

**SHIELD WALL EVALUATION OF HOT CELL FACILITY FOR ADVANCED SPENT FUEL  
CONDITIONING PROCESS**

150

(Advance spent fuel Conditioning Process)

(IMEF) - , 가

ACP

ACP

Steel 가 QADS MCNP

(a) ACP (b)

(c) QADS MCNP (d)

**ABSTRACT**

The future hot cell is located in the irradiated material experiment facility (IMEF) at the Korea Atomic Energy Research Institute (KAERI). It is  $\beta$ - $\gamma$  type hot cell that was constructed on the base floor in IMEF building for irradiated material testing. And this hot cell will be used for carrying out the advanced spent fuel conditioning process (ACP).

The radiation shielding capability of hot cell should be sufficient to meet the radiation dose requirements in the related regulations. Because the radioactive sources of ACP are expected to be higher than radioactive sources of IMEF design criteria, the future hot cell in current status is unsatisfactory to hot test of ACP. So the shielding analysis of the future hot cell is performed to evaluate shielding ability of concrete shield wall. The shielding analysis included (a) identification of ACP source term; (b) photon source spectrum; (c) shielding analysis by QADS and MCNP-4C; and (d) enhancement of concrete shield wall. In this research, dose rates are obtained according to ACP source, geometry and hot cell shield wall thickness. And the evaluation and reinforcement thickness of the shield wall about future hot cell are concluded.

1.

(ACP) ,  
 - ACP  
 (8000 zone) 0.15 mSv/hr (7000 zone) 0.01 mSv/hr,  
 Fe-59 35Ci 가 가 70 ~ 80 cm  
 가  
 가가 , QADS[1] MCNP[2]  
 SCALE QADS SCALE , QAD-CGGP QAD-CGGP Point Kernel  
 SCALE ,  
 QADS MARS (combinatorial geometry method for modeling a  
 Multiple-ARray System) 3 가  
 가  
 MCNP Monte Carlo , , / ,  
 가

2.

*IDENTIFICATION OF SOURCE TERM*

- : 20 kg – HM/batch
- U-235 : 3.5 wt%
- : 43,000 Mwd/tU
- : 10

가 ORIGEN-2

batch 20 kg-HM 1batch, 5batch, 1 .  
 22,800 Ci . 2

*PHOTON SOURCE SPECTRUM*

SCALE 44 ORIGENS 18  
 3.013 × 10<sup>14</sup> γ/sec ,  
 가 가

1/3

가

가 (Case I)

(Case II)

44

18

Heavy Metal,

가

2

가

3

DOSE RATE ANALYSIS

hot cell

hot cell

11 m,

2 m,

4.55 m

4

Fe-59 35 Ci (1.2 MeV)

β-γ type

1

( : 2.5 g/cm<sup>3</sup>)

80 cm,

70 cm

1

80 cm

( : 3.5 g/cm<sup>3</sup>)

QADS

MCNP

30 cm

가

80 cm

steel

IMEF

5

QADS

Geometrical Progression approximation (GP method)

QADS

가

QADS

ANSI/ANS-6.11( 6), MCNP ICRP 74[3]

3.

CASE I

CASE II

1

steel

2

80 cm

가 가

steel

MCNP

가 QADS

20 cm

QADS

0.91 mrem/hr

0.31 mrem/hr

, MCNP

0.18 mrem/hr

0.09 mrem/hr

. Steel

, QADS

9

cm, 6 cm

MCNP

5 cm, 4 cm

7

4.

steel

QADS MCNP

가

QADS 가 MCNP QADS  
 QADS MCNP 가 , 가 가  
 , steel QADS MCNP  
 가

5.

1. B. L. BROADHEAD, "QADS: A Multidimensional Point Kernel Analysis Module," NUREG/CR-5468 (ORNL/CSD/TM-270), U.S. Nuclear Regulatory Commission (May 1990).
2. "MCNP4C Monte Carlo N-Particle Transport Code System," ORNL RSIC CCC-700, Radiation Safety Information Computational Center, Oak Ridge National Lab
3. Conversion Coefficients for Use in Radiological Protection against External Radiation, ICRP Publication 74, Volume 26 No. 3/4 , 1996.

