APPENDIX B

LASALLE DEWATERED RESIN FLAMMABLE GAS GENERATION ASSESSMENT

1 DEWATERED RESIN FLAMMABLE GAS GENERATING ASSESSMENT

This appendix provides an evaluation of potential flammable gas generation under the worst-case assumed full Class B/C radwaste loading conditions considering extended storage, i.e. greater than 5 years.

1.1. Combustible Gas Evolution

Gases, including some potentially flammable gases, are generated in radioactive ion-exchange resins from a radiolytic reaction due to radiation. Most of the flammable gas is hydrogen, but there is a small percentage of methane, and carbon monoxide. These gases are potentially explosive in high concentrations. Gas generated is in direct proportion to the Curie loading.

1.1.1. High Integrity Containers (HICs)

In this assessment, 8-120 standard HDPE containers supplied by Energy Solutions are assumed to be used for storing radioactive waste in the LaSalle IRSF storage bay: See Table 1 for detailed information on this container.

Table 1

HDPE High Integrity Container (HIC) 8-120

Parameter	Value		Value	
Internal Volume	107.6	ft^3	3.05E+03	L
Diameter	61.5	in	156.2	cm
Height	73.5	in	186.7	cm
Port opening	22.5	in	57.2	cm
Disposal Volume	120.3	ft^3	3.41E+03	L
Gross weight	10,000.0	lb	4,536	kg

For extended storage in the past, waste package deformation was observed due to an increase in internal pressure. For this reason, a passive vent (HEPA) device was installed on the container to automatically vent gases, designed to resist plugging by resins.

1.1.2. LaSalle Existing IRSF Capacity

Table 2, indicates LaSalle IRSF storage area dimensions. For more details see Attachment C- LaSalle IRSF Dimensions.

Table 2- LaSalle Existing IRSF Capacity by Volume

Parameter	Volume Up to Rail		Total IRSF Volume	
Height	34	ft	49	ft
Length	95	ft	95	ft
Width	60	ft	60	ft
IRSF Storage Area	3,230	ft^2	4,655	ft^2
IRSF Storage Volume	193,800	ft^3	279,300	ft^3
IRSF Storage Volume	5,486,478	L	7,906,983	L
Maximum HIC Capacity	270	containers		

1.1.3. Flammable Gas Generation Volumes

A major study was performed and published via ASTM (post- TMI accident) relative to combustible gas evolution from resins generated during water cleanup operations using EPICOR 2 System prefilters coated with organic resins (see reference 4, page 1240). The hydrogen gas generation in each vessel is concluded to be directly proportional to the curie content present. The study documents that flammable gas generation in bead resin Radwaste is found to be 6 x 10^{-6} L/h-Ci at standard temperature and pressure. Assuming waste isotopes are primarily Co-60 (conservative assumption, see Reference 4, page A1-2), a 100 R/hr HIC will have a curie content of approximately 300 Ci and a hydrogen gas generation rate of about 1.8 x 10^{-3} L/hr. See Attachment D-Hydrogen Gas Generation Calculation Excel Spreadsheet, Rev A..

Exelon is expecting to have an average container contact dose rate of 50 R/hr on a regular basis. Some containers are expected to have higher dose rates depending on the site,;

therefore, a linear evaluation is performed for hot containers cases using 100 R/hr, 300 R/hr, and 500 R/hr. See a summary of inputs below.

Input Summary List			
Flammable Gas Generation	6.00E-06	L/(hr-Ci)	See Reference 4, page 1240
Assuming Co-60 isotope content only (conservative assumption)			See Reference 4, page A1-2
Dose Rate per HIC	100	R/hr	
Curie Content	300	Ci	
Hydrogen Gas generated	1.8E-03	L/hr	
HIC Volume	107.6	ft^3	3046.156 L
Maximum HIC Capacity Stored	270	Containers	(double stacked)

Table 3- Flammable Gas Generation

Cases	**Dose Rates**		**Hydrogen Gas Generation Rate per container**		**Flammable Gas Generation in the Storage Area at Maximum Capacity (270 HICs) per Hour**		**Flammable Gas Generation in the Storage Area at Maximum Capacity (270 HICs) per Year**	
Expected Case	50	R/hr	9.0E-04	L/hr	0.24	L/hr]	2,129	L/yr
Hot Container	100	R/hr	1.8E-03	L/hr	0.49	L/hr	4,257	L/yr
Hot Container	300	R/hr	5.4E-03	L/hr	1.46	L/hr	12,772	L/yr
Hot Container	500	R/hr	9.0E-03	L/hr	2.43	L/hr	21,287	L/yr

As indicated in Table 3, the hydrogen gas volumes generated at LaSalle Station for 50 R/hr, 100 R/hr, 300 R/hr, and 500 R/hr containers are 0.24 L/hr, 0.49 L/hr, 1.46 L/hr, and

2.43 L/hr respectively. At maximum capacity, the total amount of gas generated is 2,129 L/yr, 4,257 L/yr, 12,772 L/yr, and 21,287 L/yr for the respective cases. See Figure 1.

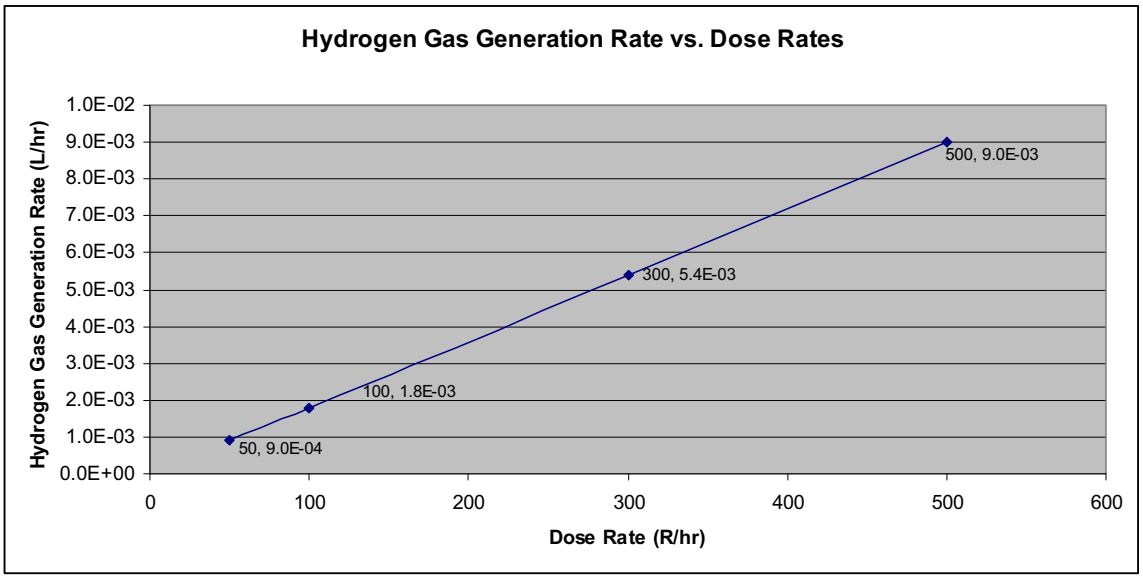


Figure 1

For the case where it is postulated that the ventilation system fails over a period of 6 weeks (42 days) during which operational maintenance is expected to be able to return the ventilation system back to normal, the hydrogen gas generation is evaluated to determine the flammable gas generation volumes in the entire storage bay. See Table 4 for detail.

Table 4- Flammable Gas Generation per 42 Days without Ventilation

Cases	Dose Rates	Time Period without Operational Ventilation System	Hydrogen Gas Generation per HIC in 42 days	Hydrogen Gas Generation at Maximum Capacity (270 HICs)
Expected Case	50 R/hr	42 day	0.91 L/container	245 L
Hot Container	100 R/hr	42 day	1.81 L/container	490 L
Hot Container	300 R/hr	42 day	5.44 L/container	1,470 L
Hot Container	500 R/hr	42 day	9.07 L/container	2,449 L

Assuming the HICs are stored without proper ventilation for a period of 42 days, the expected hydrogen generation volume per HIC would be about 0.91 liters, 1.81 liters, 5.44 liters, and 9.07 liters according to the containers dose rates. If 270 HICs are stored for 42 days, the amount of gas generation volume is 245 liters, 490 liters, 1,470 liters and 2,449 liters, respectively.

For the maximum hot container case (500 R/hr), at maximum capacity (270 containers), the hydrogen concentration would be well below the hydrogen flammability limits at about 0.03% of the storage bay volume (see Section 1.2.5). It is not expected that the ventilation system would be out of service for as long as 42 days.

1.1.4. Flammability Risk Analysis

Due to flammable gas generated internal to the container and vented into the IRSF storage bay area, an evaluation of the potential buildup of combustible gases needs to be considered. NRC Information Notice. 84-72 stipulates that the hydrogen generated must be limited to a molar quantity no more than 5% by volume in the container gas void (or equivalent limits for other flammable gases). However, the NFPA hydrogen flammability rating is 4 (red), with an autoignition temperature of 1060°F (571°F). The Lower Flammability Limit (LFL) is 4.0% in air by volume; for administrative purposes, 2% will be considered the limit of hydrogen gas accumulated by total volume. In this case, FLF values in Table 5- Hydrogen Gas Explosivity Values are limits for the storage bay cell.

Table 5- Hydrogen Gas Explosivity Values

Lower Flammability Limit (LFL) for Hydrogen	4	%	316,279	L
Hydrogen Administrative Limit	2	%	109,730	L

The building ventilation system should be in continuous operation to offset flammable gas concentration buildup. In case of a ventilation failure, the maximum period of time without venting before reaching the maximum flammability limits is determined below.

Table 6 evaluates the percentage hydrogen gas generation at maximum storage capacity per year, 270 double stacked containers, without any building ventilation credit. (Note, that even buildings without forced ventilation will experience air exchange rates on the order of 1 per day through doors, cracks, exhaust paths, etc.) In addition, the calculated time periods for storing the maximum capacity containers in the storage bay per dose rate case are given in this table.

Table 6- IRSF Hydrogen Gas Evaluation

Cases	Dose Rates		Hydrogen Gas Generation % Volume per Year		Duration of IRSF Saturation w/ Hydrogen Gas (2% Admin Limit)	
Expected Case	50	[R/hr]	0.0269	%	74	yr
Hot Container	100	[R/hr]	0.0538	%	37	yr
Hot Container	300	[R/hr]	0.1615	%	12	yr
Hot Container	500	[R/hr]	0.2692	%	7	yr

Based on the extended period of time (years) required to reach the administrative limit, and reasonable expectations on natural ventilation, it is not credible that flammable concentrations could accumulate in the LaSalle IRSF atmosphere due to hydrogen gas generation in and ventilation from stored radioactive material. Vents in storage containers (or shield bells) are required to alleviate in-container gas build-up.

Figure 2 depicts the gas generation % volume per year relationship to container dose rate graphically.

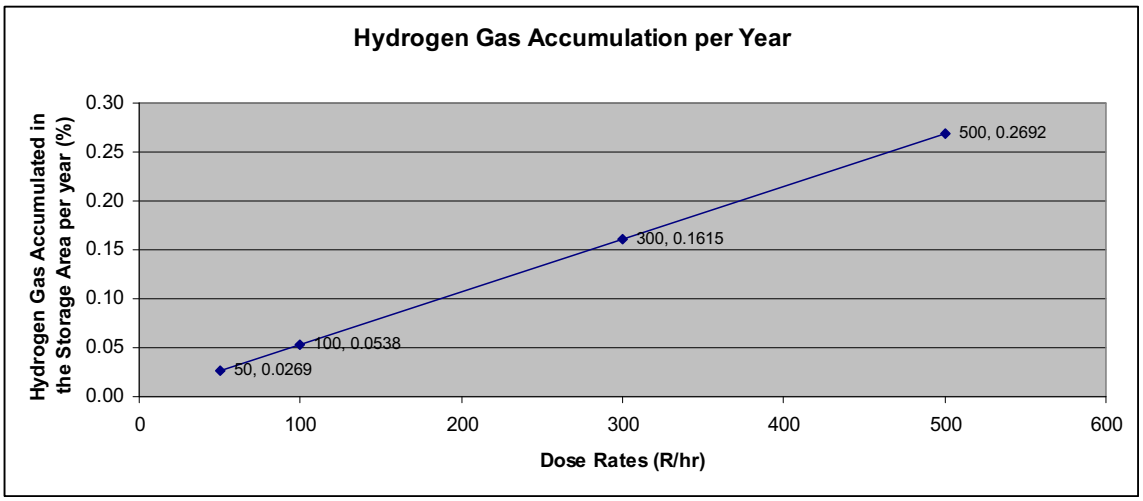


Figure 2

1.1.5. Hydrogen Gas Pocket Assessment

The analysis of flammable gas generation indicates that projected hydrogen gas releases will NOT reach the administrative 2% concentration limit even for extended periods without ventilation system operation. Hydrogen gas pockets could only be generated if large quantities of hydrogen are rapidly released and if the hydrogen is not evenly mixed. This is not considered credible.

In the expected case, 9.0 $x10^{-3}$ L/hr per HIC (for the maximum dose rate container case) is **slowly released**. The hydrogen gas is expected to diffuse and be evenly mixed in the open storage bay air, so no segregation into pockets of the hydrogen is expected to occur. Additionally, the LaSalle ventilation system has ten (10) air vent vertical discharges of 1,662 cfm each. With adequate air circulation, hydrogen will be well mixed in the present medium, so no hydrogen concentrations will be further diluted.

1.1.6. Gas Generation Rates from Biodegradation and Chemical Reaction

Regarding the special case of methane evolution due to organic material experiencing bacterial activity, NRC Information Notice 90-50 recommends that the stations control methane generation at the source and minimize microbiological-contaminated compounds in the Radwaste system, followed by prevention of microbiological recontamination. Exelon Chemistry Department has endorsed these recommendations and has a Procedure in effect to minimize biological contamination in the waste streams.

Radwaste containing reactive components will not be authorized for IRSF storage until their relative components are removed or neutralized in accordance with the Exelon approved Process Control Program, as per reference [2].

1.2. Conclusion

Flammable gas generation in the LaSalle IRSF storage bay for the proposed waste forms even at maximum theoretical container quantities and dose rate is not of concern as long as the containers (and shield bells, if used) are adequately vented. This conclusion holds even without storage bay forced air ventilation in operation for extended periods.

1.3. References:

1. Exelon IRSF Extended Storage Issues Report Report-Draft, email from Don Gardner, to Howard James, CC. Paul Reichert, Ed Taylor, Robert Murr, and Irving Tsang on Friday 9/12/2008.

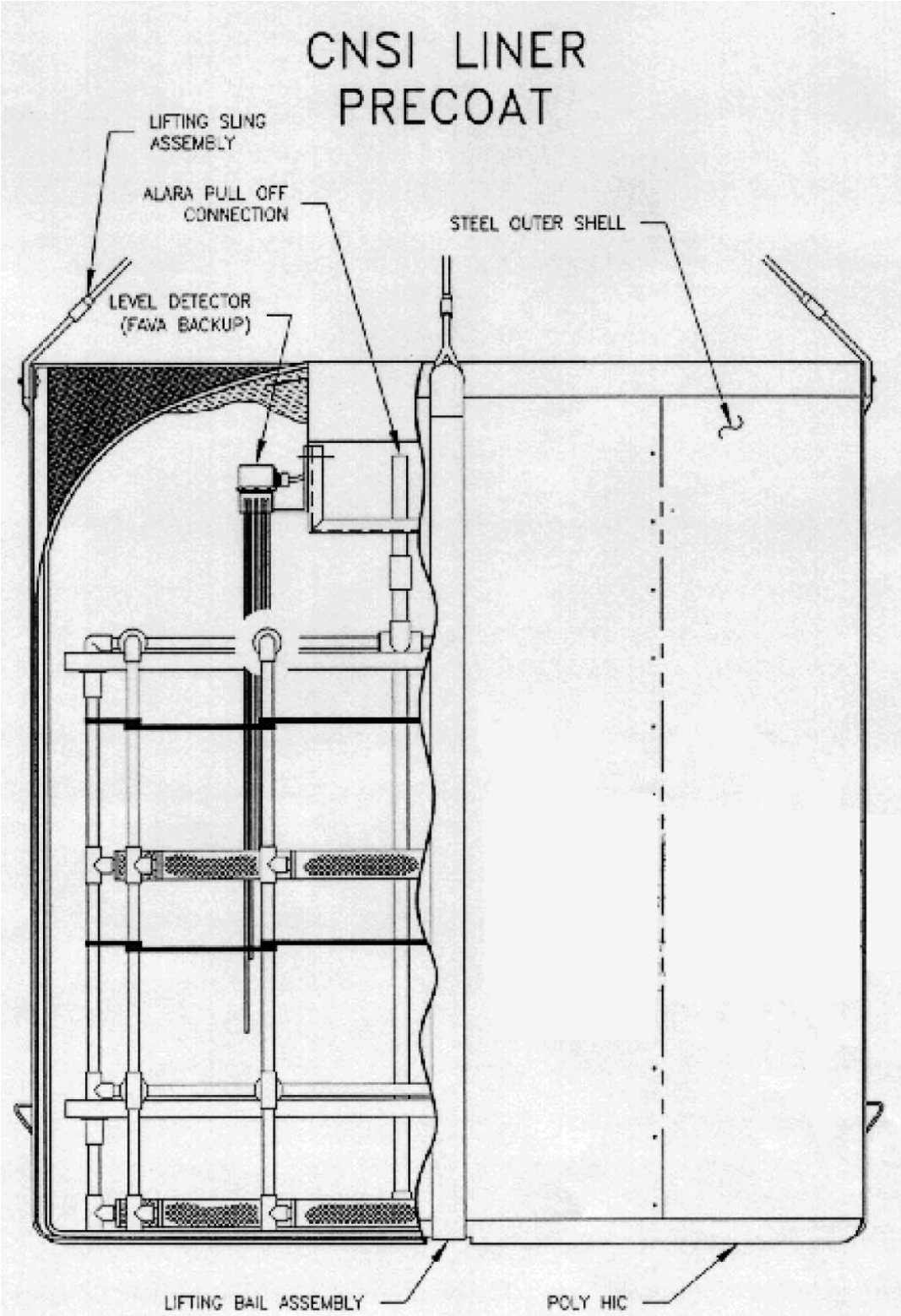
2. Transmittal of LaSalle On-Site Review, Independent Review Director, D.J.Ray, Station Manager, 7/20/94

3. Waste Containers for Extended Storage of Class A, Class B and C, Rev1, EPRI, Dec 6, 2006.

4. Effects of Radiation on Materials: Twelfth International Symposium, Radiation Effects on Resins and Zeolites at Three Mile Island Unit II, J.K. Reilly, P.J. Grant, G.J. Quinn, T.C. Runion, K.J. Hofstetter, ASTM, 1985

5. Hydrogen Material Safety Data Sheet, Airgas, document #001026

Attachment A – HIC Drawing



Attachment B – Radwaste Summary of Waste Sample

********** Data Base Summary for Waste Type 9**********
..... as of 05/18/94.....

****** Waste Characteristic File (WASDAT.DAT) Summary ******

RSR Information		Calculation Information	
Waste:	LR-D-NA120 HIC	Waste Volume(Ft3):	90.0
Physical Form:	SOLID	Density(Lbs/Ft3):	40.0
Chemical Form:	METAL OXIDES	Waste Weight(Lbs):	3550.0
Package Type:	POLY HIC	Limit Factor:	0
Package Vol(Ft3):	120.3	Activity Factor:	51.0
Package Wt(Lbs):	4200.0		

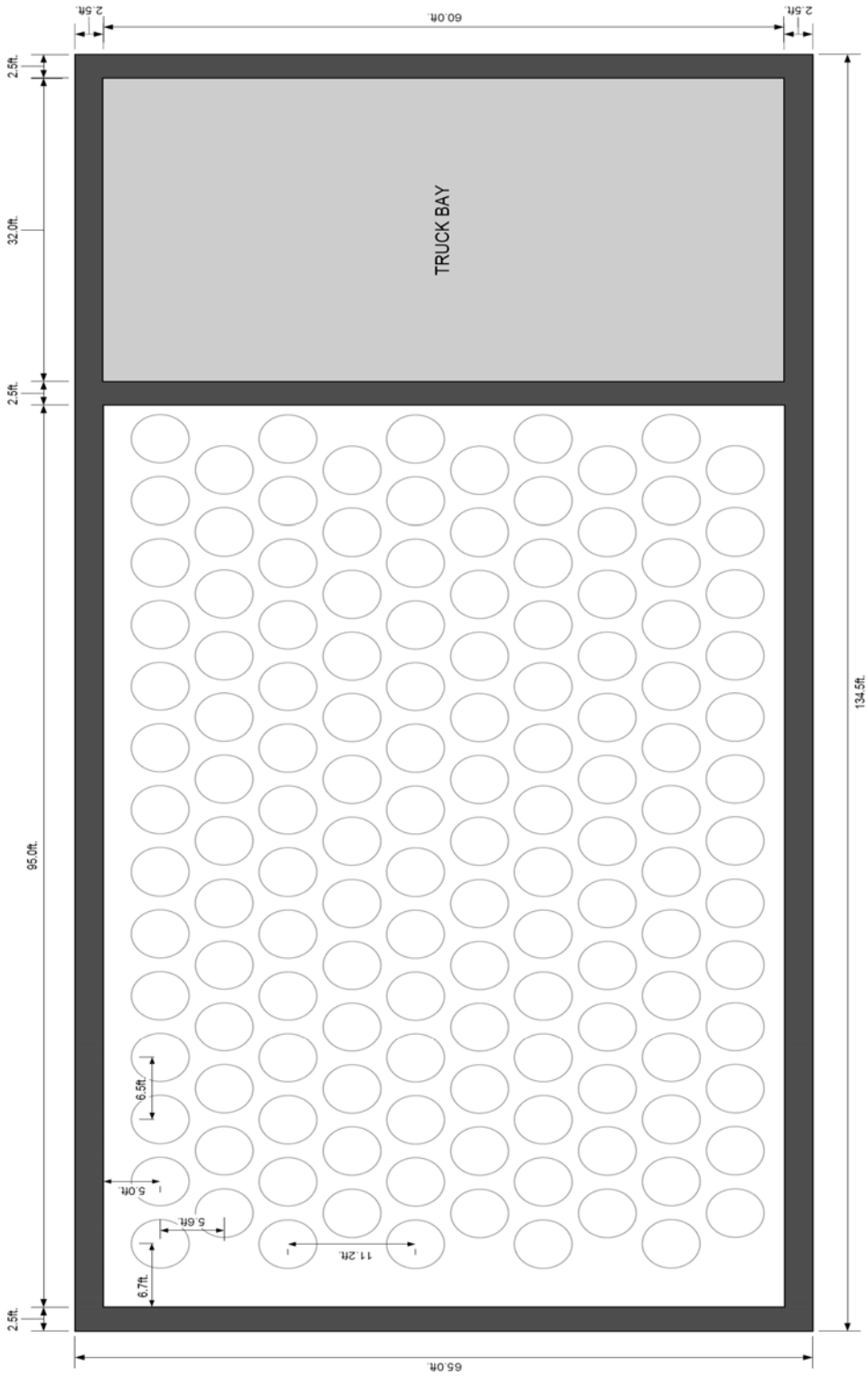
********** Summary of Waste Sample Data File **********

Nuclide	Sample Data	Abundance (Percent)	Scaling Factor
Mn-54	2.21E+00	6.08	1.04E-01
Fe-55	8.31E+00	22.80	3.90E-01
Co-58	3.39E+00	9.32	1.59E-01
Co-60	2.13E+01	58.60	1.00E+00
Fe-59	1.11E+00	3.05	5.21E-02
Ni-59	2.33E-03	.01	1.09E-04
H-3	4.40E-04	.00	8.80E-03
C-14	6.80E-05	.00	3.19E-06
Tc-99	<1.30E-05	<LLD>	<LLD>
I-129	<9.00E-05	<LLD>	<LLD>
Cs-137	5.00E-02	.14	1.00E+00
Ce-141	5.27E-04	.00	1.05E-02
Ce-144	2.00E-04	.00	1.00E+00
Sr-89	1.65E-04	.00	3.30E-03
Pu-241	8.42E-05	.00	4.21E-01
Cm-242	1.07E-06	.00	5.35E-03
Cm243/44	5.67E-07	.00	2.83E-03

Average Gamma Mev: 1.6448

< - indicates LLD Value

Attachment C – LaSalle IRSF Dimensions



Attachment D – Hydrogen Gas Generation Calculation Excel Spreadsheet, Rev 0

Note:
The values determined in this analysis were calculated using a Microsoft™ Excel™ spreadsheet, and are calculated to a greater number of significant figures than presented in this document.

Polyethylene Line SS High Integrity Container (HIC) 8-120

Parameter	Value		Value	
Internal Volume	107.6	[ft³]	3.05E+03	[L]
Diameter	61.5	[in]	156.2	[cm]
Height	73.5	[in]	186.7	[cm]
Port opening	22.5	[in]	57.2	[cm]
Disposal Volume	120.3	[ft³]	3.41E+03	[L]
Gross weight	10,000.0	[lb]	4536	[kg]

LaSalle Station

Parameter	Value		Total Volume + Top of the Rail	
Height	34	[ft]	49	[ft]
Length	95	[ft]	95	[ft]
Width	60	[ft]	60	[ft]
IRSF Storage Area	3,230	[ft²]	4,655	[ft²]
IRSF Storage Volume	193,800	[ft³]	279,300	[ft³]
IRSF Storage Volume	5,486,478	[L]	7,906,983	[L]
Estimated HICs quantities	270	[Containers]		

CALCULATION METHOD

Extracted from Radiation Effects on Resins and Zeolites at TMI Unit II, by J. Reilly, P. Grant, G. Quinn, T. Runion, and K. Hofstetter

GAS GENERATION	6.00E-06	[L/(hr-Ci)]

RELATIONSHIP ASSUMPTION

Assuming Co-60 (conservative Assumption)

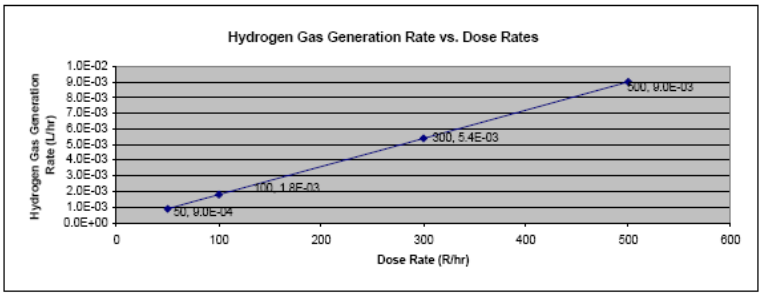
See Reference [2] page A1-2

Dose Rate per HIC	100	[R/hr]
Curie Content	300	[Ci]
Hydrogen Gas generated	1.8E-03	[L/hr]

Maximum HIC Volume	107.6	[ft³]	3,046	[L]

			LaSalle Station LEL	
LOWER FLAMMABILITY LIMIT (LFL) FOR HYDROGEN	4	%	316,279	[L]
HYDROGEN ADMINSTRATIVE LIMIT	2	%	158,140	[L]

						LaSalle Station		
Cases	Dose Rates		Hydrogen Gas Generation Rate per container		Hydrogen Gas Generation in the Storage Area at Maximum Capacity (270 HICs) per Hour		Hydrogen Gas Generation in the Storage Area at Maximum Capacity (270 HICs) per Year	
Expected Case	50	[R/hr]	9.0E-04	[L/hr]	0.24	[L/hr]	2,129	[L/yr]
Hot Container	100	[R/hr]	1.8E-03	[L/hr]	0.49	[L/hr]	4,257	[L/yr]
Hot Container	300	[R/hr]	5.4E-03	[L/hr]	1.46	[L/hr]	12,772	[L/yr]
Hot Container	500	[R/hr]	9.0E-03	[L/hr]	2.43	[L/hr]	21,287	[L/yr]

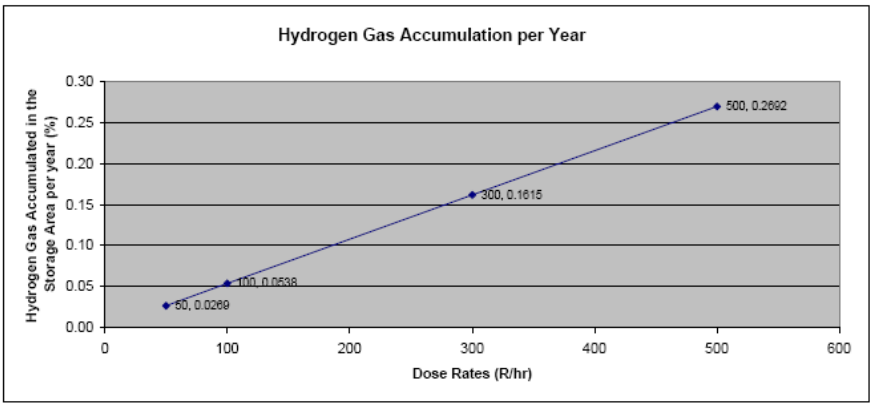


					LaSalle Station		
Cases	Dose Rates		Time Period without Operational Ventilation System		Hydrogen Gas Generation Per HIC in 42 days		LaSalle Station Total Gas Accumulated	
Expected Case	50	[R/hr]	42	[day]	0.91	[L/container]	245	[L]
Hot Container	100	[R/hr]	42	[day]	1.81	[L/container]	490	[L]
Hot Container	300	[R/hr]	42	[day]	5.44	[L/container]	1,470	[L]
Hot Container	500	[R/hr]	42	[day]	9.07	[L/container]	2,449	[L]

EVALUATION

Flammability Evaluation

			LaSalle Station			
Cases	Dose Rates		Hydrogen Gas Generation % Volume per Year		Duration of IRSF Storage Saturation w/ Gas (2% Admin Limit)	
Expected Case	50	[R/hr]	0.0269	%	74	yr
Hot Container	100	[R/hr]	0.0538	%	37	yr
Hot Container	300	[R/hr]	0.1615	%	12	yr
Hot Container	500	[R/hr]	0.2692	%	7	yr



LaSalle Case I (Maximum Capacity of containers -double stacked)

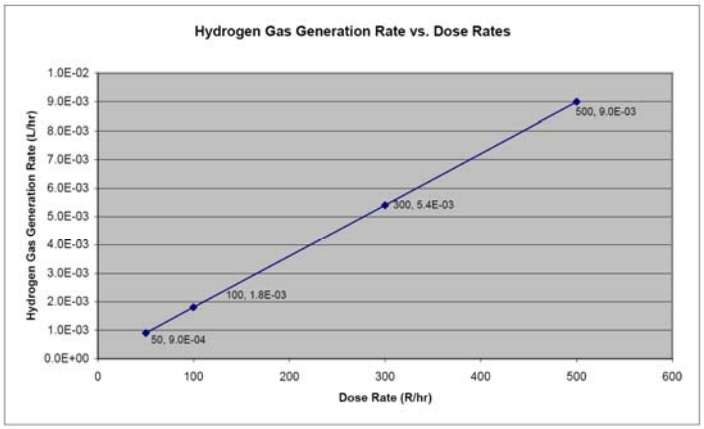
Total Numbers of containers =	270

Cases	Dose Rates		Hydrogen Gas Generation Rate per container		Hydrogen Gas Generation in the Storage Area at Maximum Capacity (270 HICs) per Hour		Hydrogen Gas Generation in the Storage Area at Maximum	% Volume
Expected Case	50	[R/hr]	9.0E-04	[L/hr]	2.4E-01	[L/hr]	2,129 [L/yr]	0.0269%
Hot Container	100	[R/hr]	1.8E-03	[L/hr]	4.9E-01	[L/hr]	4,257 [L/yr]	0.0538%
Hot Container	300	[R/hr]	5.4E-03	[L/hr]	1.5E+00	[L/hr]	12,772 [L/yr]	0.1615%
Hot Container	500	[R/hr]	9.0E-03	[L/hr]	2.4E+00	[L/hr]	21,287 [L/yr]	0.2692%

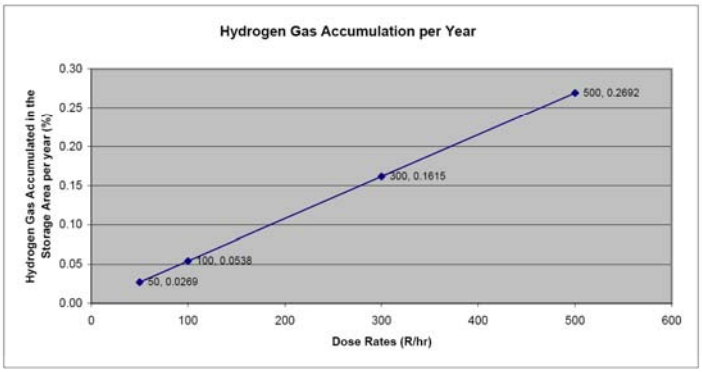
Attachment E – Hydrogen Gas Generation Calculation Excel Spreadsheet Formulas, Rev 0

	A	B	C	D	E	F	G
1							
2							
3		**Polyethylene Line SS High Integrity Container (HIC) 8-120**					
4		Parameter	Value		Value		
5		Internal Volume	107.6	[ft^3]	=C5*28.31	[L]	
6		Diameter	61.5	[in]	=C6*2.54	[cm]	
7		Height	73.5	[in]	=C7*2.54	[cm]	
8		Port opening	22.5	[in]	=C8*2.54	[cm]	
9		Disposal Volume	120.3	[ft^3]	=C9*28.31	[L]	
10		Gross weight	10000	[lb]	=C10*0.4536	[kg]	
11							
12							
13		**LaSalle Station**					
14		Parameter	Value		Total Volume + Top of the Rail		
15		Height	34	[ft]	49	[ft]	
16		Length	95	[ft]	=C16	[ft]	
17		Width	60	[ft]	=C17	[ft]	
18		IRSF Storage Area	=C16*C15	[ft^2]	=E16*E15	[ft^2]	
19		IRSF Storage Volume	=C17*C16*C15	[ft^3]	=E17*E16*E15	[ft^3]	
20		IRSF Storage Volume	=C19*28.31	[L]	=E19*28.31	[L]	
21		Estimated HICs quantities	270	[Containers]			
22							
23							
24							
25							
26		**CALCULATION METHOD**					
27							
28		Extracted from Radiation Effects on Resins and Zeolites at TMI Unit II, by J. Reilly, P. Grant, G. Quinn, T. Runion, and K. Hofstetter					
29		GAS GENERATION	0.000006	[L/(hr-Ci)]			
30							
31		RELATIONSHIP ASSUMPTION					
32		Assuming Co-60 (conservative Assumption)			See Reference [2] page A1-2		
33		Dose Rate per HIC	100	[R/hr]			
34		Curie Content	300	[Ci]			
35		Hydrogen Gas generated	=C29*C34	[L/hr]			
36							
37		Maximum HIC Volume	=C5	[ft^3]	=C37*28.31	[L]	
38							
39					**LaSalle Station LEL**		
40		LOWER FLAMMABILITY LIMIT (LFL) FOR HYDROGEN	4	%	=E20*C40/100	[L]	
41		HYDROGEN ADMINSTRATIVE LIMIT	2	%	=E20*C41/100	[L]	
42							

43							LaSalle Station			
44	Cases	Dose Rates		Hydrogen Gas Generation Rate per container		Hydrogen Gas Generation in the Storage Area at Maximum Capacity (270 HICs) per Hour		Hydrogen Gas Generation in the Storage Area at Maximum Capacity (270 HICs) per Year	
45	Expected Case	50	[R/hr]	=C45*$C$35/$C$33	[L/hr]	=$C$21*E45	[L/hr]	=G45*24*365	[L/yr]
46	Hot Container	100	[R/hr]	=C46*$C$35/$C$33	[L/hr]	=$C$21*E46	[L/hr]	=G46*24*365	[L/yr]
47	Hot Container	300	[R/hr]	=C47*$C$35/$C$33	[L/hr]	=$C$21*E47	[L/hr]	=G47*24*365	[L/yr]
48	Hot Container	500	[R/hr]	=C48*$C$35/$C$33	[L/hr]	=$C$21*E48	[L/hr]	=G48*24*365	[L/yr]



49									
50						LaSalle Station			
51	Cases	Dose Rates		Time Period without Operational Ventilation System		Hydrogen Gas Generation Per HIC in 42 days		LaSalle Station Total Gas Accumulated	
52	Expected Case	50	[R/hr]	42	[day]	=E45*24*E52	ainer]	=G52*$C$21	[L]
53	Hot Container	100	[R/hr]	42	[day]	=E46*24*E53	[L/cont	=G53*$C$21	[L]
54	Hot Container	300	[R/hr]	42	[day]	=E47*24*E54	[L/cont	=G54*$C$21	[L]
55	Hot Container	500	[R/hr]	42	[day]	=E48*24*E55	ainer]	=G55*$C$21	[L]
56	Hot Container	700	[R/hr]	43	[day]	=#REF!*24*E5	ainer]	=G56*$C$21	[L]
57									
58	**EVALUATION**								
59									
60	Flammability Evaluation			LaSalle Station					
61	Cases	Dose Rates		Hydrogen Gas Generation % Volume per Year		Storage Saturation w/ Gas (2% Admin Limit)			
62	Expected Case	50	[R/hr]	=I45*100/$E$20	%	=$E$41/I45	yr		
63	Hot Container	100	[R/hr]	=I46*100/$E$20	%	=$E$41/I46	yr		
64	Hot Container	300	[R/hr]	=I47*100/$E$20	%	=$E$41/I47	yr		
65	Hot Container	500	[R/hr]	=I48*100/$E$20	%	=$E$41/I48	yr		
66									



67									
68	**LaSalle Case I (Maximum Capacity of containers -double stacked)**								
69									
70	Total Numbers of containers =	270							
71									
72	Cases	Dose Rates		Hydrogen Gas Generation Rate per container		Hydrogen Gas Generation in the Storage Area at Maximum Capacity		Hydrogen Gas Generation in the Storage Area at Maximum Capacity	% Volume
73	Expected Case	50	[R/hr]	=C73*$C$35/$C$33	[L/hr]	=$C$70*E73	[L/hr]	=G73*24*365	[L/yr]	=I73/$E$20
74	Hot Container	100	[R/hr]	=C74*$C$35/$C$33	[L/hr]	=$C$70*E74	[L/hr]	=G74*24*365	[L/yr]	=I74/$E$20
75	Hot Container	300	[R/hr]	=C75*$C$35/$C$33	[L/hr]	=$C$70*E75	[L/hr]	=G75*24*365	[L/yr]	=I75/$E$20
76	Hot Container	500	[R/hr]	=C76*$C$35/$C$33	[L/hr]	=$C$70*E76	[L/hr]	=G76*24*365	[L/yr]	=I76/$E$20

APPENDIX C
HDPE (POLY) HIGH INTEGRITY CONTAINERS (HIC)
CONTAINER INTEGRITY ASSESSMENT

Historical Background

On March 1989 the United States Nuclear Regulatory Commission (NRC) issued Information Notice (IN) 89-27, "Limitations on the use of Waste Forms and High Integrity Containers for the Disposal of Low-Level Radioactive Waste" following the review of various vendors Topical Reports (TRs) on HICs. The NRC staff concluded that High Density Polyethylene (HDPE) did not satisfy the requirements for waste form stability in accordance with 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste" and the subsequent Branch Technical Position Paper on waste form, unless special provisions are made at the disposal site. As a result the NRC did not approve HDPE containers as HICs for the disposal of Low-Level Radioactive Waste (LLRW). The special provision cited here involves placement of the HDPE containers in concrete overpacks for burial. In this burial configuration the concrete overpack is the HIC not the HDPE container. The NRC did not approve HDPE containers as HICs due to concerns relating to container integrity for a period of 10 half lives of the longest lived significant isotope which equates to 300 years for resin waste. In resin waste, the predominant isotope is Cs-137 with a half life of 30 years. This concern was substantiated by several studies conducted in the 1980s by Brookhaven National Laboratory (BNL) for the NRC (see Section 2.0 of this report). In essence multiple BNL studies concluded that HDPE materials displayed a susceptibility to crack formation due to exposure to oxygen, and increased cross-linking leading to embrittlement after prolonged exposure to gamma radiation.

