Two loadings were modelled: 1 fuel assembly centered in the cask; and 2 assemblies centered side by side. For the 2 assembly case, two additional shielding geometries were analyzed: a cylindrical insert, with wall thickness of either 1 inch or 2 inches, was added. [Note: the nominal 2 inch shield was modelled with a wall thickness of 5.00 cm, as a 5.08 cm thick insert does not fit.] The insert itself was modelled as either stainless steel or depleted uranium. Results are given in Table 4.

Table 4. Dose Rate at Cask Midplane as Function of Distance, Loading and Shielding (mrem/hr)

	1 asbly	2 asbly	2 asbly 1" steel	2 asbly 2" steel	2 asbly 1" DU	2 asbly 2" DU
Contact (ave)	346 (2.6)	483 (4.5)	145 (6.2)	49.6 (8.2)	19 (10)	0.3 (42)
Contact (x-axis)		501 (11)	187 (14)	67 (27)	15 (17)	1. (63)
Contact (y-axis)		485 (14)	162 (16)	55 (19)	19 (22)	0.3 (25)
1 meter (ave)	114 (1.8)	154 (3.4)	47 (4.7)	18 (6.6)	6.2 (8.3)	0.7 (21)
2 meter (ave)	60 (1.9)	80 (3.5)	26 (5.0)	10 (7.9)	4.2 (7.9)	0.9 (14)
3 meter (ave)	12 (2.6)	17 (4.7)	6. (6.3)	2. (9.4)	1.2 (10)	0.4 (13)

Notes:

1. Results are in mrem/hr.
2. Contact dose is calculated 2 inches from the surface.
3. The "average" dose rate is an azimuthal average at cask midplane.

The number in parentheses is the MCNP-calculated per cent uncertainty in the stated result. It should be noted that, while uncertainties of less than 10 per cent indicate generally reliable answers, uncertainties in the range of 10 to 20 percent indicate questionable results, 20 to 50 per cent indicate order of magnitude results, and results with greater than 50 per cent uncertainty should be discounted completely.

Appendix B contains a sample MCNP input file and file listing.

3.0 REFERENCES

1. ISOSHL--A Computer Code for General Purpose Isotope Shielding Analysis, BNWL-236, R. L. Engel, J. Greenborg, M. M. Hendrickson, dated June 1966.
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3. Rittmann, P. D., CCC-636, *ISO-PC Ver. 2.1*, WHC-SD-WM-UM-030, Radiation Safety Information Computational Center, Oak Ridge, TN, 1996.
4. Duderstadt, J.J. & L.J. Hamilton, *Nuclear Reactor Analysis*, Wiley & Sons, New York, New York, 1976.
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7. Breisemeister, J. F., Editor, 1993, *MCNP - A General Monte Carlo N-Particle Transport Code, Version 4A*, Los Alamos National Laboratory report LA-12625, Los Alamos, New Mexico.

APPENDIX A. ISOSHL D INPUT FILES

```

0      2 MCO cask with LWR fuel
Case 1: Cask side, near fuel
&INPUT NEXT=1, ISPEC=3, OPTION=0, ICONC=0, IGEOM=7, DUNIT=6,
X= 40.683, Y= 183.00, SLTH= 366.00, T(1)= 12.181,
T(2)= 2.07, T(3)= 1.27, T(4)= 1.52, T(5)= 18.562
NPSI=51, NTHETA= 51, DELR= 1.0, NSHLD=5, JBUF=5,
WEIGHT(496)= 9.20E+2, WEIGHT(499)= 6.37E-0,
WEIGHT(498)= 6.40E+0, WEIGHT(505)= 6.82E+0,
WEIGHT(336)= 2.70E+4, WEIGHT(206)= 1.05E+1,
WEIGHT(504)= 5.27E+0, WEIGHT(506)= 4.68E+0,
WEIGHT(500)= 4.26E+2, WEIGHT(472)= 7.88E+2,
WEIGHT(319)= 3.07E+2, WEIGHT(335)= 2.85E+4,
WEIGHT(415)= 1.20E+3, WEIGHT(418)= 2.97E+2,
WEIGHT(290)= 1.26E-2, WEIGHT( 55)= 1.31E+3,
WEIGHT(502)= 1.34E-1, WEIGHT(503)= 6.82E+0,
WEIGHT(388)= 8.17E+2, WEIGHT(492)= 1.04E+3,
WEIGHT(493)= 1.25E+2, WEIGHT(494)= 2.12E+2,
WEIGHT(495)= 2.38E+4, WEIGHT(497)= 6.84E-1,
WEIGHT(172)= 4.36E+0, WEIGHT(170)= 4.34E+0,
WEIGHT(269)= 1.05E+2, WEIGHT(403)= 1.23E+2,
WEIGHT( 82)= 1.98E+4, WEIGHT(141)= 5.21E+0,
WEIGHT(270)= 2.56E+1, WEIGHT(520)= 4.72E-1,
WEIGHT(476)= 6.91E-3, WEIGHT(491)= 5.83E-1,
WEIGHT(526)= 1.27E-1, WEIGHT( 84)= 1.98E+4
&
air   3      0.0      0.00122      0.0      0.00122      0.0
u: f 15      2.652      0.0      0.0      0.0      0.0
o: f 23      0.3565      0.0      0.0      0.0      0.0
zr: f 11      0.2993      0.0      0.0      0.0      0.0
1 Fe 09      0.0      0.0      7.8      0.0      7.8
dose rate 1 meter from side
&INPUT NEXT=4, X= 135.603 &
dose rate 6 meter from side
&INPUT NEXT=4, X= 635.603 &
end
&INPUT NEXT=6 &

```

```

0      2 MCO cask with LWR fuel
Case 2: Cask side, far fuel
&INPUT NEXT=1, ISPEC=3, OPTION=0, ICONC=0, IGEOM=7, DUNIT=6,
X= 63.406, Y= 183.00, SLTH= 366.00, T(1)= 12.181,
T(2)= 22.72, T(3)= 1.27, T(4)= 3.59, T(5)= 18.562
NPSI=51, NTHETA= 51, DELR= 1.0, NSHLD=5, JBUF=5,
WEIGHT(496)= 9.20E+2, WEIGHT(499)= 6.37E-0,
WEIGHT(498)= 6.40E+0, WEIGHT(505)= 6.82E+0,
WEIGHT(336)= 2.70E+4, WEIGHT(206)= 1.05E+1,
WEIGHT(504)= 5.27E+0, WEIGHT(506)= 4.68E+0,
WEIGHT(500)= 4.26E+2, WEIGHT(472)= 7.88E+2,
WEIGHT(319)= 3.07E+2, WEIGHT(335)= 2.85E+4,
WEIGHT(415)= 1.20E+3, WEIGHT(418)= 2.97E+2,
WEIGHT(290)= 1.26E-2, WEIGHT( 55)= 1.31E+3,
WEIGHT(502)= 1.34E-1, WEIGHT(503)= 6.82E+0,
WEIGHT(388)= 8.17E+2, WEIGHT(492)= 1.04E+3,
WEIGHT(493)= 1.25E+2, WEIGHT(494)= 2.12E+2,
WEIGHT(495)= 2.38E+4, WEIGHT(497)= 6.84E-1,
WEIGHT(172)= 4.36E+0, WEIGHT(170)= 4.34E+0,
WEIGHT(269)= 1.05E+2, WEIGHT(403)= 1.23E+2,
WEIGHT( 82)= 1.98E+4, WEIGHT(141)= 5.21E+0,
WEIGHT(270)= 2.56E+1, WEIGHT(520)= 4.72E-1,
WEIGHT(476)= 6.91E-3, WEIGHT(491)= 5.83E-1,
WEIGHT(526)= 1.27E-1, WEIGHT( 84)= 1.98E+4
&
air   3      0.0      0.00000      0.0      0.00122      0.0