1. Inventory basis of radioactivity in future hot cell

Radioactive Source Terms	Radioactivity (Ci)
1 batch of Spent fuel (20 kg-HM)	9,950
5 batches of Volatile Fission Products (H, Kr)	680 (136 x 5)
2 batches of Molten Salts	12,170 (6,085 x 2)
Total	22,800

2. 44- group photon spectrum of 20kg HM, molten salts, and volatile fission products

Energy Interval (MeV)			20 kg HM	Molten salt	Volatile FP
			1 batch	2 batches	5 batches
1.00E-02	to	2.00E-02	9.8135E+11	1.0040E+11	0.0000E+00
2.00E-02	to	3.00E-02	7.9600E+11	6.1948E+11	0.0000E+00
3.00E-02	to	4.50E-02	6.7117E+12	1.2906E+13	0.0000E+00
4.50E-02	to	6.00E-02	9.2653E+11	7.2121E+11	0.0000E+00
6.00E-02	to	7.00E-02	9.9127E+09	1.8273E+10	0.0000E+00
7.00E-02	to	7.50E-02	1.8779E+10	1.8779E+09	0.0000E+00
7.50E-02	to	1.00E-01	5.4530E+11	1.0579E+12	0.0000E+00
1.00E-01	to	1.50E-01	2.3512E+12	4.5560E+12	0.0000E+00
1.50E-01	to	2.00E-01	9.2762E+10	3.3929E+10	0.0000E+00
2.00E-01	to	3.00E-01	3.5320E+11	6.5450E+11	0.0000E+00
3.00E-01	to	4.00E-01	4.0303E+10	3.3630E+10	0.0000E+00
4.00E-01	to	4.50E-01	3.7692E+11	1.0106E+11	0.0000E+00
4.50E-01	to	5.10E-01	2.2780E+11	2.3656E+11	0.0000E+00
5.10E-01	to	5.12E-01	1.3126E+11	1.5789E+10	4.9179E+10
5.12E-01	to	6.00E-01	2.0956E+12	3.8885E+12	4.5199E+10
6.00E-01	to	7.00E-01	7.5724E+13	1.4777E+14	0.0000E+00
7.00E-01	to	8.00E-01	7.6852E+12	1.5062E+13	0.0000E+00
8.00E-01	to	1.00E+00	1.7314E+12	3.3885E+12	0.0000E+00
1.00E+00	to	1.20E+00	9.2465E+11	1.7938E+12	0.0000E+00
1.20E+00	to	1.33E+00	1.8566E+12	3.6393E+12	0.0000E+00
1.33E+00	to	1.44E+00	2.2742E+11	4.4633E+11	0.0000E+00
1.44E+00	to	1.50E+00	3.4012E+10	6.5481E+10	0.0000E+00
1.50E+00	to	1.57E+00	4.0744E+09	6.2958E+09	0.0000E+00
1.57E+00	to	1.66E+00	8.2774E+10	1.6207E+11	0.0000E+00
1.66E+00	to	1.80E+00	4.8321E+08	4.3815E+08	0.0000E+00
1.80E+00	to	2.00E+00	3.6033E+08	1.6387E+08	0.0000E+00
2.00E+00	to	2.15E+00	2.1628E+08	2.1628E+07	0.0000E+00
2.15E+00	to	2.35E+00	1.2120E+09	1.2204E+08	0.0000E+00
2.35E+00	to	2.50E+00	2.5934E+08	2.5936E+07	0.0000E+00
2.50E+00	to	3.00E+00	8.3258E+07	8.3271E+06	0.0000E+00
3.00E+00	to	3.50E+00	1.4115E+07	1.4115E+06	0.0000E+00
3.50E+00	to	4.00E+00	4.7599E+05	4.7599E+04	0.0000E+00
4.00E+00	to	4.50E+00	2.7595E+05	2.7595E+04	0.0000E+00
4.50E+00	to	5.00E+00	1.5998E+05	1.5998E+04	0.0000E+00
5.00E+00	to	5.50E+00	9.2759E+04	9.2759E+03	0.0000E+00
5.50E+00	to	6.00E+00	5.3779E+04	5.3779E+03	0.0000E+00
6.00E+00	to	6.50E+00	3.1180E+04	3.1180E+03	0.0000E+00
6.50E+00	to	7.00E+00	1.8078E+04	1.8078E+03	0.0000E+00
7.00E+00	to	7.50E+00	1.0482E+04	1.0482E+03	0.0000E+00
7.50E+00	to	8.00E+00	6.0776E+03	6.0776E+02	0.0000E+00
8.00E+00	to	1.00E+01	7.1784E+03	7.1784E+02	0.0000E+00
1.00E+01	to	1.20E+01	3.7114E+02	3.7114E+01	0.0000E+00
1.20E+01	to	1.40E+01	0.0000E+00	0.0000E+00	0.0000E+00
1.40E+01	to	2.00E+01	0.0000E+00	0.0000E+00	0.0000E+00