Since the closure of the Barnwell, SC commercial low-level radioactive waste disposal site to non-compact members in July 1, 2008; thirty six (36) states, the District of Columbia, the Commonwealth of Puerto Rico and the U.S. Territories are unable to ship Class B and Class C wastes to a disposal site. Class A waste can still be disposed of at the Envirocare, Clive Utah site. Extended storage of LLRW at onsite Radwaste storage facilities is now the only available option for non-compact LLRW generators. The NRC position on HDPE as HICs is problematic for extended storage of HICs in air before ultimate disposal. The use of concrete overpacks for each HIC in an on-site storage facility is not a feasible option due to cost and space constraints. Therefore the service life for HDPE containers for storage in air must be estimated to determine how long the container will maintain its physical integrity under site specific storage conditions before the onset of material degradation effects.

1.0 Introduction

Exelon Corporation (Exelon) has full or majority ownership of eleven (11) nuclear power plants, all of which (except for Oyster Creek located in New Jersey) are affected by the closure of the Barnwell disposal site. New Jersey, Connecticut and South Carolina are members of the Atlantic Interstate Low-Level Radioactive Waste Management Compact. Exelon has an immediate need to utilize its existing interim Radwaste storage facility (IRSF) at LaSalle (Illinois) for extended storage of Class B and C LLRW generated at its Byron, Braidwood, and Clinton Stations. Exelon plans to use Energy Solutions (ES) stackable-grapple compatible HDPE 8-120B containers for storage of Class B/C LLRW. Exelon has requested that URS Washington Division conduct an assessment of the service life of HDPE containers when used as HICs for extended storage in air.

The ultimate objective of this assessment is to determine whether HDPE containers exposed to air, gamma radiation and stacking stresses under storage conditions will maintain their physical integrity for the duration of the extended storage period and will not rupture when subjected to handling for transportation to a future disposal site. The NRC does not give a time frame for extended storage. Exelon has defined extended storage as life of plant plus 40 years which is established as 80 years.

2.0 Summary of Concerns

Brookhaven National Laboratory HDPE Study Results

The NRC commissioned BNL to perform a series of tests to investigate the effects of chemical environments on the mechanical properties of HDPE. BNL produced several publications on this subject all of which had essentially the same conclusion. For brevity this assessment will focus on BNL-NUREG-52196 (Reference 1) because the testing conducted in this study represents typical site specific conditions to which HDPE containers will be exposed during extended storage at LaSalle IRSF. BNL contends that an oxidized layer (about 5 microns) is introduced to the internal surface of HDPE material during the high temperature (300°C) rotational molding process making it prone to crack initiation under relatively low stresses. U-bend samples from as-received HDPE container material exhibited this phenomenon. BNL conducted U-bend tests on as-received container materials to observe the effects of chemical environments on polymer material properties. The U-bend samples were segregated into three groups as follows:

- Type I – as-received HDPE material with oxidized surface intact, which had "natural" cracks present due to bending into U-bend configuration.
- Type II – same as Type I material but with 0.010 inch of the oxidized surface removed with fine abrasive paper prior to bending. No cracks were seen after bending.
- Type III – as-received, non-oxidized HDPE material (that is the surface in contact with the mold during the manufacturing process which does not get oxidized). No cracks were seen after bending.

This study concluded based on the test results, that exposure to atmospheric oxygen occurring simultaneously with gamma radiation exacerbates the propagation and nucleation of "natural" cracks present in oxidized HDPE material resulting in an eventual loss of ductility. This study also concluded that the onset of failure/rupture of HDPE containers will be increased by the rate of creep due to application of high stresses in these environments.

BNL U-bend Test Results for exposure to atmospheric oxygen

Since oxygen is known to be detrimental to HDPE properties, BNL performed U-bend tests in air, deionized water (DIW), Nitrogen (N_2) and vacuum (oxygen-free) environments at 20°C (68 ^{o}F) using 1/8 inch thick samples cut from the walls of as-received HDPE rotationally-molded drums. The test was conducted in two cycles, the first lasting a period of 227 days and the second cycle for an additional 210 days, for a total of 437 days. Neither the width nor the depth of cracks was quantified in this study. Large cracks were classified as cracks with lengths measuring greater than ¼ inch and small cracks were classified as cracks with lengths less than ¼ inch. Table 1 and Table 2 from the study provide a summary

of the test results. BNL concluded from these results that specimens tested in air, water and nitrogen give larger crack growth rates than those for the vacuum. The abundance of oxygen was identified as the most likely reason for this enhanced cracking.

Table 1: Cracking in Type I HDPE U-bend specimens exposed for 227 d to various test environments at room temperature.[1].

(Table 1 extracted from BNL HDPE study Reference 1)

Environment	Cracks Before Exposure			Cracks After Exposure			Percent Change in Number of Cracks		
	Large	Small	Total	Large	Small	Total	Large	Small	Total
Air	48	58	106	70	63	133	45.8	8.6	25.5
DIW	41	48	89	69	50	119	68.3	4.2	33.7
N_2	44	34	78	63	36	99	43.2	5.9	26.9
Vacuum[2]	58	52	110	80	46	126	37.9	-11.5	14.6

Notes:

1. The numbers of cracks are the totals counted for each batch of 8 replicate specimens.
2. Vacuum not maintained throughout test period.

Table 2: Cracking in Type I HDPE U-bend specimens exposed for 437 d to various test environments at room temperature.[1]

(Table 2 extracted from BNL HDPE study Reference 1)

Environment	Cracks Before Exposure			Cracks After Exposure			Percent Change in Number of Cracks		
	Large	Small	Total	Large	Small	Total	Large	Small	Total
Air	48	58	106	85	51	136	77.1	-12.1	28.3
DIW	41	48	89	79	45	124	68.3	-6.3	39.3
N_2	44	34	78	67	36	103	52.3	+5.9	32.1
Vacuum[2]	58	52	110	87	42	129	50.0	-19.2	17.3

Notes:

1. The numbers of cracks are the totals counted for each batch of 8 replicate specimens.
2. Vacuum maintained throughout the second test period of 210 d.

BNL U-bend Test Results for exposure to gamma radiation

BNL conducted two different sets of U-bend tests for gamma irradiation utilizing Co-60. Eight 1/8 inch thick large specimens (10”L x 1”W) were prepared for scoping tests on irradiation embrittlement. Table 3 summarizes observations made on the large U-bend specimens. A second 1/8” thick U-bend sample (4”L x 0.5”W) was prepared and separated into Type I, Type II and Type III samples as

described above. These samples were subjected to gamma radiation environments for a duration of 350 days for the first cycle and for an additional 180 days for the second cycle for a total of 530 days, at a temperature of 10°C (50°F) to determine crack propagation effects for three gamma dose rates of 1.4 x 10^3 rad/hr, 8.4 x 10^4 rad/hr and 4.4 x 10^5 rad/hr in air. A set of unirradiated control samples were stored in a refrigerator at 10°C (50 °F). Type I test results are summarized in Table 4 (first cycle) and Table 5 (second cycle). For the first irradiation cycle all irradiated specimens showed a larger increase in the numbers of cracks compared to unirradiated specimens. After the second irradiation cycle the largest numbers of new cracks were found in unirradiated material; the irradiated samples showed no new crack initiations. Type II and Type III sample results were not summarized in a table for this study, but these samples generally displayed less numerous and fine cracks compared to Type I samples. This was attributed to the fact that the oxidized layer introduced into the samples from the manufacturing process, was removed in the Type II samples, and was not present in the Type III samples.

BNL concluded from these findings that, overall, gamma irradiation in air led to rapid growth in both small and large crack densities (Table 3). Low and intermediate dose rates give the larger cracking effects (due to the number of full penetration cracks at these rates, (see Table 4 and Table 5), and the lack of new crack initiations at low and intermediate doses may be a result of stress relaxation in the irradiated U-bend samples caused by polymer chain scission mechanisms.

Table 3: Observations on Marlex CL-100 HDPE U-bend specimens exposed to gamma radiation

(Table 3 extracted from BNL HDPE study Reference 1)

Dose (rad)	Dose Rate (rad/h)		
	3.4 x 10^3	**5.6 x 10^4**	**2.1 x 10^6**
4.9 x 10^6	Cracks appear to grow.	Specimen color is light brown	-
1.6 x 10^7	Cracks definitely growing. Specimen color is tan.	-	-
2.0 x 10^7	One crack propagated through specimen	-	-
2.9 x 10^7	Little additional crack propagation. Specimen still flexible.	-	-
3.6 x 10^7	Large crack at apex still propagating. Another crack also growing rapidly. Both cracks almost full penetration. Specimens have slight odor.	-	-
9.9 x 10^7	(a)	-	Specimen color dark brown

1.6×10^8	(a)	Specimen color medium brown. One crack growing.	-
3.2×10^8	(a)	Several cracks growing in size	-
5.9×10^8	(a)	Noticeable crack growth in both specimens. Cracks about 50% through thickness of specimen.	-
1.2×10^9	(a)	(a)	Specimen becoming sticky. Small shiny areas developing.
2.9×10^9	(a)	(a)	Specimen very sticky, brown/black color. Strong aroma noticed.
5.8×10^9	(a)	(a)	Small surface bubbles form on original shiny areas.
8.8×10^9	(a)	(a)	Many bubbles now seen on surface. Specimen black.
1.7×10^{10}	(a)	(a)	Tests terminated. Specimens completely brittle, no longer sticky.
(a) Dose not yet reached.			

Table 4: <u>Crack initiation and propagation in Type I HDPE U-bend specimens after the first gamma irradiation cycle</u>[(1)]

(Table 4 extracted from BNL HDPE study Reference 1)

Irradiation	Cracks Before Irradiation			Cracks After Irradiation			Percent Change in Numbers of Cracks			Full Penet. Cracks	Near Full Penet. Cracks
Dose	Large	Small	Total	Large	Small	Total	Large	Small	Total		
0	84	11	95	90	13	103	7	18	8	0	0
7.5×10^6 (at 1.4×10^3 R/h)	81	3	84	97	3	100	20	0	19	2	1
6.0×10^7 (at 8.4×10^4 R/h)	78	2	80	95	4	99	22	100	24	2	4
1.3×10^9 (at 4.4×10^5 R/h)	69	3	72	82	4	86	19	33	19	0	1

<u>Note</u>: [(1)] The numbers of cracks are the totals counted for each batch of eight replicate samples.

Table 5: <u>Crack initiation and propagation in Type I HDPE U-bend specimens after the second gamma irradiation cycle[1]</u>

(Table 5 extracted from BNL HDPE study Reference 1)

Irradiation Dose	Cracks Before Irradiation			Cracks After Irradiation			Percent Change in Numbers of Cracks			Full Penet. Cracks	Near Full Penet. Cracks
	Large	Small	Total	Large	Small	Total	Large	Small	Total		
Unirradiated Controls	84	11	95	95	15	110	13	36	16	0	0
1.3×10^7 (at 1.4×10^3 R/h)	81	3	84	97	3	100	20	0	19	7	1
9.5×10^7 (at 8.4×10^4 R/h)	78	2	80	94	8	102	21	300	28	7	1
3.1×10^9 (at 4.4×10^5 R/h)	69	3	72	83	3	86	21	0	19	1	0

<u>Note</u>: [1] The numbers of cracks are the totals counted for each batch of eight replicate samples.

<u>BNL Test for Creep effects</u>

BNL conducted creep tests on 1/8 inch thick samples at 20°C (68°F) using a simple constant load system. Strains were measured using Linearly Variable Differential Transducers (LVDTs). Figure 1 is a plot of test results for the different test environments. The graph depicts a linear relationship between applied stress and time. <u>BNL concluded that if the stress levels in a waste container are kept significantly below 6.89 MPa (1,000 psi) then HDPE should be immune to a creep-type failure mode.</u> Figure 2 from the creep test, shows the relationship between applied stress and ductility. BNL found that for samples which can be readily examined during the test, such as those exposed to air, fine cracks in the oxidized surface formed after about 20% (>8 MPa or 1,160 psi) elongation.

Irradiation during creep tests were also conducted in air at gamma dose rates of 5×10^3 rad/hr and 2×10^4 rad/hr. <u>This BNL study concluded that irradiation causes increased cross-linking in HDPE and reduced creep rate at low dose during creep.</u>

Figure 1: <u>Stress-rupture results for Marlex CL-100 HDPE tested at 20°C in various environments</u>

(Figure 1 extracted from BNL HDPE study Reference 1)

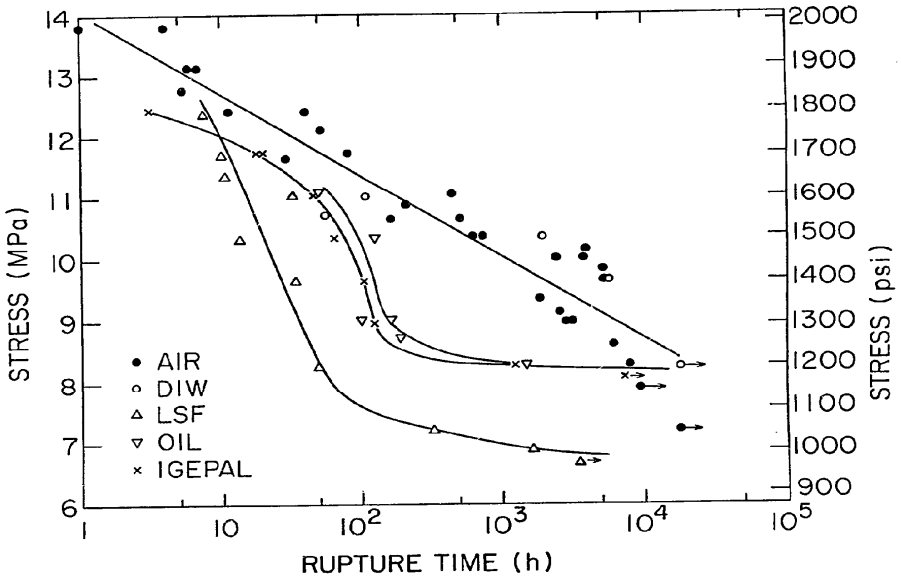
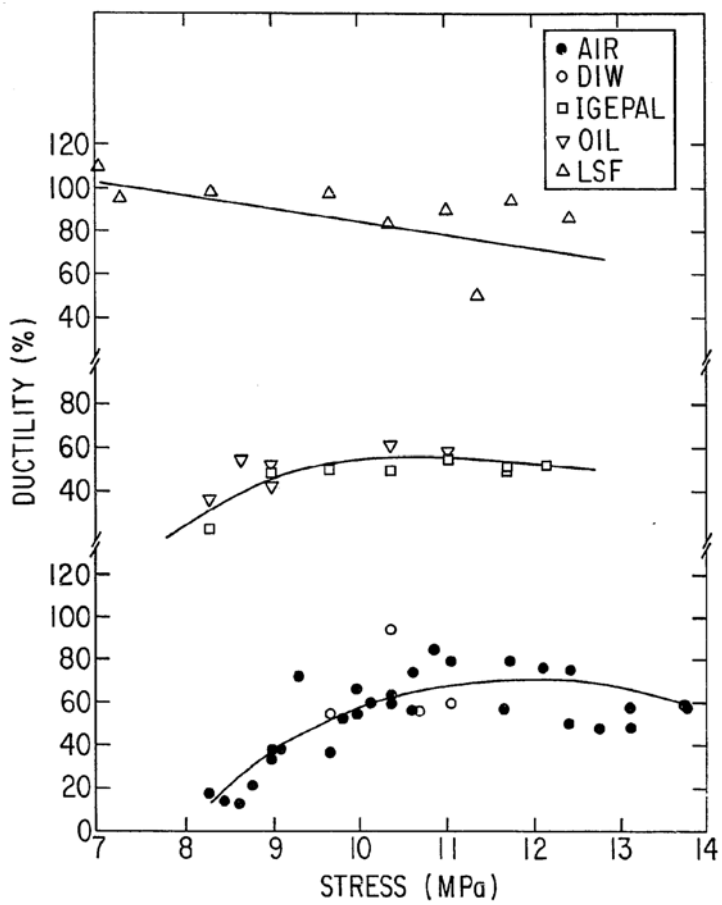


Figure 2: <u>Elongations at failure for Marlex CL-100 HDPE tested at 20°C in various environments</u>

(Figure 2 extracted from BNL HDPE study Reference 1)



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3.0 Discussion

3.1 Oxidation Effects on ES HDPE 8-120B Container

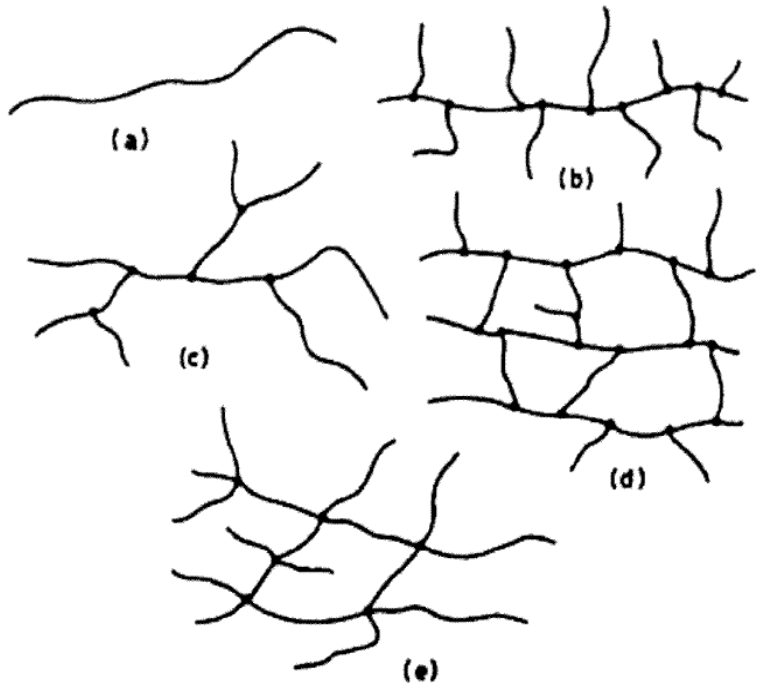
The BNL-NUREG-52196 study shows that chemical aging takes place in the HDPE material eventually leading to a reduction in engineering properties, and that creep due to high stresses is a phenomenon that will lead to deformation in HDPE materials. The containers to be stored in LaSalle's IRSF will be exposed to an environment of air and gamma radiation (beta radiation will accompany the gamma radiation, but the short range of betas effectively removes them from consideration here). The proposed IRSF storage configuration is to stack the containers atop each other two high. For this application, the chemical aging of the containers in storage is of primary concern and will be assessed in detail in this report. The effect of creep is considered as a secondary concern due to the intended arrangement of the proposed HDPE containers, as ES, the vendor of the stackable–grapple compatible HDPE 8-120B containers, attests that the design of the stackable lifting baskets in which the HDPE container is emplaced transfers the stresses due to stacking and lifting from the HDPE container to the steel basket, and then to the floor. This will be discussed in greater detail in Section 3.3 of this assessment.

Changes in HDPE material properties due to exposure to air and gamma radiation are inevitable. The challenge is to determine how these changes may be mitigated under IRSF-specific conditions and the resulting expected service life of the container in this facility. This assessment will consider mitigating factors such as (a) the addition of anti-oxidants in the polyethylene (PE) resin which retards the degradation effects of oxygen until the anti-oxidants are depleted, (b) the calculated actual total integrated dose (TID) expected in the IRSF over the maximum established 80 year storage period compared to the relatively high TID used in the BNL study which resulted in crack initiation, propagation and nucleation and (c) the thickness of the proposed HDPE container compared to the 1/8 inch sample specimen used in the BNL study.

Addition of anti-oxidants in PE resin

The 8-120B HDPE container proposed for extended storage is manufactured from SCHULINK XL-350S-01G HDPE resin (see Attachment A for technical and material safety data sheets). This resin is a thermosetting plastic, meaning it can be cured, set or hardened into a permanent shape. The curing (rotational molding) process is an irreversible chemical reaction known as cross linking (see Figure 3, (d and e)). The finished cross linked product is a crystalline structure with increased density, tensile strength, and stiffness capable of withstanding higher temperatures.

Figure 3: Schematic of Cross-linked Polyethylene
(Figure 3 extracted from Plastics Technology Handbook, Reference 12)



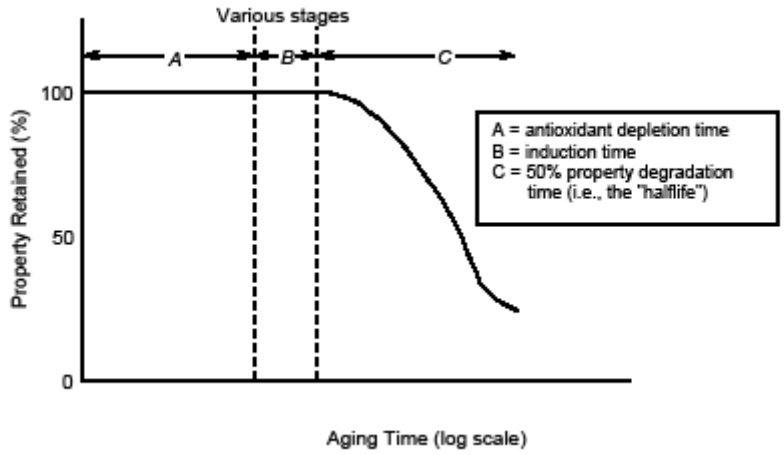
Schematic representation of (a) linear, (b and c) branched, and (d and e) cross-linked polymers. The branch points and junction points are indicated by heavy dots.

HDPE reacts with atmospheric oxygen resulting in oxidation, the effect of which is the breaking of bonds or chain scission in the polymer structure, eventually causing material degradation and failure. Polymers are formulated with anti-oxidants (AO) to prevent oxidation reactions from occurring. The XL-350S PE resin used to manufacture the 8-120B container, is formulated with an AO package (see Attachment B, for manufacturer confirmation of an AO package). The AO package prevents oxidation by deactivating emerging free radicals and unstable intermediate products. In this deactivating process, the AO are consumed to the point where polymer oxidation can no longer be avoided. (M.C Cramez et al, Reference 13). The time to reach complete consumption of the AO package is the oxidation induction time (OIT). **Thus, the effects of atmospheric oxygen on polymer material degradation are not a factor until the AO in the polymer structure are depleted.**

According to the Geo-synthetic Institute (GSI) which has performed numerous experimental and field studies on the service life of HDPE geo-membranes, the oxidation process involves three distinct stages (see Figure 4):

- Depletion time of antioxidants where no property changes occur
- Induction time for oxidation to begin with minor property changes
- Time to reach a specified reduction in the value of a significant engineering property, e.g. elongation, tensile strength, etc.

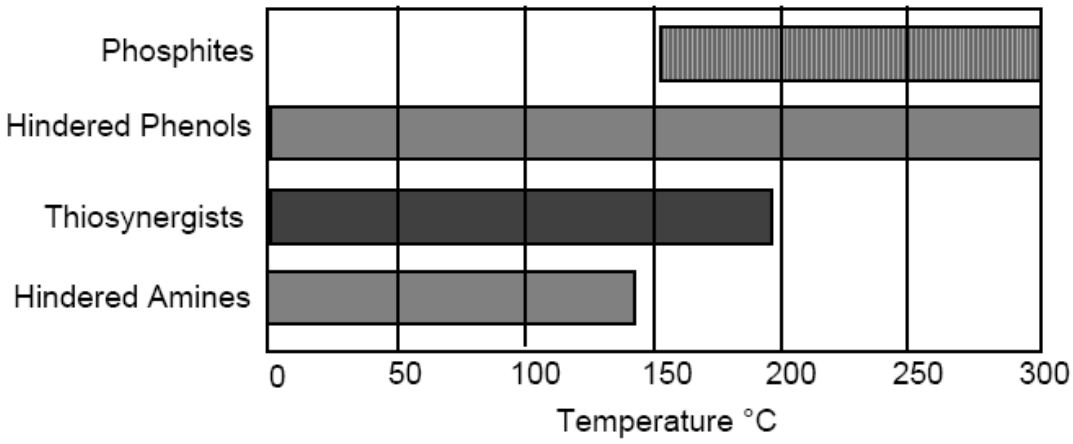
Figure 4: The <u>Three conceptual stages of chemical aging of HDPE Geo-membranes (GMs)</u>
(Figure 4 extracted from EPA geo-membrane study Reference 2)



<u>Stage A – Anti-oxidants depletion time</u>

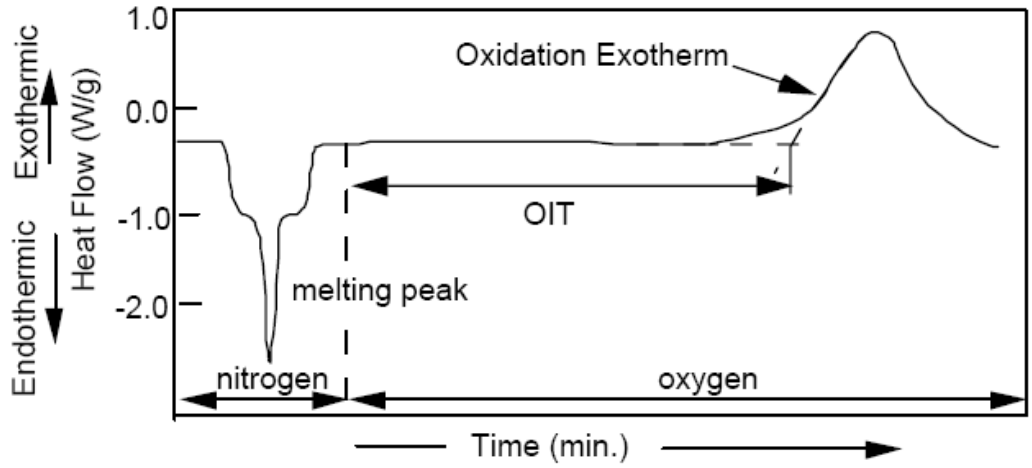
The length of time for anti-oxidants to deplete in a polymeric material is greatly dependent on its formulation which varies from manufacturer to manufacturer. As a minimum the anti-oxidant package should contain primary category chemicals such as hindered phenols and hindered amine light stabilizers (HALS) and secondary category chemicals such as phosphites, sulfur compounds, HALS and thiosynergists; to ensure that the product is protected at both the high temperature rotational molding process and the lower temperature during its lifetime. To ensure long term service life, a manufacturer will use two or more types of anti-oxidants; typically one from a primary category and another from the secondary category. Figure 5 is a depiction of the effective temperature ranges of the different types of AO packages.

Figure 5: <u>Effective temperature ranges of the four anti-oxidant types</u>
(Figure 5 extracted from EPA geo-membrane study Reference 2)



The chemical type, chemical name and percentage of AO in the XL-350S PE resin are proprietary information, but an indication of AO formulation can be determined from ASTM testing methods such as OIT. Two options are available to evaluate the AO depletion time they are the standard OIT test (STD-OIT) per ASTM D3895 and high pressure OIT test (HP-OIT) per ASTM D5885. Both tests are conducted using a differential scanning calorimeter (DSC). For the STD-OIT test the polymer sample is melted at room temperature to 200° C under a nitrogen atmosphere. When the 200° C is achieved the sample is maintained in an isothermal condition for 5 minutes, then the gas is switched from nitrogen to oxygen. The test is terminated when an exothermal peak is detected. The HP-OIT differs from the STD-OIT in temperature and pressure range only. For the HP-OIT test the polymer melt temperature is 150° C at a pressure of 5500 kPa as opposed to 35 kPa for the STD-OIT. The purpose of the difference in test temperatures is to compensate for the effective temperature ranges for HALS type AO formulation (see Figure 5), which will rapidly volatilize in a STD-OIT test, thereby giving a low OIT value which may not be indicative of the actual service life of the AO package. The purpose of the higher pressure is to compensate for the lower temperature at which the HP-OIT test is conducted which results in a long test duration at the standard 35 kPa pressure, therefore a higher pressure is applied for a practical test duration. Figure 6 is a typical thermal curve for both STD-OIT and HP-OIT.

Figure 6: Thermal Curve of OIT test
(Figure 6 extracted from EPA geo-membrane study Reference 2)



From figure 6, the first (very large) downward peak is the melting of the HDPE sample (under nitrogen gas) due to the temperature going from room temperature up to 200°C or 150°C for STD-OIT and HP-OIT respectively. The second small peak is the replacement of nitrogen gas environment with oxygen gas. From this second peak onward the antioxidants (AOs) are protecting the resin from being consumed (i.e., oxidized) by the oxygen gas. Thus, the time frame from this <u>second</u> peak to where the curve begins to rise is the OIT-value, i.e., the time duration for the oxygen gas to consume the AOs and start degrading the resin. The OIT time in minutes obtained from either test can be used to determine the AO depletion time in years in the resin formulation. GSI under the sponsorship of the United States Environmental Protection Agency (USEPA) conducted years of research on HDPE geo-membranes to determine the longevity of the material in in-situ applications, and a summary of their testing is presented in Reference 14. Essentially GSI performed incubation testing of HDPE geo-membranes under various temperatures and pressures over a period of 24 months and the OIT test was performed on these incubated samples at specified intervals. The OIT depletion rate (min/month) was determined from this testing by plotting the natural log of OIT against the incubation time. Next, the OIT depletion rate is extrapolated to a site-specific temperature (from the experimental temperature) by using the Arrhenius equation. The Arrhenius equation is based on a time-temperature superposition principle. It uses high temperature incubation of the polymer material in question, followed by lab testing (in this case OIT), to extrapolate the incubation experimental behavior to a site-specific, and lower temperature. The assumption is that the material's behavior at the high incubation temperature (indicated by the material's activation energy) is constant within this range and can be extrapolated to the lower temperature behavior of interest. Using this methodology, GSI calculated the AO depletion time on the geo-

membranes tested to be 200 years. GSI established, based on their studies, that 200 years of service life of geo-membranes equates to 100 minutes STD-OIT or 400 minutes HP-OIT.

A 6 inch square sample from a newly rotational molded 8-120B HDPE container was provided by Assmann Corporation (manufacturer of Energy Solutions 8-120B container) was tested for both STD-OIT and HP-OIT. Table 6 is a summary of the test results (Attachment H is the summary and computer output of ASTM D3895 and ASTM D5885 lab testing by TRI/Environmental Inc – a GSI certified laboratory).

Table 6: OIT test result for 8-120B HDPE Sample

Parameter	Test Replicate Number	OIT (minutes)
STD-OIT (ASTM D3895)	1	17
HP-OIT (ASTM D5885)	1	303

The results give an indication that the AO formulation of the 8-120B HDPE container is of the HALS variety, since it produces a much shorter STD-OIT time. The HP-OIT results will thus be used to determine the service life of the 8-120B HDPE container. Before establishing the AO depletion time in years based on above test results, it is important to understand that there are factors that may accelerate the otherwise slow process of AO depletion.

The depletion of anti-oxidants is a slow process and can be caused by two mechanisms, chemical reactions of the anti-oxidants and physical loss of anti-oxidants from the polymers by leaching (Koerner et al, Reference 2). The depletion of anti-oxidants due to chemical reactions is dependent on the chemical formulation of the product (the OIT results will give an indication of the package formulation). The depletion of anti-oxidants due to physical loss is a function of the anti-oxidants volatility and extractability. The volatility of anti-oxidants is a thermally activated process; wherein temperature changes affect the evaporation of the stabilizers from the polymer surface as well as its diffusion from the interior to the surface layer. For the proposed HDPE container the low temperature condition in the IRSF is expected to be nominally 75°F therefore volatility of anti-oxidants will not be a factor. Extractability of anti-oxidants becomes a factor if the proposed HDPE container comes into contact with liquids such as water. This is not a concern because the proposed HDPE container will contain dewatered resin beads. Dewatering removes all free standing water in the container to less than 1% by volume in accordance with NRC regulatory guidance (Generic Letter 81-38). All remaining water is absorbed, i.e., adsorbed in the resin beads or entrapped in the interstitial space between resin beads. Another

BNL study, BNL-NUREG-51841 (Reference 3), states that ion-exchange resins lose their ability to retain water and release free liquid at increased radiation dose. For anion resin this phenomenon was seen at 3 x 10^8 Rads and for cation resin at 5 x 10^8 Rads. Dewatered ion-exchange resins to be stored in the LaSalle IRSF are not expected to ever see an accumulated dose greater than 10^8 Rads (see Section 3.2 for detailed gamma radiation discussion) for the maximum storage period of 80 years. Therefore the ion-exchange resins are not expected to lose their ability to retain water and release free liquid. Furthermore, Table 7 extracted from the Plastics Technology Handbook shows that the water absorption of polyethylene is less than 0.01% for a 1/8 inch (3.2 mm) sample tested. This indicates that polyethylene is fairly resistant to water absorption. In addition, the LaSalle IRSF is not equipped with a fire suppression system (i.e. sprinklers), so the containers will not be exposed to standing water resulting from a sprinkler system activation or malfunction. Based on the foregoing conditions, it can be concluded that the proposed HDPE container is not expected to be exposed to significant leaching effects of bulk free standing water, so extractability of anti-oxidants from the HDPE container is not expected to be significant.