```

```

u: f 15 2.652 2.652 0.0 0.0 0.0
o: f 23 0.3565 0.3565 0.0 0.0 0.0
zr: f 11 0.2993 0.2993 0.0 0.0 0.0
1 Fe 09 0.0 0.0 7.8 0.0 7.8
  dose rate 1 meter from side
&INPUT NEXT=4 , X= 135.603 &
  dose rate 6 meter from side
&INPUT NEXT=4 , X= 635.603 &
  end
&INPUT NEXT=6 &

```

```

0      2 300 Area LWR Fuel
Case 3a: top, 1 ft above fuel assembly, steel plug--1 inch
&INPUT NEXT=1, ISPEC=3, OPTION=0, ICONC=0, IGEOM=9, DUNIT=6,
SFAC= 3.0, X=416.426, SLTH= 21.098, T(1)= 366.00,
T(2)= 19.946, T(3)= 2.54,
NPSI=51, NTHETA= 51, DELR= 1.0, NSHLD=3, JBUF=3,
WEIGHT(496)= 9.20E+2, WEIGHT(499)= 6.37E-0,
WEIGHT(498)= 6.40E+0, WEIGHT(505)= 6.82E+0,
WEIGHT(336)= 2.70E+4, WEIGHT(206)= 1.05E+1,
WEIGHT(504)= 5.27E+0, WEIGHT(506)= 4.68E+0,
WEIGHT(500)= 4.26E+2, WEIGHT(472)= 7.88E+2,
WEIGHT(319)= 3.07E+2, WEIGHT(335)= 2.85E+4,
WEIGHT(415)= 1.20E+3, WEIGHT(418)= 2.97E+2,
WEIGHT(290)= 1.26E-2, WEIGHT( 55)= 1.31E+3,
WEIGHT(502)= 1.34E-1, WEIGHT(503)= 6.82E+0,
WEIGHT(388)= 8.17E+2, WEIGHT(492)= 1.04E+3,
WEIGHT(493)= 1.25E+2, WEIGHT(494)= 2.12E+2,
WEIGHT(495)= 2.38E+4, WEIGHT(497)= 6.84E-1,
WEIGHT(172)= 4.36E+0, WEIGHT(170)= 4.34E+0,
WEIGHT(269)= 1.05E+2, WEIGHT(403)= 1.23E+2,
WEIGHT( 82)= 1.98E+4, WEIGHT(141)= 5.21E+0,
WEIGHT(270)= 2.56E+1, WEIGHT(520)= 4.72E-1,
WEIGHT(476)= 6.91E-3, WEIGHT(491)= 5.83E-1,
WEIGHT(526)= 1.27E-1, WEIGHT( 84)= 1.98E+4
&
u: f 15 2.652 0.0 0.0
o: f 23 0.3565 0.0 0.0
zr: f 11 0.2993 0.2993 0.0
1 Fe 09 0.0 0.0 7.8
  Case 3b: top, 1 ft above fuel assembly, steel plug--2 inch
&INPUT NEXT=4 , T(3)= 5.08 &
  Case 3c: top, 1 ft above fuel assembly, steel plug--3 inch
&INPUT NEXT=4 , T(3)= 7.62 &
  Case 3d: top, 1 ft above fuel assembly, steel plug--4 inch
&INPUT NEXT=4 , T(3)=10.16 &
  end
&INPUT NEXT=6 &

```

```

0      2 300 Area LWR Fuel
Case 3a: top, 1 ft above fuel assembly, steel plug--6 inch
&INPUT NEXT=1, ISPEC=3, OPTION=0, ICONC=0, IGEOM=9, DUNIT=6,
SFAC= 3.0, X=416.426, SLTH= 21.098, T(1)= 366.00,
T(2)= 19.946, T(3)= 15.24,
NPSI=51, NTHETA= 51, DELR= 1.0, NSHLD=3, JBUF=3,
WEIGHT(496)= 9.20E+2, WEIGHT(499)= 6.37E-0,
WEIGHT(498)= 6.40E+0, WEIGHT(505)= 6.82E+0,
WEIGHT(336)= 2.70E+4, WEIGHT(206)= 1.05E+1,
WEIGHT(504)= 5.27E+0, WEIGHT(506)= 4.68E+0,
WEIGHT(500)= 4.26E+2, WEIGHT(472)= 7.88E+2,
WEIGHT(319)= 3.07E+2, WEIGHT(335)= 2.85E+4,
WEIGHT(415)= 1.20E+3, WEIGHT(418)= 2.97E+2,
WEIGHT(290)= 1.26E-2, WEIGHT( 55)= 1.31E+3,
WEIGHT(502)= 1.34E-1, WEIGHT(503)= 6.82E+0,
WEIGHT(388)= 8.17E+2, WEIGHT(492)= 1.04E+3,
WEIGHT(493)= 1.25E+2, WEIGHT(494)= 2.12E+2,
WEIGHT(495)= 2.38E+4, WEIGHT(497)= 6.84E-1,

```

```

WEIGHT(172)= 4.36E+0, WEIGHT(170)= 4.34E+0,
WEIGHT(269)= 1.05E+2, WEIGHT(403)= 1.23E+2,
WEIGHT( 82)= 1.98E+4, WEIGHT(141)= 5.21E+0,
WEIGHT(270)= 2.56E+1, WEIGHT(520)= 4.72E-1,
WEIGHT(476)= 6.91E-3, WEIGHT(491)= 5.83E-1,
WEIGHT(526)= 1.27E-1, WEIGHT( 84)= 1.98E+4
&
u: f 15 2.652 0.0 0.0
o: f 23 0.3565 0.0 0.0
zr: f 11 0.2993 0.2993 0.0
1 Fe 09 0.0 0.0 7.8
Case 3b: top, 1 ft above fuel assembly, steel plug--8 inch
&INPUT NEXT=4 , T(3)= 20.32 &
end
&INPUT NEXT=6 &

0 2 300 Area LWR Fuel
Case 4a: top, 1 ft above fuel assembly, lead plug--1 inch
&INPUT NEXT=1, ISPEC=3, OPTION=0, ICONC=0, IGEOM=9, DUNIT=6,
SFACT= 3.0, X=416.426, SLTH= 21.098, T(1)= 366.00,
T(2)= 19.946, T(3)= 2.54,
NPSI=51, NTHETA= 51, DELR= 1.0, NSHLD=3, JBUF=3,
WEIGHT(496)= 9.20E+2, WEIGHT(499)= 6.37E-0,
WEIGHT(498)= 6.40E+0, WEIGHT(505)= 6.82E+0,
WEIGHT(336)= 2.70E+4, WEIGHT(206)= 1.05E+1,
WEIGHT(504)= 5.27E+0, WEIGHT(506)= 4.68E+0,
WEIGHT(500)= 4.26E+2, WEIGHT(472)= 7.88E+2,
WEIGHT(319)= 3.07E+2, WEIGHT(335)= 2.85E+4,
WEIGHT(415)= 1.20E+3, WEIGHT(418)= 2.97E+2,
WEIGHT(290)= 1.26E-2, WEIGHT( 55)= 1.31E+3,
WEIGHT(502)= 1.34E-1, WEIGHT(503)= 6.82E+0,
WEIGHT(388)= 8.17E+2, WEIGHT(492)= 1.04E+3,
WEIGHT(493)= 1.25E+2, WEIGHT(494)= 2.12E+2,
WEIGHT(495)= 2.38E+4, WEIGHT(497)= 6.84E-1,
WEIGHT(172)= 4.36E+0, WEIGHT(170)= 4.34E+0,
WEIGHT(269)= 1.05E+2, WEIGHT(403)= 1.23E+2,
WEIGHT( 82)= 1.98E+4, WEIGHT(141)= 5.21E+0,
WEIGHT(270)= 2.56E+1, WEIGHT(520)= 4.72E-1,
WEIGHT(476)= 6.91E-3, WEIGHT(491)= 5.83E-1,
WEIGHT(526)= 1.27E-1, WEIGHT( 84)= 1.98E+4
&
u: f 15 2.652 0.0 0.0
o: f 23 0.3565 0.0 0.0
zr: f 11 0.2993 0.2993 0.0
1 Pb 14 0.0 0.0 11.35
Case 4b: top, 1 ft above fuel assembly, lead plug--2 inch
&INPUT NEXT=4 , T(3)= 5.08 &
Case 4c: top, 1 ft above fuel assembly, lead plug--3 inch
&INPUT NEXT=4 , T(3)= 7.62 &
Case 4d: top, 1 ft above fuel assembly, lead plug--4 inch
&INPUT NEXT=4 , T(3)=10.16 &
end
&INPUT NEXT=6 &

0 2 300 Area LWR Fuel
Case 5a: top, 1 ft above fuel assembly, DU plug--1 inch
&INPUT NEXT=1, ISPEC=3, OPTION=0, ICONC=0, IGEOM=9, DUNIT=6,
SFACT= 3.0, X=416.426, SLTH= 21.098, T(1)= 366.00,
T(2)= 19.946, T(3)= 2.54,
NPSI=51, NTHETA= 51, DELR= 1.0, NSHLD=3, JBUF=3,
WEIGHT(496)= 9.20E+2, WEIGHT(499)= 6.37E-0,
WEIGHT(498)= 6.40E+0, WEIGHT(505)= 6.82E+0,
WEIGHT(336)= 2.70E+4, WEIGHT(206)= 1.05E+1,
WEIGHT(504)= 5.27E+0, WEIGHT(506)= 4.68E+0,
WEIGHT(500)= 4.26E+2, WEIGHT(472)= 7.88E+2,
WEIGHT(319)= 3.07E+2, WEIGHT(335)= 2.85E+4,