3. The photon spectrum for each case

Results			Case 1		Case 2			
			SF + VF + MS		SF + VF		MS	
Energy Interval (MeV)			44 group	18 group	44 group	18 group	44 group	18 group
1.00E-02	To	2.00E-02	1.0818E+12	2.3762E+13	9.8135E+11	9.4156E+12	1.0040E+11	1.4347E+13
2.00E-02	To	3.00E-02	1.4155E+12		7.9600E+11		6.1948E+11	
3.00E-02	To	4.50E-02	1.9617E+13		6.7117E+12		1.2906E+13	
4.50E-02	To	6.00E-02	1.6477E+12		9.2653E+11		7.2121E+11	
6.00E-02	To	7.00E-02	2.8185E+10	2.8185E+10	9.9127E+09	9.9127E+09	1.8273E+10	1.8273E+10
7.00E-02	To	7.50E-02	2.0656E+10		1.8779E+10		1.8779E+09	
7.50E-02	To	1.00E-01	1.6032E+12		5.4530E+11		1.0579E+12	
1.00E-01	to	1.50E-01	6.9072E+12	6.9072E+12	2.3512E+12	2.3512E+12	4.5560E+12	4.5560E+12
1.50E-01	to	2.00E-01	1.2669E+11		9.2762E+10		3.3929E+10	
2.00E-01	to	3.00E-01	1.0077E+12	1.0077E+12	3.5320E+11	3.5320E+11	6.5450E+11	6.5450E+11
3.00E-01	to	4.00E-01	7.3933E+10	7.3933E+10	4.0303E+10	4.0303E+10	3.3630E+10	3.3630E+10
4.00E-01	to	4.50E-01	4.7798E+11	7.1678E+12	3.7692E+11	2.9259E+12	1.0106E+11	4.2419E+12
4.50E-01	to	5.10E-01	4.6436E+11		2.2780E+11		2.3656E+11	
5.10E-01	to	5.12E-01	1.9623E+11		1.8044E+11		1.5789E+10	
5.12E-01	to	6.00E-01	6.0292E+12		2.1408E+12		3.8885E+12	
6.00E-01	to	7.00E-01	2.2349E+14	2.4624E+14	7.5724E+13	8.3409E+13	1.4777E+14	1.6283E+14
7.00E-01	to	8.00E-01	2.2748E+13		7.6852E+12		1.5062E+13	
8.00E-01	to	1.00E+00	5.1199E+12	5.1199E+12	1.7314E+12	1.7314E+12	3.3885E+12	3.3885E+12
1.00E+00	to	1.20E+00	2.7184E+12	8.2142E+12	9.2465E+11	2.7812E+12	1.7938E+12	5.4330E+12
1.20E+00	to	1.33E+00	5.4958E+12		1.8566E+12		3.6393E+12	
1.33E+00	to	1.44E+00	6.7374E+11	1.0284E+12	2.2742E+11	3.4828E+11	4.4633E+11	6.8017E+11
1.44E+00	to	1.50E+00	9.9493E+10		3.4012E+10		6.5481E+10	
1.50E+00	to	1.57E+00	1.0370E+10		4.0744E+09		6.2958E+09	
1.57E+00	to	1.66E+00	2.4484E+11		8.2774E+10		1.6207E+11	
1.66E+00	to	1.80E+00	9.2136E+08	1.4456E+09	4.8321E+08	8.4354E+08	4.3815E+08	6.0202E+08
1.80E+00	to	2.00E+00	5.2420E+08		3.6033E+08		1.6387E+08	
2.00E+00	to	2.15E+00	2.3790E+08	1.8572E+09	2.1628E+08	1.6876E+09	2.1628E+07	1.6960E+08
2.15E+00	to	2.35E+00	1.3340E+09		1.2120E+09		1.2204E+08	
2.35E+00	to	2.50E+00	2.8528E+08		2.5934E+08		2.5936E+07	
2.50E+00	to	3.00E+00	9.1585E+07	9.1585E+07	8.3258E+07	8.3258E+07	8.3271E+06	8.3271E+06
3.00E+00	to	3.50E+00	1.5526E+07	1.6050E+07	1.4115E+07	1.4591E+07	1.4115E+06	1.4591E+06
3.50E+00	to	4.00E+00	5.2359E+05		4.7599E+05		4.7599E+04	
4.00E+00	to	4.50E+00	3.0354E+05	4.7952E+05	2.7595E+05	4.3593E+05	2.7595E+04	4.3593E+04
4.50E+00	to	5.00E+00	1.7598E+05		1.5998E+05		1.5998E+04	
5.00E+00	to	5.50E+00	1.0203E+05	1.9549E+05	9.2759E+04	1.7772E+05	9.2759E+03	1.7772E+04
5.50E+00	to	6.00E+00	5.9157E+04		5.3779E+04		5.3779E+03	
6.00E+00	to	6.50E+00	3.4298E+04		3.1180E+04		3.1180E+03	
6.50E+00	to	7.00E+00	1.9886E+04	3.8102E+04	1.8078E+04	3.4638E+04	1.8078E+03	3.4638E+03
7.00E+00	to	7.50E+00	1.1531E+04		1.0482E+04		1.0482E+03	
7.50E+00	to	8.00E+00	6.6853E+03		6.0776E+03		6.0776E+02	
8.00E+00	to	1.00E+01	7.8962E+03	8.3045E+03	7.1784E+03	7.5495E+03	7.1784E+02	7.5495E+02
1.00E+01	to	1.20E+01	4.0825E+02		3.7114E+02		3.7114E+01	
1.20E+01	to	1.40E+01	0.0000E+00		0.0000E+00		0.0000E+00	
1.40E+01	to	2.00E+01	0.0000E+00		0.0000E+00		0.0000E+00	
TOTAL			3.0130E+14		1.0403E+14		1.9727E+14	