Table 7: Assessment of Plastics and Rubbers Resistance
(Extracted from Plastics Technology Handbook, Reference 12)

Material	Water abs. (%) (24 hr on sample 3.2 mm thick)
Polyester resins (flexible)	0.1-2.4
Poly(methyl methacrylate)	0.3-0.4
Polyethylene	<0.01
Polypropylene	0.01-0.1
Polystyrene	0.03-0.05
Polytetrafluoroethylene	0.00
Nylon (molded)	1.5
Rubbers (extruded)	0.4
Chlorinated rubber	0.1-0.3

Based on GSI's GRI-GM 13 specification, "Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes"(Reference 15) it is established that 100 minutes STD-OIT equates to 200 years AO depletion time and 400 minutes HP-OIT equates to 200 years AO depletion time. As indicated from OIT test results of 8-120B HDPE sample, the AO formulation is of the HALS variety due to the higher OIT time for this test, therefore, the HP-OIT time will be used to calculate the AO depletion time in years. Assuming that the AO package for the 8-120B container responds similarly to the experimental samples used to create GRI-GM 13 specification, a linear scaling will suggest the following:

HP-OIT Results

$$AO(years) = \frac{303\,\text{min}\,utes}{400\,\text{min}\,utes}(200\,years) = 152\,years$$

For conservatism the AO depletion time for the purpose of this study is established as 100 years per the recommendation of Dr. Koerner, Director GSI; to compensate for standard deviation in the test and site specific extended storage conditions. Dr. Koerner recommends additional testing such as UV and oven aging of the proposed 8-120B container sample to augment the OIT test results. The only purpose of these additional tests will be to serve as additional indicators that the 8-120B AO package continues to behave in a manner similar to the AO packages of the experimental samples from which the GRI-GM13 specification was formulated (see Attachment D for correspondences with Dr. Koerner, establishing 100 years AO depletion time for 8-120B HDPE sample).

Stage B – Induction Time

Once the AO is completely depleted, oxygen will begin to attack the polymer, leading to the induction time. PE resins manufactured without an AO package do not immediately begin to degrade or show signs of degradation. Instead studies have shown that an appreciable amount of time elapses before degradation of material properties due to oxidation effects is observed. It is impossible to determine the length of time after AO depletion that degradation due to oxidation occurs. Therefore, to be conservative, no credit is taken for stage B induction time.

Stage C – 50% Property Degradation

This stage, by definition, represents the half-life or length of time for a HDPE material to reach 50% degradation in its engineering properties. The rate at which this stage occurs is dependent on factors such as temperature, chemical environments and stresses on the HDPE material. The proposed HDPE container

in the LaSalle IRSF will be exposed to atmospheric oxygen, gamma radiations, ambient temperature conditions, and low stacking stresses which are discussed in Sections 3.2 and 3.3.

3.2 Site Specific Gamma Irradiation Effects

To quote Dr. Peter Soo the author of BNL-NUREG-52196, "without atmospheric oxygen, gamma radiation is far less damaging to plastics" (see Attachment C for email correspondence with Dr. Soo). This is in agreement with Parkinson and Sisman's work (Reference 4), wherein they stated that the net result on the effect of oxygen on the rate of radiation damage appears to be predominantly an increase in scission rate when oxygen is present. It can be concluded then that the effects of gamma radiation on the proposed HDPE containers will not be a factor until after the anti-oxidants in the container material have been depleted and oxidation due to atmospheric oxygen begins to diffuse within the material. To assess how damaging gamma radiation will affect the proposed container properties, the TID over a period of 80 years must be calculated. To obtain this, a sample isotopic mix of waste generated at Exelon's Peach Bottom Generating Station was used and is considered conservative. The isotopic mix comprised of more than typical short lived and long lived isotopes such as Ag-110m, Co-58, Co-60, Cs-134, Cs137/Ba137m, Mn-54, Nb-95, Sr-92 and Zn-65. Co-60 was the most important isotope in the mix but not completely dominant. The TID at 5 years is calculated to be 5 x 10^6 Rads and at 80 years to be 1.2 x 10^7 Rads at a dose rate of 241 rad/hr of which 109 rad/hr is from Co-60 (see Attachment E for calculation spreadsheet). Figure 7, is a graphical representation of calculated TID versus number of storage years.

From BNL gamma radiation testing (Table 3) it was observed that at 4.9 x 10^6 Rads cracks appear to grow and at 1.6 x 10^7 Rads cracks were definitely growing. These two doses closely represent Exelon site expected actual dose at 5 years and 80 years respectively (Figure 7). It can be concluded based on Table 3 results that the proposed HDPE container in LaSalle IRSF will display growth in surface cracks within 5 years and will show signs of definite crack growth around 80 years. These cracks are not expected to propagate to failure since maximum IRSF TID at 80 years is 1.2 x 10^7 Rads, which is less than 5.9 x 10^8 Rads at which sample specimen in Table 3 displayed cracks propagating through 50% of the specimen thickness. Also the proposed HDPE container in the LaSalle IRSF will maintain its ductility throughout the 80 years storage period since the TID at 80 years is significantly less than the 1.2 x 10^9 Rads at which the 1/8 inch sample specimen from Table 3 starts to show signs of embrittlement.

The Polymer Volume 36 (Reference 13) documents a study on structural changes due to irradiation in the presence of air using infra-red spectroscopy on HDPE samples. The samples were irradiated by a Co-60 gamma ray source at room temperature in air. Doses up to 1.0 x 10^8 Rads at a dose rate of 4.72 x 10^5 Rads/hr

were used. The findings were as follows (a) at doses less than or equal to 1.0 x 10^7 Rads no formation of carboxylic groups (byproduct of oxidation) was detected and cross linking of the HDPE sample was the predominant effect of irradiation at this dose (b) at doses between 1.0 x 10^7 Rads to 2.0 x 10^7 Rads cross linking and degradation are the predominant phenomena and (c) for doses greater than 2.0 x 10^7 Rads oxidative degradation predominates which was evidenced by the increase in carboxylic groups. Applying the results from the infra-red spectroscopy results to LaSalle IRSF TID conditions it can be concluded that from 5 – 30 years (dose $\leq$ 1.0 x 10^7 Rads) the proposed HDPE container will primarily undergo low density cross linking as a result of gamma radiation. There will likely be some increase in tensile strength, density and stiffness, although the HDPE material is expected to maintain its ductility. The thickness of the container minimizes the rate of cross linking (this will be discussed further in material thickness section). Between 40 – 80 years no degradation of the material is expected to occur because the maximum TID at 80 years never equals or exceeds 2.0 x 10^7 Rads at which degradation predominates.

Effect of Radiation on Material Thickness

Table 4 and Table 5 of BNL study also shows near full and full penetration cracks at low and intermediate doses. It is important to note that the specimen tested were 1/8 inch thick and bent into the U-bend configuration prior to gamma irradiation in air. It is assumed that the oxygen rich testing environment, together with the gamma dose and applied stress on the small, thin specimen may have been the cause of the full penetration cracks. In Parkinson and Sisman's work (Reference 4) it is stated that the diffusion of oxygen into the polymer material will be limited to the surface for thicker specimen and may not affect the bulk properties of the material. Table 8 is extracted from Parkinson and Sisman's work. It summarizes the effect of radiation on mechanical properties of plastics. It shows that for the thicker HDPE material (Super Dylan) which is 0.12 inch (1/8") 80% - 100% of material strength and elongation properties are retained even at greater than 10^9 Rads exposure. For the 0.002 inch thick HDPE material (Marlex-50), only 50 -80% of strength and elongation properties are retained after 10^7 Rads exposure. This indicates a definite relationship with thickness and material degradation properties as a function of gamma dose. In addition the proposed HDPE containers are ½ inch thick cross-linked HDPE material which is denser than the linear HDPE material in this study, so it can be concluded that the rate of diffusion in this material will be significantly less aggressive to material bulk properties, thereby limiting crack propagation and penetration.

Parkinson and Sisman's work is in agreement with the study documented in the Polymer Volume 36 (reference 13) in which the mechanical behavior of HDPE samples of various thicknesses (0.2 mm, 0.3 mm and 0.4 mm) were studied. The effects of gamma radiation on the samples were investigated using a modified dynamic resonance technique. It was found that the polymer chain cross linking

rate, as a result of irradiation by gamma ray doses up to 2.0 x 10^7 Rads depends on the sample thickness. The internal friction and stiffness of the HDPE samples were investigated under irradiation. It was found that at doses up to 2.0 x 10^7 the internal friction (the force resisting motion between the elements making up a solid material while it undergoes deformation) is lower. This was attributed to oxygen diffusing into the samples, with the thinner the samples, the greater the effect of oxygen, causing a greater number of chain scissions. The same phenomenon was discovered in the stiffness of the HDPE samples at the same dose. Oxygen diffusion was credited for the decrease in stiffness in the thinner samples, with a higher diffusion of oxygen into the thinner samples causing greater oxidative degradation, and reduction in sample's stiffness. These results indicate that the thickness of HDPE material controls the oxygen diffusion process at low to intermediate doses.

Thus, based on the foregoing assessment, it can be concluded that following AO depletion in the HDPE container and the onset of atmospheric oxygen and gamma radiation degradation effects, the thickness of the proposed container will limit the diffusion of oxygen within the material at the calculated TID doses expected throughout the extended storage period. The material is expected to maintain greater than 80% of its mechanical properties over an extended period of time as indicated by Table 8.

Figure 7: Peach Bottom Accumulated Dose to Container during storage duration

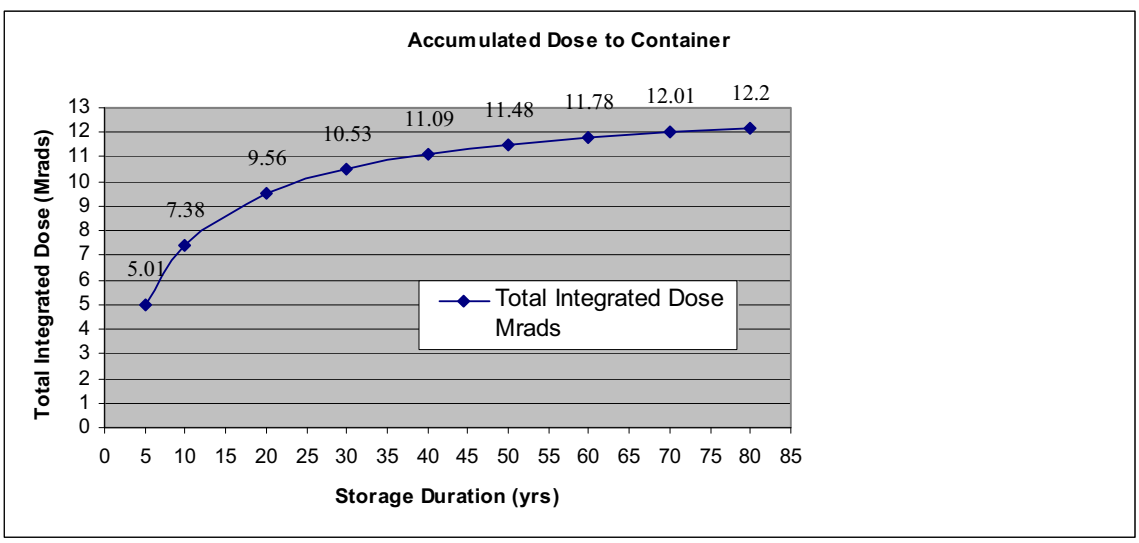
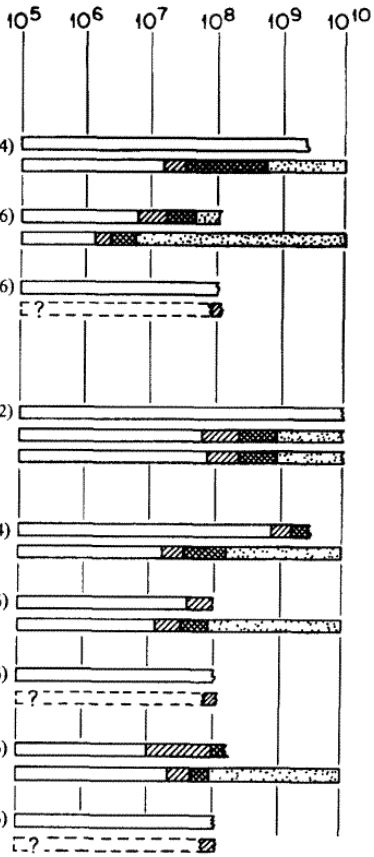


Table 8: Effects of Radiation on Mechanical Properties of Plastics

(Irradiated in air at 25°C unless otherwise noted)

Material	Initial Value[b]	Dose Rate Mrads/hr	Thickness, (in.)	Percent of Initial Value Retained at Given Dose (rads)[a,c]
Thermoplastic Polymers				
A. Hydrocarbon Polymers				
1. High-density (linear) polyethylene				
a. Super Dylan:				
Tensile Strength, psi	3000	2	0.12	(4)
Elongation at Break, %	170			
b. Marlex-50.				
Tensile Strength, psi	4280	1	0.002	(6)
Elongation at Break, %	600			
Irradiated in vacuum:				
Tensile Strength, psi				(6)
Elongation at Break, %				?
Low-density (branched) polyethylene				
a. Alathon:				
Tensile Strength, psi	1400	2	0.19	(2)
Elongation at Break, %	250			
Notch Impact Strength, ft-lb/in.	11.2			
b. Alathon 10				
Tensile Strength, psi	1820	2	0.13	(4)
Elongation at Break, %	450			
c. Alathon 3				
Tensile Strength, psi	1915	1	0.003	(6)
Elongation at Break, %	380			
Irradiated in vacuum:				
Tensile Strength, psi				(6)
Elongation at Break, %				?
d. Irrathene 101:	2390			
Tensile Strength, psi	525	1	0.010	(6)
Elongation at Break, %				
Irradiated in vacuum:				
Tensile Strength, psi		1		(6)
Elongation at Break, %				?



[a]Key for radiation effects:

- 100 to 80% of initial value retained.
- 80 to 50% of initial value retained.
- 50 to 10% of initial value retained.
- 10 to 0% of initial value retained.

[b]To convert lb/in² to Kg/mm², divide by 1422 so that 14220 lb/in² equals 10 Kg/mm². To convert ft-lb to Kg-m/cm, divide by 18.36 so that 0.3672 ft-lb/in equals 0.02 Kg-m/cm.

[c]rad equals 100 ergs/gram of sample material.

3.3 Creep effects due to applied stresses

Stresses due to Stacking

The ES HDPE 8-120B container is enclosed in a steel basket configuration (see Attachment F), for stacking and lifting purposes. The steel basket is comprised of four 1 inch thick straps for wall support, four ¼ inch thick straps for bracing at mid height of the container, four ¼ inch thick straps for securing the base of the container, and one ¼ inch thick rolled angle iron ring at the top for securing components into the basket configuration. The stacking arrangement of the basket is comprised of 3/8 inch thick rolled angle iron ring welded all around the top head of the basket and a ½ inch thick stacking plate with a ¼ inch grapple ring welded to the plate for lifting of the stacking plate. The 3/8 inch angle ring doubles as a lifting arrangement when a grapple is used, otherwise lifting slings designed in accordance with ANSI B30.9 can be provided.

Prior to stacking the HDPE container, a stacking plate is placed between the bottom and top HDPE container assembly. All materials are constructed of ASTM A-36 carbon steel and all load bearing welds are full penetration welds. All steel components are coated with zinc chromate primer and painted with a coat of industrial enamel. Any long term corrosion effects will also be picked up by the periodic video surveillance program. The HDPE container assemblies receive a polyurethane foamed flat top in the void space at the top of the dome head of the HDPE container and the top of the basket for stacking purposes (Reference 5).

ES attests that the design of the lifting basket isolates the HDPE container from service loads due to stacking, which are transferred to the steel basket uprights then to the floor. ES Calculation ST-098 Structural Evaluation of the Stackable-Grapple compatible HIC baskets (Reference 11) analyzes the stresses imposed on the basket as a result of stacking two (2) high. The maximum top load for stacking of the 8-120B is set at 13,500 lbs. Table 9 below summarizes the results of the analysis.

Table 9: Stress Evaluation Results for 8-120B Stackable-Grapple Basket
(Extracted from Energy Solutions Structural Analysis ST-098)

Description	Calculated Value	Allowable	Check
Tensile Stress at weld	4,333 psi	11,610 psi	4,333 psi < 11,610 psi
Bolt shear stress	10,105 psi	14,400 psi	10,105 psi < 14,400 psi
Shear out of angle	6,368 psi	6,960 psi	6,368 psi < 6,960 psi
Bending Stress of stacking plate	21,271 psi	36,000 psi	21,271 psi < 36,000 psi
Deflection of Stacking plate	0.743 in	1.625 in	0.743 in < 1.625 in
Critical buckling load under bolt	393,519 lb		
Critical buckling load in four (4) uprights	14,724 lb		
Buckling safety factor	4.4	3	4.4 > 3

Based on these results it can be concluded that the stacking plate and basket can withstand the maximum gross weight of a loaded 8-120B HDPE container stacked atop without failure while isolating the enclosed HDPE container from stacking loads.

Stresses due to container contents

Since the ES HDPE container assembly design isolates the HDPE container from stresses due to stacking (see Table 9), it can be deduced that the only stresses imposed on the HDPE container will be internal stresses from the dewatered ion-exchange resin (hoop and meroidional stresses). Attachment G is a spread sheet computation of the hoop and meriodional stresses on the HDPE container as a result of the internal pressure of container contents. BNL concluded that if the stress levels in a waste container are kept significantly below 6.89 MPa (1,000 psi) then HDPE should be immune to a creep-type failure mode (Reference 1). From Attachment G the Combined Principal Stress (hoop and meriodional) on the HDPE container resulting from internal pressure of contents is calculated to be 282 psi which is less than 1,000 psi. Therefore it can be concluded that the HDPE container should be immune to a creep type failure.

4.0 Conclusions and Recommendations

4.1 General

The NRC has not approved HDPE container as HICs for burial of LLRW due to concerns relating to container integrity for a 300 years period. This is due in part to studies performed by BNL under the auspices of the NRC. BNL-NUREG 52196 concluded that HDPE material is oxidized during the high temperature rotational molding process and that the oxidized layer formed from this process is susceptible to crack formation and propagation at relatively low stresses and that exposure of HDPE to chemical environments such as air and gamma radiation exacerbates cracking which may lead to failure. This assessment takes into consideration mitigating factors such as the addition of anti-oxidants in the polyethylene formulation, the thickness of the proposed HDPE container, and the calculated low total accumulated dose rate expected over the extended storage period.

4.2 Anti-oxidants Effects

Studies have shown that anti-oxidants added to polyethylene formulation retard the effect of oxidation in the polymer structure until the anti-oxidants are depleted, thereby increasing the service life of the container. The HP-OIT test results for the proposed 8-120B HDPE container is 303 minutes which is equivalent to 152 years AO depletion time. **To allow for standard deviation in testing and the effects of site-specific conditions on the 8-120B HDPE container, the AO depletion time is established as at least <u>100 years</u>**.

With the effects of oxidative environment subverted by anti-oxidants, oxygen atoms are unable to interact with free radicals generated by the radiation field (Reference 1). Therefore gamma radiation effects are minimized without oxygen as a catalyst. This is shown in Table 4 and 5 of this assessment where the largest number of new cracks initiation were found in the second cycle of unirradiated controls exposed to air. No new crack initiations were found in the irradiated samples during the second cycle. This is evidence that gamma radiation alone does not exhibit accelerated crack initiation rate.

Table 5 also show cracks propagating to failure at intermediate doses which are similar to accumulated dose calculated at the end of the extended storage period (see Figure 7). It is concluded based on Table 8 extracted from Parkinson and Sisman's work (Reference 4) that thicker HDPE material is fairly resistant to gamma radiation and will maintain 80% - 100% of its material properties at $>10^9$ Rads. This is in agreement with the dynamic resonance technique testing of HDPE materials documented in Reference 13. It was concluded in this study that at low to intermediate doses polymer chain degradation depends on the sample

thickness, with thinner samples exhibiting a higher oxygen diffusion rate causing a greater number of chain scission and reduction in material stiffness.

4.3 Creep Effects

Creep effect is not a concern for HDPE container storage in air. The design of the HDPE container assembly isolates the HDPE container from service loads due to stacking and lifting. Table 9 of this assessment is a result summary from ES structural analysis ST-098. The stresses due to stacking and lifting are transferred to the basket assembly. The calculated stresses are less than the allowable stresses for tensile, shear, bending, deflection and buckling. The hoop and meriodional stresses on the HDPE container from internal pressure of container contents is calculated to be 282 psi (see Attachment G) which is less than 1,000 psi (6.89 MPa) making the HDPE container material immune to creep type failure.

4.4 Expected Service Lifetime of ES 8-120B HDPE HIC

The life cycle of HDPE material includes three stages (a) AO depletion time, (b) induction and (c) half-life or material properties degradation. The AO depletion time can be derived from either STD-OIT or HP-OIT test results. For this assessment the HP-OIT test result is used to obtain an AO depletion time of at least 100 years for the ES 8-120B HDPE container sample tested. The induction stage is the period immediately following the complete consumption of the AO package. This period lasts an appreciable amount of time dependending on several factors. It is difficult to assign a time frame for this period due to lack of field experimentation in this area. Any amount of years assigned to this period will be based on intuitive engineering judgment; therefore URS Washington Division has not included an induction stage lifetime for this assessment. The material degradation is the final life cycle stage for HDPE material. Again this stage lasts an appreciable amount of time based on chemical makeup of the material and the physical conditions affecting the material's mechanical properties. URS Washington Division believes that the thickness of the ES 8-120B HDPE container, coupled with the low TID expected in LaSalle's IRSF, will minimize the rate of oxygen diffusion into the HDPE material. This belief is supported by recent dynamic resonance technique studies which show that HDPE material thickness controls oxygen diffusion, with thinner material displaying a higher susceptibility to oxygen diffusion within the material structure. **Thus, URS Washington Division, with the support of Dr. Koerner's assessment of HP-OIT test results, has determined that the estimated overall lifetime for ES 8-120B HDPE containers in air for extended storage inside an ambient temperature storage bay is at least 100 years. This lifetime is based only on AO depletion time since no credit is taken for induction and material degradation life cycle stages**.

4.5 Recommendations

It is recommended per Dr. Koerner that additional testing such as oven aging and UV resistance testing be conducted on ES 8-120B HDPE container coupons to augment initial HP-OIT test results. Oven aging and UV resistance testing will give an indication of the percentage of OIT remaining after material exposure to this test environment. In accordance with GSI's GRI-GM13 specification, for HP-OIT following oven aging and UV exposure, the amount of OIT remaining in the HDPE sample tested shall be in the range of 80% and 50% for oven aging and UV, respectively. That is, if after oven aging the HP-OIT value is 242 minutes (80% of initial HP-OIT of 303 minutes), and 152 minutes (50% of initial HP-OIT) after UV exposure, then it can be stated with a greater degree of certainty that the AO depletion time of ES 8-120B HDPE container equates to 152 years (see HP-OIT calculation).

5.0 References

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9. International Atomic Energy Agency (IAEA), "Development of Specifications for Radioactive Waste Packages." IAEA-TECDOC-1515. October 2006.
10. Nuclear Regulatory Commission (NRC), Information Notice No. 89-27: Limitations on the use of Waste Forms and High Integrity Containers for the Disposal of Low-Level Radioactive Waste." March 8, 1989.
11. ST-098, Structural Evaluation of Stackable, Grapple Compatible HIC Baskets Revision 1. January 7, 1993.
12. Manas Chanda, Salil K. Roy, "Plastics Technology Handbook (Plastics Engineering , Vol 47).
13. A.M Shaban, N. Kinawy, Polymer Vol.36 No. 25, pp 4767 – 4770, 1995, "Crosslinking rate dependence on the thickness of high-density polyethylene sheets after gamma-ray irradiation in the presence of air."
14. Y. G. Hsuan and R. M. Koerner, Journal of Geotechnical and Geoenvironmental Engineering / JUNE 1998: "Antioxidant Depletion Lifetime in High Density Polyethylene Geomembranes."

15. GRI Test Method GM13:"Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes" Revision 9, June 2009.

Attachment A

Technical Data

www.aschulman.com

A. Schulman
COMPOUNDING YOUR SUCCESS™

SCHULINK® XL350S

SchuLink XL350 is a cross-linkable high density polyethylene used for rotational molding. This resin offers high impact strength, good abrasion resistance, good stiffness, and excellent environmental stress crack resistance. It is typically used for chemical containment and gas tanks.
NOTE: Physical properties are based on rotationally molded samples from unpigmented resins. Density and ESCR tests were performed on compression molded samples.

Properties	Standard	Parameters		Unit
Chemical				
ESCR	ASTM D1693	100% Igepal	>1000	hours F50
UV stabilization			UV-6	
General				
Density	ASTM D792	-----	.942	g/cc
Melt Index	ASTM D1238	2.16/190	n/a	g/10 minutes
Mechanical				
ARM Impact		(-40°C), 1/8 Specimen	63	ft-lbs
Flexural Modulus	ASTM D790	@ 1% Secant	702	MPa
Flexural Modulus	ASTM D790	@1% Secant	102,000	psi
Tensile Strength @ Yield	ASTM D638	2"/minute	19.3	MPa
Tensile Strength @ Yield	ASTM D638	2"/minute	2,800	psi
Ultimate Elongation	ASTM D638	2"/minutes	350	%
Thermal				
Heat Deflection Temperature	ASTM D648	@ 66 psi	60	°C

Reported values pertain only to natural resins: pigmenting may vary properties. Pellet cut, size, color, and other properties may vary depending on the manufacturing location.

NOTE: While the information herein is believed to be reliable and correct, nothing herein is intended and should not be construed as a representation of warranty, expressed or implied as to results obtained or to be obtained by others who may make use of this information or with respect to the absence, existence or validity of patent rights, if any of others involving any composition or process herein referred to; or an inducement or recommendation for the violation of any such patent rights; and responsibility therefore is disclaimed.

Attachment A

(Cont'd)

Material Safety Data Sheet

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SECTION 1 **PRODUCT AND COMPANY IDENTIFICATION**

Product Name: Schulink XL 350S-01 Natural
Description: Thermoplastics
Item Number: 1020731
Revision Date: January 29, 2009

Contact for Information / Manufacturer Identification:

A. Schulman Inc.
1183 Home Ave.
Akron, OH 44310
Environmental Affairs: 1-800-532-7786
(8:00 am - 5:00 pm EST - Monday through Friday)
Customer Service: 1-800-54-RESIN
Email: ea@us.aschulman.com

SECTION 2 **HAZARDS IDENTIFICATION**

2.1 Emergency Overview
HMIS (US only): Health 1, Fire Hazard 1, Reactivity 0
NFPA: Health 0, Flammability 0, Reactivity 0

2.2 OSHA Regulatory Status
All ingredients are encapsulated by the polymer and therefore not considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

2.3 Potential Health Effects
Routes of entry for solids include eye and skin contact, ingestion, and inhalation. Refer to Section 4 for First Aid Measures.

2.4 Potential Environmental Effects
None Known.

SECTION 3 **COMPOSITION / INFORMATION ON INGREDIENTS**

Attachment A

(Cont'd)

This product does not contain chemicals that are considered hazardous under 29 CFR 1910.1200.

SECTION 4 FIRST AID MEASURES

Eyes: Flush with water. If irritation persists seek medical attention.

Skin: For thermal burns, immediately flush with cold water. Do not attempt to remove polymer from skin. Seek medical attention.

Inhalation: Leave exposed area and seek fresh air. If irritation persists seek medical attention.

Ingestion: Do not induce vomiting. Seek medical attention.

SECTION 5 FIRE FIGHTING MEASURES

Wear protective clothing and use self-contained breathing equipment. Extinguishing media to include water, foam, CO2, and dry chemical.

SECTION 6 ACCIDENTAL RELEASE MEASURES

Spilled material may cause a slip hazard. Vacuum or sweep material and place in a disposal container.

SECTION 7 HANDLING AND STORAGE

Handling: See 8.3 Personal Protective Equipment

Storage: Keep container closed to prevent contamination

SECTION 8 EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Exposure Guidelines

This product does not contain chemicals that are considered hazardous under 29 CFR 1910.1200.

Special characteristics or information:

This product contains a cross-linking agent which decomposes and emits small pyrolytic by-products. Avoid inhalation and skin contact with ground resin. Pyrolytic decomposition by-products may cause eye, skin, and mucous membrane irritation. Some by-products accumulate on the interior surface of molded parts in an oily form. Avoid skin contact with this substance.

Attachment A

(Cont'd)

8.2 Engineering Controls

Localized ventilation is recommended.

8.3 Personal Protective Equipment

Eyes/Face: Safety Glasses.
Hands: Cotton Gloves for handling molten plastic.
Skin: Protective clothing for contact with molten plastic.
Respirator: NIOSH approved respirator for dust generation from normal processing operations.
Hygiene: Wash thoroughly after handling and before eating or drinking.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Physical Condition:	Solid Pellet
Odor:	Odorless at ambient temperature Characteristic plastic odor during heating
Flash Point:	Over 400°F
Flammability (solid, gaseous):	Not reasonably applicable
Minimum limit of Explosion:	Not reasonably applicable
Maximum limit of Explosion:	Not reasonably applicable
Vapor Pressure:	Not reasonably applicable
Relative density:	0.5 - 1.5 g/ml
Bulk density:	No data available
Water solubility:	Insoluble
pH Value:	Not reasonably aplicable
VOC Content:	Less than 5 parts per million

SECTION 10 STABILITY AND REACTIVITY

This product is stable and non-reactive. Hazardous decomposition of products can occur if overheated or ignited.

SECTION 11 TOXICOLOGICAL INFORMATION

Based on our experience and the information available, no adverse health effects are expected if handled as recommended with suitable precautions for designated uses.

SECTION 12 ECOLOGICAL INFORMATION

Refer to Section 6.

Attachment A

(Cont'd)

SECTION 13 DISPOSAL CONSIDERATIONS

Preferred options for disposal are (1) recycling, (2) incineration with energy recovery, and (3) landfill. Treatment, storage, transportation, and disposal must be in accordance with applicable Federal, State/Provincial, and Local regulations.

SECTION 14 TRANSPORT INFORMATION

This Product is not regulated under the following regulations:
United States Department of Transportation (DOT)
United States Coast Guard Regulations
International Maritime Organization (IMO) regulations
International Civil Aviation Organization (ICAO) regulations
International Air Reports Association (IATA) regulations
Canadian Transportation of Dangerous Goods (TDG) regulations
European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) regulations
European Agreement Concerning the International Carriage of Dangerous Goods by Rail (RID) regulations
Australian Dangerous Goods (ADG) regulations

SECTION 15 REGULATORY INFORMATION

Reference Section 3.
All Components of this product are on or exempt from listing on the US TSCA inventory and on Canadian DSL inventory.
SARA Title III Reporting: Not Required

SECTION 16 OTHER INFORMATION

Definitions:
CAS = Chemical Abstract Number
DSL = Domestic Substance List
OSHA = Occupational Safety and Health Act
PEL = Permissible Exposure Limit
TSCA = Toxic Substance Control Act
SARA = Superfund Amendments & Reclamation Act
VOC = Volatile Organic Chemical
N/E = Not Established

Prepared By: smf

Attachment B- Schulman Email Correspondence

Davies, Lisa

From: Tom_Wyszynski@aschulman.com
Sent: Friday, May 01, 2009 11:23 AM
To: Davies, Lisa
Subject: Re: HDPE Resins

All receive an AO package but only the black would receive carbon black
T
Tom Wyszynski

----- Original Message -----
From: "Davies, Lisa" [Lisa.Davies@wgint.com]
Sent: 05/01/2009 10:20 AM EST
To: Tom Wyszynski
Subject: HDPE Resins

Hi Tom:
Are carbon black and antioxidants added to your HDPE resin beads?

[A. Schulman Inc. - Email Disclaimer]

The content(s) of this e-mail and attachment(s) are confidential, may be legally privileged and is in error, please delete and e-mail confirmation to the sender.

A. Schulman Inc. does not guarantee that the information sent and/or received by or with this e-ma

Attachment C -Dr. Peter Soo Expert Opinion Correspondences

Davies, Lisa

From: Peter Soo [psoo@optonline.net]
Sent: Monday, April 20, 2009 9:00 AM
To: Davies, Lisa
Subject: Re: BNL-NUREG-33641 - Radiation Resistance Testing of High Density Polyethylene

Hi Ms. Davies:

I will look up the references for work we did many years ago on HDPE HICs. I carried out a very relevant study for the NY State Energy Research and Development Agency many years ago to address the lifetime of such containers for low-level waste. However, the report was funded by that agency and I don't think it is available for general distribution.

As I remember, the HDPE will become embrittled after several decades of service. The challenge is to specify a defensible end-of-life criterion. Is it zero tensile elongation, or some other criterion? From our work, we never did get t complete embrittlement even for very high megarad doses. There was always about 1-2% elongation, if my memory serves me well. This may be associated with the elastic deformation prior to fracture. However, one thought is to estimate the loads on the container during long term service. If the loads are low (containers not stacked on top of each other, no seismic loads, no fires, etc.) then what loading scenario could lead to failure? Even completely brittle containers will not fail if the loads are very low. If one stores LLW in glass containers, will the glass fracture? It's already completely brittle. Therefore, defining the service loads on the container over the expected lifetime should be estimated.

I've been retired for nearly 5 years now, and most of my technical publications have been discarded. I will go back to Brookhaven National Laboratory where the work was done and try to get a list of my publications from the library. I wil send you a list of reports that you may obtain for study. This should give you the guidance that you seek. I will let you know how soon I can get you the information. It might be a week depending on the library staff work load.

By the way, what company do you work for?

Peter Soo

On Apr 17, 2009, at 12:50 PM, Davies, Lisa wrote:

> Thank you so much Mr. Adams.
> Dr. Soo I look forward to receiving your assessment of HDPE HICs and the additional references. I sincerely appreciate your timely response.
>
> Lisa Davies
> 803-578-7066
>
> **From:** Adams, Jay W [mailto:jadams@bnl.gov]
> **Sent:** Friday, April 17, 2009 12:20 PM
> **To:** Davies, Lisa
> **Cc:** Peter Soo
> **Subject:** RE: BNL-NUREG-33641 - Radiation Resistance Testing of High Density Polyethylene
>
> Hi Lisa,
> I passed your request on to Dr. Peter Soo, retired now but also involved in HDPE radiation

5/19/2009

Attachment C

(Cont'd)

effects /mechanical characterization at that time. He said he'd get you some additional references and give you his assessment of HDPE HICs.
Jay

From: Davies, Lisa [mailto:Lisa.Davies@wgint.com]
Sent: 2009-04-17 10:33
To: Adams, Jay W
Subject: BNL-NUREG-33641 - Radiation Resistance Testing of High Density Polyethylene

Good Morning Mr. Adams:
I am writing this email to solicit some answers to my questions on above report (BNL-NUREG-33641) you co-authored in the 1980s I believe (see attached). I understand that you have completed numerous studies on various topics and may not recall this particular one. Essentially the study is about the use of HDPE as HICs for Low-level Radioactive Waste Storage and disposal. Your study highlighted the fact that after irradiation (47 MRad – 93 MRad), HDPE exhibits loss of necking and subsequent cracks. I am conducting an assessment for the use of HDPE as HICs for interim storage at Radwaste Facilities for lifetime of facilities (i.e. 50-60 years). My questions are:

(1) In your esteemed opinion, do you believe HDPE will sustain its integrity for a period of 50-60 years after continued exposure to radiation levels of 500 R/hr? If so, why and if not, why?

Please not that the storage facility will be dark and cool at all times and the 500 R/hr is absolute worse case, container radiation will vary between 100 -150 R/hr for BWR and 50 R/hr for PWR. I wish I can ask you many more questions on the subject but I am learning and hope that any knowledge you have on this subject matter will enlighten me and help me ask more questions that will assist me in this assessment. I know that you are a very busy man and may not have the time to engage in this discussion, but if you decide to I will be very honored and appreciative of your valued time and cooperation.