```

```

WEIGHT(415)= 1.20E+3, WEIGHT(418)= 2.97E+2,
WEIGHT(290)= 1.26E-2, WEIGHT( 55)= 1.31E+3,
WEIGHT(502)= 1.34E-1, WEIGHT(503)= 6.82E+0,
WEIGHT(388)= 8.17E+2, WEIGHT(492)= 1.04E+3,
WEIGHT(493)= 1.25E+2, WEIGHT(494)= 2.12E+2,
WEIGHT(495)= 2.38E+4, WEIGHT(497)= 6.84E-1,
WEIGHT(172)= 4.36E+0, WEIGHT(170)= 4.34E+0,
WEIGHT(269)= 1.05E+2, WEIGHT(403)= 1.23E+2,
WEIGHT( 82)= 1.98E+4, WEIGHT(141)= 5.21E+0,
WEIGHT(270)= 2.56E+1, WEIGHT(520)= 4.72E-1,
WEIGHT(476)= 6.91E-3, WEIGHT(491)= 5.83E-1,
WEIGHT(526)= 1.27E-1, WEIGHT( 84)= 1.98E+4
&
u: f 15 2.652 0.0 0.0
o: f 23 0.3565 0.0 0.0
zr: f 11 0.2993 0.2993 0.0
1 DU 15 0.0 0.0 18.90
Case 5b: top, 1 ft above fuel assembly, DU plug--2 inch
&INPUT NEXT=4 , T(3)= 5.08 &
Case 5c: top, 1 ft above fuel assembly, DU plug--3 inch
&INPUT NEXT=4 , T(3)= 7.62 &
Case 5d: top, 1 ft above fuel assembly, DU plug--4 inch
&INPUT NEXT=4 , T(3)=10.16 &
end
&INPUT NEXT=6 &

0 2 300 Area LWR Fuel
Case 5a: top, 6 in above fuel assembly, DU plug--1 inch
&INPUT NEXT=1, ISPEC=3, OPTION=0, ICONC=0, IGEOM=9, DUNIT=6,
SFACT= 3.0, X=401.186, SLTH= 21.098, T(1)= 366.00,
T(2)= 19.946, T(3)= 2.54,
NPSI=51, NTHETA= 51, DELR= 1.0, NSHLD=3, JBUF=3,
WEIGHT(496)= 9.20E+2, WEIGHT(499)= 6.37E-0,
WEIGHT(498)= 6.40E+0, WEIGHT(505)= 6.82E+0,
WEIGHT(336)= 2.70E+4, WEIGHT(206)= 1.05E+1,
WEIGHT(504)= 5.27E+0, WEIGHT(506)= 4.68E+0,
WEIGHT(500)= 4.26E+2, WEIGHT(472)= 7.88E+2,
WEIGHT(319)= 3.07E+2, WEIGHT(335)= 2.85E+4,
WEIGHT(415)= 1.20E+3, WEIGHT(418)= 2.97E+2,
WEIGHT(290)= 1.26E-2, WEIGHT( 55)= 1.31E+3,
WEIGHT(502)= 1.34E-1, WEIGHT(503)= 6.82E+0,
WEIGHT(388)= 8.17E+2, WEIGHT(492)= 1.04E+3,
WEIGHT(493)= 1.25E+2, WEIGHT(494)= 2.12E+2,
WEIGHT(495)= 2.38E+4, WEIGHT(497)= 6.84E-1,
WEIGHT(172)= 4.36E+0, WEIGHT(170)= 4.34E+0,
WEIGHT(269)= 1.05E+2, WEIGHT(403)= 1.23E+2,
WEIGHT( 82)= 1.98E+4, WEIGHT(141)= 5.21E+0,
WEIGHT(270)= 2.56E+1, WEIGHT(520)= 4.72E-1,
WEIGHT(476)= 6.91E-3, WEIGHT(491)= 5.83E-1,
WEIGHT(526)= 1.27E-1, WEIGHT( 84)= 1.98E+4
&
u: f 15 2.652 0.0 0.0
o: f 23 0.3565 0.0 0.0
zr: f 11 0.2993 0.2993 0.0
1 DU 15 0.0 0.0 18.90
Case 5b: top, 6 in above fuel assembly, DU plug--2 inch
&INPUT NEXT=4 , T(3)= 5.08 &
Case 5c: top, 6 in above fuel assembly, DU plug--3 inch
&INPUT NEXT=4 , T(3)= 7.62 &
Case 5d: top, 6 in above fuel assembly, DU plug--4 inch
&INPUT NEXT=4 , T(3)=10.16 &
end
&INPUT NEXT=6 &

0 2 300 Area LWR Fuel
Case 6a: top, 1 ft above fuel assembly, W plug--1 inch

```

```

&INPUT NEXT=1, ISPEC=3, OPTION=0, ICONC=0, IGEOM=9, DUNIT=6,
SFAC= 3.0, X=416.426, SLTH= 21.098, T(1)= 366.00,
T(2)= 19.946, T(3)= 2.54,
NPSI=51, NTHETA= 51, DELR= 1.0, NSHLD=3, JBUF=3,
WEIGHT(496)= 9.20E+2, WEIGHT(499)= 6.37E-0,
WEIGHT(498)= 6.40E+0, WEIGHT(505)= 6.82E+0,
WEIGHT(336)= 2.70E+4, WEIGHT(206)= 1.05E+1,
WEIGHT(504)= 5.27E+0, WEIGHT(506)= 4.68E+0,
WEIGHT(500)= 4.26E+2, WEIGHT(472)= 7.88E+2,
WEIGHT(319)= 3.07E+2, WEIGHT(335)= 2.85E+4,
WEIGHT(415)= 1.20E+3, WEIGHT(418)= 2.97E+2,
WEIGHT(290)= 1.26E+2, WEIGHT( 55)= 1.31E+3,
WEIGHT(502)= 1.34E-1, WEIGHT(503)= 6.82E+0,
WEIGHT(388)= 8.17E+2, WEIGHT(492)= 1.04E+3,
WEIGHT(493)= 1.25E+2, WEIGHT(494)= 2.12E+2,
WEIGHT(495)= 2.38E+4, WEIGHT(497)= 6.84E-1,
WEIGHT(172)= 4.36E+0, WEIGHT(170)= 4.34E+0,
WEIGHT(269)= 1.05E+2, WEIGHT(403)= 1.23E+2,
WEIGHT( 82)= 1.98E+4, WEIGHT(141)= 5.21E+0,
WEIGHT(270)= 2.56E+1, WEIGHT(520)= 4.72E-1,
WEIGHT(476)= 6.91E-3, WEIGHT(491)= 5.83E-1,
WEIGHT(526)= 1.27E-1, WEIGHT( 84)= 1.98E+4
&
u: f 15 2.652 0.0 0.0
o: f 23 0.3565 0.0 0.0
zr: f 11 0.2993 0.2993 0.0
1 w 13 0.0 0.0 19.30
Case 6b: top, 1 ft above fuel assembly, W plug--2 inch
&INPUT NEXT=4 , T(3)= 5.08 &
Case 6c: top, 1 ft above fuel assembly, W plug--3 inch
&INPUT NEXT=4 , T(3)= 7.62 &
Case 6d: top, 1 ft above fuel assembly, W plug--4 inch
&INPUT NEXT=4 , T(3)=10.16 &
end
&INPUT NEXT=6 &