#### 4. Specification of hot cell

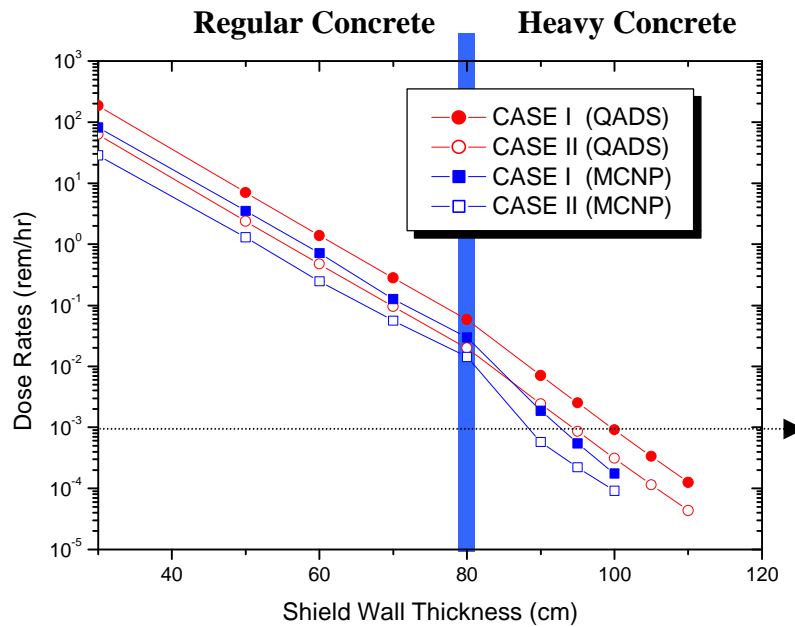
Hot Cell No.	Shielding Material	Wall Thickness (cm)					Dimension of Cell (W × D × H) m	Radioactivity (max Ci)
		Front	Rear	Side (L)	Side (R)	Ceiling		
Future Hot cell	Heavy Concrete					70	11 × 2 × 4.55	35 (Fe-59)
	Ordinary Concrete	80	80	70	80			