Sincerely,
Lisa Davies
803-578-7066

Attachment C

(Cont'd)

Davies, Lisa

From: Peter Soo [psoo@optonline.net]
Sent: Monday, May 04, 2009 8:27 AM
To: Davies, Lisa
Subject: Re: BNL-NUREG-52196

Hi Lisa:

I'm almost certain that all plastics use antioxidants. You could do a literature survey and confirm this, or even call the manufacturer. The antioxidant preferentially uses up the oxygen in the atmosphere until the antioxidant is depleted. Then the plastic itself is attacked and begins to lose its desirable properties. Without atmospheric oxygen, gamma radiation is far less damaging to plastics. The cracks are macroscopic in size and are readily visible by eye by orientating the surfaces to catch the light in certain directions. I used to gamma irradiate the U-bend sample and periodically check the initiation of new cracks, and the growth of existing ones. It was difficult to take photos of the cracks on a curved surface, so I just eyeballed them and sketched the changes. Under a microscope one probably could detect cracks earlier. However, such tiny cracks don't do any damage until they become very large. Remember that if your containers do not have significant tensile stresses on them the cracks will not grow to failure. My advice to you is to not stack containers on top of each other unless you can show the stresses will not cause the bottom containers to creep and become barrel shaped. Once this occurs, distortion will accelerate unless radiation strengthening stiffens the plastic and helps to minimize further creep.

Peter

On May 4, 2009, at 7:47 AM, Davies, Lisa wrote:

Good Morning Dr. Soo:
I have read BNL-NUREG-52196, A study of the use of cross-linked HDPE for LLRW waste containers. I have a few questions:

(1) The Type I samples in your study (as received Marlex CL-100), did it have anti-oxidants in its composition?
(2) The cracks that resulted from bending the samples into a U-bend configuration for testing are described as surface cracks. Were they visible with the naked eye or under a microscope?

I understand that it has been twenty years since you conducted this study, but any recollection you may have on the subject will be greatly appreciated. Thank you so much for your time and cooperation.

Lisa Davies
803-578-7066

Attachment D - Dr. Robert Koerner Geo-membrane Expert Opinion Email Correspondence

Davies, Lisa

From: Marilyn Ashley [mvashley@verizon.net]
Sent: Thursday, May 07, 2009 9:47 AM
To: Davies, Lisa

Attachments: Attachment-Davies.doc

Attachment-Davies.doc (262 KB)...

Dear Lisa,

Here is the experimental data for HDPE geomembrane (manufactured according to the GRI-GM13 Specification) for incubation in the Fluorescent Tube Weatherometer. The testing protocol is per ASTM D7238 at 70°C. (Please disregard the LLDPE and PE-R information since they are not relevant to your needs).

The data on HDPE indicates a lifetime of approximately 40,000 light hours and we are nowhere near 50% reduction of either strength or elongation. How much longer it will last, I do not know.

Our correlation to field failures is that 1000 light hours under these conditions is approximately 1.0 year in a hot climate (Texas or Southern California). Therefore, this HDPE projects to greater than 40-years service life.

Regarding a correlation to your situation without ultraviolet exposure (the temperature and oxygen levels are included), this 40-year prediction is conservative. Unfortunately, how much so is unknown. To ferret this out one would have to do oven aging studies, i.e., without UV-exposure, which would need a separate funding source and lots of time.

Hope this helps.

Very truly yours,

Robert M. Koerner, Ph.D., P.E., NAE
Director - Geosynthetic Institute

Attachment D

(Cont'd)

Davies, Lisa

From: robert koerner [robert.koerner@coe.drexel.edu]
Sent: Thursday, September 10, 2009 5:45 PM
To: Davies, Lisa
Subject: RE: STD OIT and HP OIT Results from TRI

Dear Lisa, Estimating short lifetimes is far easier than estimating long lifetimes. That said, if the antioxidant package responds similar to those in the samples that we crafted the specification from, a linear scaling would suggest at least 100 years. The assumption here is that the oven ageing and ultraviolet exposure results give similar proportions of AO decrease as stated in the specification. I really don't want to say anything more definitively than this and even this value is a "leap of faith" in prediction.

If the situation is indeed a critical one then the subsequent exposures followed by HP-OIT test results will add considerable confidence to the prediction……Bob Koerner

From: Davies, Lisa [mailto:Lisa.Davies@wgint.com]
Sent: Thursday, September 10, 2009 10:23 AM
To: robert koerner
Subject: RE: STD OIT and HP OIT Results from TRI

Thank you Dr. Koerner. I will forward your recommendation to our client, I am confident that they will pursue further testing. This is a very critical assessment for them. At this time though, their immediate request is determining an approximate anti-oxidant depletion time based on OIT test results. From our initial OIT test results you approximated a service life of 20 years for 10 minutes STD OIT. Based on our results of 303 minutes for HP OIT, what does that equate to for OIT depletion time for this HDPE sample tested? In addition, TRI labs provided results in an impressive quick turnaround time, our client was extremely pleased. We appreciate all your assistance to date.

Regards,
Lisa

From: robert koerner [mailto:robert.koerner@coe.drexel.edu]
Sent: Thursday, September 10, 2009 2:37 PM
To: Davies, Lisa
Subject: RE: STD OIT and HP OIT Results from TRI

Dear Lisa, In reviewing the data that you received from TRI Labs, the 303 minutes is somewhat short of the required 400 minutes we require in our GRI GM13 Specification for HDPE geomembranes. In such an instance it would not pass our specification. Please note, however, that this is for the amount of antioxidants. Equally important is the type of AOs. For type we require both oven ageing and ultraviolet light exposure to assess the percentage of AOs remaining after each type of exposure.

I really think you need to take this next step in the acceptance process. Incidentally, TRI Labs are quite familiar with both procedures and will supply you with an estimate. Do contact Sam Allen or Dr. Patel in this regard….Bob Koerner

From: Davies, Lisa [mailto:Lisa.Davies@wgint.com]
Sent: Tuesday, September 08, 2009 12:57 PM
To: robert koerner
Cc: Gardner, Donald
Subject: STD OIT and HP OIT Results from TRI

Hello Dr. Koerner:
Attached is result for TRI Environmental Labs for both STD and HP OIT for your review and analysis. Please let us know what you think. We appreciate your time.

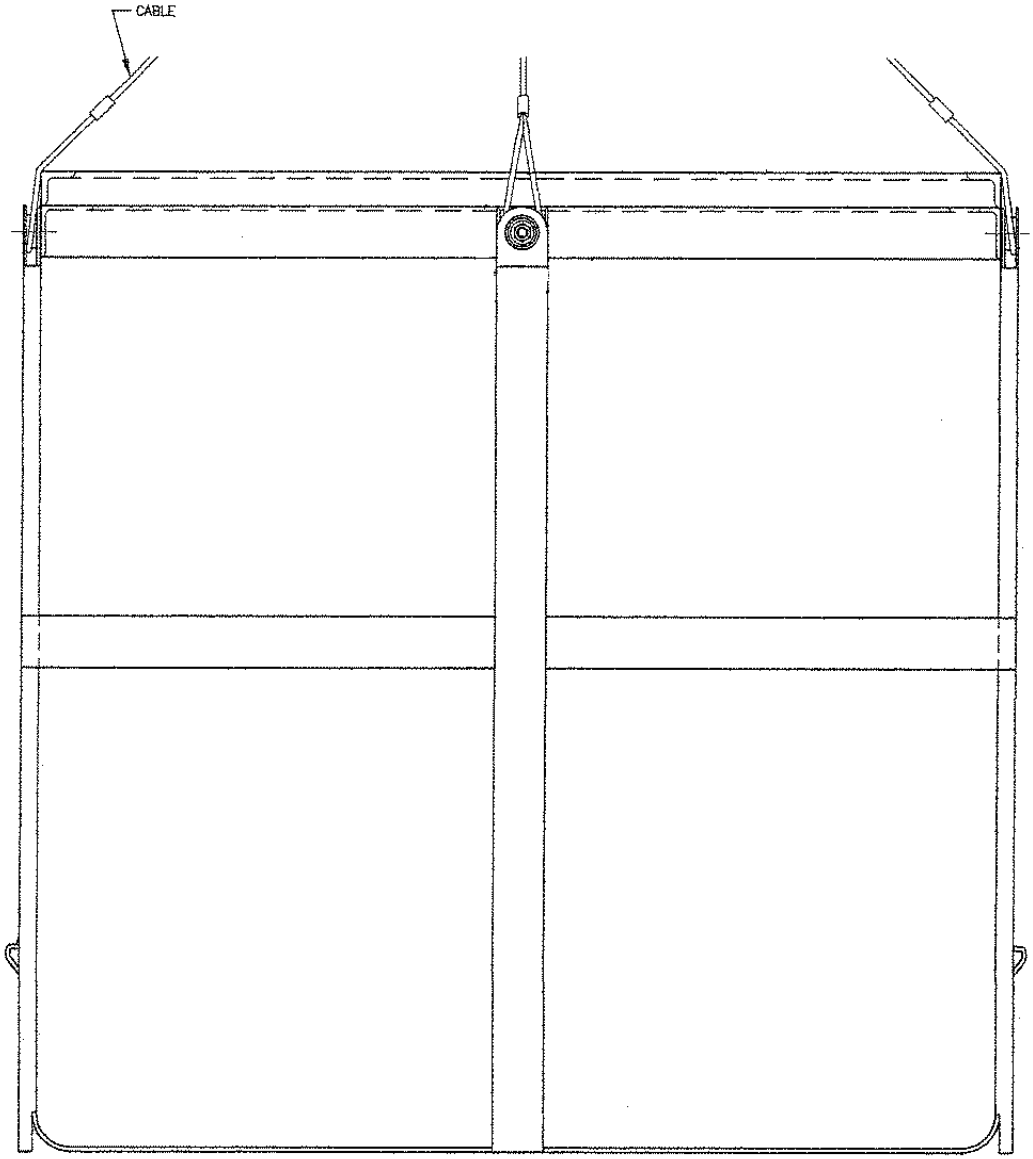
Regards,

Attachment E-Peach Bottom Generating Station Isotopic Mix TID Calculation

Input Values:

	A	B	C	D	E	F	G	H	I	J	K
1	**Test of accumulated dose to container, using a PBAPS isotopic mix**										
2		ignores beta because of short range									
3		**80 storage duration (years)**									
4											
5	Ag110m	Co58	Co60	Cs134	Cs137/Ba137m	Mn-54	Nb-95	Sr-92	Zn-65	Isotope	**Total**
6	3.671	3.273	109.2	27.86	11.76	1.816	0.575	38.89	43.96	initial contact dose rate (rads/hr)	**241.0**
7	6.842E-01	1.938E-01	5.271E+00	2.062E+00	3.000E+01	8.556E-01	9.624E-02	3.091E-04	6.678E-01	half-life (years)	
8	1.156E-04	4.079E-04	1.500E-05	3.835E-05	2.636E-06	9.242E-05	8.217E-04	2.558E-01	1.184E-04	decay constant (1/hours)	
9	**3.18E-02**	**8.02E-03**	**7.28E+00**	**7.27E-01**	**3.76E+00**	**1.96E-02**	**7.00E-04**	**1.52E-04**	**3.71E-01**	**accumulated dose (Mrads)**	**12.20**
10	0.3%	0.1%	59.7%	6.0%	30.8%	0.2%	0.0%	0.0%	3.0%	percent of accumulated dose	
11											
12											
13	MicroShield Results (mR/hr), isotopic effects										1092
14	241	All									
15	131.8	Less Co-60	109.2								
16	87.84	Less Zn-65	43.96								
17	48.95	Less Sr-92	38.89								
18	21.09	Less Cs-134	27.86								
19	9.335	Less Cs-137	11.755								
20	6.062	Less Co-58	3.273								
21	2.391	Less Ag-110m	3.671								
22	0.5747	Less Mn-54	1.8163								
23		Nb-95 only									

Attachment F - Typical HDPE Container Lifting Basket



Attachment G - Effect of Internal Stresses on ES 8-120B HDPE Container

1 Objective and Introduction

The main objective of this spreadsheet computation is to perform analysis of unconstrained stress on the walls and bottom of the 8-120B HDPE HIC container due to the internal pressure of dewatered resin beads. The results will determine whether the container could be susceptible to a creep type failure over an extended period of time.

Specific items to be calculated and/or derived include:

- Pressure at base of container
- Meriodional stress
- Hoop stress

2 Inputs

The 8-120B container input data is taken from Reference 1 and is shown on Table 1.

Table 1 – 8-120B Container Dimensions

Liner	Diameter (inches)	Radius (inches)	Height (inches)	Thickness (inches)
8-120B	61.5	30.75	73.5	0.5

3 Assumptions

- The density of the dewatered resin 72.0 lb/ft^3
- The density of water 62.4 lb/ft^3
- Pressure at which HDPE should be immune to a creep-type failure ≤ 1,000 psi

  This is based on creep tests on 1/8 inch thick HDPE samples using a simple constant load system. Strains were measured using Linearly Variable Differential Transducers (LVDTs).
  This testing was performed by Brookhaven National Laboratory (BNL) for the Nuclear Regulatory Commission (NRC) (Reference 2).
- Application of the BNL creep test results for 1/8 inch sample coupons to ½ inch 8-120B HDPE HIC is conservative.
- The pressure at the base of the container is assumed to be the most limiting case.
- Unless otherwise noted the formulas used in this calculation are derived from Roark's Formulas for Stress and Strain, Seventh Edition.

4 Methodology

This calculation was performed using a Microsoft™ Excel™ spreadsheet. The equations are simple stress and pressure calculations as described below and are used to calculate the meriodional stress and hoop stress on the 8-120B container.

5 Calculation

Pressure

The pressure at the bottom of the 8-120B container is considered to be the most limiting case. Using the density of water = 62.4 lb/ft^3 (0.036 lb/in^3) the pressure is calculated as:

$P_{bottom} = \rho_{water} \times H$

Where:
P = Pressure, (psi)
ρ = Density, lb/ft^3
H = Height, (in)

$P_{bottom} = \rho_{water} \times H = 0.036 lb/ft^3 \times 73.5 in = 2.65 psi$

Correction factor = $\frac{\rho_{resin}}{\rho_{water}} = \frac{72 lb/ft^3}{62.4 lb/ft^3} = 1.15$

$P_{bottom} = 1.15 \times 2.65 psi = 3.05 psi$

Meriodional Stress

The equation for calculating the meriodional stress on the 8-120B container is:

$$\sigma_1 = \frac{P_{bottom} R}{2t}$$

Where:
σ_1 = Meroidional Stress (psi)
R = Radius, (in)
t = Thickness, (in)

$$\sigma_1 = \frac{3.05 lb/in^2 \times 30.75 in}{2 \times 0.5 in} = 94 psi$$

Hoop Stress

The equation for calculating the hoop stress on the 8-120B container is:

$$\sigma_2 = \frac{P_{bottom} R}{t}$$

Where:

σ_2 = Hoop Stress (psi)

$$\sigma_2 = \frac{3.05 lb/in^2 \times 30.75 in}{0.5 in} = 188 psi$$

Combined Principal Stress

The Combined Principal Stress σ_T is the sum of σ_1 and σ_2:

$$\sigma_T = 94 psi + 188 psi = 282 psi$$

6 Summary of Results

The results are summarized in Table 2. The combined stresses (hoop and meriodional) acting on the 8-120B container as a result of internal pressure is 282 psi. It can be concluded based on this result that since the combined stresses 282 psi is less than 1000 psi, the 8-120B container will be immune to a creep type failure.

Table 2 Result Summary

Calculation	Value (psi)		Allowable (psi)	
Pressure (P)	3.05			
Meriodional Stress (σ_1)	94			
Hoop Stress (σ_2)	188			
Combined Principal Stress (σ_T)	282	<	1,000 psi	**OK**

7 References

[1] EPRI Report 1007863, Waste Containers for Extended Storage of Class A, B and C Wastes, Revision 1, August 2003.

[2] P Soo, et al, NUREG/CR-5363 (BNL-NUREG-52196), A Study of the Use of Crosslinked High-Density Polyethylene for Low-Level Radioactive Waste Containers, June 1989.

Attachment 1 – Excel Spreadsheet

Input Values:

	A	B
1	**Pressure Calculation**	
2	Density of Water (lb/in^3)	0.03611
3	Density of Resin (lb/in^3)	0.04167
4	Height (in)	73.5
5	Correction Factor ($\rho_{resin}/\rho_{water}$)	1.15385
6	**Pressure (psi)**	**3.06**
7		
8	**Meriodional Stress Calculation**	
9	Pressure	3.06
10	Radius (in)	30.75
11	Thickness (in)	0.5
12	**Meriodional Stress σ_1, (psi)**	**94.17**
13		
14	**Hoop Stress Calculation**	
15	Pressure	3.06
16	Radius (in)	30.75
17	Thickness (in)	0.5
18	**Hoop Stress σ_2, (psi)**	**188.34**
19		
20	**Combined Principal Stress Calculation**	
21	Meriodional Stress σ_1, (psi)	94.17
22	Hoop Stress σ_2, (psi)	188.34
23	**Combined Principal Stress (psi)**	**283**

Formulas:

	A	B
1	**Pressure Calculation**	
2	Density of Water (lb/in^3)	=62.4*(1/12)^3
3	Density of Resin (lb/in^3)	=72*(1/12)^3
4	Height (in)	73.5
5	Correction Factor ($\rho_{resin}/\rho_{water}$)	=B3/B2
6	**Pressure (psi)**	**=B5*(B2*B4)**
7		
8	**Meriodional Stress Calculation**	
9	Pressure	=B6
10	Radius (in)	30.75
11	Thickness (in)	0.5
12	**Meriodional Stress σ_1, (psi)**	**=(B9*B10)/(2*B11)**
13		
14	**Hoop Stress Calculation**	
15	Pressure	=B6
16	Radius (in)	30.75
17	Thickness (in)	0.5
18	**Hoop Stress σ_2, (psi)**	**=(B15*B16)/B17**
19		
20	**Combined Principal Stress Calculation**	
21	Meriodional Stress σ_1, (psi)	=B12
22	Hoop Stress σ_2, (psi)	=B18
23	**Combined Principal Stress (psi)**	**=B21+B22**

Attachment H: TRI/Environmental Labs Standard OIT (ASTM D3895) and HP OIT (ASTM D5885) Test Results

TRI / Environmental, Inc.
A Texas Research International Company

September 8, 2009

Mail To:

Lisa Davies
URS - Washington Division
3023 HSBC Way, Mailroom 400
Fort Mill, S. C. 29715

email: lisa.davies@wgint.com

Bill To:

<= Same

Dear Ms. Davies

Thank you for consulting TRI/Environmental, Inc. (TRI) for your geosynthetics testing needs. TRI is pleased to submit this final report for laboratory testing.

Project:	**EXELON-ECR**
TRI Job Reference Number:	E233-76-09
Material(s) Tested:	1 HDPE Geomembrane(s)
Test(s) Requested:	High Pressure Oxidative Induction Time (ASTM D 5885) Oxidative Induction Time (ASTM D 3895)

If you have any questions or require any additional information, please call us at 1-800-880-8378.

Sincerely,

Dr. Mansukh Patel
Sr. Laboratory Coordinator
Geosynthetic Services Division
www.GeosyntheticTesting.com

cc: Sam R. Allen, Vice President and Division Manager

GeosyntheticTesting.com
9063 Bee Caves Road / Austin, TX 78733 / 512 263 2101 / fax: 512 263 2558

Attachment H
(Cont'd)

TRI / Environmental, Inc.
A Texas Research International Company

GEOMEMBRANE TEST RESULTS

TRI Client: URS - Washington Division
Project: EXELON-ECR

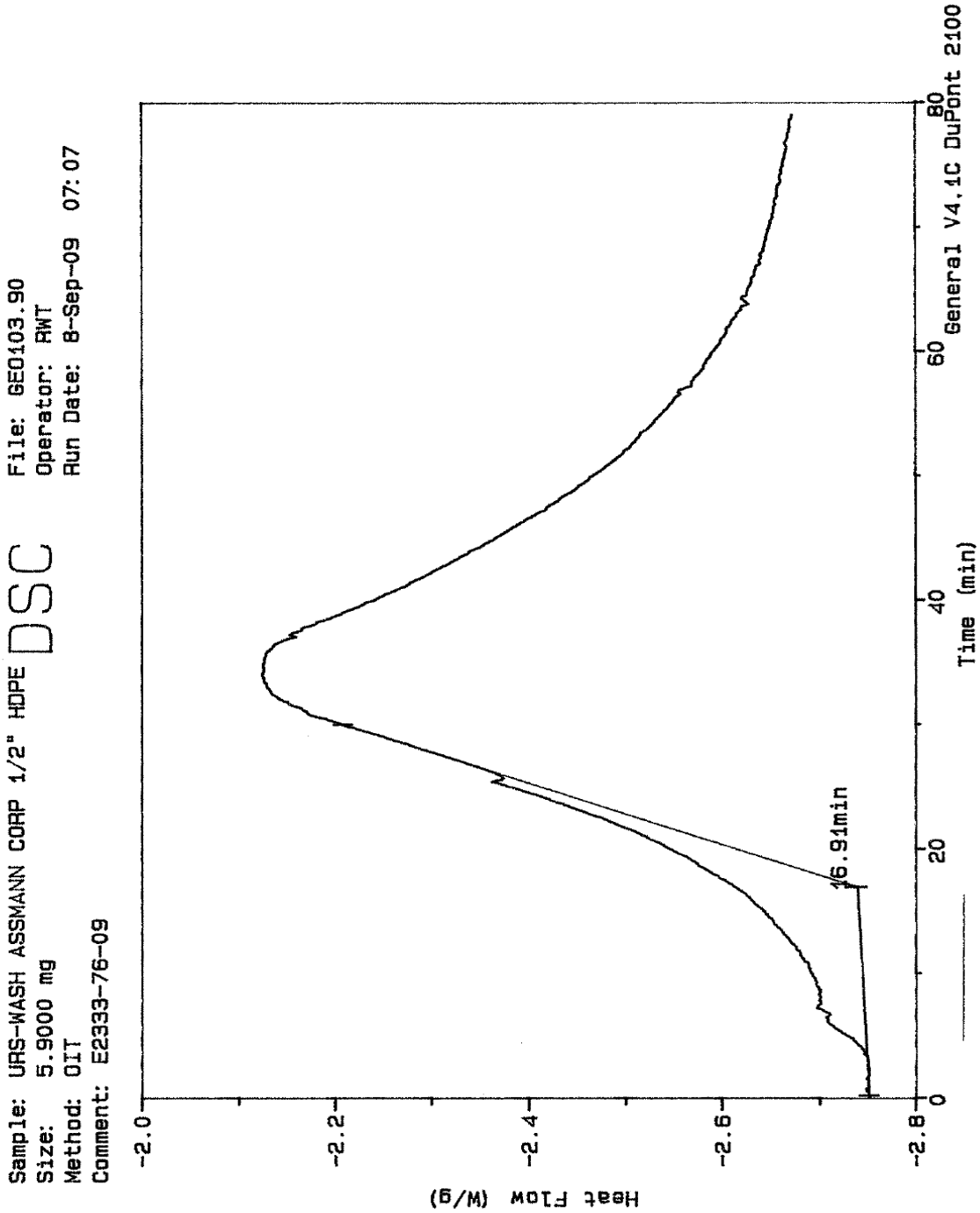
Material: 1 HDPE Geomembrane
Sample Identification: ASSMANN CORP, 1/2" THK
TRI Log #: E233-76-09

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	6	7	8	9	10	MEAN	STD. DEV.
Oxidative Induction Time (ASTM D 3895)												
OIT (minutes)	17										17	
High Pressure Oxidative Induction Time (ASTM D 5885)												
HPOIT (minutes)	303										303	

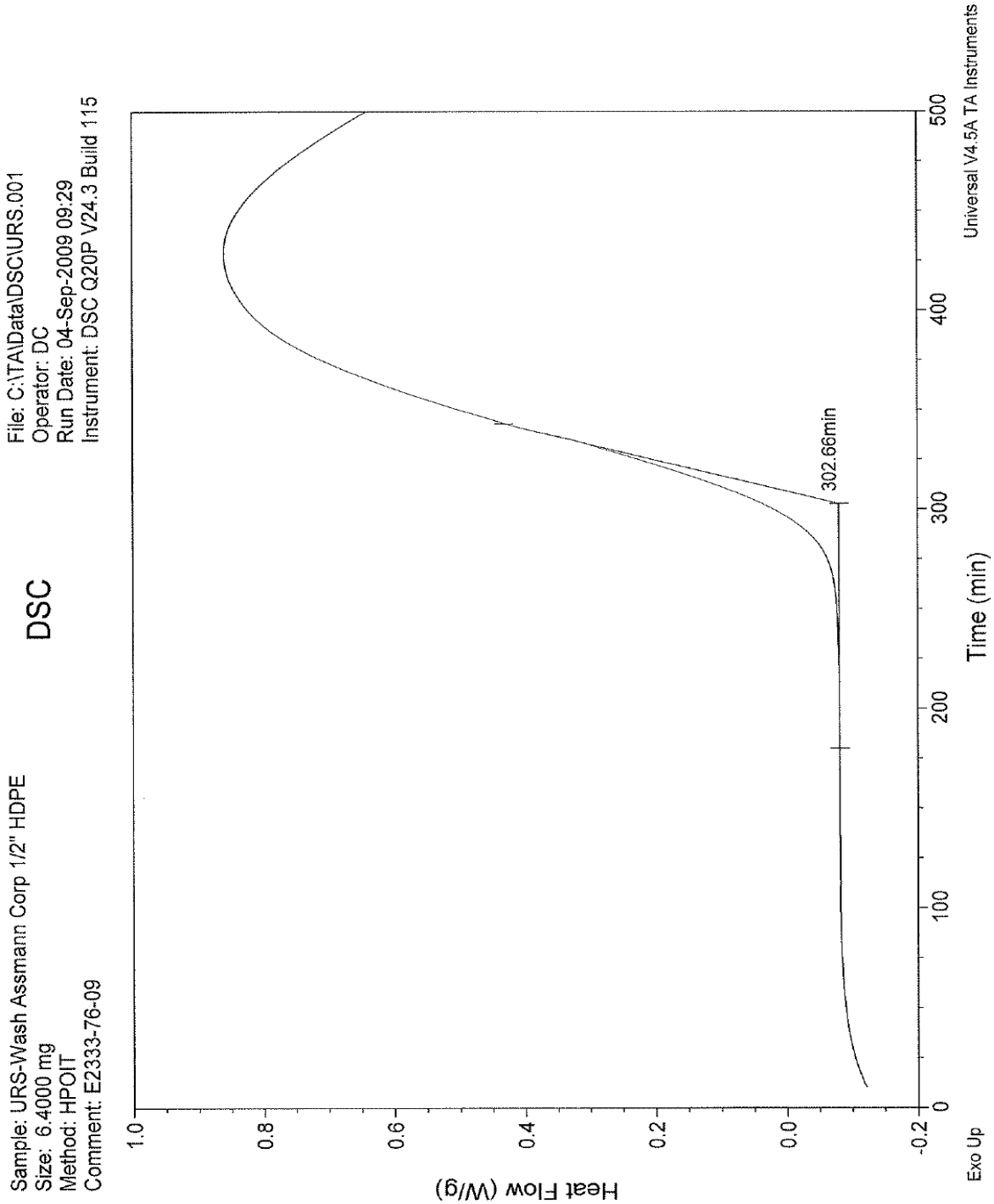
The testing is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

GeosyntheticTesting.com
9063 Bee Caves Road / Austin, TX 78733 / 512 263 2101 / fax: 512 263 2558

Attachment H
(Cont'd)



Attachment H
(Cont'd)



APPENDIX D
WASTE ACCEPTANCE CRITERIA (WAC)
FOR
INTERIM RADWASTE STORAGE FACILITY
LASALLE COUNTY NUCLEAR STATION

1.0 INTRODUCTION

Class B/C radioactive waste is expected to be transported from Braidwood, Byron, and Clinton Stations in Illinois to LaSalle County Station Interim Radwaste Storage Facility (IRSF). To make sure that the waste radioactive waste form and packaging received by LaSalle County IRSF are acceptable for long-term (greater than five years) storage and eventual shipment for disposal, specific criteria identifying conditions of acceptance is needed. The waste acceptance criteria provided herein is based on the Barnwell Waste Management Facility (Barnwell, South Carolina) License Amendment No. 49 (Attachment 1).

The Barnwell WAC text was used in its entirety for the IRSF WAC except for where:
a) Specific text did not apply
b) Specific text was modified or replaced.

Applicable Barnwell WAC text was not transferred to the IRSF WAC and therefore, its attachment to this document is necessary for completeness.

1.1 PURPOSE

The purpose of LaSalle County Station IRSF Waste Acceptance Criteria (WAC) is to provide the authorized radioactive material, form, and packaging for emplacement in the facility for long-term storage and eventual transshipment to a disposal facility.

1.2 WASTE ACCEPTANCE CONDITIONS

The following conditions constitute the requirements necessary for radioactive waste packages to be received at the IRSF for long-term storage and shipped to a disposal facility when one is identified. These conditions numbers and text are identical to those found in the Reference 1 document, accept as indicated.

Conditions 1 - 4 Does not Apply

Condition 5 - Is replaced with the following:
"Authorized Material - Any radioactive material, excluding source and special nuclear material, except as authorized by this WAC."

Condition 6 - Is replaced with the following:
"Chemical and/or Physical Form - Dry packaged radioactive waste except as authorized or excluded by this WAC."

Condition 7 - Does not Apply

Condition 8 – Is replaced with the following:
"Authorized Radioactive Materials - Class B and C quantities of radioactive waste materials packaged in accordance with this WAC."

General Conditions Starts at Condition

Condition 9 – Does Not Apply

Condition 10 – Does Not Apply

Condition 11 - Is replaced with the following:
"LaSalle County IRSF will remain in compliance with all Station policies, practices, and procedures. If a conflict arises between Station directives and the facility's ability to receive waste, receiving operations will be suspended until compliance can be assured."

Condition 12 - Is replaced with the following:
"Operations authorized in the "LaSalle County IRSF are performed in accordance with the following Station and Exelon Corporate Procedures:

a. Station procedures
    - Abnormal IRSF Operation Procedure
    - IRSF General Use Procedure (LOP-WX-32)
b. Exelon Corporate Procedures
    - Radwaste Storage Facility/Waste Container Inspections (RW-AA-104)
    - Guidelines for Operating an Interim On Site Low Level Radioactive Waste Storage Facility (RW-AA-105)

Condition 13 - All station soliciting waste to LaSalle County IRSF including LaSalle Facility shall comply with Exelon's training procedures as stated in Condition 12.

Condition 14 - Is replaced with the following:
"Operations of the LaSalle County IRSF will be conducted by the Station's Radwaste Supervisor or his designee in accordance with the Condition 12 procedures."

Condition 15 - Does Not Apply

Condition 16 - Is replaced with the following:

"Documented inspections of facility operations and storage bay surveillances are conducted in accordance with the applicable Condition 12 procedure."

Condition 17 - Is replaced with the following:
"

a. All waste received for long term-storage must be in compliance with applicable US Department of Transportation (DOT), US Nuclear Regulatory Commission (NRC), and the requirements of this WAC.

b. Exception, on-site generated waste destined for long-term storage may exceed transportation radiation dose limits, as long as handling and placement of those waste packages are conducted in accordance with applicable Condition 12 procedures and RegGuide 8.8 "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be As Low As is Reasonably Achievable" (Reference 1)."

Condition 18 - Is replaced with the following:
"All records and shipment manifest pertinent to the transportation, receipt, package decontamination, repackaging, and transshipment of long-termed stored waste packages must be maintained according to the applicable Condition 12 procedure.

Condition 19 - Is replaced with the following:
"All records of shipments and transshipments must be maintained according to the requirements of the applicable Condition 12 procedures in accordance with 10 CFR 61.80 (c) "Maintenance of Records, Reports, and Transfers requirements" (Reference 2).

Condition 20 - Is replaced with the following:
Semi-annual reports identifying facility operations (including, waste receiving, surveillances, transshipments, and unusual occurrences) must be submitted to the Exelon Corporate Radioactive Waste Manager.

Condition 21 - Does Not Apply

Receipt, Acceptance and Inspection Conditions

Condition 22 - Is replaced with the following:

The facility shall not accept radioactive waste for long-term storage unless 1) it's from an authorized shipper and 2) the shipper has provided the following:

a. Annual waste forecast identifying the quantity and types of waste expected to be shipped to the facility for long term storage. This criterion includes shipments from on-site sources.

b. US NRC Uniform Low-Level Radioactive Waste Manifest Forms 540 (Shipping Paper), 541 (Container and Waste Description), and 542 (Manifest Index and Regional Compact Tabulation) as needed according to the applicable Conditions 12 procedure.

Condition 23 - Does Not Apply

Condition 24 - Does Not Apply (see Condition 22)

Condition 25 - Is replaced with the following:
"No waste will be shipped to the IRSF for long-term storage until it has been certified as passing the applicable Condition 12 inspection procedure.

Received waste not passing inspection may 1) be return to the sending Station as long as all DOT and NRC transportation requirements are met or 2) reprocessed and other issues causing the package to be rejected resolved. Any case of unusual occurrence reported per the station Corrective Action Process."

Condition 26 - Is replaced with the following:
"The facility will not accept radioactive waste shipments containing unusual hazards or potential hazards including but not limited to, physical, gaseous, chemical, pyrophoric, or unexpected high radiation levels at the container surfaces.

Additionally, the facility will not accept any waste package containing radioactive mixed waste as described in Information

Notice 90-09 "Extended Interim Storage of Low-Level Radioactive Waste by Fuel Cycle and Material Licensees (Reference 3)."

Condition 27 - Does Not Apply

Condition 28 - Does Not Apply

Condition 29 - Is replaced with the following:
"

a. The facility operator shall notify the shipping Station when it has been determined that a radioactive waste shipment or part of a shipment cannot be accepted for long-term storage and selected Condition 25 resolution.

b. The facility operator shall notify the shipping Station before the end of the next business day if a shipment has failed to arrive at the disposal facility within the 24-hour time frame indicated in the advance notification or manifest."

Condition 30 - Is replaced with the following:

a. "The facility operator shall acknowledge receipt of the waste within 7 days of its acceptance for long-term storage by returning a signed copy of the shipment manifest or shipping papers to the shipping Station.

b. The facility operator shall indicate on the returned copy of the shipment manifest or shipping papers any discrepancy between the waste description listed on the manifest or papers and the waste materials received in the shipment and discrepancy resolution."

Waste Characteristics and Waste Form Conditions

Condition 31 - Is replaced with the following:
"The facility operator shall not accept any radioactive waste for long-term storage unless the shipping Station has marked each disposal container, as specified by the applicable Condition 12 procedure, to identify its classification as either Class B, or Class C waste, and certifies that the waste materials have been classified and prepared in accordance with the following waste classification table, as appropriate. Additionally, the waste's stability classification will also be marked on the container."

Class B/C Columns of the Table are included in their entirety.

A. Is utilized in its entirety.

B. Does Not Apply

C. Is utilized in its entirety.

D. Is utilized in its entirety.

E. Is utilized in its entirety.

F. Is utilized in its entirety.

G. Is replaced with the following:

"If the concentration of any single radionuclide exceeds Class C values in the table, the waste is not acceptable for long-term storage"

H. Is utilized in its entirety.

I. Does Not Apply

Condition 32 - Is replaced with the following:
"

a. Liquid wastes are not authorized for receipt in the IRSF regardless of the chemical or physical form.

b. Solidified or dewatered radioactive waste shall have no detectable free standing liquids in excess of one-half percent (0.5%) by waste volume of non-corrosive liquids per container.

c. In lieu of the requirements of paragraph b. above, solidified or dewatered waste containing noncorrosive liquids in excess of one-half percent (0.5%) by waste volume, and less than on percent (1%) non-corrosive liquids by waste volume, may be received and disposed of in high integrity containers (HICs) approved by the Exelon Corporate Radwaste Manager"

Condition 33 – Is replaced with the following:

"

a. The facility shall only receive aqueous liquids and other applicable waste forms which have been solidified or otherwise stabilized with one of the following solidification media:

1. Vinyl Ester Styrene
2. Cement
3. Bitumen (see Subparagraph d. below)
4. Vinyl Chloride
5. TBD

b. Solidification media and processes used to stabilize Class B and C waste, shall meet and have been evaluated in accordance with the "Stability Guidance" requirements of the US NRC Waste Management Division, Technical Position on Waste Form, Revision 1, dated January 1991 (Reference 4) and Exelon/Station procedure specifically prepared to address its requirements.

c. Other solidification media and processes shall be acceptable for which a topical report has been prepared and received approval from the US NRC and approved by the Exelon Corporate Radwaste Manager.

d. The facility shall only receive for disposal, full formula, oxidized bitumen (asphalt) solidified waste, which is a free standing monolith as received for disposal, and certified as such by the shipping Station."