```

APPENDIX B. MCNP INPUT AND OUTPUT FILES

INPUT/OUTPUT FILES

The MCNP input and output files can be found in the directory:
 /home/w80502/projects/lwr324.

lwr1, l1out, l1out2: Input and output files for the 1 fuel assembly load,
 no insert shield case.

lwr2, l2out, l2out2: 2 fuel assembly load, no insert shield.

lwr3, l3out, l3out2: 2 fuel assembly load, 1 inch steel insert shield.

lwr4, l4out, l4out2: 2 fuel assembly load, 2 inch steel insert shield.

lwr5, l5out, l5out2: 2 fuel assembly load, 1 inch DU insert shield.

lwr6, l6out, l6out2: 2 fuel assembly load, 2 inch DU insert shield.

Sample input file: lwr3

```

Cask: TN 6/10/96 drawing, MCO:Thomas rev.5, Ruf plug, Bldg 324 LWR fuel,2 asby,1 in fe ring
1 0 -808 31 -52 #801
801 10 -3.309 801 -802 803 -804 56 -500 $ fuel assembly
802 304 -8.0 -20 808 31 -52 $ring shield
3 316 -8.0 (20:-31) -207 32 -52 (-801:802:-803:804) $ MCO pipe wall
4 0 21 57 -22 (-214:-210) -502 $ gap
400 0 300 -594 -320 502 $ gap
5 304 -8.0 223 -23 57 -52 $ 1" shield side
6 304 -8.0 23 -24 57 -52 $ 2" shield side
7 304 -8.0 24 -25 57 -52 $ 3" shield side
8 304 -8.0 25 -26 33 -52 (-584:582:-583) $ 4" shield side
9 304 -8.0 26 -27 34 -52 (-584:582:-583) $ 5" shield side
10 304 -8.0 27 -28 35 -52 (-584:582:-583) $ 6" shield side
11 304 -8.0 28 -29 36 -52 (-584:582:-583) $ 7" shield side
12 304 -8.0 29 -30 37 -52 (-584:585:582:-583) $ 8" shield side
13 0 581 -578 -526 (-255:252:258) $ outside the cask
14 0 (578:526:-581) $ outside world
15 7 0.0000512 18 -53 u=3 $ between fuels
16 3 -6.55 -18 17 -53 u=3 $ Zr-2 clad
17 5 -18.77 -17 16 -53 u=3 $ 0.947% U-235
18 3 -6.55 -16 15 -53 u=3 $ Zr-2 clad
19 7 0.0000512 -15 14 -53 u=3 $ H2O
20 3 -6.55 -14 13 -53 u=3 $ Zr-2 clad
21 5 -18.77 -13 12 -53 u=3 $ 0.947% U-235
22 3 -6.55 -12 11 -53 u=3 $ Zr-2 clad
23 7 0.0000512 -11 -53 u=3 $ H2O
24 7 0.0000512 -51 u=2 $ fictitious cl
25 7 0.0000512 52 -500 -20 #801 u=3 $ 2" gap at top
26 7 0.0000512 53 u=3 $ gap at top of fuel
30 7 0.0000512 596 -256 -250 (30:515) $ Air, top, up to 1m
31 7 0.0000512 38 -256 -596 807 $ Air, side, out to 1m
831 7 0.0000512 38 -807 -596 30 $ Air, side, out to 2 inches
32 7 0.0000512 253 -256 -38 $ Air, bottom, down to 1m
33 7 0.0000512 596 -257 -251 (250:256) $ Air, top, up to 2m
34 7 0.0000512 38 -257 -596 (256) $ Air, side, out to 2m
35 7 0.0000512 254 -257 -38 (-253:256) $ Air, bottom, down to 2m
36 7 0.0000512 596 -258 -252 (257:251) $ Air, top, up to 3m
37 7 0.0000512 38 -258 -596 (257) $ Air, side, out to 3m

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38 7 0.0000512 255 -258 -38 (-254:257) $ Air, bottom, down to 3m
40 0 56 -32 -21 (-801:802:-803:804) $ bottom of MCO, air space
41 316 -8.0 310 -56 -21 311 $ bottom of MCO, top .88"
42 316 -8.0 310 57 -21 $ bottom of MCO, bottom .88"
43 0 310 -56 -311 $ divit at bottom of MCO
44 304 -8.0 -57 33 -25 (-584:585:582:-583) $ 1" shield bottom
    592
45 304 -8.0 -33 34 -26 (-584:585:582:-583) $ 2" shield bottom
    (-593:590:584) (-591:592) (593:591:590:592)
46 304 -8.0 -34 35 -27 (-584:585:582:-583) $ 3" shield bottom
47 304 -8.0 -35 36 -28 (-584:585:582:-583) $ 4" shield bottom
48 304 -8.0 -36 37 -29 $ 5" shield bottom
49 304 -8.0 -37 38 -30 $ shield bottom
500 0 19 -20 500 -509 $ gap: plug/MCO wall
501 316 -8.0 500 -501 -19 542 546 (541:-561) $ 1" shield top
502 316 -8.0 501 -502 -19 $ 2" shield top
    546 (544:-564) (541:-561) 542 $(546:-420)to546, (-562:542:-561) to 542
    (551:421:-546:-544) (556:-557:-546:-544)
503 316 -8.0 502 -503 -19 $ 3" shield top
    (546) (544:563:-564) $from E1
    (542) (541:-561:560) $from E2
    (556:558:-557) $from f1
    (-540:551:421) $(546:-420)to 546,
504 316 -8.0 503 -504 -19 $ 4" shield top;
    (543:-405:-544)(544:563:-564) $ #537 #538
    (538:-541:505:(-556 557):(-551 -421)) $ #533
    (546:420:-544)(542:-541:562) $ #540 #536
    (541:560:-561)(556:-557:558:-546:-544) $ #535 #550
    (550:-551)(555:-556) $ #545 #549
    (551:-540:421:-541) $ #546
505 316 -8.0 504 -505 -19 $ 5" shield top
    543 538 555 (556:558) 550 (551:-540) $(544:563)to(544:563:-564)
506 316 -8.0 505 -506 -19 $ 6" shield top
    535 534 555 550
507 316 -8.0 506 -507 -19 $ 7" shield top
    535 534 555 550 $(427:-428:425:-426:-429)
508 316 -8.0 507 -508 -19 $ 8" shield top
    535 534 554 550 $(427:-428:425:-426:-429)
509 316 -8.0 508 -509 -19 $ 9" shield top
    535 534 554 550 $(427:-428:425:-426:-429)
510 316 -8.0 509 -510 -300 535 534 554 549 (-305:-306) $ 10" shield top$
511 316 -8.0 510 -511 -306 537 536 553 548 $ 11" shield top
512 316 -8.0 511 -512 -306 537 536 553 548 $ 12" shield top
c 530 0 426 -425 429 -512 428 427 $ grapple cutout
    (-432:431) (-430:-434:433)
520 0 -300 305 306 -594
531 0 -534 505 -510 $ E2 main body
532 0 -535 505 -510 $ E1 main body
533 0 -538 503 541 -505 (556:-557) (551:421) $ E2 vent - top segment