#### 5. Material composition of the hot cell wall for radiation shielding analysis

Heavy Concrete			Regular Concrete		
Atomic Number	Atomic Symbol	Partial Density (g/cm <sup>3</sup> )	Atomic Number	Atomic Symbol	Partial Density (g/cm <sup>3</sup> )
1	H	0.01035	1	H	0.00484
8	O	1.104	6	C	0.13
12	Mg	0.0207	8	O	1.149
13	Al	0.10005	12	Mg	0.00486
14	Si	0.12075	13	Al	0.0119
15	P	0.005865	14	Si	0.438
16	S	0.036915	16	S	0.00192
20	Ca	0.210105	20	Ca	0.581
22	Ti	0.0966	28	Ni	0.00726
25	Mn	0.002415	Total		2.33
26	Fe	1.74225			
Total		3.450			

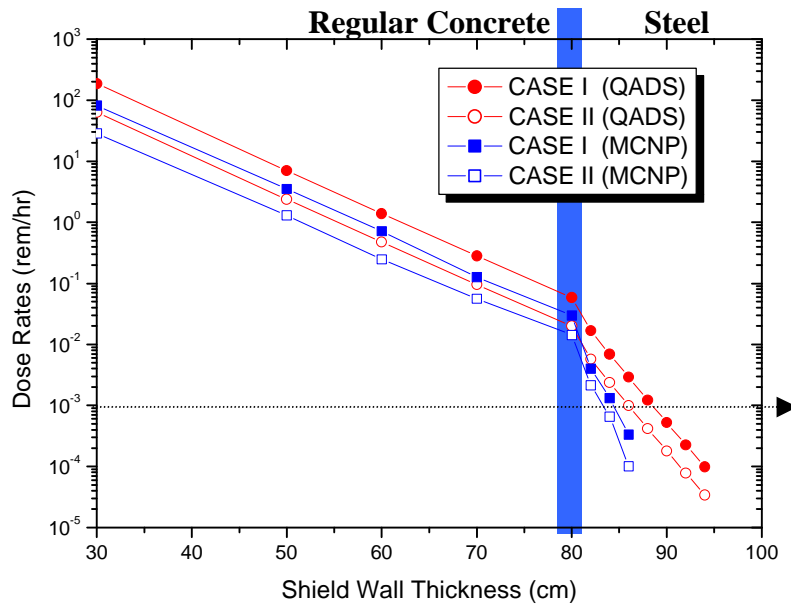
6. Dose to flux conversion factor - ANSI /ANS-6.1.1 (1977) standard

Group	Photon, MSv/hr/photons/cm <sup>2</sup> · sec	
	Upper Energy, MeV	Conversion Factor
1	1.0E+1	9.792E-5
2	8.0E+1	8.280E-5
3	6.5E+1	6.840E-5
4	5.0E+1	5.760E-5
5	4.0E+1	4.752E-5
6	3.0E+1	3.960E-5
7	2.5E+1	3.492E-5
8	2.0E+1	2.988E-5
9	1.66E+1	2.412E-5
10	1.33E+1	1.908E-5
11	1.0E+0	1.602E-5
12	8.0E-1	1.260E-5
13	6.0E-1	9.126E-6
14	4.0E-1	6.327E-6
15	3.0E-1	4.392E-6
16	2.0E-1	2.376E-6
17	1.0E-1	1.404E-6
18	5.0E-2	3.024E-6



1. Dose rates as a function of shielding thickness for regular and heavy concrete.





2. Dose rates as a function of shielding thickness for regular concrete and steel.

7. Reinforcement thickness of future hot cell for satisfying the design criteria (1 mrem/hr)

Codes	Heavy Concrete		Steel	
	Case I	Case II	Case I	Case II
QADS	20 cm	15 cm	9 cm	7 cm
MCNP	14 cm	10 cm	5 cm	4 cm