Condition 34 - Does Not Apply

Condition 35 - Is replaced with the following:
"The facility shall not receive evaporator bottoms or concentrates, residues, sludges, or other waste which may contain free standing liquids, unless they are solidified in accordance with Condition 33, and meet the requirements as specified in Condition 32. Evaporator bottoms or concentrates which contain no free standing water and are not free flowing are acceptable for disposal when processed by a method specifically approved by the Exelon Corporate Radwaste Manager."

Condition 36 - Is utilized in its entirety, accept "licensee" is replaced with "facility.

Condition 37 - Is utilized in its entirety, accept "licensee" is replaced with "facility.

Condition 38 - Is replaced with the following:
"Regardless of the waste classification of Condition 31, ion exchange resins and filter media containing isotopes with greater than five (5) year half-lives having a specific activity of all these isotopes of 1 microcurie/cubic centimeter or greater must be stabilized by solidification in accordance with Condition 33 and meet the free standing liquid requirements of Condition 32.a. However, in lieu of solidification, these waste forms meeting the free standing liquid requirements of Condition 32.C. can receive long-term storage in approved high integrity containers or other methods of stabilization are acceptable for long-term storage approved by the Exelon Corporate Radwaste Manager."

Condition 39 - Does Not Apply

Condition 40 - Is replaced with the following:
"Radioactive waste containing transuranic radionuclides or other special nuclear materials within the limits specified in Condition 31 are acceptable provided that the transuranic radionuclides or other special nuclear materials are evenly distributed within a homogeneous waste form and are incidental to the total radioactivity. Incidental in this condition is defined as not more than one percent (1%) of the total activity."

Condition 41 - Does Not Apply

Condition 42 - Does Not Apply

Condition 43 - Does Not Apply

Condition 44 - Does Not Apply

Condition 45 - Is replaced with the following:
"The facility shall not receive radioactive waste in the forms of incinerator ash or powder which may be dispersible unless solidified with a media specified in Condition 33."

Condition 46 - Is utilized in its entirety, accept "Department" is replaced with "Exelon Corporate Radwaste Manager".

Condition 47 - Is replaced with the following:
"Gaseous radioactive wastes are not acceptable for IRSF storage."

Condition 48 - Does Not Apply

Condition 49 - Is utilized in its entirety, accept "licensee" is replaced with "facility.

Condition 50 - Is replaced with the following:
"The facility shall not receive radioactive waste which contains or is capable of generating quantities of toxic gases, vapors, or fumes harmful to persons transporting, handling, or disposing of the waste."

Condition 51 - Is utilized in its entirety, accept "licensee" is replaced with "facility and "or disposed" is deleted.

Condition 52 - Is replaced with the following:
"The facility shall not receive for long-term storage petroleum based materials in any physical form. However, this does not prohibit the receipt of waste containing incidental or trace amounts of oil or petroleum based materials which have been absorbed, provided that the amount of absorbed oil and petroleum based materials does not exceed one percent (1%) by waste volume in a container."

Condition 53 - Is replaced with the following:
"The facility shall not receive radioactive waste containing hazardous biological, pathogenic, or infectious material."

Condition 54 - Does Not Apply

Contamination Limit Conditions

Condition 55 - Is utilized in its entirety, accept "Barnwell Suite" is replaced with "at the facility"

Condition 56 - Is utilized in its entirety.

Condition 57 - Is utilized in its entirety.

Condition 58 - Is utilized in its entirety, accept "licensee" is replaced with "facility".

Condition 59 - Is replaced with the following:
The IRSF decontamination facility will remain in inoperative. All decontamination efforts will be provided in the Radwaste Building or a facility as identified by the Radwaste Supervisor.

General Packaging Conditions

Condition 60 - Is replaced with the following:
"All radioactive waste shall be packaged and loaded in accordance with applicable US DOT Regulations, US NRC Regulations 10 CFR Part 71, and the requirements of this WAC."

Condition 61 - Does Not Apply

Condition 62 - Does Not Apply

Condition 63 - Is replaced with the following:
"The facility shall, to the extent practicable, repair or repackage any damaged package accepted for storage."

Condition 64 - Is replaced with the following:
Prior to transshipment for disposal, the facility shall, to the extent practicable, remove all liquids from waste packages found in excess of allowable limits. Container dewatering or reprocessing is not authorized in the facility and therefore most be performed in another Station area.

Condition 65 - Is utilized in its entirety, accept "Barnwell Suite" is replaced with "at the facility"

Condition 66 - Is utilized in its entirety, accept "Barnwell Suite" is replaced with "at the facility"

Condition 67 - 100 - Do Not Apply
(Environmental Surveillance Conditions are handed in another document which is not part of the WAC)

1.3 References

1. RegGuide 8.8 "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be As Low As is Reasonably Achievable", Revision 3

2. 10 CFR 61.80 (c) "Maintenance of Records, Reports, and Transfers requirements"

3. Information Notice 90-09 "Extended Interim Storage of Low-Level Radioactive Waste by Fuel Cycle and Material Licensees"

4. US NRC Waste Management Division, Technical Position on Waste Form, Revision 1, dated January 1991

5. Environmental Surveillance Conditions to be determined

ATTACHMENT A- South Carolina Department of Health and Environmental Control Radioactive Material License

SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL
RADIOACTIVE MATERIAL LICENSE

Pursuant to the Atomic Energy and Radiation Control Act, Section 13-7-40 et. seq. of S.C. Code of Laws of 1976 as amended and Supplements thereto, and the South Carolina Department of Health and Environmental Control Regulation 61-63 Radioactive Material (Title A), and in reliance on statements and representations heretofore made by the applicant, a license is hereby issued authorizing the licensee to receive, acquire, possess, and transfer radioactive material listed below; and to use such radioactive material for the purpose(s) and at the place(s) designated below. The license is subject to all applicable rules of the South Carolina Department of Health and Environmental Control now or hereafter in effect and to any conditions specified below.

Amendment No. 49 amends

LICENSEE		3. License Number
1. Name	Chem-Nuclear Systems, LLC. Barnwell Waste Management Facility	097 in its entirety
2. Address	740 Osborn Road Barnwell, S.C. 29812	4. Expiration Date Five year term to be determined

5. Radioactive Material (Element and Mass Number)	6. Chemical and/or Physical Form	7. Maximum Radioactivity and/or quantity of material which licensee may possess at any one time.
A. Any Radioactive material excluding source material and special nuclear material.	A. Dry packaged radioactive waste except as authorized in this license.	A. 50,000 curies
B. Source material	B. Dry packaged radioactive waste except as authorized in this license.	B. 60,000 pounds
C. Special Nuclear Material	C. Dry packaged radioactive waste except as authorized in this license.	C. 350 grams total of ^{235}U or 200 grams ^{233}U or 200 grams of plutonium or any combination of these provided the sum of the ratios of the quantities does not exceed unity.

8. Authorized Use:

A., B. and C.

Radioactive material as low-level radioactive waste may be received, stored, and disposed of by enhanced shallow land burial in approved engineering barriers (vaults) unless otherwise specifically authorized by the Department . The licensee shall not receive an annual volume of more than the authorized limits of South Carolina Code of Laws of 1976, as amended.

Unless otherwise authorized by the Department, only radioactive waste consigned for burial shall be received at the location specified in Condition No. 9 of this license. The maximum radioactivity and/or quantity of radioactive material indicated in Item 7. A, B, and C applies to the above-ground activities.

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General Conditions

9. Unless otherwise specified, the authorized place of use is a site located approximately five miles northwest of Barnwell, South Carolina, in the Seven Pines School District, Red Oak Township, Barnwell County, South Carolina within the boundary of the land area described in Lease agreement dated April 6, 1976, as amended.

10. The licensee shall comply with the provisions of the South Carolina Department of Health and Environmental Control (SC DHEC) Regulation 61-63, Radioactive Material, (Title A), Part I - General Provisions; Part II - Licensing of Radioactive Materials; Part III - Standards for Protection Against Radiation; Part VI - Notices, Instructions, and Reports to Workers; Inspections, and Part VII - Licensing Requirements for Land Disposal of Radioactive Waste; Department Regulation 61-83, Transportation of Radioactive Waste Into or Within South Carolina.

11. Unless otherwise specified in this license, the licensee shall make no changes in the internal safety audits, Safety Review Board, ALARA Review Committee, Site Criteria, or procedures governing these specific activities without approval from the Department.

12. Operations authorized by this license shall be conducted in accordance with Chem-Nuclear Systems (CNS) procedures and subsequent revisions and additions approved by the Department. However, the licensee may upon notification to the Department but without Department approval, make minor changes to these procedures provided that:

    A. The change does not affect requirements of any other license condition in this license;

    B. The change does not increase the potential for personnel exposure;

    C. The change does not diminish operational safety;

    D. The change does not increase the potential for release of radioactive material to unrestricted areas; and

    E. The change does not reduce the licensee's record keeping and reporting system.

    The licensee shall maintain records of these changes including evaluations which provide the basis for the change.

13. The licensee shall ensure that all site personnel have satisfactorily completed the training program requirements as specified in the CNS Barnwell Site Training Program. Changes and additions to the program shall be submitted to the Department for review. Time intervals for personnel indoctrination, training, examinations, certification, retraining specified in CNS Procedure S20-AD-004, "Barnwell Radioactive Waste Burial Site Personnel Training", shall not be changed without Department approval.

14. Operations shall be conducted by or under the supervision of: William A. Veronee, (RSO), James W. Latham, Joseph J. Still, William B. House, Michael J. Benjamin, Wayne Inabinett, Edward F. Boyles, Jr. or other individuals designated by the licensee's Radiation Safety Officer upon successful completion of the licensee's training program and approval by the licensee's Safety Review Board.

15. The licensee shall to the extent necessary, continue the employment of all personnel involved in the operation of the Barnwell Waste Management Facility in accordance with all requirements in the license and applicable regulations and, in the event replacement of employees becomes necessary, only individuals of comparable qualifications and experience will be hired.

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16. A documented weekly inspection of site operations and the restricted area of the site for compliance with applicable conditions of this license shall be conducted by a named authorized user in Condition 14 or other individual approved by the Department.

17. The transportation of radioactive materials and radioactive waste within the State of South Carolina shall be in accordance with applicable regulations of the United States Department of Transportation (US DOT), the United States Nuclear Regulatory Commission (US NRC), Section RHA 2.22, Department Regulation 61-63, Radioactive Material (Title A), and Department Regulation 61-83, "Transportation of Radioactive Waste Into or Within South Carolina".

18. The licensee shall maintain all records and shipment manifest pertinent to the transportation, receipt, and disposal of radioactive material at the location specified in Condition 9 of this license until authorization is given by the Department for transfer or disposal of such records.

19. The licensee shall maintain records for each shipment of waste disposed of at the site. The records shall conform with the requirements of RHA 7.32, Department Regulation 61-63, Radioactive Material (Title A). The licensee shall maintain all records required in the Department Regulations 61-63 and 61-83, and 10 CFR Part 61 at the disposal facility in readable form to include electronic and microfilm, and stored in an environmentally-controlled facility to prevent damage.

20. A monthly site receipt and burial activities report shall be submitted no later than the 10th day following the month to the Assistant Director, Division of Waste Management, Bureau of Land & Waste Management, SC DHEC, 2600 Bull Street, Columbia, SC 29201.

21. Except as specifically provided otherwise by this license, the licensee shall possess and use radioactive material described in Items 5, 6, and 7 of this license and conduct site operations in accordance with statements, representations, operating procedures, and disposal criteria, heretofore made by the licensee or his authorized representative in application for and subsequent to issuance of SC Radioactive Material License No. 097, and amendments thereto.

Receipt, Acceptance and Inspection Conditions

22. The licensee shall not accept radioactive waste for storage or disposal unless the shipper has completed the required information for the waste shipment on the US NRC Uniform Low-Level Radioactive Waste Manifest Forms 540 (Shipping Paper), 541 (Container and Waste Description), and 542 (Manifest Index and Regional Compact Tabulation) as applicable, or approved equivalent forms.

23. The licensee shall not accept radioactive waste for storage or disposal unless the generator of such waste has a valid, unsuspended Radioactive Waste Transport Permit issued by the SC DHEC.

24. The licensee shall not accept radioactive waste for storage or disposal unless the shipper has provided a properly executed Department Form, DHEC-803, Radioactive Waste Shipment Certification Form, Part I and II. Shipments consisting of more than 75 cubic feet or containing more than one (1) curie shall also be accompanied by a properly completed and executed Department Form, DHEC-802, Radioactive Waste Prior Notification and Manifest Form. Changes to the shipment identification number on the forms may be made by the licensee, provided that the Department is notified of the change no later than the last day of the month for which the shipment was originally scheduled. Forms shall not be carried over more than one month.

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25. The licensee shall only accept radioactive waste shipments for storage or disposal which have been inspected by a representative of the Department. The licensee shall assist the Department in inspection, sampling and analysis of the waste as deemed necessary by the Department to ensure compliance with the requirements of this license. The licensee shall perform radiological analysis of liquids found in waste packages and interstitial spaces of shipping casks as deemed necessary by the Department.

26. Notwithstanding other conditions of this license, the licensee shall not accept radioactive waste for storage or disposal unless he has received advanced written notification of any waste shipment containing unusual hazards or potential hazards including but not limited to, physical, gaseous, chemical, pyrophoric, or excessive removable contamination on the disposal containers shipped inside casks or excessive internally contaminated casks, and unexpected high radiation levels at the disposal container surfaces.

27. The licensee shall immediately notify the Department or the Department's on-site representative of any waste shipments where a violation of applicable regulations or license conditions has been found.

28. The licensee shall notify the shipper and the Department when any shipment of radioactive waste or part of a shipment has not arrived within 60 days after the advance copy of the shipment manifest or shipping papers was received by the licensee.

29. The licensee shall notify the shipper when it has been determined that a radioactive waste shipment or part of a shipment cannot be accepted for disposal by the licensee. The licensee shall notify the waste generator/shipper before the end of the next business day if a shipment has failed to arrive at the disposal facility within the 24-hour time frame indicated in the advance notification or manifest.

30. The licensee shall acknowledge receipt of the waste within 7 days of its acceptance for disposal by returning a signed copy of the shipment manifest or shipping papers to the shipper. The licensee shall indicate on the returned copy of the shipment manifest or shipping papers any discrepancy between the waste description listed on the manifest or papers and the waste materials received in the shipment.

Waste Characteristics and Waste Form Conditions

31. The licensee shall not accept any radioactive waste for storage or disposal unless the shipper has marked each disposal container, as specified by the licensee, to identify its classification as either Class A, stable or unstable (S or U), Class B, or Class C waste, and certifies that the waste materials have been classified and prepared in accordance with the following waste classification table:

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RADIONUCLIDES		CONCENTRATION LIMITS IN CURIES/CUBIC METER*				
Table I (long-lived)		Class A		Class B		Class C
C-14	≤	0.8			≤	8
C-14 in activated metal	≤	8			≤	80
Ni-59 in activated metal	≤	22			≤	220
Nb-94 in activated metal	≤	0.02			≤	0.2
Tc-99	≤	0.3			≤	3
I-129	≤	0.008			≤	0.08
		CONCENTRATION LIMITS IN NANOCURIES/GRAM				
Alpha emitting transuranics with half-life greater than 5 years	≤	10			≤	100
Ra-226	≤	10			≤	100
Pu-241	≤	350			≤	3500
Cm-242	≤	2000			≤	20000
		CONCENTRATION LIMITS IN CURIES/CUBIC METER*				
Table II (short-lived)		Class A		Class B		Class C
Total of all with half-life less than 5 years	≤	700	>	700		
H-3	≤	40	>	40		
Co-60	≤	700	>	700		
Ni-63	≤	3.5	≤	70	≤	700
Ni-63 in activated metal	≤	35	≤	700	≤	7000
Sr-90	≤	0.04	≤	150	≤	7000
Cs-137	≤	1	≤	44	≤	4600

*curies/cubic meter is equivalent to microcuries/cubic centimeter

A. The concentration of a radionuclide or radionuclide mixture may be averaged over the volume of the waste and, if used, the solidification agent or matrix if the waste form is a homogenous mixture. The concentration of radionuclides in filters/sealed sources encapsulated with a solidification agent or matrix shall be averaged over the volume of the filter/sealed source not the solidification agent. The volume of packaging, containers, liners, or overpacks shall not be included in this calculation, nor shall the volume of the waste mixture be artificially increased with the addition of non-dispersible solids or objects even if considered as waste.

If expressed in units of nanocuries per gram, concentration may be averaged over the weight of the waste and, if used, the solidification agent if homogenous, except in the case of encapsulation of filters which shall be over the weight of the filter. The weight of packaging, containers, liners, or overpacks shall not be included in this calculation, nor shall the weight of the waste mixture be artificially increased by the addition of heavy, non-dispersible solids or objects even if considered as waste.

B. The waste is Class A if none of the listed radionuclides are present.

C. There are no upper limits in Class B waste for the first three radionuclides listed in Table II.

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D. There are no Class B values for the first nine (9) radionuclides listed; their presence classifies the waste as either Class A or Class C according to their concentrations.

E. The waste class for mixtures of radionuclides is determined by deriving for each radionuclide the ratio between its concentration in the mixture and its concentration limit in the table and adding the resulting ratio values for each radionuclide group. All limits used in the calculation must be for the same waste class. The sum of the ratios for each group must be less than or equal to 1.0 or the waste is of a higher classification than that used for the calculation.

F. If Class C limits are used in the calculation and the sum of the ratios for either group is equal to or exceeds 1.0, the waste is not acceptable for disposal without prior written approval from the Department.

G. If the concentration of any single radionuclide exceeds Class C values in the table, the waste is not acceptable for disposal without prior written approval from the Department.

H. Concentrations for C-14, Ni-59, Ni-63, and Nb-94 in activated metal must be evaluated for any irradiated metal component, filters and filter material associated with spent fuel pools.

I. Waste containing radium may be accepted only if the requirements of condition 44 of this license are met.

32. A. Unless otherwise specified in this license, the licensee shall not receive any liquid radioactive waste regardless of the chemical or physical form. Absorbent materials may be placed in packages of dry, solid waste to absorb unintentional and incidental amounts of liquids. Further, liquids in the interstitial spaces of transport casks and containers shall be removed to the extent practical.

B. Solidified or dewatered radioactive waste shall have no detectable free standing liquids in excess of one-half percent (0.5%) by waste volume of non-corrosive liquids per container.

C. In lieu of the requirements of paragraph B. above, solidified or dewatered waste containing non-corrosive liquids in excess of one-half percent (0.5%) by waste volume, and less than on percent (1%) non-corrosive liquids by waste volume, may be received and disposed of in high integrity containers approved by the Department.

33. A. Unless otherwise specified, the licensee shall only receive aqueous liquids and other applicable waste forms which have been solidified or otherwise stabilized with one of the following solidification media:

a. Vinyl Ester Styrene
b. Cement
c. Bitumen (see Subparagraph E. below)
d. Vinyl Chloride

B. Solidification media and processes used to stabilize Class A aqueous liquids and other Class A wastes containing isotopes with greater than five (5) year half-lives having a total specific activity if all these isotopes of 1 microcurie/cubic centimeter or greater, and all applicable Class B and C waste, shall meet and have been evaluated in accordance with the "Stability Guidance" requirements of the

US NRC Waste Management Division, Technical Position on Waste Form, (Revision 1), dated January 1991, or other evaluation criteria or methods specifically approved by the NRC or the Department.

C. Solidified Class A aqueous liquids and other applicable waste forms with a specific activity of less than 1 microcurie/cubic centimeter, shall meet the requirements of the "Solidified Class A Waste Products" of the NRC Technical Position on Waste Form, (Revision 1) dated January 1991.

D. Other solidification media and processes shall be acceptable for which a topical report has been prepared and received approval from the US NRC with concurrence from the Department or approval by the Department.

E. The licensee shall only receive for disposal, full formula, oxidized bitumen (asphalt) solidified waste, which is a free standing monolith as received for disposal, and certified as such by the waste generator.

34. Except as specifically provided in this license, the licensee shall not accept liquid radioactive waste packaged in absorbent materials, or where absorbent materials have been used to absorb liquids rather than properly solidified with an approved media.

35. Regardless of the waste classification of Condition 31, and unless otherwise authorized by the Department, the licensee shall not receive evaporator bottoms or concentrates, residues, sludges, or other waste which may contain free standing liquids, unless they are solidified in accordance with Condition 33, and meet the requirements as specified in Condition 32. Evaporator bottoms or concentrates which contain no free standing water and are not free flowing are acceptable for disposal when processed by a method specifically approved by the Department.

36. The licensee may receive resins and filter media in a dewatered form provided that the free standing liquid requirements of Condition 32 and the requirements of Condition 38 are met.

37. The licensee shall not receive containers of ion exchange resins or filter media (dewatered or solidified) unless records of complete radiological analyses (quantitative and qualitative) are provided. The records must specify the specific activity of each radionuclide expressed in microcuries/cubic centimeter and transuranic radionuclides in nanocuries/gram.

38. Regardless of the waste classification of Condition 31, ion exchange resins and filter media containing isotopes with greater than five (5) year half-lives having a specific activity of all these isotopes of 1 microcurie/cubic centimeter or greater must be stabilized by solidification in accordance with Condition 33 and meet the free standing liquid requirements of Condition 32.B. However, in lieu of solidification, the Department will authorize disposal of these waste forms meeting the free standing liquid requirements of Condition 32.C. in approved high integrity containers or other approved methods of stabilization.

39. Unless specifically provided otherwise, the licensee shall dispose of all classes of wastes in concrete overpacks or vaults which are approved by the Department and provided by the site operator. Void spaces within the waste and between the waste and its packaging shall be reduced to the extent practicable, but in no case shall less than eighty-five percent (85%) of the capacity of the containers be filled for all waste classes unless placed in a High Integrity Container. The licensee may allow a variance from this condition in certain instances, but only after receiving a written justification from the waste generator prior to receiving the waste shipment. Variance justifications and approvals shall be maintained for review by the Department.

40. Radioactive waste containing transuranic radionuclides within the limits specified in Condition 31 are acceptable provided that the transuranic radionuclides are evenly distributed within a homogeneous waste form and are incidental to the total radioactivity. Incidental in this condition is defined as not more than one

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percent (1%) of the total activity. This license does not authorize the receipt of disposal of components or equipment primarily contaminated with transuranic radionuclides on vehicles, equipment, or components, with contamination limits in excess of those specified in Condition 55.

41. Household or industrial smoke or gas detectors containing Americium-241 foils which may exceed the transuranic radionuclide limit specified in Condition 31 of this license may be accepted for disposal provided the entire detector is received for disposal.

42. The licensee shall not receive or dispose of sealed sources or special form radioactive materials containing more than 5 curies of radioactive material with half-lives greater than 5 years except in a container which provides long term containment. Such containers are subject to approval by the Department. Irradiated metal components which have similar characteristics of special form radioactive materials are subject to Department review for disposal container requirements.

The licensee may accept the following sealed sources and maximum total activities provided that the sources are encapsulated with a minimum of four (4) inches of cement on all sides having a minimum compressive strength of 2,500 pounds per square inch.

Radionuclide	Maximum Total Activity (microcuries)
C-14	100
Ni-59	100
Nb-94	0.01
Tc-99	10
I-129	0.01
Radionuclides in Condition 31. Table II	10^7

43. The licensee shall not receive toluene, xylene, dioxane, scintillation liquids which exhibit hazardous properties or other organic liquids or solids with similar chemical properties except as specified below:

A. Containers which have contained any of the liquids mentioned above are acceptable for disposal after treatment as specifically authorized by the Department.

B. The ash and/or residue from the incineration of these wastes are acceptable in accordance with Condition 45 of this license.

44. Unless otherwise authorized by the Department the licensee shall not receive any radioactive waste containing Radium except for:

A. Radium contained in solid homogeneous waste forms in which the Radium activity is incidental (incidental is defined as not more that one percent of the total activity) and the concentration of Radium has not been technologically enhanced or,

B. Radium contained in the following devices: self-luminous dials, hands of dials, timepieces, compasses, and electron tubes provided that the entire device is received and buried, or

C. Radium contained in biological research waste, or

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D. Radium sources specifically approved by the Department.

45. The licensee shall not receive radioactive waste in the forms of incinerator ash or powder which may be dispersible unless solidified with a media specified in Condition 33 of this license, or packaged to prevent dispersion as specifically approved by the Department. In lieu of solidification, these waste forms may be received in high integrity containers approved by the Department, provided the waste is rendered nondispersible with a binding matrix.

46. Radioactive waste containing chelating agents between 0.1 percent and 8 percent by weight in the waste as received for disposal shall be in High Integrity Containers or shall be stabilized by solidification with a media specified in Condition 33 of this license or an alternative method specifically approved by the Department.

47. The licensee may only receive gaseous radioactive materials of Krypton 85, Xenon 133, and Tritium for burial provided they meet the following criteria:

A. For Krypton 85 and Xenon 133:

a. Burial containers must be US DOT specification cylinders or U.S. Nuclear Regulatory Commission approved sealed sources.

b. Internal pressure of containers may not exceed 1.5 atmospheres.

c. Total activity of containers shall not exceed 100 curies each.

B. For Tritium:

a. Only sources approved by the US NRC or an Agreement State may be received for disposal.

b. The source/device must be received intact.

c. The internal pressure of the source/device shall not exceed 1.5 atmospheres.

d. Sources/devices must be packaged to prevent breakage.

e. The maximum activity per disposal container shall not exceed 1000 curies.

f. Devices requiring stabilization based on waste classification (using the volume of the source/device only) must be placed in a high integrity container or encapsulated with an appropriate stabilization media.

48. A. Unless otherwise authorized, the licensee shall not receive for storage nor disposal any mixed low-level radioactive waste defined as waste that satisfies the definition of low-level radioactive waste specified in the Low-Level Radioactive Waste Policy Amendments Act of 1985 (P.L. 99-240), and contains waste that either (1) is listed as hazardous waste in Subpart D, 40 CFR 261, or (2) causes the waste to exhibit any of the hazardous waste characteristics identified in Subpart C, 40 CFR Part 261.

B. The licensee may however receive waste that has been treated by acceptable methods to render it nonhazardous and therefore not subject to the jurisdiction of the Resource Conservation and Recovery Act (RCRA). Waste which may contain discrete quantities of hazardous or toxic materials may be evaluated for disposal by the licensee and such evaluations provided to the Department for consideration of approval.

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49. The licensee shall not receive radioactive waste that is readily capable of detonation or of explosive decomposition or reaction at normal pressures and temperature, or of explosive or exothermic reaction with water.

50. The licensee shall not receive radioactive waste which contains or is capable of generating quantities of toxic gases, vapors, or fumes harmful to persons transporting, handling or disposing of the waste. This does not apply to radioactive gaseous waste packaged in accordance with Condition 47 of this license.

51. The license shall not receive or dispose of any pyrophoric material or flammable solids. These materials contained in waste shall be treated, prepared and packaged to be nonflammable and the final waste form rendered nonpyrophoric and nonflammable prior to transportation and receipt.

52. The licensee shall not receive or bury oil or petroleum based materials in any physical form. However, this does not prohibit the receipt and disposal of waste containing incidental or trace amounts of oil or petroleum based materials which have been absorbed, provided that the amount of absorbed oil and petroleum based materials does not exceed one percent (1%) by waste volume in a container.

53. The licensee shall not receive radioactive waste containing hazardous biological, pathogenic, or infectious material unless treated to reduce to maximum extent practicable the potential hazard from the materials. In addition, radioactive waste containing biological, pathogenic, or infectious material shall be doubly packaged in new or properly recertified containers which meet the general packaging requirements of DOT as follows:

    A. First, the inner container having a capacity of 55-gallon or less shall have a water tight liner at least 4 mils thick hermetically sealed after filling.

    B. The biological material shall be thoroughly layered in the inner container in a ratio of thirty (30) parts biological material to at least one (1) part slaked lime and ten (10) parts absorbent, which shall be agricultural grade 4 vermiculite or medium grade diatomaceous earth, or other adsorbents that have received approval from the Department by volume. The addition of formaldehyde is strictly prohibited.

    C. The closure on the inner container shall be a standard lid with securely attached ring and bolt. Lever locks are not acceptable.

    D. Unless otherwise authorized by the Department, the outer container, which shall have a volume of at least 1.5 times the inner container shall be filled initially with at least 4 inches of absorbent material, specified in B., the inner container in an upright position, and the remaining volume filled with the absorbent material, then securely closed and properly sealed.

54. Unless otherwise authorized by the Department, the licensee shall receive Special Nuclear Material (SNM) as authorized in Conditions 5, 6, 7, and 8 of this license in 55 gallon or larger containers only. Any SNM shipment in which there is evidence that SNM is missing or that the waste packages have been tampered with in transport shall be received by the licensee and safely stored pending notification to the Department. The licensee shall not dispose of such packages unless authorized by the Department.

Contamination Limit Conditions

55. For receipt at the Barnwell Site, all shipments shall comply with contamination control limits as prescribed in US DOT Regulations, 49 CFR 173.443.

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Enclosed radioactive material transport vehicles used solely for transporting radioactive materials and marked "For Radioactive Material Use Only" and accessible surface of transport casks and trailer shall not be released from the site if contamination limits exceed the following:

A. Fixed contamination of 10 mR/hr on contact with the interior surface or 2 mR/hr at 1 meter from the interior surface.

B. Removable contamination of 2200 dpm/100 sq. cm. Beta-gamma or 220 dpm/100 sq. cm. Alpha. This applied to interior and exterior surfaces.

C. Fixed contamination of 0.5 mR/hr on contact with any exterior surface.

Internally contaminated (fixed or removable) shipping casks released from the site are subject to applicable shipping regulations of the US DOT. The licensee shall inform the recipient of such casks of the contaminated nature of the cask. Shipping documentation for the casks must be maintained by the licensee for review by the Department.

56. Vehicles used solely for transporting radioactive material and are not marked "For Radioactive Material Use Only" shall not be released from the site if the contamination limits exceed the following:

A. Fixed contamination of 0.5 mR/hr at any accessible surface.

B. Removable contamination of 2200 dpm/100 sq. cm. Beta-gamma, or 220 dpm/100 sq. cm. Alpha.

57. Vehicles or items for unrestricted use shall not be released from the site if the contamination limits exceed the following unless specifically authorized by the Department:

A. Fixed contamination of 0.1 mR/hr at any accessible surface.

B. Removable contamination of 220 dpm/100 sq. cm. Beta-gamma, or 22 dpm/100 sq. cm. Alpha.

58. The licensee shall perform decontamination on vehicles, equipment, or components, with contamination limits in excess of those specified in Condition 56 in a controlled environment.

59. The licensee shall not use its vehicle wash-down facility for any vehicles or equipment with removable contamination limits in excess of those specified in Condition 56 unless specifically approved by the Department.

General Packaging Conditions

60. All radioactive waste shall be packaged and loaded in accordance with applicable US DOT Regulations, US NRC Regulations 10 CFR Part 71, the requirements of this license, and the disposal site criteria.

61. Unless otherwise authorized, all radioactive waste shall be received and buried in closed containers. Containers which have been altered, and solidification or encapsulation media intended to serve as containers or container closures, are not acceptable unless approved by the Department. Loose radioactive waste and solidification residuals within shipping casks or other reusable containers are prohibited.

62. The licensee shall not receive any package to be used as the final burial container that is corroded to the point of degradation or damage. Any package used as the final burial container shall be of such material

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construction that there will be no significant chemical, galvanic, or other reaction among the packaging components, or between the packaging components and the package contents.

63. The licensee shall, to the extent practicable, repair or repackage any damaged package used as the final burial container if such packages are approved for acceptance by the Department.

64. Prior to burial, the licensee shall, to the extent practicable, remove all liquids from waste packages found in excess of allowable limits if such packages are approved for acceptance by the Department.

65. The licensee shall not receive shipments of radioactive materials unless appropriate lifting devices of sufficient length has been provided and securely attached to containers and palletized shipments within a cask.

66. The licensee is not authorized to open any packages at its facility, except for the following:

A. For purposes of repairing or repackaging damaged containers.

B. For purposes of inspecting to insure compliance with this license.

C. For purposes of returning outer shipping containers.

D. For purposes of confirming package contents.

Site Design, Construction and Maintenance Conditions

67. Construction of waste burial trenches shall be in accordance with CNS Procedure S20-AD-008, "Trench Construction" and Department approved drawings and specifications. Any changes to these drawings, specifications, or procedures must have approval from the Department before implementation.

68. The licensee shall not begin construction of any trench prior to approval of the Department as to location, trench bottom elevation and intended use.

69. The licensee shall not initiate burial operations in newly excavated trenches until the Department has inspected and approved the trenches. Trench construction inspections shall be performed in accordance with CNS Procedure S20-AD-008, "Trench Construction" and any additional inspections deemed necessary by the Department.

70. Trench backfill and completion shall be performed in accordance with CNS Procedure S20-AD-008, "Trench Construction".

71. A. Completed trenches shall at no time be used for stockpiling large volumes of earth not withstanding provisions for a final grading plan.

B. The licensee shall design trench covers to minimize to the extent practicable water infiltration, to direct percolating or surface water away from the disposed waste, and to resist degradation by surface geologic processes and biotic activity.

72. Open trenches to include trenches under construction and partially filled trenches shall be protected to prevent runoff water from entering trenches. Radioactive waste shall not be placed into trench areas where water has

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accumulated. Burial of radioactive waste into trenches with unusual amounts of water shall immediately cease until the origin of water has been determined and corrective action taken.

73. The licensee shall use proper surface water management techniques on the site to insure that:

A. Erosion is minimized.

B. Surface runoff is directed away from the trenches.

C. Accumulation of standing water is minimized.

D. Standing water in the immediate disposal area is prevented.

74. All monitoring wells, sumps, shall be sufficiently capped or covered to prevent the introduction of extraneous material or infiltration of water. All well and sump pipes shall be protected from damage.

75. The licensee shall perform inspections of completed trenches and capped areas in accordance with CNS Procedure S20-OP-007, "Completed Trench Inspection Procedure", to ascertain any erosion, settling, cracking, subsidence, or loss of ground cover grasses and make corrections immediately. Documentation of the inspection findings and all repairs even if the repairs were performed as a routine maintenance function shall be made and incorporated into a permanent record and submitted with the stabilization plan for final site closure.

76. The licensee shall initiate closure and stabilization measures as each trench is filled and covered. Interim or final grades shall be established at no more than one year following final trench burial operations. Completed trenches shall be continuously and properly maintained to control erosion. Active waste disposal operations must not have an adverse effect on completed closure and stabilization measures.

77. The licensee shall use any reasonable means, including but not limited to fencing and security personnel, to prevent unauthorized entry into the restricted area of the site.

78. The boundaries and locations of each disposal trench shall be accurately located and mapped by means of a land survey. Temporary trench boundary markers and trench identification markers shall be erected upon completion of backfill operations until permanent markers are installed.

79. A series of markers, one at the end of each completed trench and on each corner, shall be installed upon completion of the seeding of trench covers. End monuments shall be constructed of granite. Trench corner markers shall be constructed in accordance with CNS Drawing No. B-215-C-0010. The following information shall be reported to the Assistant Director, Division of Waste Management, Bureau of Land & Waste Management, SC DHEC, 2600 Bull Street, Columbia, SC 29201:

A. Total activity of radioactive material in curies total amount of source material in pounds, and total amount of special nuclear material in grams in the trench.

B. Date of completion of the burial operations; and

C. Volume of waste in the trench.

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Burial Operation Conditions

80. Unless specifically authorized by the Department, the licensee shall not exhume previously buried waste.

81. All waste shall be placed in vaults which will provide additional structural stability. Structural evaluations for large components may be submitted to the Department for review and with concurrence from the Department will not require disposal in a vault. The licensee shall construct the vaults in accordance with procedures, drawings, standards, and a quality assurance plan that have received approval from the Department.

82. The disposal trenches and vaults shall be designed and constructed to meet the following objectives:

    A. to minimize the migration of water onto the disposal trench.

    B. to minimize the migration of waste or waste contaminated water out of the disposal units.

    C. to detect water or other liquids in the trenches for assessment and potential remedial measures.

    D. to facilitate remedial methods without disturbing other disposal trenches.

    E. to provide reasonable assurance that the waste will be isolated for at least the institutional control period.

    F. to prevent contact between the waste and the surrounding earth, except for earthen materials used for backfilling within the disposal unit.

83. Wastes designated as Class C pursuant to Condition 31 of this license, shall be disposed of so that the top of the waste is a minimum of 5 meters below the top surface of the cover or shall be disposed of with intruder barriers that are designed to protect against an inadvertent intrusion for at least 500 years. Such intruder barrier designs must be specifically approved by the Department.

84. The licensee shall handle and emplace packages of radioactive waste in disposal trenches in such a manner that maintains packaging integrity during handling, emplacing, and subsequent backfilling. Waste packages deposited in trenches shall be protected from any adverse operations which may cause damage to them.