535 0 -541 -560 561 $ E2 vent - mid segment;add (542:562)
536 0 -542 500 541 -562 $ E2 vent - bottom segment;562 to -562
537 0 -543 405 -505 544 $ E1 vent - top segment
538 0 -544 -563 564 $ E1 vent - mid segment 546 to nothing
540 0 -546 500 -420 544 $ E1 vent - bottom segment:-420 to -420 add 544
541 0 -536 511 -512 $ Port E2 - above blind flange
542 0 -537 511 -512 $ Port E1 - above blind flange
543 0 -548 406 -512 $ Port F2 - above blind flange
544 0 -549 509 -510 $ Port F2 main body
545 0 -550 503 -509 551 $ Port F2 vent - top segment
546 0 -551 540 -421 541 $ Port F2 vent - mid segment 546 544
547 0 -553 406 -512 $ Port F1 - above blind flange
548 0 -554 507 -510 $ Port F1 main body
549 0 -555 503 -507 556 $ Port F1 vent - top segment; 504 to 503
550 0 -556 557 -558 546 544 541 $ Port F1 vent - mid segment;541,
562 0 -582 583 584 -585 $ drain port cavity
565 0 -584 593 -590 $ horiz drain pipe
566 0 591 (590:-593) -592 -57 $ vert drain pipe
567 0 -591 -593 -590 -592 $ drain pipe elbow
570 316 -8.0 -536 510 -511 $ E2 blind flange

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571 316 -8.0 -537 510 -511          $ E1 blind flange
572 316 -8.0 -548 510 -406          $ F2 blind flange
573 316 -8.0 -553 510 -406          $ F1 blind flange
580 0      518 -30 519 -515          $ above cask body
581 304 -8.0 -513 596 -28 (594:323) (-516:-506) $ first 1" of lid
      (215:595)
582 304 -8.0 ((-514 506 -29 (513:516) (-517:-507)) $ second 1" of lid
      : (596 -506 28 -29 ) )
583 304 -8.0 ((-515 507 -30 (514:517) (-518:-519) ) $ third 1" of lid
      : (596 -507 29 -30 ) )
584 304 -8.0 596 -215 323 -595 $ lip
585 0 512 -594 -306 $ Air space above plug, under lid

c
c   MCO pipe wall
590 316 -8.0 20 -207 52 -500          $ MCO pipe wall fuel to plug bottom
591 316 -8.0 20 -207 500 -501          $ MCO pipe wall 1"+plug bottom
592 316 -8.0 20 -207 501 -502          $ MCO pipe wall 2"+plug bottom
593 316 -8.0 20 -303 502 -503          $ MCO pipe wall 3"+plug bottom
594 316 -8.0 20 -303 503 -504          $ MCO pipe wall 4"+plug bottom
595 316 -8.0 20 -303 504 -505          $ MCO pipe wall 5"+plug bottom
596 316 -8.0 20 -303 505 -506          $ MCO pipe wall 6"+plug bottom
597 316 -8.0 20 -303 506 -507          $ MCO pipe wall 7"+plug bottom
598 316 -8.0 20 -303 507 -508          $ MCO pipe wall 8"+plug bottom
599 316 -8.0 20 -303 508 -509          $ MCO pipe wall 9"+plug bottom

c   side shield - top of fuel to bottom of plug
600 304 -8.0 223 -23 52 -214          $ 1" shield side
601 304 -8.0 323 -23 214 -500          $ 1" shield side
602 304 -8.0 23 -24 52 -500          $ 2" shield side
603 304 -8.0 24 -25 52 -500          $ 3" shield side
604 304 -8.0 25 -26 52 -500          $ 4" shield side
605 304 -8.0 26 -27 52 -500          $ 5" shield side
606 304 -8.0 27 -28 52 -500          $ 6" shield side
607 304 -8.0 28 -29 52 -500          $ 7" shield side
608 304 -8.0 29 -30 52 -500          $ 8" shield side

c   side shield - 1" above bottom of plug
611 304 -8.0 323 -23 500 -502          $ 1" shield side
612 304 -8.0 23 -24 500 -502          $ 2" shield side
613 304 -8.0 24 -25 500 -502          $ 3" shield side
614 304 -8.0 25 -26 500 -502          $ 4" shield side
615 304 -8.0 26 -27 500 -502          $ 5" shield side
616 304 -8.0 27 -28 500 -502          $ 6" shield side
617 304 -8.0 28 -29 500 -502          $ 7" shield side
618 304 -8.0 29 -30 500 -502          $ 8" shield side

c   side shield - 2" above bottom of plug
621 304 -8.0 323 -23 502 -503          $ 1" shield side
622 304 -8.0 23 -24 502 -503          $ 2" shield side
623 304 -8.0 24 -25 502 -503          $ 3" shield side
624 304 -8.0 25 -26 502 -503          $ 4" shield side
625 304 -8.0 26 -27 502 -503          $ 5" shield side
626 304 -8.0 27 -28 502 -503          $ 6" shield side
627 304 -8.0 28 -29 502 -503          $ 7" shield side
628 304 -8.0 29 -30 502 -503          $ 8" shield side

c   side shield - 3" above bottom of plug
631 304 -8.0 323 -23 503 -504          $ 1" shield side
632 304 -8.0 23 -24 503 -504          $ 2" shield side
633 304 -8.0 24 -25 503 -504          $ 3" shield side
634 304 -8.0 25 -26 503 -504          $ 4" shield side
635 304 -8.0 26 -27 503 -504          $ 5" shield side
636 304 -8.0 27 -28 503 -504          $ 6" shield side
637 304 -8.0 28 -29 503 -504          $ 7" shield side
638 304 -8.0 29 -30 503 -504          $ 8" shield side

c   side shield - 4" above bottom of plug
641 304 -8.0 323 -23 504 -596          $ 1" shield side
642 304 -8.0 23 -24 504 -596          $ 2" shield side
643 304 -8.0 24 -25 504 -596          $ 3" shield side
644 304 -8.0 25 -26 504 -596          $ 4" shield side
645 304 -8.0 26 -27 504 -596          $ 5" shield side
646 304 -8.0 27 -28 504 -596          $ 6" shield side
647 304 -8.0 28 -29 504 -596          $ 7" shield side