85. The licensee shall emplace disposal vaults in such a manner to minimize voids between vaults and permit voids between vaults to be filled with earth to reduce future trench subsidence.

86. The licensee shall be a "Registered User" of all licensed casks delivered to the site containing radioactive waste for disposal.

87. At least one health physics technician shall be present during all waste handling, offloading, and disposal operations.

88. The licensee shall maintain radiation levels at the edge of the open trenches at or below 100 mR/hr.

89. Licensee personnel shall wear appropriate protective clothing, apparatus, and gloves at all times while handling or disposing of radioactive waste.

90. Vaults shall be covered within six (6) months of being filled with waste unless otherwise approved by the Department.

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91. The licensee shall bury containers of Krypton 85 and Xenon 133 gaseous radioactive materials in upright positions within concrete overpacks or vaults. Each gas container shall be disposed in different overpacks or vaults unless otherwise authorized by the Department.

92. Unless specifically authorized, the licensee shall not store any package containing radioactive waste for a period greater than six months from the date of receipt of the package prior to burial. Radioactive waste shall not be stored in the trench area or an open environment for a period greater than ten (10) days from receipt, and shall be protected from damage and inclement weather conditions.

Environmental Surveillance Conditions

93. The licensee shall conduct an on-site monitoring and environmental monitoring program capable of detecting the potential contribution of radioactive material and hazardous constituents from the site to the environment. The monitoring program shall be performed in accordance with CNS Procedures

94. Should any samples taken from the monitoring wells, or air samples reveal increases in the concentration of radioactive material which were determined prior to commencement of the burial operations, the licensee shall perform further surveys to determine whether or not the increase is due to the land burial operations. The licensee shall notify the Assistant Director, Division of Waste Management, Bureau of Land & Waste Management, SC DHEC, within 48 hours of any such increases.

95. The licensee shall submit results of all scheduled environmental sampling and analysis to the Department quarterly.

96. Monitoring wells shall be placed outside the trenches but in the trench area. Specific locations shall be determined through consultation. All wells shall be grouted, sealed and capped.

97. As radioactive material buried may not be transferred by abandonment or otherwise, unless specifically authorized by the Department, the expiration date of this license applies only to the above ground activities and to authority to bury radioactive material wastes at the site specified in Condition 9. The license continues in effect and the responsibility and authority for possession of buried radioactive material waste continues until the Department finds that the plan established for preparation of the Barnwell Site for transfer to another person has been satisfactorily implemented in a manner to reasonably assure protection of the public health and safety and the Department takes action to terminate the licensee's responsibility and authority under this license. All requirements for environmental monitoring, site inspection, maintenance and site security continue whether wastes are being buried or not.

98. The licensee shall develop a site closure and stabilization plan that addresses, as a minimum, the following performance objectives:

    A. Bury all waste in accordance with the requirements of the license.

    B. Dismantle, decontaminate, as required, and dispose of all structures, equipment, and materials that are not to be transferred to the site custodian.

    C. Document the arrangements and the status of the arrangements for orderly transfer of site control and for long term care by the government custodian. Also document the agreement, if any, of state or federal governments to participate in, or accomplish, any performance objective. Specific funding arrangements to assure the availability of funds to complete the site closure and stabilization plan must be made.

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D. Direct gamma radiation from buried wastes should be essentially background.

E. Demonstrate by measurement and/or model during operations and after site closure that concentrations of radioactive material which may be released to the general environment in ground water, surface water, air, soil, plants, or animals will not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public.

F. Render the site suitable for surface activities during custodial care. Planned custodial care may be limited to activities such as vegetation control, minor maintenance, and environmental monitoring. However, use of the site surface for activities such as parking lots may be planned. Final conditions at the site must be acceptable to the government custodian and compatible with its plan for the site.

G. Demonstrate that all trench elevations are above water table levels taking into account the complete history of seasonable fluctuations.

H. Eliminate the potential for loss of site or trench integrity due to factors such as erosion, surface water, wind, subsidence, and frost action. For example, an overall site surface water management system must be established for humid sites to drain rainwater and snowmelt away from the burial trenches. All slopes must be sufficiently gentle to prevent slumping or gullying. The surface must be stabilized with established short rooted grass, rock, riprap, or other measures. Trench caps must be stabilized to minimize erosion, settling, or slumping of caps.

I. Demonstrate that trench markers are in place, stable, and keyed to benchmarks. Identifying information must be clearly and permanently marked.

J. Compile and transfer to the Department complete records of site maintenance and stabilization activities, trench elevation and locations, trench inventories, and monitoring data for use during custodial care for unexpected corrective measures and date interpretation.

K. Establish a buffer zone surrounding the site sufficient to provide space to stabilize slopes, incorporate surface water management features, assure that future excavation on adjoining areas would not compromise trench or site integrity, and provide working space for unexpected mitigating measures in the future. The buffer zone must also be transferred to the custodial agency. The buffer zone may generally be less than 300 feet but not less than 100 feet.

L. Provide a secure passive site security system (e.g., a fence) that requires minimum maintenance.

M. Stabilize the site in a manner to minimize environmental monitoring requirements for the long-term custodial phase and develop a monitoring program based on the stabilization plan.

N. Investigate the causes of any statistical increases in environmental samples which have occurred during operation and stabilization. In particular, any evidence of unusual or unexpected rates or levels of radionuclide or hazardous constituent migration in or with the groundwater must be analyzed and corrective measures implemented.

O. Eliminate the need for active water management measures, such as sump or trench pumping and treatment of the water to assure that wastes are not leached by standing water in the trenches.

P. Evaluate present and zoned activities on adjoining areas to determine their impact on the long-term performance of the site and take reasonable action to minimize the effects.

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99. An interim site closure and stabilization plan, assessment of current operating practices, and the long term care plan for the site shall be submitted for review one year prior to the expiration date listed in Condition 4 of this license. The plan shall be consistent with Condition 98 of this license and shall include demonstration that funds are being set aside or other measures being taken are adequate to finance site closure and long term care. The plan shall also include preliminary estimates of costs, environmental impacts, data needs, personnel needs, material and equipment needs, planned documentation and quality assurance, and detailed plan for trench locations and elevations, expected capacities, planned surface contours, and buffer zones.

100. The licensee shall periodically assess the adequacy of the Decommissioning Trust accounts and any other financial mechanisms to assure that sufficient funds are available to complete the remaining activities required to close and stabilize the site in accordance with the latest revision of the site closure fund. The licensee shall provide an annual report of this assessment in accordance with RHA 7.30.3 to the Department by June 30.

For the South Carolina Department of Health and Environmental Control

Date of Issuance _____ By: _____

Henry J. Porter, Assistant Director
Division of Waste Management
Bureau of Land and Waste Management

APPENDIX E
FIRE HAZARD ANALYSIS REPORT
FOR
INTERIM RADWASTE STORAGE FACILITY
LASALLE COUNTY NUCLEAR STATION

1.0 INTRODUCTION

1.1 Scope

This section consists of a review of fire protection and life safety related to the Interim Radwaste Storage Facility Project for LaSalle County Nuclear Station. Information gathered for the analysis includes drawings and specifications as referenced documents herein.

1.2 Limitations

This analysis was performed as part of the LaSalle County Station IRSF 10 CFR 50.59 LAR Support Technical Report, and presumes no significant changes to the Interim Radwaste Storage Facility were made since 1994.

1.3 Criteria for Evaluation

Combustible fire loadings used in developing the results of this Fire Hazard Analysis are as follows:

Combustible	Fire Loading
Electrical insulation	10,500 btu/lb
Class A (wood, paper, etc.)	8,000 btu/lb
Vehicle tires	14,000 btu/lb
Oil (any type, 2, one pint each)	150,000 btu/gal
High-density polyethylene	20,000 btu/lb
Diesel fuel	150,000 btu/gal
Resins (when dried)	18,800 btu/lb

Transient combustibles and their use in the project's facilities are considered to be limited. Materials used during maintenance activities and paper supplies are considered transient.

Electric power, control, and instrumentation cable construction meet the smoke and flame test requirements of IEEE 383/UL 1277. The contribution of cable within conduit to the fire loading in an area is dependent on the severity of the postulated design basis fire. Due to the non-propagating properties of the cable and the fact that the cable is enclosed in non-combustible metal conduit, cable will not be considered to pyrolyze inside the conduit unless the temperature shown on the standard time-temperature curve corresponding to the calculated equivalent severity is above 1100 ^{o}F (Reference NFPA

Fire Protection Handbook, pages 7-109 through 7-111, “Fire Severity" and "Standard Time-Temperature Curve”, Attachment C.).

Occupancy for this facility is considered to be Special Purpose Industrial with regard to NFPA 101, Life Safety Code, 1988, Group B, Div. 2 with regard to the Uniform Building Code (UBC) and Ordinary Hazard, Group 2 with regard to NFPA 13, Standard for the Installation of Sprinkler Systems, 1991.

The Interim Radwaste Storage Facility serves for interim and long term (extended) storage of containerized Radwaste. This facility is not reactor safe-shutdown related (safety-related).

1.4 Evaluation Assumptions

For the purposes of this report, outside walls are not considered requiring a fire rating unless an exterior combustible (i.e., oil filled transformer, etc.) exists, which creates an exposure hazard.

Small quantities of grease (< one pound) or oil (< one quart) used as a lubricant in valves, motors, pans, damper operators and pumps will not be considered as contributing to a fire when contained within packing glands, bearings, or reservoirs.

Electric power and electric equipment such as motor control centers will not contribute significantly to the fire loading due to their metal enclosures. Similarly, totally enclosed electric motors are not considered to contribute significantly to fire loading.

It is assumed that a postulated fire is unlikely to exist if only electrical cables are involved. The construction of the specified electrical power, control, and instrumentation cable meets IEEE 383/UL 1277 which certify the cables non-propagational and fire resistance capabilities.

Electrical faults will be mitigated by selective tripping of breakers or blowing of fuses.

All cables, except festoon cables servicing the bridge crane, are in conduit.

1.5 Definitions

FIRE AREA- An area of a facility that is separated from other areas by complete fire barriers with at least a two hour rating. This includes walls, floors, and ceilings, with any openings therein protected with seals or closures having a fire resistance rating equal to that of the barriers.

FIRE ZONE- the subdivisions of fire areas (as defined above) which are subdivided by fire rated partitions or special separation.

HIGHLY PROTECTED RISK - The term involves the use and application of judgment and thus does not lend itself to a precise, fixed definition applicable, in all locations and situations. It has the same meaning and intent as is commonly understood when this or the term, "improved risk", is used in the insurance industry. Generally, a "Highly Protected Risk" property is one that would qualify for complete insurance coverage by the Factory Mutual System, the Industrial Risk Insurers, and other industrial insurance companies that limit their insurance underwriting to the best protected class of industrial risk. The most evident characteristic of such a property is the existence of reliable, automatic fire extinguishing systems throughout all buildings of combustible construction or content where the building is vital to operational, continuity or may experience a large property loss from fire in the absence of an automatic extinguishing system.

DESIGN BASIS FIRE - A fire that is the most severe accident of this type. In postulating such a fire, failure of automatic and manual fire suppression provisions is assumed except for those safety class items/systems that are specifically designed to remain available (structurally or functionally) through the event.

FIRE HAZARD ANALYSIS - An analysis, documented in report form, which establishes a systematic approach to fire protection design which will ensure that all fire protection requirements are met and will facilitate a fire protection review. The analysis is documented in report form in the facility project files and referenced by the Safety Analysis Report.

MAXIMUM CREDIBLE FIRE LOSS - The maximum loss that could occur from a combination of events resulting from a single fire. Any installed fire protection systems are assumed to function as designed. Due to the uncertainties of predicting human action, the effect of emergency response is generally omitted except for post-fire actions such as salvage work, shutting down water systems, and restoring production.

MAXIMUM POSSIBLE FIRE LOSS - The maximum possible loss that could occur in a single fire area assuming the failure of both automatic and manual fire extinguishing actions.

2.0 PURPOSE AND OBJECTIVES

Fire Protection Design Analysis

The purpose and objectives of this analysis are to:

- Demonstrate that the hazards to on-site personnel and off-site population as a result of a fire are maintained as low as reasonably achievable, in accordance with NRC regulations and LaSalle County Nuclear Station policy.

- To insure facility compliance with the applicable NFPA requirements in the areas of fire protection and life safety.

- Determine and recommend those special fire prevention and protection features and controls necessary to achieve a level of "Highly Protected Risk" fire protection.

3.0 REFERENCE CODES, STANDARDS, AND DRAWINGS

The following codes, standards, and reference documents have been utilized in the development of this report And, except for NFPA 801, were current when the IRSF was originally assessed via a 50.59 evaluation (1992).

Codes and Standards (and other references)

National Fire Protection Association (NFPA) Standards and References:

NFPA 10 Portable Extinguishers, 1988

NFPA 13 Installation of Sprinkler Systems, 1989

NFPA 14 Standpipe and Hose Systems, 1990

NFPA 15 Water Spray Fixed Systems, 1990

NFPA 24 Installation of Private Fire Service Mains, 1987

NFPA 26 Supervision of Valves Controlling Water Supplies, 1988

NFPA 70 National Electric Code, 1990

NFPA 72 Installation, Maintenance, and Use of Local protective signaling Systems, 1990

NFPA 72E Automatic fire Detectors, 1990

NFPA 72H Testing Procedures for Local, Auxiliary, Remote Station and Proprietary Protective Signaling Systems, 1988

NFPA 80 Fire Doors and Windows, 1990

NFPA 80A Exterior Fire Exposures, 1987

NFPA 90A Installation of Air Conditioning and NFPA 101, Ventilating Systems, 1989

NFPA 101 Life Safety Code, 1991

NFPA 203M Roof Coverings and Roof Deck Construct ions, 1987

NFPA 241 Safeguarding Construction, Alteration, and Demolition Operations, 1989

NFPA Fire Protection Handbook, 16th Edition, 1986

NFPA 801 Standard for Fire Protections for Facilities Handling Radioactive Material, 2008

Uniform Building Code, 1988

Edison Electric Institute, "Suggested Guidelines for Completing a Fire Hazards Analysis for Electric Utility Facilities," April 1981

U.S. Government-"Occupational Safety and Health Administration (OSHA) Part 1910, Title 29 of Federal Regulation", 1984

10CFR50.59- "Domestic Licensing of Production and Utilization Facilities", Changes, Tests, and Experimentsm,1991

Underwriters Laboratory (UL), Fire Resistance Directory, 1989

Drawings

As listed on the Fire Hazard Analysis Detail Sheets

Specifications

None

4.0 FACILITY OVERVIEW

4.1 Description, Location, Construction

This facility provides long-term storage of Class B/C radioactive wastes resulting from normal operations. In July 2008, Barnwell Burial Facility stopped receiving generated Radwaste material from out of compact nuclear facilities. Class B/C radioactive wastes generated by the LaSalle Station and potentially Byron, Braidwood and Clinton stations will be accepted at this facility.

This facility is located on the site of LaSalle County Nuclear Station.

The exterior of the storage and truck bays of the structure is reinforced concrete, including the roof. Control room and mechanical equipment exterior walls are cement

masonry units. Floors are slab-on-grade. The storage area is surrounded by walls of minimum 30 inches thick reinforced concrete up to a height of 34 feet and is 12-15 inches thick in the roof. The storage area is separated from the truck bay by a 30 inch reinforced concrete wall up to a height of 34 feet. There is no separating wall above the 34 feet elevation. There is an opening notch 7 feet by 7 feet at the top of this wall. The truck bay is surrounded by minimum 15 inches thick concrete exterior walls for passing containers through/from the storage bay. A truck entrance is located at one end of the truck bay while personnel doors are located at each end of the truck bay. In addition, a forklift entrance is located in the truck bay near the truck entrance.

4.2 Important Processes, Equipment, and Cabling

Quantities of Radwaste that will be moved into the storage area are limited to the size of one transportation vehicle at any given time (normally a single HIC). Waste is expected to be either processed waste in the form of dewatered bead resins (e.g., DOWEX) or powdered resins (e.g., Powdex). Dewatered resin waste will be contained in HICs made of molded high-density polyethylene or poly HIC's in metal shells. The HICs feature filtered vents and are corrosion resistant. The new container size limitation is no larger than a standard size 195 cu. ft. due to the wall opening limitation of 7 feet by 7 feet. The standard HIC will be 8-120 , having an internal volume of 107.6 ft^3, 61.5 in diameter, and 73.5 in height, but others container sizes have been generated and are currently waiting for a long-term storage.

Corrosive, reactive, and other radioactive mixed wastes are not authorized for IRSF storage.

The following paragraph describes the IRSF waste loading process.

A tractor-trailer is moved into the truck bay area. The tractor is disengaged and the truck removed from the facility. The truck bay doors are then closed. The ventilation system is shut down. The trailer's contents are removed by a remote-operated crane and hoisted into the storage area. The IRSF crane is equipped with a winch system which permits it to be manually retracted over the truck bay without electrical power or functioning drive motors. The design of container lifting equipment is such that dropping a container is highly unlikely. Additionally, containers are constructed in accordance with DOT standards and are, therefore, highly resistant to impact damage. Consequently, the probability that a container drop will occur and the contents be released within the truck bay is low, and in any case will not credibly spread beyond the Truck Bay zone.

With the truck cab removed, significant sources of potential ignition are not available in the truck bay. Additionally, Manual Fire Suppression and smoke detectors are provided

for the truck bay. Consequently, the probability that any combustible contents will be released or exposed to any source of ignition within the truck bay is low.

4.3 Epoxy Coating

The LaSalle County Station IRSF Specification No. 70160-2000-14 for Field Painting specifies epoxy coating applied to the storage bay floor and from the floor up to 10' on the four side walls of the storage bay as follows: interior concrete floors with sprayed on one coat of Keeler & Long No. 3500 Kolor-Poxy self-priming surfacing enamel primer/finish, with a dry film thickness (DFT) of 10 to 30 mils; interior concrete walls with a seal coat of Keeler & Long No. 4129 Epoxy Clear Curing Compound, 0.5 to 1.5 DFT, + strike flush coat of Keeler & Long No. 3500 Kolor-Poxy self-priming surfacing enamel, 1.0 to 5.0 DFT, + body coat of Keeler & Long No. 3500 Kolor-Poxy self-priming surfacing enamel) thickness, 20 to 40 mils DFT.

NRC Industry Notice 2007-26 on "Combustibility of Epoxy Floor Coatings at Commercial Nuclear Power Plants" defines a non-combustible material as:

a. A material which in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat; and

b. Material having a structural base of noncombustible material, as defined in a., above, with a surfacing not over 1/8-inch thick that has a flame spread rating not higher than 50 when measured using the test protocol of American Society for Testing and Materials (ASTM) E 84, "Standard Test Method for Surface Burning Characteristics of Building Materials."

On July 22, 2009, URS – Washington Division personnel met with Mr. John De Barba, Field Technical Service Manager for PPG Protective & Marine Coatings, the current owner of Keeler & Long, to discuss the flame spread rating of the Keeler & Long epoxy surface finish 4500. Mr. De Barba initially provided test results performed in accordance with ASTM Standard E-84, indicating tested values of 45 for all thicknesses tested up to 25 mils dry film thickness. Mr. De Barba indicated that thicknesses above this level would not be applicable despite the Field Painting Specification, as cracking of the coating takes place above these thicknesses which would render them as unacceptable upon inspection. However, in response to a URS – Washington Division request for additional information regarding flame spread ratings of thicker Keeler & Long epoxy No. 3500, Mr. De Barba provided additional ASTM Standard E-84 test results of a flame spread index of 53.059 for coatings up to 30 mils in dry mil thickness.

Industry Notice 2007-26 indicates that epoxy floor coverings at the Donald C. Cook Nuclear Power Plant with thickness between 0.115 inches (115 mils) and 0.230 inches (230 mils) with flame spread ratings of 140 to 150, and at the Duane Arnold Energy Center with a flame spread rating of 110, were acceptable with respect to not causing fires to propagate. As Exelon IRSF epoxy floor coating thicknesses and flame spread ratings are both less than one-half those considered acceptable with respect to combustibility at other plants, the Exelon IRSF epoxy floor coating is considered acceptable with respect to not causing fires to propagate.

In conclusion, although testing for up to 30 mils dry film thickness of KL3500 resulted in Flame Spread Rating slightly above 50, **the LaSalle IRSF epoxy coating is considered non-combustible based on:**

- Epoxy dry film thicknesses sufficient to result in flame spread ratings above 50 would be subject to unacceptable cracking upon application, and therefore actual thicknesses would have flame spread ratings below 50.
- Industry Notice 2007-26 actual plant data indicates non-combustibility of epoxies at much greater thicknesses and higher flame spread ratings.

4.4 Fire Detection Systems

The fire alarm systems in the IRSF are "Class A" supervised, designed and installed in accordance with NFPA 72, 1990 and NFPA 72E, 1990 and UBC, 1990. The local panel alarms locally and remotely in the reactor control room (manned 24/7) and in the IRSF control room. The fire detection system causes closure of duct-mounted fire dampers by melting a fusible link when high temperatures are obtained in cases of a fire.

There are no fire detection systems in the storage area. However, a single fire detector is located directly over the storage bay/truck bay interface wall, and three (3) duct smoke detectors are located in the ventilation recirculation return ducts from the storage bay. Additionally, likelihood of fire in the storage bay area is considered extremely remote.

The truck bay is protected by smoke detectors which transmit an alarm to the local alarm panel.

The mechanical equipment room is protected by ionization type smoke detectors which transmit an alarm to the local alarm panel. Supply air ducts are equipped with duct-mounted smoke detectors which cause interruption of fan operation in addition to transmitting an alarm signal.

The IRSF control room is protected by ionization type detectors which transmit an alarm to the local alarm panel.

4.5 Fire Suppression Systems

Exterior:

A looped fire main is provided at the site. Hydrants are spaced so that the distance to all portions of buildings and structures is not more than 300 ft. At least two hydrants are within 500 feet of the structure.

Mobile fire units are available on a 24-hour-per-day basis from the Marseilles, IL Fire Department. These units are available to respond to an emergency.

Interior:

Dry chemical fire extinguishers are provided per NFPA 10 in the truck bay.

4.6 Ventilation Description

The Interim Radwaste Storage Facility HVAC system is comprised of three subsystems. This non-safety-related system is designed to maintain temperature within the facility for storage of Radwaste, control and mechanical equipment ventilation; and limits the minimum IRSF temperature to 50°F.

The system is designed to maintain the control room at 75°F nominal; the equipment room at 70-120°F; and the storage area/truck bay at 50-120°F.

The IRSF system is designed to function with variable quantities of outside air intake, from maximum recycle to 100% outside air intake. This ventilation system is adequate to prevent the buildup of potential combustible gases vented from containers of dewatered waste and to maintain an inside thermal environment without excessive temperature extremes.

Heating and ventilation in the truck bay and storage bay are provided by a 19,500 cfm fan with an electric coil. During cooling season the system operates on 100% outside air. During heating season outside air dampers move to the minimum position, allowing 3,450 cfm of outside air into the building. The remaining 16,050 cfm of ventilation air is recirculated. Auxiliary heating in the truck bay is provided by a duct-mounted electric coil and electric unit heaters. Truck bay and storage bay exhaust is via a louvered vent located on the mezzanine level in the truck bay.

Ventilation in the mechanical equipment room is provided by a 4000 cfm rooftop exhaust fan and motor operated wall louvers. Heating is provided by unit heaters.

Heating, ventilation and air conditioning is provided in the control room by a ducted split system air conditioning unit located in the mechanical equipment room. Heat is provided by duct-mounted electric coils. Outside air is taken in via a louver with motor operated damper connected to the return air duct in the mechanical equipment room. Air is exhausted via a rooftop exhaust fan.

5.0 DESIGN BASIS FIRE ANALYSES

Design Basis Fire Analysis Data Sheets

The sheets in Section 6.0 (Attachments) provide detailed information for each fire zone and/or area.

5.2 Ignition Sources

Ignition sources in the IRSF storage bay are relatively limited. NFPA reported that 29% of fires initiates by an electrical ignition source and 34% by open flames. See Figure 1 for detail . In the IRSF, there is no human accessibility in the storage bay; therefore the only credible ignition source is failure of the crane cable and direct contact with the combustible material. As calculated in *IRSF Storage Bay Fire HIC Spacing Assessment L-003429, Rev 000,* such direct contact would be required for a period of 1,386 seconds to result in ignition.

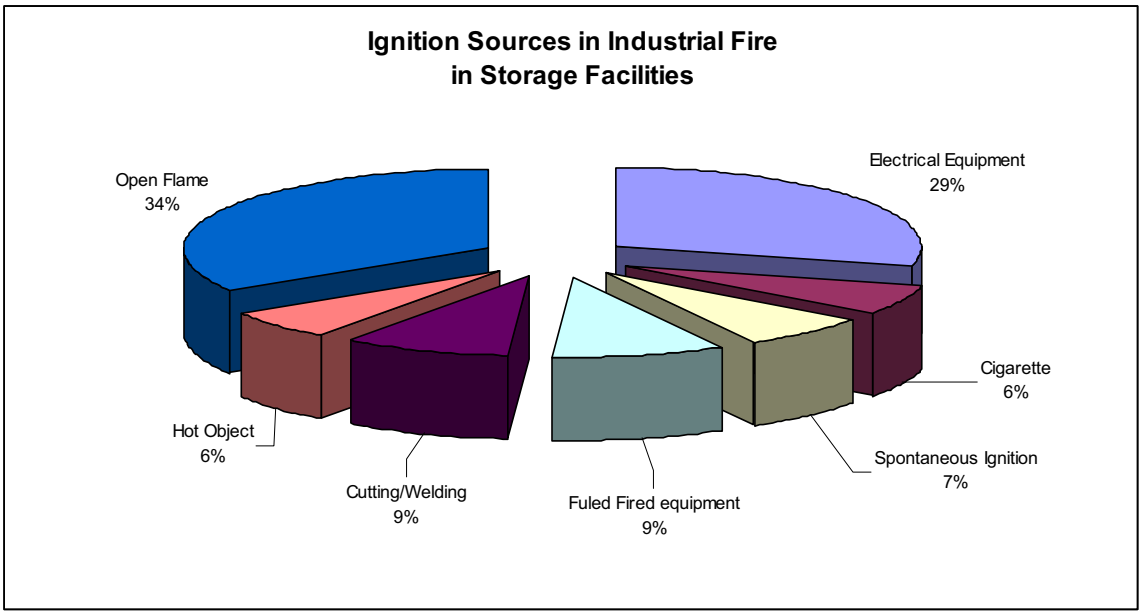


Figure 1- Ignition Sources in Industrial Fire in Storage Facilities

Extracted from Industrial Fire Protection Engineering pg 18

based on NFPA large data excluding fires with unknown ignition sources

In addition, LaSalle created procedures to minimize the risk of fire in the IRSF building such as loading/unloading containers (see Section 4.2), periodic surveillance, and detectors.

6.0 ATTACHMENTS

Design Basis Fire Analysis Data Sheets:

6.1 DESIGN BASIS FIRE ANALYSIS TRUCK BAY AREA

6.2 DESIGN BASIS FIRE ANALYSIS CONTROL ROOM

6.3 DESIGN BASIS FIRE ANALYSIS EQUIPMENT ROOM

6.4 DESIGN BASIS FIRE ANALYSIS STORAGE AREA

6.4.1 CASE 1-HDPE HICS

6.4.2 CASE 2-6 HDPE HICS ARRAYED WITH ADEQUATE SEPARATION DISTANCE TO OTHER HICS TO ELIMINATE FIRE SPREAD

6.4.3 CASE 3-STEEL SHELL HICS

6.1 DESIGN BASIS FIRE ANALYSIS TRUCK BAY AREA

1.0 BUILDING: Interim Radwaste Storage Facility (IRSF)

2.0 FIRE AREA OR ZONE: IRSF-F1-Z1

2.1 ROOM: Truck Bay Area

2.2 LOCATION: N/A

2.3 REFERENCE DRAWING NOS. A-961, A-962, A-965, A-966, A-970, S-1473, S-1474, S-1476, S-1477, M-737; shts. 1-7, 1E-0-3341, 1E-0-334, 1E-0-3755, 1E-0-4673AA

3.0 CONSTRUCTION OF FIRE AREA OR ZONE BOUNDARIES

BOUNDARIES		MATERIAL	MIN. FIRE RATING
3.1	**WALL**		
	NORTH	30” & 15” concrete	N/A ext. wall
	EAST	30” & 15” concrete	N/A ext. wall
	SOUTH	30” conc. (part.)	None
	WEST	30” & 15” concrete	N/A ext. wall
3.2	**FLOOR**	30” concrete	N/A slab on grade
3.3	**CEILING**	N/A	N/A
3.4	**DOORS**		
	1000	17’x14’ stl. Rollup	N/A ext.
	1001	7’-2”x3’ HM	N/A ext.
	1002	8’x10’ stl. rollup	N/A ext.
	1003	6’8” x 3’ HM	90 min. –B label
3.5	**ROOF**	15” conc.	N/A ext.

4.0 FLOOR AREA: 1920 SQ.FT.

LENGTH: 60' 0" **WIDTH:** 32' 0" **HEIGHT:** 49' 0"

5.0 VOLUME: 94,080 CU.FT

6.0 FLOOR DRAINS YES___X___NO_____(drains to Truck Bay Sump)

7.0 VENTILATION SYSTEM DESCRIPTION

2,880 cfm of ventilation air is provided to the truck bay and 16,620 cfm to the storage area by a common supply fan. Outside intake is variable between 19,500 and 3,450 cfm. The balance of supply air is ducted return. Ratio of return to outside air is controlled by operable louvers. Intake air is preheated in HV unit in the mechanical room upstream of the main supply fan by an electric duct heater. There is a thermostatically controlled heater in the duct branch leading to the truck bay for additional tempering. Duct passing through the control room is provided with fire dampers at points of penetration through fire rated walls. The truck bay is provided with an independent exhaust fan with 2880 cfm capacity, intended to remove diesel exhaust fumes during truck start-up. The truck bay is equipped with electric unit heaters.

8.0 FIRE PROTECTION		**TYPE**
8.1	**SUPPRESSION**	None
8.2	**DETECTION**	Smoke detectors in truck bay
8.3	**MANUAL**	Hydrant within 300'
8.4	**EXTINGUISHERS**	20 lb class ABC or BC per NFPA 10
8.5	**OTHER**	None

9.0 FIRE LOADING IN AREA

9.1 FLAMMABLES/COMBUSTIBLES FIRE LOADING IN AREA/ZONE

COMBUSTIBLE	AMOUNT	HEAT OF COMBUSTION	TOTAL HEAT POTENTIAL	HEAT POTENTIAL
Electrical Insulation	500 lbs	10,500 Btu/lb	5,250,000 Btu	2,875 Btu/sq.ft
Diesel fuel	200 gal	150,000 Btu/gal	30,000,000 Btu	15,625 Btu/sq.ft
Vehicle tires	800 lbs	14,000 Btu/lb	25,200,000 Btu	13,125 Btu/sq.ft
HIC	850 lbs	20,000 Btu/lb	17,000,000 Btu	8,855 Btu/sq.ft.
Class A:	150 lbs	8,000 Btu/lb	1,200,000 Btu	625 Btu/sq.ft.
Transients:	0 lbs			

9.2 TOTAL FIRE LOADING IN AREA: 41,105 BTU/sq.ft.

9.3 TOTAL HEAT POTENTIAL: 78,921,609 BTU

9.4 Equivalent Severity: approximately 35 minutes

9.5 TEMPERATURE: 1575 ^{O}F

10.0 PROCESS HAZARDS

None.

11.0 DESIGN BASIS FIRE DESCRIPTION

A fire starting in the truck bay is not considered credible because the three elements of fire (combustible material, ignition source, and unlimited oxygen supply) are not present at the same time. Exelon loading and unloading procedures are followed to minimize fire potential risks. See Section 4.2 for loading/unloading procedure description. In case of an incredible fire in the truck bay, manual and fire brigade are available for immediate remediation.

Only during this transient loading/unloading event there is a possible fire risk, which would be controlled.

12.0 CONSEQUENCES OF DESIGN BASIS FIRE

No consequences are postulated.

13.0 LIFE SAFETY CONSIDERATIONS

13.1	**OCCUPANCY: NFPA 101:**	SPECIAL PURPOSES UBC: GROUP B.DIV 2 INDUSTRIAL
13.2	**PROCESS HAZARDS:**	None
13.3	**EMERGENCY LIGHTING:**	Meets all requirements
13.4	**EXIT LIGHTING/SIGNS:**	Meets all requirements
13.5	**CORRIDOR WIDTH:**	N/ A
13.6	**EXITS AND EGRESS:**	Meets all requirements
13.7	**TRAVEL DISTANCE TO EXIT:**	Meets all requirements
13.8	**STAIRS:**	N/A
13.9	**DOOR HARDWARE:**	Meets all requirements

6.2 DESIGN BASIS FIRE ANALYSIS CONTROL ROOM

1.0 BUILDING: Interim Radwaste Storage Facility (IRSF)

2.0 FIRE AREA OR ZONE: IRSF-F2

2.1 ROOM: Control Room

2.2 LOCATION: N/A

2.3 REFERENCE DRAWING NOS. A-962, A-962, A-966, A-965, A-970, M-737; shts. 1-7, 1E-0-3341, 1E-0-3341, 1E-0-3344, 1E-0-3755, 1E-0-4673AA

3.0 CONSTRUCTION OF FIRE AREA OR ZONE BOUNDARIES

BOUNDARIES		MATERIAL	MIN. FIRE RATING
3.1	**WALL**		
	NORTH	12” CMU	N/A ext. wall
	EAST	6” CMU	N/A ext. wall
	SOUTH	6” CMU	2-hr (lower)
	WEST	30” conc.	3-hr (lower)
3.2	**FLOOR**	6” conc.	N/A slab on grade
3.3	**CEILING**	N/A	
3.4	**DOORS**		
	1003	6’ 8” X 3’ HM	90 min. B-label
	1004	7’ -2” X 3’ HM	N/A ext.
	1005	(2) 7’ 2” X 3’ HM	90 min. B-label
3.5	**ROOF**	12” concrete.	N/A ext.

4.0 FLOOR AREA: 266 SQ.FT.

LENGTH: 19' 0" **WIDTH:** 14' 0" **HEIGHT:** 16' 4"

5.0 VOLUME: 4,344 CU.FT

6.0 FLOOR DRAINS YES_____NO___X____(drains to Truck Bay Sump)

7.0 VENTILATION SYSTEM DESCRIPTION

Heating and cooling for the control room are provided by a split system air conditioning unit with heating coil. The unit supplies 1600 CFM of conditioned air. Return air volume is variable between 0 and 1440 CFM. Control room design conditions are 70°F minimum, 78°F maximum. Fire dampers are provided at points of penetration through fire-rated walls.

8.0 FIRE PROTECTION		**TYPE**
8.1	**SUPPRESSION:**	None
8.2	**DETECTION:**	Smoke detectors in control room
8.3	**MANUAL:**	Hydrant within 300'
8.4	**EXTINGUISHERS:**	20 lb class ABC or BC per NFPA 10
8.5	**OTHER:**	None

9.0 FIRE LOADING IN AREA

9.1 FLAMMABLES/COMBUSTIBLES FIRE LOADING IN AREA/ZONE

COMBUSTIBLE	AMOUNT	HEAT OF COMBUSTION	TOTAL HEAT POTENTIAL	HEAT POTENTIAL
Electrical insulation (see 11.0)	400 lbs	10,500 Btu/lb	4,200,000 Btu	15,800 Btu/sq.ft
Class A:	150 lbs	8,000 Btu/lb	1,200,000 Btu	4,525 Btu/sq.ft
Transients:	300 lbs	8,000 Btu/lb (computer paper stocks)	2,400,000 Btu	9,025 Btu/sq.ft.
Others	none			

9.2 TOTAL FIRE LOADING IN AREA: 29,350 BTU/sq.ft.

9.3 TOTAL HEAT POTENTIAL: 7,807,000 BTU

9.4 Equivalent Severity: less than 30 minutes

10.0 PROCESS HAZARDS

None.

11.0 DESIGN BASIS FIRE DESCRIPTION

During maintenance operations, welding spark ignites pile computer paper stock. Fire spreads to consume 150 lbs of class A combustibles. Cable within conduit pyrolyzes due to intensity of fire, adding additional heat of combustion.

12.0 CONSEQUENCES OF DESIGN BASIS FIRE

Loss of ordinary combustible In control room (i.e. , paper, wood products, cloth, etc.). Loss of electrical cable in conduit. Heat damage to cable and electronic components of control equipment. Loss of use of facility during repair period.