```


648	304	-8.0	29	-30	504	-596	\$ 8" shield side
c	MCO wall						
650	316	-8.0	207	-208	32	-58	\$ MCO pipe wall from bottom of MCO
651	316	-8.0	207	-208	58	-59	\$ MCO pipe wall from bottom of MCO
652	316	-8.0	207	-208	59	-60	\$ MCO pipe wall from bottom of MCO
653	316	-8.0	207	-208	60	-52	\$ MCO pipe wall from bottom of MCO
654	316	-8.0	207	-208	52	-500	\$ MCO pipe wall fuel to plug bottom
655	316	-8.0	207	-208	500	-501	\$ MCO pipe wall 1" plug bottom
656	316	-8.0	207	-208	501	-502	\$ MCO pipe wall 2" plug bottom
657	316	-8.0	303	-302	502	-503	\$ MCO pipe wall 3" plug bottom
658	316	-8.0	303	-302	503	-504	\$ MCO pipe wall 4" plug bottom
659	316	-8.0	303	-302	504	-505	\$ MCO pipe wall 5" plug bottom
660	316	-8.0	303	-302	505	-506	\$ MCO pipe wall 6" plug bottom
661	316	-8.0	303	-302	506	-507	\$ MCO pipe wall 7" plug bottom
662	316	-8.0	303	-302	507	-508	\$ MCO pipe wall 8" plug bottom
663	316	-8.0	303	-302	508	-509	\$ MCO pipe wall 9" plug bottom
c	MCO wall						
670	316	-8.0	208	-209	32	-58	\$ MCO pipe wall from bottom of MCO
671	316	-8.0	208	-209	58	-59	\$ MCO pipe wall from bottom of MCO
672	316	-8.0	208	-209	59	-60	\$ MCO pipe wall from bottom of MCO
673	316	-8.0	208	-209	60	-52	\$ MCO pipe wall from bottom of MCO
674	316	-8.0	208	-209	52	-500	\$ MCO pipe wall fuel to plug bottom
675	316	-8.0	208	-209	500	-501	\$ MCO pipe wall 1" plug bottom
676	316	-8.0	208	-209	501	-502	\$ MCO pipe wall 2" plug bottom
677	316	-8.0	302	-301	502	-503	\$ MCO pipe wall 3" plug bottom
678	316	-8.0	302	-301	503	-504	\$ MCO pipe wall 4" plug bottom
679	316	-8.0	302	-301	504	-505	\$ MCO pipe wall 5" plug bottom
680	316	-8.0	302	-301	505	-506	\$ MCO pipe wall 6" plug bottom
681	316	-8.0	302	-301	506	-507	\$ MCO pipe wall 7" plug bottom
682	316	-8.0	302	-301	507	-508	\$ MCO pipe wall 8" plug bottom
683	316	-8.0	302	-301	508	-509	\$ MCO pipe wall 9" plug bottom
c	MCO wall						
690	316	-8.0	209	-21	32	-58	\$ MCO pipe wall from bottom of MCO
691	316	-8.0	209	-21	58	-59	\$ MCO pipe wall from bottom of MCO
692	316	-8.0	209	-21	59	-60	\$ MCO pipe wall from bottom of MCO
693	316	-8.0	209	-21	60	-52	\$ MCO pipe wall from bottom of MCO
694	316	-8.0	209	-21	52	-500	\$ MCO pipe wall fuel to plug bottom
695	316	-8.0	209	-21	500	-501	\$ MCO pipe wall 1" plug bottom
696	316	-8.0	209	-21	501	-502	\$ MCO pipe wall 2" plug bottom
697	316	-8.0	301	-300	502	-503	\$ MCO pipe wall 3" plug bottom
698	316	-8.0	301	-300	503	-504	\$ MCO pipe wall 4" plug bottom
699	316	-8.0	301	-300	504	-505	\$ MCO pipe wall 5" plug bottom
700	316	-8.0	301	-300	505	-506	\$ MCO pipe wall 6" plug bottom
701	316	-8.0	301	-300	506	-507	\$ MCO pipe wall 7" plug bottom
702	316	-8.0	301	-300	507	-508	\$ MCO pipe wall 8" plug bottom
703	316	-8.0	301	-300	508	-509	\$ MCO pipe wall 9" plug bottom
c	cask wall						
710	316	-8.0	22	-221	57	-58	\$ 1" side shield from bottom of MCO
711	316	-8.0	22	-221	58	-59	\$ 1" side shield from bottom of MCO
712	316	-8.0	22	-221	59	-60	\$ 1" side shield from bottom of MCO
713	316	-8.0	22	-221	60	-52	\$ 1" side shield from bottom of MCO
714	316	-8.0	22	-221	52	-214	\$ 1" side shield fuel to plug bottom
715	316	-8.0	210	-302	214	-500	\$ 1" side shield fuel to plug bottom
716	316	-8.0	210	-302	500	-501	\$ 1" side shield 1" plug bottom
717	316	-8.0	210	-302	501	-502	\$ 1" side shield 2" plug bottom
718	316	-8.0	320	-321	502	-503	\$ 1" side shield 3" plug bottom
719	316	-8.0	320	-321	503	-594	\$ 1" side shield 4" plug bottom
c	cask wall						
720	316	-8.0	221	-222	57	-58	\$ 1" side shield from bottom of MCO
721	316	-8.0	221	-222	58	-59	\$ 1" side shield from bottom of MCO
722	316	-8.0	221	-222	59	-60	\$ 1" side shield from bottom of MCO
723	316	-8.0	221	-222	60	-52	\$ 1" side shield from bottom of MCO
724	316	-8.0	221	-222	52	-214	\$ 1" side shield fuel to plug bottom
725	316	-8.0	302	-322	214	-500	\$ 1" side shield fuel to plug bottom
726	316	-8.0	302	-322	500	-501	\$ 1" side shield 1" plug bottom
727	316	-8.0	302	-322	501	-502	\$ 1" side shield 2" plug bottom
728	316	-8.0	321	-322	502	-503	\$ 1" side shield 3" plug bottom
729	316	-8.0	321	-322	503	-594	\$ 1" side shield 4" plug bottom
c	cask wall						

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730	316	-8.0	222	-223	57	-58	\$ 1" side shield from bottom of MCO
731	316	-8.0	222	-223	58	-59	\$ 1" side shield from bottom of MCO
732	316	-8.0	222	-223	59	-60	\$ 1" side shield from bottom of MCO
733	316	-8.0	222	-223	60	-52	\$ 1" side shield from bottom of MCO
734	316	-8.0	222	-223	52	-214	\$ 1" side shield fuel to plug bottom
735	316	-8.0	322	-323	214	-500	\$ 1" side shield fuel to plug bottom
736	316	-8.0	322	-323	500	-501	\$ 1" side shield 1" plug bottom
737	316	-8.0	322	-323	501	-502	\$ 1" side shield 2" plug bottom
738	316	-8.0	322	-323	502	-503	\$ 1" side shield 3" plug bottom
739	316	-8.0	322	-323	503	-594	\$ 1" side shield 4" plug bottom
1	p	0.86602540	-0.5	0.0	3.556		
2	p	0.86602540	-0.5	0.0	-3.556		
3	p	0.86602540	0.5	0.0	3.556		
4	p	0.86602540	0.5	0.0	-3.556		
5	py				3.556		
6	py				-3.556		
11	cz	0.6083		\$ H2O			
12	cz	0.6591		\$ Zr-2 clad			
13	cz	1.5481		\$ fuel			
14	cz	1.6243		\$ Zr-2 clad			
15	cz	2.1603		\$ H2O			
16	cz	2.2110		\$ Zr-2 clad			
17	cz	3.0163		\$ fuel			
18	cz	3.0798		\$ Zr-2 clad			
19	cz	29.083		\$ plug radius			
20	cz	29.21		\$ MCO inner wall			
207	cz	29.78		\$ gap region			
208	cz	30.18		\$ gap region			
209	cz	30.38		\$ gap region			
21	cz	30.480		\$ MCO outer wall			
210	cz	30.7975		\$ cask lip inner radius			
214	pz	370.84		\$ bottom of jog			
215	pz	391.16		\$ top of lip			
c	216	pz	381.1778	\$ top of jog			
22	cz	31.9913		\$ shd inner wall			
221	cz	32.0913		\$ gap region			
222	cz	32.2913		\$ gap region			
223	cz	32.6913		\$ gap region			
300	cz	32.0548		\$ upper gap region, inner edge			
301	cz	31.9548		\$ upper gap region, imp region			
302	cz	31.7548		\$ upper gap region, imp region			
303	cz	31.3548		\$ upper gap region, imp region			
305	1	pz	25.0698	\$ bottom of plug grapple region			
306	cz	23.8125		\$ inside radius of plug grapple region			
310	pz	2.352		\$ split in bottom of MCO			
311	kz	-0.9579429	0.9886686	1.0	\$ MCO bottom divit cone		
320	cz	32.385		\$ top of cask, inner radius			
321	cz	32.485		\$ top of cask, inner imp zone			
322	cz	32.685		\$ top of cask, inner imp zone			
323	cz	33.085		\$ top of cask, inner imp zone			
23	cz	33.655		\$.69" shield			
24	cz	36.195		\$ 1.69" shield			
25	cz	38.735		\$ 2.69" shield			
26	cz	41.275		\$ 3.69" shield			
27	cz	43.815		\$ 4.69" shield			
28	cz	46.355		\$ 5.69" shield			
29	cz	48.895		\$ 6.69" shield			
30	cz	50.5587		\$ 7.31" shield			
31	pz	8.28041		\$ 1.760" bottom of MCO shielding			
32	pz	8.2804		\$ 1.76" + 1.5" above bottom			
33	pz	-2.540		\$ 1" from bottom			
34	pz	-5.080		\$ 2" from bottom			
35	pz	-7.620		\$ 3" from bottom			
36	pz	-10.160		\$ 4" from bottom			
37	pz	-12.7		\$ 5" from bottom			
38	pz	-15.5702		\$ 6.13" from bottom			
51	cz	10000.000		\$ for u=1 purpose			
52	pz	361.9501		\$ lattice height			