13.0 LIFE SAFETY CONSIDERATIONS

13.1 OCCUPANCY: NFPA 101: Special Purposes UBC:

Group B.Div 2 Industrial

13.2 PROCESS HAZARDS: None

13.3	**EMERGENCY LIGHTING:**	Meets all requirements
13.4	**EXIT LIGHTING/SIGNS:**	Meets all requirements
13.5	**CORRIDOR WIDTH:**	N/ A
13.6	**EXITS AND EGRESS:**	Meets all requirements
13.7	**TRAVEL DISTANCE TO EXIT:**	Meets all requirements
13.8	**STAIRS:**	N/A
13.9	**DOOR HARDWARE:**	Meets all requirements

6.3 DESIGN BASIS FIRE ANALYSIS EQUIPMENT ROOM

1.0 BUILDING: Interim Radwaste Storage Facility (IRSF)

2.0 FIRE AREA OR ZONE: IRSF-F3

2.1 ROOM: Mechanical Equipment Room

2.2 LOCATION: N/A

2.3 REFERENCE DRAWING NOS. A-961, A-962, A-966, A-965, A-970, M-737; shts. 1-7, 1E-0-3341, 1E-0-3341, 1E-0-3344, 1E-0-3755, 1E-0-4673AA

3.0 CONSTRUCTION OF FIRE AREA OR ZONE BOUNDARIES

BOUNDARIES		MATERIAL	MIN. FIRE RATING
3.1	**WALL**		
	NORTH	6” CMU	2 – HR
	EAST	12” CMU	N/A ext. wall
	SOUTH	12” CMU	N/A ext. wall
	WEST	30” conc.	3 – HR
3.2	**FLOOR**	6” conc.	N/A slab on grade
3.3	**CEILING**	N/A	
3.4	**DOORS**		
	1005	(2) 7’ 2” X 3’ HM	90 min. B-label
	1006	(2) 7’ 2” X 3’ HM	N/A ext.
3.5	**ROOF**	12” concrete.	N/A ext.

4.0 FLOOR AREA: 826.5 SQ.FT.

LENGTH: 43' 6" **WIDTH:** 19' 0" **HEIGHT:** 16' 4"

5.0 VOLUME: 13,500 CU.FT

6.0 FLOOR DRAINS YES X NO (drains to Sump in mech. Equip. room)

7.0 VENTILATION SYSTEM DESCRIPTION

Ventilation is provided to the mechanical room by exhaust fans and motorized louvers. Heat is provided by electric unit heaters.

8.0 FIRE PROTECTION **TYPE**

8.1 SUPPRESSION: None

8.2 DETECTION: Ionization smoke detectors

8.3 MANUAL: Hydrant within 300'

8.4 EXTINGUISHERS: 20 lb class ABC or BC extinguishers

8.5 OTHER: None

9.0 FIRE LOADING IN AREA

9.1 FLAMMABLES/COMBUSTIBLES FIRE LOADING IN AREA/ZONE

COMBUSTIBLE	AMOUNT	HEAT OF COMBUSTION	TOTAL HEAT POTENTIAL	HEAT POTENTIAL
Electrical insulation (see 11.0)	1,000 lbs	10,500 Btu/lb	10,500,000 Btu	12,700 Btu/sq.ft
Class A:	300 lbs	8,000 Btu/lb	2,400,000 Btu	2,900 Btu/sq.ft
Transients:	300 lbs	8,000 Btu/lb (computer paper stocks)	2,400,000 Btu	2,900 Btu/sq.ft.
Others	none			

9.2 TOTAL FIRE LOADING IN AREA: 18,500 BTU/sq.ft.

9.3 TOTAL HEAT POTENTIAL: 15,290,250 BTU

9.4 Equivalent Severity: less than 30 minutes

10.0 PROCESS HAZARDS

None.

11.0 DESIGN BASIS FIRE DESCRIPTION

During maintenance activities, welding spark ignites 300 pounds of transient combustibles brought in for use in maintenance. Fire spreads to consume 300 pounds of class A combustibles ordinarily used and/or stored in area. Intensity of fire causes pyrolization of cable in conduit, adding to heat of combustion released in area.

12.0 CONSEQUENCES OF DESIGN BASIS FIRE

Loss of all combustibles in area (i.e., filters in HVAC equipment, and items stored in tool crib). Loss of all electrical equipment in area. Loss of electric cables in area. Loss of use of facility during repair period.

13.0 LIFE SAFETY CONSIDERATIONS

13.1 OCCUPANCY: NFPA 101: Special Purposes UBC:

Group B.Div 2 Industrial

13.2 PROCESS HAZARDS: None

13.3 EMERGENCY LIGHTING: Meets all requirements

13.4 EXIT LIGHTING/SIGNS: Meets all requirements

13.5 CORRIDOR WIDTH: N/ A

13.6 EXITS AND EGRESS: Meets all requirements

13.7 TRAVEL DISTANCE TO EXIT: Meets all requirements

13.8 STAIRS: N/A

13.9 DOOR HARDWARE: Meets all requirements

6.4 DESIGN BASIS FIRE ANALYSIS STORAGE AREA –

6.4.1 CASE 1-HDPE HICS

1.0 BUILDING: Interim Radwaste Storage Facility (IRSF)

2.0 FIRE AREA OR ZONE: IRSF-F1-Z2

2.1 ROOM: Storage Area

2.2 SCENARIO: 270 units of 8-120 High Density Polyethylene (HDPE) (Non-steel shelled) High Integrity Containers (HIC), Double Stacked.

2.3 LOCATION: N/A

2.4 REFERENCE DRAWING NOS. A-961, A-962, A-966, A-965, A-970, M-737; shts. 1-7, 1E-0-3341, 1E-0-3341, 1E-0-3344, 1E-0-3755, 1E-0-4673AA

3.0 CONSTRUCTION OF FIRE AREA OR ZONE BOUNDARIES

BOUNDARIES		MATERIAL	MIN. FIRE RATING
3.1	WALL		
	NORTH	30” & 15” concrete	
	EAST	30” & 15” concrete	None
	SOUTH	30” & 15” concrete	3-hr (lower)
	WEST	30” & 15” (part.)	N/A ext. wall
3.2	FLOOR	30” concrete	N/A ext. wall
3.3	CEILING	N/A	N/A slab on grade
3.4	DOORS	None	
3.5	ROOF	15” concrete.	
			N/A ext.

4.0 FLOOR AREA: 5,700 SQ.FT.

LENGTH: 95' 0" **WIDTH:** 60' 0" **HEIGHT:** 49' 0"

5.0 VOLUME: 279,300 CU.FT

6.0 FLOOR DRAINS YES__X__NO_____(drains to Truck Bay Sump)

7.0 VENTILATION SYSTEM DESCRIPTION

16,620 cfm of ventilation air is provided to the storage area and 2,880 cfm to the truck bay by a common supply fan. Outside air intake is variable between 19,500 and 3,450 cfm. The balance of supply air is ducted return. Ratio of return to outside air is controlled by operable louvers. Intake air is preheated in the HV unit in the mechanical room upstream of the main supply fan by an electric duct heater.

8.0 FIRE PROTECTION

8.1 SUPPRESSION: None

8.2 DETECTION: Duct detectors in the ventilation system and detectors in the truck bay area

8.3 MANUAL: None

8.4 EXTINGUISHERS: None

8.5 OTHER: None

9.0 FIRE LOADING IN AREA

9.1 FLAMMABLES/COMBUSTIBLES FIRE LOADING IN AREA/ZONE

Combustible	Amount	Units	Heat of Combustion	Units	Total Heat Potential	Units	Heat Potential	Units
HICs	HDPE 270 HICs 256,500*	lbs	20,000	Btu/lb	5.13E+09	Btu	900,000	Btu/sq.ft
Electrical insulation (see 11.0)	400	lbs	10,500	Btu/lb	4.20E+06	Btu	737	Btu/sq.ft
Transients:		lbs						

***Weight is based on Energy Solutions Information. See L-003429 Rev 000, Attachment B**

9.2 TOTAL FIRE LOADING IN AREA: 900,737 BTU/sq.ft.

9.3 TOTAL HEAT POTENTIAL: 5.13×10^9 BTU

9.4 Equivalent Severity: over 11 hours

10.0 PROCESS HAZARDS

None.

11.0 DESIGN BASIS FIRE DESCRIPTION

Fire initiation of one HIC is postulated by a non-mechanistic source. The probability of source ignition in the storage area is extremely low. If HICs are sufficiently exposed to a heat source and the ignition temperature is reached, the fire could spread to other containers and could potentially consume all combustibles in the storage bay area. Cable in conduit is pyrolyzed. Heat from fire damages or destroys all electrical cabling and equipment in storage area. The crane structural steel will be damaged due to prolonged exposure to high temperatures from the fire. Potential resin dry out may occur and could ignite and contribute to the fire load.

12.0 CONSEQUENCES OF DESIGN BASIS FIRE

Loss of all HIC's in the storage area. Structural damage to building from heat resulting in roof collapse and structure debilitation. Loss of all electrical cable in area. Complete loss and use of the facility. Possible unspecified radiological releases if resins are dried out in a conflagration and ignite.

13.0 LIFE SAFETY CONSIDERATIONS

13.1 OCCUPANCY: NFPA 101: Special Purposes UBC:

Group B.Div 2 Industrial

13.2 PROCESS HAZARDS: None

13.3 EMERGENCY LIGHTING: None required

13.4 EXIT LIGHTING/SIGNS: None required

13.5 CORRIDOR WIDTH: N/ A

13.6 EXITS AND EGRESS: None required

13.7 TRAVEL DISTANCE TO EXIT: N/A

13.8 STAIRS: N/A

13.9 DOOR HARDWARE: N/A

14.0 RECOMMENDATION

In the case where 270 polyethylene (poly) HICs are stored in the IRSF, addition of an automatic fire suppression system is highly recommended and required based on NFPA 801 and NFPA 804 considering the potential risk involved in burning all the containers. Results indicate sufficient heat load may be available to dry out portions of the dewatered resin, potentially resulting in resin ignition. The IRSF would likely be destroyed by the fire.

6.4.2 CASE 2-HDPE HICS ARRAYED WITH ADEQUATE SEPARATION DISTANCE TO OTHER HICS TO ELIMINATE FIRE SPREAD

1.0 BUILDING: Interim Radwaste Storage Facility (IRSF)

2.0 FIRE AREA OR ZONE: IRSF-F1-Z2

2.1 ROOM: Storage Area

2.2 SCENARIO: 100 units of double stacked non-steel shelled 8-120 HDPE HICs (Balance of 170 are steel shelled)

2.3 LOCATION: N/A

2.4 REFERENCE DRAWING NOS. A-961, A-962, A-966, A-965, A-970, M-737; shts. 1-7, 1E-0-3341, 1E-0-3341, 1E-0-3344, 1E-0-3755, 1E-0-4673AA

3.0 CONSTRUCTION OF FIRE AREA OR ZONE BOUNDARIES

BOUNDARIES		MATERIAL	MIN. FIRE RATING
3.1	**WALL**		
	NORTH	30” & 15” concrete	None
	EAST	30” & 15” concrete	2-hr (lower)
	SOUTH	30” & 15” concrete	N/A ext. wall
	WEST	30” & 15” (part.)	N/A ext. wall
3.2	**FLOOR**	30” concrete	N/A slab on grade
3.3	**CEILING**	N/A	
3.4	**DOORS**	None	
3.5	**ROOF**	15” concrete.	N/A ext.

4.0 FLOOR AREA: 5,700 SQ.FT.

LENGTH: 95' 0" **WIDTH:** 60' 0" **HEIGHT:** 49' 0"

5.0 VOLUME: 279,300 CU.FT

6.0 FLOOR DRAINS YES___X___NO_____(drains to Truck Bay Sump)

7.0 VENTILATION SYSTEM DESCRIPTION

16,620 cfm of ventilation air is provided t o the storage area and 2,880 cfm t o the truck bay by a common supply fan. Outside air intake is variable between 19,500 and 3,450 cfm . The balance of supply air is ducted return. Ratio of return t o outside air is controlled by operable louvers. Intake air is preheated in the HV unit in the mechanical room upstream of the main supply fan by an electric duct heater.

8.0 FIRE PROTECTION

8.1 SUPPRESSION: None

8.2 DETECTION: Duct detectors in the ventilation system and detectors in the truck bay area

8.3 MANUAL: None

8.4 EXTINGUISHERS: None

8.5 OTHER: None

9.0 FIRE LOADING IN AREA

9.1 FLAMMABLES/COMBUSTIBLES FIRE LOADING IN AREA/ZONE

Combustible	Amount	Units	Heat of Combustion	Units	Total Heat Potential	Units	Heat Potential	Units
HICs	HDPE 6 5,700*	HICs lbs	20,000	Btu/lb	1.14×10^8	Btu	20,000	Btu/sq.ft
Electrical insulation (see 11.0)	400	lbs	10,500	Btu/lb	42×10^5	Btu	737	Btu/sq.ft
Transients:	0	lbs						

***Weight is based on Energy Solutions Information. See L-003429 Rev 000, Attachment B**

9.2 TOTAL FIRE LOADING IN AREA: 20,737 BTU/sq.ft.

9.3 TOTAL HEAT POTENTIAL: 1.18 x10^8 BTU

9.4 Equivalent Severity: 16 minutes

10.0 PROCESS HAZARDS

None.

11.0 DESIGN BASIS FIRE DESCRIPTION

The fire initiation of (6) non-steel shelled poly HIC is postulated based on a non-mechanistic source. The probability of fire ignition in the storage area is extremely low and is considered incredible. In the event of an incredible non-mechanistic fire, the (6) HICs configuration will have sufficient separation distance of 6.6 feet from the adjacent HICs that the group is expected to self extinguish and not initiate an adjacent poly HIC fire. In case of an incredible fire in the storage bay area during loading/unloading operations, the smoke detector located directly over the 34'x60' storage bay/truck bay shield wall will detect and alert the operators of smoke in the IRSF. Therefore, it is required that Exelon procedures instruct operators to open the main truck bay door (17'x14') so the heat and smoke can be vented from the facility through the open door. See calculation L-003429 IRSF Storage Bay HIC Spacing to Prevent Spread of a Postulated HIC Fire, Rev 000 for details.

12.0 CONSEQUENCES OF DESIGN BASIS FIRE

Loss of (6) poly HICs in the storage area. Generated heat from fire is not sufficient to damage or destroy the IRSF. The fire will not spread to other HIC's since the minimum distance of 6.6 feet is maintained. A postulated radiological release from such an event results in doses within the regulatory limit of 10% of 10CFR100, as demonstrated in calculation L-003430 IRSF Design Basis Event Dose Assessment.

13.0 LIFE SAFETY CONSIDERATIONS

13.1 OCCUPANCY: NFPA 101: Special Purposes UBC:

Group B.Div 2 Industrial

13.2 PROCESS HAZARDS: None

13.3 EMERGENCY LIGHTING: None required

13.4 EXIT LIGHTING/SIGNS: None required

13.5 CORRIDOR WIDTH: N/ A

13.6 EXITS AND EGRESS: None required

13.7 TRAVEL DISTANCE TO EXIT: N/A

13.8 STAIRS: N/A

13.9 DOOR HARDWARE: N/A

14.0 RECOMMENDATION

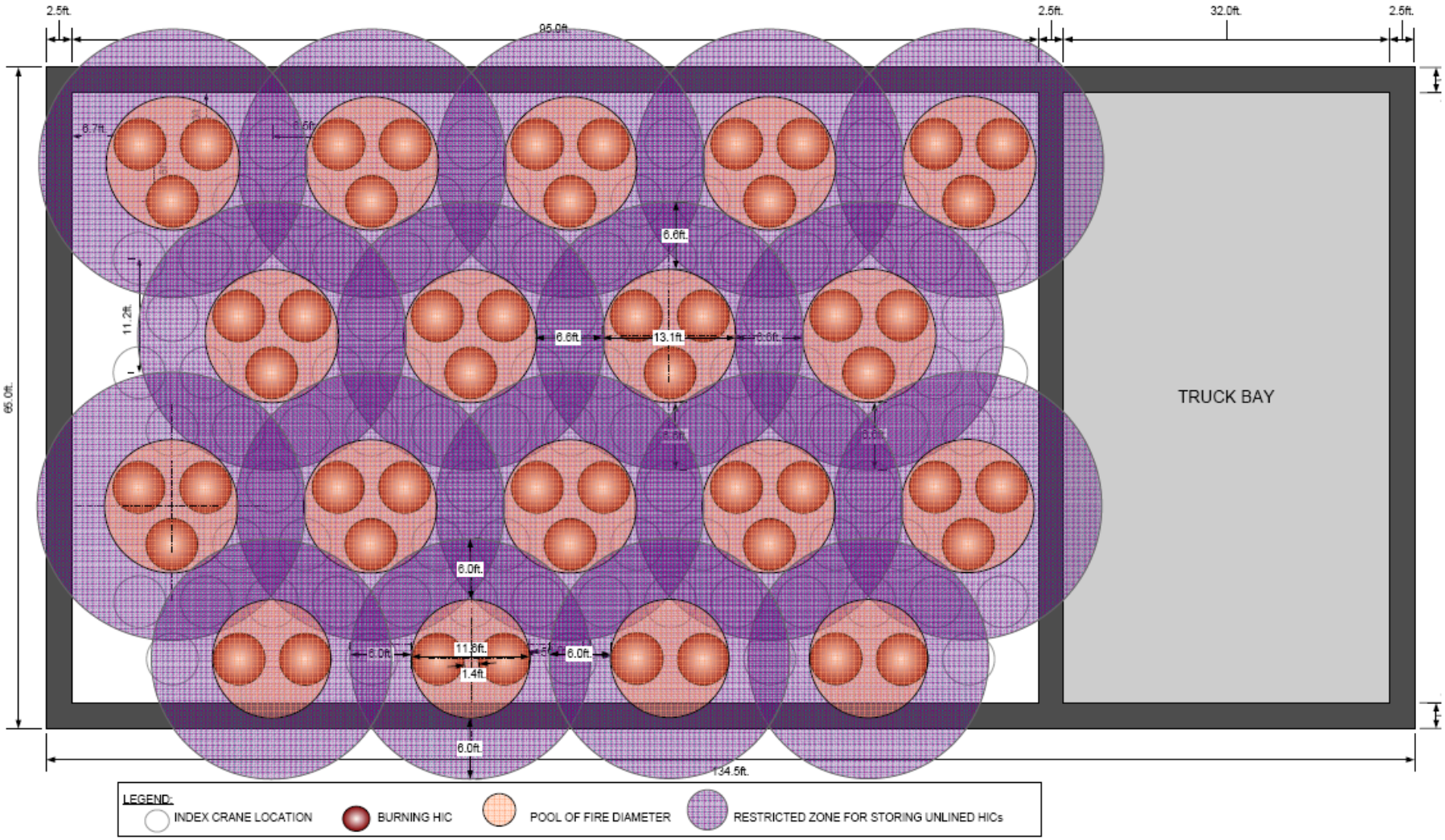
The (6) non-steel shelled poly HIC configuration arrayed with adequate separation distance to other non-steel shelled poly HICs to eliminate fire spread ,has been shown to be acceptable.. Using the LaSalle current crane indexing system to determine the container arrangement, 100 non-steel shelled poly HICs can be stored per Sketch 15.0 (100 HICs Configuration Arrangement Sketch) without implementing additional fire detection and suppression systems.

The balance of storage bay capacity (270 HICs) can be achieved by loading steel-shelled poly HICs in the open spaces, stacked 2 high if needed.

Additional fire detection or suppression systems **are not** required for this case.

URS Washington Division recommends this case (Case 2).

15.0 100 HICS CONFIGURATION ARRANGEMENT SKETCH (CURRENT LASALLE CRANE INDEX SYSTEM)


2.5ft.
95.0ft.
2.5ft.
32.0ft.
2.5ft.
6.7ft.
6.6ft.
11.2ft.
6.6ft.
13.1ft.
6.6ft.
65.0ft.
TRUCK BAY
6.0ft.
6.0ft.
11.8ft.
1.4ft.
6.0ft.
6.0ft.
134.5ft.
LEGEND:
INDEX CRANE LOCATION
BURNING HIC
POOL OF FIRE DIAMETER
RESTRICTED ZONE FOR STORING UNLINED HICs

6.4.3 CASE 3-STEEL SHELL HICS

1.0 BUILDING: Interim Radwaste Storage Facility (IRSF)

2.0 FIRE AREA OR ZONE: IRSF-F1-Z2

2.1 ROOM: Storage Area

2.2 SCENARIO: 270 units of Steel Shell HDPE HICs. The HIC is completely covered by steel with no large exposed areas of the HIC.

2.3 LOCATION: N/A

2.4 REFERENCE DRAWING NOS. A-961, A-962, A-966, A-965, A-970, M-737; shts. 1-7, 1E-0-3341, 1E-0-3341, 1E-0-3344, 1E-0-3755, 1E-0-4673AA

3.0 CONSTRUCTION OF FIRE AREA OR ZONE BOUNDARIES

BOUNDARIES		MATERIAL	MIN. FIRE RATING
3.1	**WALL**		
	NORTH	30” & 15” concrete	None
	EAST	30” & 15” concrete	2-hr (lower)
	SOUTH	30” & 15” concrete	N/A ext. wall
	WEST	30” & 15” (part.)	N/A ext. wall
3.2	**FLOOR**	30” concrete	N/A slab on grade
3.3	**CEILING**	N/A	
3.4	**DOORS**	None	
3.5	**ROOF**	15” concrete.	N/A ext.

4.0 FLOOR AREA: 5,700 SQ.FT.

LENGTH: 95' 0" **WIDTH:** 60' 0" **HEIGHT:** 49' 0"

5.0 VOLUME: 279,300 CU.FT

6.0 FLOOR DRAINS YES___X___NO_____(drains to Truck Bay Sump)

7.0 VENTILATION SYSTEM DESCRIPTION

16,620 cfm of ventilation air is provided t o the storage area and 2,880 cfm t o the truck bay by a common supply fan. Outside air intake is variable between 19,500 and 3,450 cfm. The balance of supply air is ducted return. Ratio of return t o outside air is controlled by operable louvers. Intake air is preheated in the HV unit in the mechanical room upstream of the main supply fan by an electric duct heater.

8.0 FIRE PROTECTION

8.1 SUPPRESSION: None

8.2 DETECTION: Duct detectors in the ventilation system and detectors in the truck bay area

8.3 MANUAL: None

8.4 EXTINGUISHERS: None

8.5 OTHER: None

9.0 FIRE LOADING IN AREA

9.1 FLAMMABLES/COMBUSTIBLES FIRE LOADING IN AREA/ZONE

Combustible	Amount	Units	Heat of Combustion	Units	Total Heat Potential	Units	Heat Potential	Units
HICs	Steel Shell 1 2,150*	HICs lbs	20,000	Btu/lb	4.3E+07	Btu	7,544	Btu/sq.ft
Electrical insulation (see 11.0)	400	lbs	10,500	Btu/lb	4.20E+06	Btu	737	Btu/sq.ft
Transients:	0	lbs						

***Weight is based on Energy Solutions Information. See L-003429 Rev 000, Attachment B**

9.2 TOTAL FIRE LOADING IN AREA: 8,574 BTU/sq.ft.

9.3 TOTAL HEAT POTENTIAL: 4.72×10^7 BTU

9.4 Equivalent Severity: 19 minutes

10.0 PROCESS HAZARDS

None.

11.0 DESIGN BASIS FIRE DESCRIPTION

In case of an unspecified ignition source in the storage bay area, it is not considered credible for the poly HIC inside the steel shell to ignite. Assuming that a poly HIC container is somehow ignited by a non-mechanistic source, no significant impact would occur in the steel shell container case since the steel shell acts as a fire retardant material for a limited period of time and will contain the burning HIC. The poly HIC is not expected to sustain significant combustion because of a lack of oxygen. Never-the-less, the poly material for one HIC is assumed in this fire scenario to continue to smolder until exhausted. No propagation to other steel shelled HICs occurs.

12.0 CONSEQUENCES OF DESIGN BASIS FIRE

The steel shell (casing) does not prevent the enclosed polyethylene HIC from melting or drying resin out in the case of an extreme fire scenario which is considered incredible. In any case, even in an isolated case where one poly HIC is assumed to ignite non-mechanistically and burn, the fire will not be propagated to the other steel lined poly HIC containers, if they are fully enclosed.

14.0 LIFE SAFETY CONSIDERATIONS

14.1 OCCUPANCY: NFPA 101: Special Purposes UBC:

Group B.Div 2 Industrial

14.2 PROCESS HAZARDS: None

14.3 EMERGENCY LIGHTING: None required

14.4 EXIT LIGHTING/SIGNS: None required

14.5 CORRIDOR WIDTH: N/ A

14.6 EXITS AND EGRESS: None required

14.7 TRAVEL DISTANCE TO EXIT: N/A

14.8 STAIRS: N/A

14.9 DOOR HARDWARE: N/A

15.0 RECOMMENDATION

In the case where 270 Steel shell covered poly HICs are stored in the IRSF, no automatic fire suppression is required. These containers are normally supplied with stacking plates, but should have metal lids covering the open fill port. Steel shell poly HICs are normally considered a fire resistant container when fully enclosed, even allowing for small holes in the top for venting.

ATTACHMENT 4

Calculation L-003430

LaSalle IRSF Design Basis Event Dose Assessment

ATTACHMENT 1
Page 1 of 5

Design Analysis Major Revision Cover Sheet

Design Analysis (Major Revision)		**Last Page No.** [8] 11 / Att. D-2	
Analysis No.: [1]	L-003430	**Revision:** [2]	000
Title: [3]	IRSF Design Basis Event Dose Assessment		
EC/ECR No.: [4]	375636	**Revision:** [5]	0
Station(s): [7]	LaSalle County Station	**Component(s):** [14]	
Unit No.: [8]	00	N/A	
Discipline: [9]	Mech		
Descrip. Code/Keyword: [10]	R01 / IRSF		
Safety/QA Class: [11]	Non-Safety		
System Code: [12]	N/A		
Structure: [13]	N/A		

CONTROLLED DOCUMENT REFERENCES [15]

Document No.:	From/To	Document No.:	From/To
	~~From~~		~~From~~
	~~To~~		~~From~~
	~~From~~		~~From~~
	~~From~~		~~From~~

Is this Design Analysis Safeguards Information? [16] Yes ☐ No ☒ If yes, see SY-AA-101-106

Does this Design Analysis contain Unverified Assumptions? [17] Yes ☐ No ☒ If yes, ATI/AR#:

This Design Analysis SUPERCEDES: [18] None in its Entirety.

Description of Revision (list affected pages for partials): [19] Initial Issue

Preparer: [20] William Golden (Print Name) — Sign Name — 9/28/09 (Date)

Method of Review: [21] **Detailed Review** ☒ **Alternate Calculations (attached)** ☐ **Testing** ☐

Reviewer: [22] H. Rothstein (Print Name) — pr. Neilsen for H. Rothstein (Sign Name) — 9/28/09 (Date)

Review Notes: [23] Independent review ☒ Peer review ☐ All inputs, assumptions, approaches, numerical analyses, and results were independently reviewed and checked.

(For External Analyses Only)
External Approver: [24] Donald Gardner (Print Name) — pr. Neilsen for Don Gardner (Sign Name) — 9/28/09 (Date)

Exelon Reviewer: [25] Jessica Delacosa / Eric Ballon (Print Name) — J. Delacosa / Eric Ballon (Sign Name) — 10/1/09 / 11/13/09* (Date)

Independent 3rd Party Review Reqd? [26] Yes ☐* No ☒

Exelon Approver: [27] DAN SCHMIT (Print Name) — D. J. Schmit (Sign Name) — 11/16/09 (Date)

* Note: This cover sheet form matches that in CC-AA-309-1001 rev. 5 (contains all the form information)

EB 11/13/09

Calc L-003430 page 2 of 11

ATTACHMENT 1
Owners Acceptance Review Checklist for External Design Analysis
Page 1 of 1

DESIGN ANALYSIS NO. L-003430 **REV:** 0

		Yes	No	N/A
1.	Do assumptions have sufficient rationale?	☒	☐	☐
2.	Are assumptions compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
3.	Do the design inputs have sufficient rationale?	☒	☐	☐
4.	Are design inputs correct and reasonable with critical parameters identified, if appropriate?	☒	☐	☐
5.	Are design inputs compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
6.	Are Engineering Judgments clearly documented and justified?	☒	☐	☐
7.	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
8.	Do the results and conclusions satisfy the purpose and objective of the Design Analysis?	☒	☐	☐
9.	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
10.	Does the Design Analysis include the applicable design basis documentation?	☒	☐	☐
11.	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?	☒	☐	☐ ep 11/13/09
12.	Are there any unverified assumptions?	☐	☒	☐
13.	Do all unverified assumptions have a tracking and closure mechanism in place?	☐	☐	☒
14.	Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change?	☒	☐	☐
15.	Do the sources of inputs **and** analysis methodology used meet current technical requirements and regulatory commitments? (If the input sources **or** analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent code)	☒	☐	☐
16.	Have vendor supporting technical documents and references (including GE DRFs) been reviewed when necessary?	☒	☐	☐
17.	Have margin impacts been identified and documented appropriately for any negative impacts (Reference ER-AA-2007)?	☐	☐	☒

EXELON REVIEWER: Jessica De La Rosa / Jessica De La Rosa (Cantera) **DATE:** 10/1/09
Print / Sign
or Eric Ballou / Eric Ball (LASALLE) 11/13/09

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6.2 Container Drop 9
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ATTACHMENT B: Clinton: MicroShield Runs and Excel Spreadsheets B-1
ATTACHMENT C: Byron and Braidwood: MicroShield Runs and Excel Spreadsheets C-1
ATTACHMENT D: Computer Disclosure Sheets D-1

1. Introduction & Purpose

The purpose of this calculation is to select and analyze design basis events (e.g., fire, and container drop) for the LSCS Interim Radwaste Storage Facility (IRSF). These analyses must demonstrate that dose consequences of bounding events do not exceed a small fraction (10 percent) of 10 CFR Part 100 dose limits, as per Reference (9), the General Information section of Generic Letter 81-38 entitled "Storage of Low-Level Radioactive Wastes at Power Reactor Sites", and as suggested in EPRI Guidelines for Operation IRSF (Reference (3)).

Waste stored in the IRSF will be from LSCS, but may also include waste transported for interim storage from the Byron, Braidwood, or Clinton Stations.

Bounding design basis events considered are a waste handling accident, involving a container drop, and a postulated fire in the storage bay.

2. Inputs

Parameter	Value	Basis
♦ Byron, Braidwood, or Clinton Stations Container Contact Dose Rate for Nominal Analysis	200 rem/hr	Assumption 3.1.1
♦ LSCS Container Contact Dose Rate for Bounding Analysis	380 rem/hr	Assumption 3.1.1
♦ Container Isotopic Mix: Byron and Braidwood NSSS Demineralizer	Table 11.1-10	Reference (12)
♦ Container Isotopic Mix: Byron and Braidwood Mixed Bed Demineralize	Table 12.2-13	Reference (13)
♦ Container Isotopic Mix: Clinton Power Station	Table 12.2-12	Reference (14)
♦ Container Isotopic Mix: LaSalle County Station	Table 11.2-5	Reference (15)
♦ Resin Density	0.9 g/cc	Nominal Value
♦ Number of Containers Dropped	1	Assumption 3.1.2
♦ Container Drop Height	28 ft (853.44 cm)	Reference (5)

♦ Number of Containers Burned	6	Reference (11)
♦ Mixing Credit	100%, well mixed	It is expected that the nature of the accident event will cause significant mixing
♦ Calculated 2-hour X/Q at the Exclusion Area Boundary (EAB) for ground level release (sec/m^3)	5.40E-04	Reference (8)
♦ Fraction Released: Container Drop	0.809%	Section 6.2.1
♦ Fraction Released: Container Fire	0.78%	Reference (7)
♦ Breathing Rate at EAB	3.5E-04	Reference (17)
♦ Decay	60 Days	Assumption 3.1.3

3. Assumptions

3.1 Technically Justified Assumptions

3.1.1 Analyses used to compare isotopic mixes from LaSalle, Clinton, Byron and Braidwood are based on a nominal 200 R/hr container. Accident analyses are based on a bounding 380 R/hr container dose limit for LaSalle containers. Activities released and resulting doses are proportional to container contact dose rates, isotopic mixes being equal.

3.1.2 The crane in the IRSF can only carry one container at a time and therefore one container will be assumed to drop into an area (the truck bay) permitting a relatively ready release for the drop accident.

3.1.3 Based on typical practice, resins are not packaged until at least 60 days after discharge, so 60 days is conservatively used.

3.2 Assumptions that Require Verification

There are no assumptions that require verification in this calculation.

4. References

(1) NUREG-1320, “Nuclear Fuel Cycle Facility Accident Analysis Handbook”, May 1988.

(2) 10 CFR 100, "Reactor Site Criteria".
(3) EPRI, "Guidelines for Operating an Interim On Site Low Level Radioactive Waste Storage Facility – Revision 1", February 2009.
(4) LaSalle UFSAR, Chapter 11, Table 11.2-5, current as of this calculation.
(5) LaSalle Drawing No. A-965, "General Arrangements – Sections IRSF- LaSalle Station", Section 1-1, August 1984.
(6) U.S. Department of Energy, "External Dose-Rate Conversion Factors for Calculation of Dose to the Public", July 1988. (FGR-11, per section 6.1-4)
(7) U.S. Department of Energy, "Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities", December 1994.
(8) LSCS Design Analysis L-003063, "Alternative Source Term Onsite and Offsite X/Q Values", October 2008.
(9) URS: Washington Division, Design Change Package, Stn:LAS Unit:00, "Interim Radwaste Storage Facility LAR Support".
(10) USNRC-Standard Review Plan, Section 11.4-A, "Design Guidance for Temporary Storage of Low-Level Radioactive Waste", Revision 3, March 2007.
(11) LaSalle Calculation, L-003429, "IRSF Storage Bay Fire HIC Spacing Assessment".
(12) Byron and Braidwood UFSAR, Chapter 11, Table 11.1-10, "Realistic Source Terms for NSSS Demineralizers", current as of this calculation.
(13) Byron and Braidwood UFSAR, Chapter 12, Table 12.2-13, "Mixed Bed Demineralizer", current as of this calculation.
(14) Clinton UFSAR, Chapter 12, Table 12.2-12, "Design-Basis Inventories of Radioactive Nuclides in Major Wet Solid Waste Subsystem Components – Phase Separator Tank Column", current as of this calculation.
(15) LaSalle UFSAR, Chapter 11, Table 11.2-5, "Inventory Summary RWCU Phase Separator Column", current as of this calculation.
(16) LaSalle Procedure LOP-WX-33, Revision 1, "Abnormal IRSF Operation Procedure", March 2008.
(17) NRC Regulatory Guide 1.183, Rev. 0, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents At Nuclear Power Reactors".

5. Method of Analysis

In general, these analyses determine or utilize:

(1) a bounding design basis container content;
(2) number of containers affected by the event;
(3) fraction of contained activity released for airborne dispersion
(4) appropriate dispersion factors;
(5) resulting doses at the Exclusion Area Boundary (the bounding location for the assumed instantaneous ground level release)

5.1 Design Basis Container Activity

The Chem-Nuclear system polyethylene HIC has a inner diameter of 60 inches and a fill line height of 72 inches. The HIC will have the worst isotopic mixture from one of the three plants shipping to LaSalle. The HIC contents will have decayed for a period of 60 days and are at a contact dose rate of 200 rem/hr for non-LaSalle waste and 380 rem/hr for bounding LaSalle waste.

5.2 Internal Events

5.2.1 Container Drop

In this accident, one container will be moved from the storage module, through a notch that is 27 feet from the floor, and into the truck bay, which can be seen in Figure 5.2-1. This is where the container is assumed to be released from a height of 28 feet. The container will free fall and rupture upon impact, causing a release.