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53	pz	74.5744	\$ fuel height
54	pz	80.1243	\$ individual lattice height
55	pz	8.2804	\$ bottom of lattice
56	pz	4.4704	\$ 1.76" above bottom of MCO
57	pz	0.00	\$ bottom of MCO
58	pz	88.96	
59	pz	177.93	
60	pz	266.895	
250	pz	515.56	\$ 1m from top
251	pz	615.56	\$ 2m from top
252	pz	1015.56	\$ 10m from top
253	pz	-115.5702	\$ 1m from bottom
254	pz	-215.5702	\$ 2m from bottom
255	pz	-615.5702	\$ 6m from bottom
256	cz	150.5587	\$ 1m from side
257	cz	250.5587	\$ 2m from side
258	cz	650.5587	\$ 6m from side
259	cz	3.175	\$ inner rad of divit
261	cz	19.685	\$ donut hole inner radius
c			bottom of fuel = 8.2804
c			top of fuel = 4(80.1243-8.2804)+8.2804 +74.5744 = 370.2304
c			center of fuel = 189.2554
268	pz	174.2554	\$ 189.2554 - 15
269	pz	204.2554	\$ 189.2554 + 15
c	404	1 pz	5.08
	405	1 pz	8.50
	406	1 pz	27.83
	420	5 px	8.25
	421	6 px	19.2257
			\$changed from -19.5 to 8.25
			\$21.50
c			
500	1 pz	0.000	\$ top of MCO open area/bot.of plug
501	1 pz	2.540	\$ 1" shield
502	1 pz	5.2578	\$ 2" shield
503	1 pz	7.540	\$ 3" shield
504	1 pz	10.160	\$ 4" shield
505	1 pz	13.330	\$ 5" shield
506	1 pz	15.900	\$ 6" shield
507	1 pz	18.410	\$ 7" shield
508	1 pz	20.800	\$ 8" shield
509	1 pz	23.490	\$ 9" shield
510	1 pz	26.030	\$ 10" shield
511	1 pz	28.980	\$ 11" shield
512	1 pz	30.480	\$ 12" shield
513	1 pz	34.6075	
514	1 pz	37.1475	
515	pz	415.56	\$ top of 3" lid
516	cz	34.5313	
517	cz	37.0713	
518	cz	40.005	\$ radius of lid
519	pz	398.78	\$ top of lid bottom
526	1 pz	4000	\$ top of 3" lid (402.515) + 20m
c	530	cz	3.81
534	c/z	-9.576 -6.957 5.08	\$ port E2:-16.46 -6.30 to -9.576 -6.957
535	c/z	6.957 9.576 5.08	\$ port E1; 13.49 11.33 to 6.957 9.576
536	c/z	-9.576 -6.957 10.204	\$ port E2:-16.46 -6.30 to -9.576 -6.957
537	c/z	6.957 9.576 10.204	\$ port E1; 13.49 11.33 to 6.957 9.576
538	c/z	-9.576 -6.957 1.27	\$ port E2:-16.46 -6.30 to -9.576 -6.957
540	6 px	-1.70	
541	2 cx	1.27	
542	3 cx	1.27	
543	c/z	6.957 9.576 0.635	\$ port E1; 13.49 11.33 to 6.957 9.576
544	4 cx	0.635	
545	5 cx	0.635	
548	c/z	9.483 -9.483 8.658	\$ port F2
549	c/z	9.483 -9.483 3.09	\$ port F2
550	c/z	9.483 -9.483 1.27	\$ port F2
551	6 cx	1.27	
553	c/z	-10.633 10.633 7.112	\$ port F1
554	c/z	-10.633 10.633 2.54	\$ port F1

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```

555 c/z -10.633 10.633 1.27 $ port F1
556 7 cx 1.27
557 7 px -17.61856 $-19.55
558 7 px 1.70
560 2 px 3.00 $ inside edge of E2 vent mid segment; 0.70 to 2.00
561 2 px -10.00 $ outer edge of E2 vent mid segment:-8.00 to -10
562 3 px 8.25 $ outer edge of E2 vent lower segment:3 px -24.90 to 3 px 8.25
563 4 px 2.00 $ outer edge of E1 vent mid segment
564 4 px -13.5 $ inner edge of E1 vent mid segment 19.50 to -13.5
578 cz 4000 $ 6 m is at 652
581 pz -4000 $ 6 m is at -612
c 582 c/x 0 -3.4544 4.3434 $ 4.02" from bottom of cask, 3.42" dia
582 c/x 0 -3.4544 0.0002 $ 4.02" from bottom of cask, 3.42" dia
583 px 0
584 cz 39.6875 $ Outer cask wall - (4.91-.25)
585 cz 49.6189 $ Outer cask wall - .75 in
c 168.88-(24-13.5)-6.5 = 151.88
c 590 c/x 0 -3.4544 .8001 $ Horizontal drain pipe
590 c/x 0 -3.4544 .0001 $ Horizontal drain pipe
591 pz -3.4544
c 592 c/z 25.7180 0 .8001 $ Vertical drain pipe
592 c/z 25.7180 0 .0001 $ Vertical drain pipe
593 px 25.7180
594 pz 406.67 $ bottom of lid
595 cz 37.7952 $ radius of lip
596 pz 388.62 $ top of cask sidewall
601 pz -3000
602 pz -2500
603 pz -2000
604 pz -1500
605 pz -1200
606 pz -900
607 pz -700
608 pz -644
609 pz -584
610 pz -384
611 pz -244
612 pz -184
613 pz -129
614 pz -99
615 pz -69
616 pz -39
617 pz -16
618 pz 30
619 pz 60
620 pz 90
621 pz 120
622 pz 150
623 pz 170
624 pz 190
625 pz 210
626 pz 240
627 pz 270
628 pz 300
629 pz 330
630 pz 349
631 pz 389
632 pz 399
633 pz 407
634 pz 416
635 pz 450
636 pz 500
637 pz 600
638 pz 800
639 pz 1000
640 pz 1200
641 pz 1500
642 pz 2000
643 pz 2500

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```

644 pz 3000
701 cz 5
702 cz 12.5
703 cz 21.5
704 cz 30.5
705 cz 32
706 cz 41
707 cz 51
708 cz 52
709 cz 85
710 cz 107
711 cz 130
712 cz 171.2
713 cz 197
714 cz 230
715 cz 272.2
716 cz 350
717 cz 400
718 cz 470
719 cz 540
720 cz 620
721 cz 682.5
722 cz 800
723 cz 900
724 cz 1090.87
725 cz 1200
726 cz 1500
727 cz 2000
728 cz 2500
729 cz 3000
801 px -21.5900 $ next 4 : bldg 324 lwr fuel
802 px 21.5900
803 py -10.7950
804 py 10.7950
805 pz 183.1848 $ tally segment--cask midplane - 1 inch
806 pz 188.2648 $ tally segment--cask midplane + 1 inch
807 cz 55.6387 $ tally surface 2 inches outside cask
808 cz 26.670 $ ring shield inner surface (1 inch)

*tr1 0 0 375.92 $ bottom of plug
*tr2 -9.576 -6.957 384.17 $ E2 vent mid segment;-16.46 -6.30 to -9.567 -6.957
36.0 54.0 90.0 $ changed from 37.493 72.321 58.163
*tr3 -15.925 -11.571 375.92 $ E2 vent bottom segment;0 0 to -15.925 -11.571
90.0 90.0 0.00 $ changed from 24.294 69.583 102.597
*tr4 6.957 9.576 384.17 $ E1 vent mid segment; 13.49 11.33 385.445to 6.957 9.576 384.81
54.0 36.0 90.0 $ test model E1 vent mid segment on xy plane 45 deg to x,y
*tr5 0.000 0.000 375.92 $ E1 vent bottom segment move to xy at 0.000 0.000
90.0 90.0 0.0 $ E1 vent bittin seg straight up // Z axis
*tr6 9.483 -9.483 384.170 $ F2 vent mid segment
187.550 82.45 90.00
*tr7 -10.633 10.633 384.170 $ F1 vent mid segment
93.439 -3.439 90.000

mode
c
c 2nd entry=1 of phys:p turns off brehmstrahlung
c 3rd entry=1 of phys:p turns off coherent scattering
c (procedure suggested for dxtan use)
phys:p j 1
c 1 2 802 3 4 400 5 6 7 8 9 10 11 12 13
imp:p 1 1 32 32 1 1 32 2m 2m 2m 2m 2m 2m 32768
c 14 15 16 17 18 19 20 21 22 23 24
0 1 1 1 1 1 1 1 1 1 1 1
c 25 26 30 31 831 32 33 34 35 36 37 38
1 1 32768 4096 4096 8192 32768 4096 8192 32768 4096 8192
c 40 41 42 43 44 45 46 47 48 49
1 64 2m r 2m 2m 2m 2m 2m 2m
c 500 501 502 503 504 505 506 507 508 509 510
1 32 2m 2m 2m 2m 2m 2m r r
c 511 512 520

```

```

c      r      r      1
531 532 533 535 536 537 538
1 1 1 1 1 1 1
c      540 541 542 543 544 545 546 547 548 549
1 1 1 1 1 1 1 1 1 1
c      550
1
c      562 565 566 567
1 1 1 1
c      570 571 572 573
4096 r r r
c      580 581 582 583 584 585
1 8192 2m 2m 4096 4096
c      590 591 592 593 594 595 596 597 598 599
16 2m 2m 2m 2m 2m 2m 2m r
c      600 601 602 603 604 605 606 607 608
32 2m r 2m 2m 2m 2m 2m 2m
c      611 612 613 614 615 616 617 618
256 256 256 512 r 2m 2m 2m
c      621 622 623 624 625 626 627 628
256 256 2m 2m r r 2m 2m
c      631 632 633 634 635 636 637 638
1024 r 2m r r r r 2m
c      641 642 643 644 645 646 647 648
4096 r r r r r r r
c      650 651 652 653 654 655 656 657 658 659 660 661 662 663
32 r r r r r r 256 2m 2m 2m r r r r
c      670 671 672 673 674 675 676 677 678 679 680 681 682 683
32 r r r r r r 512 2m 2m r r r r
c      690 691 692 693 694 695 696 697 698 699 700 701 702 703
32 r r r r r 4096 r r r r r
c      710 711 712 713 714 715 716 717 718 719
32 r r r r 2m 2m 2m 4096 r
c      720 721 722 723 724 725 726 727 728 729
32 r r r r 4m 4m 4096 1024 r
c      730 731 732 733 734 735 736 737 738 739
32 r r r r 64 256 1024 512 r
c      m304 SS-304 from CRC
c      m316 SS-316L from CRC
m304 6000 0.08 14000 1 25000 2 24000 19 26000 67.92 28000 10
m316 6000 0.03 14000 1 25000 2 24000 17 26000 65.47 28000 12 42000 2.5
m3 40000.01p -1.00000
m5 92235.01p -0.00947 92238.01p -0.99053 $ zirc cladding
m7 8016.01p 0.22000 7014.01p 0.78000 $ Air
m10 92235.01p -0.2652 92238.01p -2.65255 $ bldg 324 lwr fuel
8016.01p -0.3565 40000.01p -0.2993
c
c 5.32E+14 p/s/MTU * 6.34 MTU = 3.37E+15
sdef cel=801 x=d1 y=d2 z=d3
erg d7 wgt=3.762E+15
si1 -21.589 21.589
sp1 0 1
si2 -10.794 10.794
sp2 0 1
si3 4.4705 375.91
sp3 0 1
sc7 Energy spectrum from ISOSHLD using PNNL-11273 Point Beach source
# si7 sp7
l d
c Energy photons/sec
0.0143 2.277E+14
0.0247 1.152E+14
0.0337 1.375E+14
0.0445 5.679E+13
0.0561 4.381E+13
0.0649 2.665E+13
0.0749 2.368E+13
0.0851 2.425E+13
0.0949 1.856E+13

```

```

0.1344      1.106E+14
0.2433      2.903E+13
0.3447      1.197E+13
0.4619      1.100E+13
0.6611      9.340E+14
0.8237      1.857E+13
1.0007      1.362E+13
1.2562      7.559E+13
1.5319      2.054E+12
1.7169      5.221E+10
1.8666      5.152E+09
2.1478      1.407E+09
2.2716      2.372E+07
2.4868      8.937E+06
2.6842      3.668E+06
2.9165      1.598E+06
3.2000      1.060E+05
c          TOTAL      1.881E+15
c
c          ansi/ans-6.1.1-1991 fluence-to-dose,photons(mrem/hr/(p/cm**2/s)
de0        log      .01 .015 .02 .03 .04 .05
              .06 .08 .10 .15 .20 .30
              .40 .50 .60 .80 1.0 1.5
              2.0 3.0 4.0 5.0 6.0 8.0
              10. 12.
df0        log      2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
              1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
              7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
              2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
              8.892e-3 1.040e-2
c
fc2        contact 2 assemblies, 1 in fe ring
f2:p      807
fs2       -805 -806
c
fc12      1 meter 2 assemblies, 1 in fe ring
f12:p    256
fs12     -805 -806
c
fc22      2 meter 2 assemblies, 1 in fe ring
f22:p    257
fs22     -805 -806
c
fc32      6 meter 2 assemblies, 1 in fe ring
f32:p    258
fs32     -805 -806
c
fc5       pt detector contact x axis 1 in fe ring
f5:p     0.0 55.6400 185.725 5.0
c
fc15      pt detector contact y axis midplane 1 in fe ring
f15:p    55.6400 0.0 185.725 5.0
c
c          -60: dump runtime every 60 min
prdnmp   j -60 1
c
print    10 126 150 160 170
ctme     450

```

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

NUMBER: DESH-9750369

DOCUMENT REVIEWED: Shielding Analysis for 300 Area LWR SNF Within Modified MCO Canister in a Modified MCO CaskAUTHOR(s): S. R. Gedeon

I. Method(s) of Review

- (x) Input data checked for accuracy
- () Independent calculation performed
 - (x) Hand calculation
 - () Alternate computer code: _____
- () Comparison to experiment or previous results
- () Alternate method (define) _____

II. Checklist (either check or enter NA if not applied)

- (x) Task completely defined
- (x) Activity consistent with task specification
- (x) Necessary assumptions explicitly stated and supported
- (x) Resources properly identified and referenced
- (x) Resource documentation appropriate for this application
- (x) Input data explicitly stated
- (x) Input data verified to be consistent with original source
- (x) Geometric model adequate representation of actual geometry
- (x) Material properties appropriate and reasonable
- (x) Mathematical derivations checked including dimensional consistency
- (x) Hand calculations checked for errors
- (x) Assumptions explicitly stated and justified
- (x) Computer software appropriate for task and used within range of validity
- (x) Use of resource outside range of established validity is justified
- (x) Software runstreams correct and consistent with results
- (x) Software output consistent with input
- (x) Results consistent with applicable previous experimental or analytical findings
- (x) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
- (x) Conclusions consistent with analytical results and established limits
- (NA) Uncertainty assessment appropriate and reasonable
- (NA) Other (define) _____

III. Comments:

ISOSHL Code has been effectively applied to this project to meet the tight schedule.

IV. REVIEWER: J. S. Lan DATE: 3/24/97

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	Criticality and Shielding	Date March 24, 1997
Project Title/Work Order Shielding Analysis for 300 Area Light Water Reactor Spent Nuclear Fuel Within a Modified Multi-Canister Overpack Canister in a Modified Multi-Canister Overpack Transportation Cask		EDT No. 620300
		ECN No. NA

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
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A. B. Carlson	R3-86	X			
S. R. Gedeon	H0-35	X			
J. Greenborg	H0-35	X			
J. S. Lan	H0-35	X			
Central Files (1 + original)	A3-88	X			