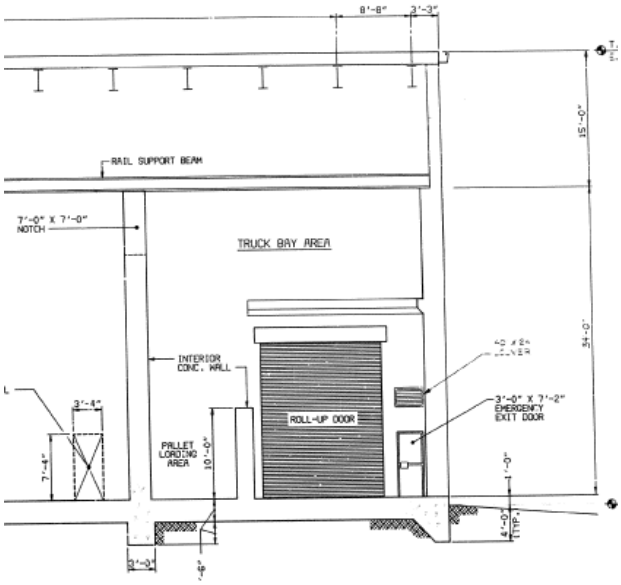


Figure 5.2-1

5.2.2 Container Fire

As stated in L-003429, the HICs are isolated from humans and equipment failure and most associated ignition sources. Only transient electrical equipment associated with the crane is brought over the storage area. Only HDPE HICs are considered to provide a credible combustible source that could lead to a fire that might involve resin drying and burning. Therefore, placement of HDPE HICs is limited to 6, which must then be separated from adjacent HDPE groups so that the heat flux from the fire will not be great enough for another fire to occur, as seen in Figure 5.2-2.

Therefore the postulated worst event would be a group fire of six HICs. In this event, the HICs are stacked in twos and are grouped together.

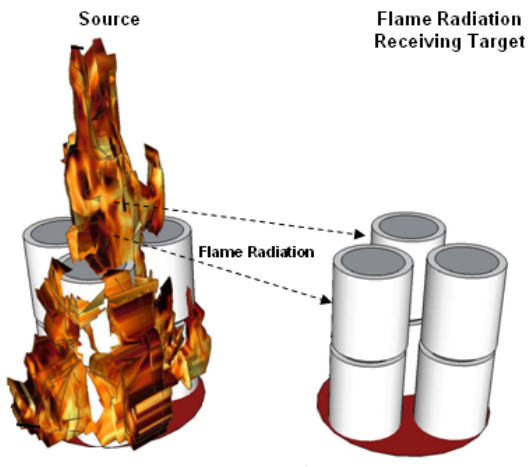


Figure 5.2-2

6. Numeric Analysis

6.1 Bounding Design Basis Container Contents

Bounding HICs generated at LaSalle are assumed to have a contact dose rate of 380 R/hr. A container with this contact dose rate may require a hold in storage for a decay period. Containers shipped from Byron, Braidwood, or Clinton are assumed to have a maximum contact dose rate 200 R/hr, because of limitations on dose rates exterior to a transport package.

Shielding analyses have been performed on an all Co-60 basis to simulate worst case conditions. However, design basis events involving postulated airborne releases and inhalation doses must consider relative inhalation dose conversion factors. For this reason, isotopic mixes from station UFSARs for the bounding resin sources were evaluated using the following process.

1. For Byron and Braidwood two mixes were collected, one from UFSAR Table 11.1-10 “Realistic Source Terms for NSSS Demineralizers” and one from Table 12.2-13 “Mixed Bed Demineralizer”. For Clinton, phase separator characteristics from UFSAR Table 12.2-12 “Design-Basis Inventories of Radioactive Nuclides in Major Wet Solid Waste Subsystem Components – Phase Separator Tank Column” were used. For LaSalle, UFSAR Table 11.2-5 “Inventory Summary RWCU Phase Separator Column” was used.
2. These 4 mixes were place in a nominal HIC to determine a contact dose rate, using MicroShield. A decay before container loading period of 60 days was

assumed, and the resulting mix of isotopes adjusted using MicroShield to result in the 200 R/hr container contact dose.

3. These isotopic mix concentrations were then multiplied by effective inhalation dose conversion factors from FGR-11 and then summed to determine which mix would yield the maximum inhalation dose. The result of this step was that LaSalle RWCU Phase Separator had the bounding isotopic mix.
4. With the bounding isotopic mix in a container, the contents are adjusted proportionally to yield the design basis 380 R/hr LaSalle Container, which based on both isotopics and contact dose rate limits, is bounding.
5. Accidents are evaluated based on multiplying the following factors: (1) Container Contents; (2) the number of containers affected; (3) the release fraction applicable to the event; (4) the LaSalle EAB X/Q for ground level releases; (5) a Breathing Rate of 3.5E-4 m^3/s; and (6) Dose Conversion Factors from Reference (6).

6.2 Container Drop

6.2.1 Airborne Release Fraction

NUREG-1320 (Ref. (1)) provides an equation for calculating the airborne release from powder spills which are a function of spill height and spill density.

Fraction airborne = $1 \times 10^{-8} \times H^2 / \rho_p$ (Ref.(1))

Where H = Spill height, cm
ρ_p= Powder density g/cm3

H = 28' = 853.44 cm

Where 28' is the elevation of the bottom of the container in relation to the floor.

The density for a dry Powdex comparable resin:

ρ_p = 0.9 g/cc

Therefore, fraction airborne = $1 \times 10^{-8} \times (853.44)^2 / (9 \times 10^{-1}) = 8.09 \times 10^{-3}$

7. Results

This calculation was performed to evaluate LSCS IRSF internal design basis events (fire and container drop) as bounding events. The methodology is conservative as discussed below. The calculated doses are:

Event	Calculated Dose	Limit
Container Drop	0.389 rem	2.5 rem
Container Fire	2.334 rem	2.5 rem

Some of the conservatisms applied in this calculation are listed below.

- All affected containers are assumed to have a contact dose rate of 380 R/hr, which is the maximum allowed in the IRSFs based on ODCM requirements.

- In the Fire Event, 6 containers are assumed to be involved(two high stacking in three positions) with a contact dose rate of 380 R/hr. Typical stacking practices would have upper containers with a significantly lower contact dose rate for skyshine minimization.

- Release Fractions for container drop use a conservative NUREG-1320 based dry powder spill scenario to determine an airborne fraction. The worst case Powdex-like resin is expected to be wet and to be less easily made airborne. Larger bead resin would be even less likely to become airborne. The assumed drop is from the maximum release height with a resulting calculated airborne release fraction of 0.00809, which is rounded to 0.01.

- Release Fractions for the Fire Event use a conservative DOE Handbook approach for resin fires and similarly round a 0.0078 value to 0.01.

- All airborne activity is assumed to be instantly released to the environment from the IRSF. No particle settling is assumed either in the IRSF or in transit to the EAB. The IRSF ventilation system is isolated during container handling to maximize the potential for such settling. For the Fire Event, procedure LOP-WX-33 (Ref (16)) directs that the ventilation system be secured.

- Selected worst case UFSAR isotopic mix which is richer in fission products than would be normally expected. For instance, 69% of above calculated doses result from Sr-89 and Sr-90.

8. Conclusion

By performing this evaluation, it has been concluded that a container fire of six containers is a bounding event. The level of conservatism includes significant safety factors for calculating an effective dose release to the EAB through a container drop or container fire analysis.

Doses from the bounding internal events in the IRSF are within 10% of 10 CFR 100 limits.

Attachment A: LaSalle

MicroShield 2
Run #1: Based on UFSAR Table Data from 11.2-5 2
Run #2: Based on UFSAR Table Data from 11.2-5 w/ 60 Day Decay 5
Run #3: Based on UFSAR Table Data from 11.2-5 w/ 60 Day Decay and Normalized Contact Dose 8
Excel Sheets 11
Drop Accident 11
Captures the isotopic mix from Run #3 in column D, and then calculates a final dose in column F.
Fire Accident 13
Captures the isotopic mix from Run #3 in column D, and then calculates a final dose in column F.
Drop Accident: Formula Version 15
Fire Accident: Formula Version 17

MicroShield 8.01
Washington Group International (8.00-0000)

Date	By	Checked

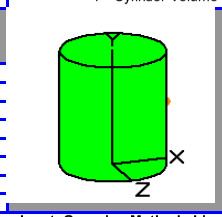
Filename	Run Date	Run Time	Duration
Lasalle.msd	11-Aug-09	8:54:48 AM	0:00:07

Project Info

Case Title	Lasalle 11.2-5
Description	before decay and resizing
Geometry	7 - Cylinder Volume - Side Shields

Source Dimensions

Height	182.88 cm (6 ft)
Radius	76.2 cm (2 ft 6.0 in)



Dose Points

A	X	Y	Z
#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)

Shields

Shield N	Dimension	Material	Density
Source	3.34e+06 cm³	Water	0.9
Transition		Air	0.00122
Air Gap		Air	0.00122

Source Input: Grouping Method - Linear Energy
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: Grove

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ag-110	1.47E-01	5.44E+09	4.41E-02	1.63E+03
Ag-110m	1.13E+01	4.18E+11	3.39E+00	1.25E+05
Ba-137m	2.96E+01	1.10E+12	8.87E+00	3.28E+05
Ba-139	1.74E+01	6.44E+11	5.22E+00	1.93E+05
Ba-140	2.20E+02	8.14E+12	6.59E+01	2.44E+06
Ba-141	3.84E+00	1.42E+11	1.15E+00	4.26E+04
Ba-142	2.26E+00	8.36E+10	6.77E-01	2.51E+04
Br-83	2.86E+00	1.06E+11	8.57E-01	3.17E+04
Br-84	1.11E+00	4.11E+10	3.33E-01	1.23E+04
Br-85	4.80E-02	1.78E+09	1.44E-02	5.32E+02
Ce-141	6.38E+00	2.36E+11	1.91E+00	7.08E+04
Ce-143	9.21E-02	3.41E+09	2.76E-02	1.02E+03
Ce-144	6.76E+00	2.50E+11	2.03E+00	7.50E+04
Co-58	5.62E+02	2.08E+13	1.68E+02	6.23E+06
Co-60	1.16E+02	4.29E+12	3.48E+01	1.29E+06
Cr-51	2.63E+01	9.73E+11	7.88E+00	2.92E+05
Cs-134	1.95E+01	7.22E+11	5.85E+00	2.16E+05
Cs-135				
Cs-136	1.52E+00	5.62E+10	4.56E-01	1.69E+04
Cs-137	3.16E+01	1.17E+12	9.47E+00	3.50E+05
Cs-138	4.37E+00	1.62E+11	1.31E+00	4.85E+04
F-18				
Fe-59	6.45E+00	2.39E+11	1.93E+00	7.15E+04
I-129	3.83E-08	1.42E+03	1.15E-08	4.25E-04
I-131	2.00E+02	7.40E+12	6.00E+01	2.22E+06
I-132	3.27E+02	1.21E+13	9.80E+01	3.63E+06
I-133	1.49E+02	5.51E+12	4.47E+01	1.65E+06
I-134	1.63E+01	6.03E+11	4.89E+00	1.81E+05
I-135	6.93E+01	2.56E+12	2.08E+01	7.69E+05
Kr-83m				
Kr-85				
Kr-85m				
La-140	2.20E+02	8.14E+12	6.59E+01	2.44E+06
La-141	4.06E+00	1.50E+11	1.22E+00	4.50E+04
La-142	2.48E+00	9.18E+10	7.43E-01	2.75E+04
Mn-54	7.82E+00	2.89E+11	2.34E+00	8.67E+04
Mn-56	1.02E+01	3.77E+11	3.06E+00	1.13E+05
Mo-99	1.17E+02	4.33E+12	3.51E+01	1.30E+06
N-16				

	A	B	C	D	E	F	G	H	I
67		Na-24			2.40E+00	8.88E+10	7.19E-01	2.66E+04	
68		Nb-95			6.29E+00	2.33E+11	1.89E+00	6.98E+04	
69		Nb-95m			8.39E-02	3.10E+09	2.52E-02	9.31E+02	
70		Nb-97			4.35E-02	1.61E+09	1.30E-02	4.82E+02	
71		Nb-97m			4.33E-02	1.60E+09	1.30E-02	4.80E+02	
72		Nd-147			2.98E-01	1.10E+10	8.93E-02	3.31E+03	
73		Ni-65			6.08E-02	2.25E+09	1.82E-02	6.74E+02	
74		Np-239			1.08E+03	4.00E+13	3.24E+02	1.20E+07	
75		P-32			5.47E-01	2.02E+10	1.64E-01	6.07E+03	
76		Pm-147			3.33E-02	1.23E+09	9.98E-03	3.69E+02	
77		Pr-143			1.08E+00	4.00E+10	3.24E-01	1.20E+04	
78		Pr-144			6.76E+00	2.50E+11	2.03E+00	7.50E+04	
79		Rh-103m			1.38E+00	5.11E+10	4.14E-01	1.53E+04	
80		Rh-106			5.26E-01	1.95E+10	1.58E-01	5.83E+03	
81		Ru-103			1.38E+00	5.11E+10	4.14E-01	1.53E+04	
82		Ru-106			5.26E-01	1.95E+10	1.58E-01	5.83E+03	
83		Sr-89			2.80E+02	1.04E+13	8.39E+01	3.11E+06	
84		Sr-90			5.46E+01	2.02E+12	1.64E+01	6.06E+05	
85		Sr-91			5.31E+01	1.96E+12	1.59E+01	5.89E+05	
86		Sr-92			2.36E+01	8.73E+11	7.07E+00	2.62E+05	
87		Tc-99			4.01E-04	1.48E+07	1.20E-04	4.45E+00	
88		Tc-99m			2.36E+02	8.73E+12	7.07E+01	2.62E+06	
89		Tc-101			2.42E+00	8.95E+10	7.25E-01	2.68E+04	
90		Te-129			1.62E+00	5.99E+10	4.86E-01	1.80E+04	
91		Te-129m			2.53E+00	9.36E+10	7.58E-01	2.81E+04	
92		Te-132			3.05E+02	1.13E+13	9.14E+01	3.38E+06	
93		W-187			5.71E+00	2.11E+11	1.71E+00	6.33E+04	
94		Xe-131m							
95		Xe-133							
96		Xe-133m							
97		Xe-135							
98		Xe-135m							
99		Y-90			5.34E+01	1.98E+12	1.60E+01	5.92E+05	
100		Y-90m							
101		Y-91			4.68E+01	1.73E+12	1.40E+01	5.19E+05	
102		Y-91m			3.12E+01	1.15E+12	9.35E+00	3.46E+05	
103		Y-92			2.38E+01	8.81E+11	7.13E+00	2.64E+05	
104		Zn-65			3.74E-01	1.38E+10	1.12E-01	4.15E+03	
105		Zn-69			3.29E-02	1.22E+09	9.86E-03	3.65E+02	
106		Zn-69m			3.28E-02	1.21E+09	9.83E-03	3.64E+02	
107		Zr-95			4.24E+00	1.57E+11	1.27E+00	4.70E+04	
108		Zr-97			4.34E-02	1.61E+09	1.30E-02	4.81E+02	
109		**Buildup: The material reference is Source**							
110		**Integration Parameters**							
111		Radial			30				
112		Circumferential			30				
113		Y Direction (axial)			60				
114					**Results**				
115						**Fluence Rate**	**Fluence Rate**	**Exposure Rate**	**Exposure Rate**
116		**Energy (MeV)**			**Activity (Photons/sec)**	**MeV/cm²/sec**	**MeV/cm²/sec**	**mR/hr**	**mR/hr**
117						**No Buildup**	**With Buildup**	**No Buildup**	**With Buildup**
118		0.0621			8.36E+13	3.70E+06	2.33E+07	7.05E+03	4.44E+04
119		0.2445			2.46E+13	6.53E+06	2.72E+07	1.20E+04	5.00E+04
120		0.3986			1.39E+13	7.20E+06	2.30E+07	1.40E+04	4.48E+04
121		0.5441			2.17E+13	1.74E+07	4.84E+07	3.41E+04	9.48E+04
122		0.7586			5.19E+13	6.71E+07	1.63E+08	1.28E+05	3.12E+05
123		0.9037			7.17E+12	1.20E+07	2.73E+07	2.24E+04	5.11E+04
124		1.0755			3.15E+12	6.78E+06	1.46E+07	1.23E+04	2.66E+04
125		1.1998			6.19E+12	1.57E+07	3.27E+07	2.79E+04	5.81E+04
126		1.3588			7.12E+12	2.17E+07	4.35E+07	3.75E+04	7.51E+04
127		1.5948			7.97E+12	3.09E+07	5.91E+07	5.11E+04	9.77E+04
128		1.7185			7.44E+11	3.22E+06	6.04E+06	5.22E+03	9.78E+03
129		1.8681			3.24E+11	1.59E+06	2.91E+06	2.51E+03	4.60E+03
130		2.0421			2.48E+11	1.39E+06	2.49E+06	2.14E+03	3.83E+03
131		2.2086			8.98E+10	5.66E+05	9.95E+05	8.48E+02	1.49E+03
132		2.3715			1.32E+11	9.26E+05	1.60E+06	1.36E+03	2.34E+03

	A	B	C	D	E	F	G	H	I
133		2.5226			3.10E+11	2.38E+06	4.05E+06	3.42E+03	5.81E+03
134		2.7363			1.07E+11	9.25E+05	1.54E+06	1.29E+03	2.16E+03
135		2.8117			2.35E+09	2.12E+04	3.51E+04	2.94E+01	4.86E+01
136		2.9944			8.63E+09	8.55E+04	1.40E+05	1.16E+02	1.89E+02
137		3.2183			1.90E+09	2.09E+04	3.36E+04	2.78E+01	4.46E+01
138		3.3487			4.13E+09	4.82E+04	7.67E+04	6.32E+01	1.01E+02
139		3.4593			3.37E+08	4.13E+03	6.52E+03	5.36E+00	8.46E+00
140		3.6364			2.17E+09	2.86E+04	4.46E+04	3.65E+01	5.69E+01
141		3.8453			2.98E+08	4.26E+03	6.56E+03	5.34E+00	8.22E+00
142		3.9336			2.94E+09	4.34E+04	6.65E+04	5.41E+01	8.28E+01
143		**Totals**			**2.29E+14**	**2.00E+08**	**4.82E+08**	**3.64E+05**	**8.85E+05**

MicroShield 8.01
Washington Group International (8.00-0000)

Date	By	Checked

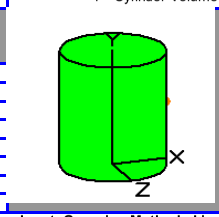
Filename	Run Date	Run Time	Duration
Lasalledecay4.msd	11-Aug-09	8:56:39 AM	0:00:07

Project Info

Case Title	Lasalle 11.2-5
Description	before resizing
Geometry	7 - Cylinder Volume - Side Shields

Source Dimensions

Height	182.88 cm (6 ft)
Radius	76.2 cm (2 ft 6.0 in)



Dose Points

A	X	Y	Z
#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)

Shields

Shield N	Dimension	Material	Density
Source	3.34e+06 cm³	Water	0.9
Transition		Air	0.00122
Air Gap		Air	0.00122

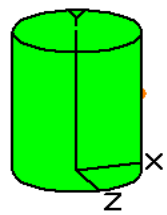
Source Input: Grouping Method - Linear Energy
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: Grove

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ac-227	1.10E-22	4.05E-12	3.28E-23	1.21E-18
Ag-110	1.27E-01	4.71E+09	3.81E-02	1.41E+03
Ag-110m	9.57E+00	3.54E+11	2.87E+00	1.06E+05
Ba-137m	2.98E+01	1.10E+12	8.93E+00	3.30E+05
Ba-139	1.8042e-312	6.68E-302	5.4084e-313	0.00E-01
Ba-140	8.51E+00	3.15E+11	2.55E+00	9.44E+04
Ba-141				
Ba-142				
Bi-211	2.46E-23	9.09E-13	7.37E-24	2.73E-19
Br-83	1.21E-181	4.48E-171	3.63E-182	1.34E-177
Br-84				
Br-85				
Ce-141	1.78E+00	6.59E+10	5.34E-01	1.97E+04
Ce-143	6.74E-15	2.49E-04	2.02E-15	7.47E-11
Ce-144	5.84E+00	2.16E+11	1.75E+00	6.48E+04
Co-58	3.12E+02	1.16E+13	9.36E+01	3.46E+06
Co-60	1.14E+02	4.20E+12	3.40E+01	1.26E+06
Cr-51	5.86E+00	2.17E+11	1.76E+00	6.50E+04
Cs-134	1.85E+01	6.83E+11	5.53E+00	2.05E+05
Cs-135	2.27E-08	8.41E+02	6.81E-09	2.52E-04
Cs-136	6.45E-02	2.39E+09	1.93E-02	7.15E+02
Cs-137	3.15E+01	1.16E+12	9.44E+00	3.49E+05
Cs-138				
F-18				
Fe-59	2.54E+00	9.40E+10	7.61E-01	2.82E+04
Fr-223	1.58E-24	5.85E-14	4.74E-25	1.75E-20
I-129	4.88E-08	1.81E+03	1.46E-08	5.42E-04
I-131	1.13E+00	4.20E+10	3.40E-01	1.26E+04
I-132	9.00E-04	3.33E+07	2.70E-04	9.98E+00
I-133	2.15E-19	7.96E-09	6.45E-20	2.39E-15
I-134				
I-135	1.82E-64	6.75E-54	5.47E-65	2.02E-60
Kr-83m	5.16E-181	1.91E-170	1.55E-181	5.72E-177
Kr-85	5.13E-09	1.90E+02	1.54E-09	5.69E-05
Kr-85m	8.98E-101	3.32E-90	2.69E-101	9.96E-97
La-140	9.80E+00	3.63E+11	2.94E+00	1.09E+05
La-141	4.17E-110	1.54E-99	1.25E-110	4.63E-106
La-142	6.47E-273	2.39E-262	1.94E-273	7.17E-269
Mn-54	6.85E+00	2.53E+11	2.05E+00	7.59E+04

	A	B	C	D	E	F	G	H	I
67		Mn-56			7.84E-168	2.90E-157	2.35E-168	8.69E-164	
68		Mo-99			3.18E-05	1.18E+06	9.53E-06	3.53E-01	
69		N-16							
70		Na-24			3.03E-29	1.12E-18	9.08E-30	3.36E-25	
71		Nb-95			3.96E+00	1.46E+11	1.19E+00	4.39E+04	
72		Nb-95m			1.88E-02	6.95E+08	5.63E-03	2.08E+02	
73		Nb-97			1.05E-27	3.87E-17	3.14E-28	1.16E-23	
74		Nb-97m			9.21E-28	3.41E-17	2.76E-28	1.02E-23	
75		Nd-147			6.75E-03	2.50E+08	2.02E-03	7.49E+01	
76		Ni-65			5.84E-174	2.16E-163	1.75E-174	6.48E-170	
77		Np-239			2.31E-05	8.55E+05	6.93E-06	2.56E-01	
78		P-32			2.98E-02	1.10E+09	8.93E-03	3.30E+02	
79		Pa-231			6.87E-20	2.54E-09	2.06E-20	7.61E-16	
80		Pb-211			2.03E-23	7.53E-13	6.10E-24	2.26E-19	
81		Pm-147			3.51E-02	1.30E+09	1.05E-02	3.89E+02	
82		Po-211			5.49E-26	2.03E-15	1.65E-26	6.09E-22	
83		Po-215			1.93E-23	7.16E-13	5.80E-24	2.15E-19	
84		Pr-143			5.08E-02	1.88E+09	1.52E-02	5.63E+02	
85		Pr-144			5.84E+00	2.16E+11	1.75E+00	6.48E+04	
86		Pr-144m			8.35E-02	3.09E+09	2.50E-02	9.26E+02	
87		Pu-239			2.89E-04	1.07E+07	8.65E-05	3.20E+00	
88		Ra-223			1.80E-23	6.66E-13	5.40E-24	2.00E-19	
89		Re-187			3.30E-13	1.22E-02	9.90E-14	3.66E-09	
90		Rh-103m			4.79E-01	1.77E+10	1.44E-01	5.31E+03	
91		Rh-106			4.70E-01	1.74E+10	1.41E-01	5.21E+03	
92		Rn-219			2.54E-23	9.39E-13	7.61E-24	2.81E-19	
93		Ru-103			4.80E-01	1.77E+10	1.44E-01	5.32E+03	
94		Ru-106			4.70E-01	1.74E+10	1.41E-01	5.21E+03	
95		Sm-147			3.77E-14	1.39E-03	1.13E-14	4.18E-10	
96		Sr-89			1.23E+02	4.55E+12	3.69E+01	1.36E+06	
97		Sr-90			5.44E+01	2.01E+12	1.63E+01	6.03E+05	
98		Sr-91			1.25E-44	4.61E-34	3.73E-45	1.38E-40	
99		Sr-92			2.61E-159	9.64E-149	7.81E-160	2.89E-155	
100		Tc-99			4.06E-04	1.50E+07	1.22E-04	4.50E+00	
101		Tc-99m			3.10E-05	1.15E+06	9.29E-06	3.44E-01	
102		Tc-101							
103		Te-129			4.62E-01	1.71E+10	1.39E-01	5.13E+03	
104		Te-129m			7.34E-01	2.72E+10	2.20E-01	8.14E+03	
105		Te-132			8.73E-04	3.23E+07	2.62E-04	9.68E+00	
106		Th-227			4.12E-23	1.52E-12	1.24E-23	4.57E-19	
107		Th-231			4.28E-14	1.59E-03	1.28E-14	4.75E-10	
108		Tl-207			2.38E-23	8.80E-13	7.13E-24	2.64E-19	
109		U-235			4.40E-14	1.63E-03	1.32E-14	4.88E-10	
110		W-187			3.68E-18	1.36E-07	1.10E-18	4.08E-14	
111		Xe-131m			1.11E-01	4.11E+09	3.33E-02	1.23E+03	
112		Xe-133			1.08E-02	4.01E+08	3.25E-03	1.20E+02	
113		Xe-133m			1.59E-08	5.88E+02	4.77E-09	1.76E-04	
114		Xe-135			4.81E-46	1.78E-35	1.44E-46	5.33E-42	
115		Xe-135m			3.13E-65	1.16E-54	9.38E-66	3.47E-61	
116		Y-90			5.44E+01	2.01E+12	1.63E+01	6.03E+05	
117		Y-90m							
118		Y-91			2.32E+01	8.58E+11	6.95E+00	2.57E+05	
119		Y-91m			7.83E-45	2.90E-34	2.35E-45	8.69E-41	
120		Y-92			3.55E-121	1.32E-110	1.07E-121	3.94E-117	
121		Zn-65			3.15E-01	1.17E+10	9.46E-02	3.50E+03	
122		Zn-69			1.10E-33	4.08E-23	3.31E-34	1.22E-29	
123		Zn-69m			1.03E-33	3.81E-23	3.09E-34	1.14E-29	
124		Zr-95			2.21E+00	8.19E+10	6.64E-01	2.46E+04	
125		Zr-97			9.72E-28	3.60E-17	2.91E-28	1.08E-23	
126		**Buildup: The material reference is Source**							
127		**Integration Parameters**							
128		Radial			30				
129		Circumferential			30				
130		Y Direction (axial)			60				
131					**Results**				
132						**Fluence Rate**	**Fluence Rate**	**Exposure Rate**	**Exposure Rate**

	A	B	C	D	E	F	G	H	I
133		**Energy (MeV)**			**Activity (Photons/sec)**	**MeV/cm²/sec**	**MeV/cm²/sec**	**mR/hr**	**mR/hr**
134						**No Buildup**	**With Buildup**	**No Buildup**	**With Buildup**
135		0.0102			3.52E+12	3.03E+03	3.53E+03	8.86E+02	1.03E+03
136		0.2239			4.63E+10	1.09E+04	4.82E+04	1.98E+01	8.71E+01
137		0.3606			1.73E+11	7.81E+04	2.62E+05	1.51E+02	5.07E+02
138		0.5262			4.56E+12	3.49E+06	9.83E+06	6.85E+03	1.93E+04
139		0.681			1.81E+12	2.00E+06	5.08E+06	3.87E+03	9.82E+03
140		0.8126			1.29E+13	1.84E+07	4.36E+07	3.49E+04	8.27E+04
141		0.9418			1.58E+11	2.80E+05	6.31E+05	5.21E+02	1.18E+03
142		1.1722			4.28E+12	1.05E+07	2.20E+07	1.87E+04	3.92E+04
143		1.3333			4.35E+12	1.29E+07	2.60E+07	2.23E+04	4.50E+04
144		1.4981			6.11E+10	2.15E+05	4.19E+05	3.62E+02	7.05E+02
145		1.6079			4.12E+11	1.62E+06	3.09E+06	2.67E+03	5.09E+03
146		1.7575			9.86E+04	4.41E-01	8.23E-01	7.10E-04	1.32E-03
147		1.9599			7.56E+05	3.98E+00	7.22E+00	6.20E-03	1.12E-02
148		2.0868			7.88E+04	4.56E-01	8.14E-01	6.96E-04	1.24E-03
149		2.1857			1.67E+09	1.04E+04	1.83E+04	1.56E+01	2.75E+01
150		2.3488			3.08E+09	2.13E+04	3.69E+04	3.13E+01	5.42E+01
151		2.5224			1.29E+10	9.92E+04	1.69E+05	1.42E+02	2.42E+02
152		2.7541			1.12E-18	9.80E-24	1.63E-23	1.37E-26	2.28E-26
153		2.8086			4.90E-264	4.42E-269	7.32E-269	6.12E-272	1.01E-271
154		2.9598			8.89E-160	8.66E-165	1.42E-164	1.18E-167	1.93E-167
155		3.1706			1.26E-264	1.36E-269	2.18E-269	1.81E-272	2.91E-272
156		3.3696			4.87E-160	5.75E-165	9.12E-165	7.52E-168	1.19E-167
157		3.4328			1.63E-264	1.98E-269	3.13E-269	2.57E-272	4.07E-272
158		3.6237			4.90E-264	6.43E-269	1.00E-268	8.22E-272	1.28E-271
159		3.8236			7.18E-22	1.02E-26	1.57E-26	1.28E-29	1.97E-29
160		**Totals**			**3.23E+13**	**4.96E+07**	**1.11E+08**	**9.15E+04**	**2.05E+05**

	A	B	C	D	E	F	G	H	I
1	MicroShield 8.01								
2	Washington Group International (8.00-0000)								
3	Date				By	Checked			
4									
5	Filename				Run Date	Run Time	Duration		
6	Lasalledecay2.msd				3-Aug-09	1:38:55 PM	0:00:07		
7	Project Info								
8	Case Title				Lasalle 11.2-5				
9	Description				After Resizing				
10	Geometry				7 - Cylinder Volume - Side Shields				
11	Source Dimensions								
12	Height	182.88 cm (6 ft)							
13	Radius	76.2 cm (2 ft 6.0 in)							
14	Dose Points								
15	A	X	Y	Z					
16	#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)					
17	Shields								
18	Shield N	Dimension	Material	Density					
19	Source	2.04e+05 in³	Water	0.9					
20	Transition		Air	0.00122					
21	Air Gap		Air	0.00122					
22	Source Input: Grouping Method - Linear Energy								
23	Number of Groups: 25								
24	Lower Energy Cutoff: 0.015								
25	Photons < 0.015: Included								
26	Library: Grove								
27	Nuclide				Ci	Bq	µCi/cm³	Bq/cm³	
28	Ac-227				1.07E-22	3.95E-12	3.20E-23	1.18E-18	
29	Ag-110				1.24E-01	4.59E+09	3.72E-02	1.38E+03	
30	Ag-110m				9.33E+00	3.45E+11	2.80E+00	1.04E+05	
31	Ba-137m				2.91E+01	1.08E+12	8.71E+00	3.22E+05	
32	Ba-139				1.7602e-312	6.51E-302	5.2765e-313	0.00E-01	
33	Ba-140				8.31E+00	3.07E+11	2.49E+00	9.21E+04	
34	Ba-141								
35	Ba-142								
36	Bi-211				2.40E-23	8.87E-13	7.19E-24	2.66E-19	
37	Br-83				1.18E-181	4.37E-171	3.54E-182	1.31E-177	
38	Br-84								
39	Br-85								
40	Ce-141				1.74E+00	6.43E+10	5.21E-01	1.93E+04	
41	Ce-143				6.57E-15	2.43E-04	1.97E-15	7.29E-11	
42	Ce-144				5.70E+00	2.11E+11	1.71E+00	6.32E+04	
43	Co-58				3.05E+02	1.13E+13	9.13E+01	3.38E+06	
44	Co-60				1.11E+02	4.10E+12	3.32E+01	1.23E+06	
45	Cr-51				5.72E+00	2.12E+11	1.71E+00	6.34E+04	
46	Cs-134				1.80E+01	6.66E+11	5.40E+00	2.00E+05	
47	Cs-135				2.22E-08	8.20E+02	6.64E-09	2.46E-04	
48	Cs-136				6.29E-02	2.33E+09	1.89E-02	6.98E+02	
49	Cs-137				3.07E+01	1.14E+12	9.21E+00	3.41E+05	
50	Cs-138								
51	F-18								
52	Fe-59				2.48E+00	9.17E+10	7.43E-01	2.75E+04	
53	Fr-223				1.54E-24	5.71E-14	4.63E-25	1.71E-20	
54	I-129				4.76E-08	1.76E+03	1.43E-08	5.28E-04	



	A	B	C	D	E	F	G	H	I
55		I-131			1.11E+00	4.09E+10	3.32E-01	1.23E+04	
56		I-132			8.78E-04	3.25E+07	2.63E-04	9.73E+00	
57		I-133			2.10E-19	7.76E-09	6.29E-20	2.33E-15	
58		I-134							
59		I-135			1.78E-64	6.58E-54	5.33E-65	1.97E-60	
60		Kr-83m			5.04E-181	1.86E-170	1.51E-181	5.58E-177	
61		Kr-85			5.00E-09	1.85E+02	1.50E-09	5.55E-05	
62		Kr-85m			8.77E-101	3.24E-90	2.63E-101	9.72E-97	
63		La-140			9.56E+00	3.54E+11	2.87E+00	1.06E+05	
64		La-141			4.07E-110	1.51E-99	1.22E-110	4.52E-106	
65		La-142			6.31E-273	2.34E-262	1.89E-273	7.00E-269	
66		Mn-54			6.68E+00	2.47E+11	2.00E+00	7.41E+04	
67		Mn-56			7.65E-168	2.83E-157	2.29E-168	8.48E-164	
68		Mo-99			3.10E-05	1.15E+06	9.30E-06	3.44E-01	
69		N-16							
70		Na-24			2.96E-29	1.09E-18	8.86E-30	3.28E-25	
71		Nb-95			3.86E+00	1.43E+11	1.16E+00	4.28E+04	
72		Nb-95m			1.83E-02	6.78E+08	5.49E-03	2.03E+02	
73		Nb-97			1.02E-27	3.78E-17	3.06E-28	1.13E-23	
74		Nb-97m			8.99E-28	3.33E-17	2.69E-28	9.97E-24	
75		Nd-147			6.58E-03	2.44E+08	1.97E-03	7.30E+01	
76		Ni-65			5.70E-174	2.11E-163	1.71E-174	6.32E-170	
77		Np-239			2.26E-05	8.34E+05	6.76E-06	2.50E-01	
78		P-32			2.91E-02	1.08E+09	8.71E-03	3.22E+02	
79		Pa-231			6.70E-20	2.48E-09	2.01E-20	7.43E-16	
80		Pb-211			1.98E-23	7.34E-13	5.95E-24	2.20E-19	
81		Pm-147			3.43E-02	1.27E+09	1.03E-02	3.80E+02	
82		Po-211			5.36E-26	1.98E-15	1.61E-26	5.94E-22	
83		Po-215			1.89E-23	6.98E-13	5.66E-24	2.09E-19	
84		Pr-143			4.95E-02	1.83E+09	1.48E-02	5.49E+02	
85		Pr-144			5.70E+00	2.11E+11	1.71E+00	6.32E+04	
86		Pr-144m			8.15E-02	3.01E+09	2.44E-02	9.04E+02	
87		Pu-239			2.82E-04	1.04E+07	8.44E-05	3.12E+00	
88		Ra-223			1.76E-23	6.50E-13	5.27E-24	1.95E-19	
89		Re-187			3.22E-13	1.19E-02	9.66E-14	3.57E-09	
90		Rh-103m			4.67E-01	1.73E+10	1.40E-01	5.18E+03	
91		Rh-106			4.58E-01	1.70E+10	1.37E-01	5.08E+03	
92		Rn-219			2.48E-23	9.16E-13	7.42E-24	2.75E-19	
93		Ru-103			4.68E-01	1.73E+10	1.40E-01	5.19E+03	
94		Ru-106			4.58E-01	1.70E+10	1.37E-01	5.08E+03	
95		Sm-147			3.68E-14	1.36E-03	1.10E-14	4.08E-10	
96		Sr-89			1.20E+02	4.44E+12	3.60E+01	1.33E+06	
97		Sr-90			5.31E+01	1.96E+12	1.59E+01	5.88E+05	
98		Sr-91			1.22E-44	4.50E-34	3.64E-45	1.35E-40	
99		Sr-92			2.54E-159	9.41E-149	7.62E-160	2.82E-155	
100		Tc-99			3.96E-04	1.47E+07	1.19E-04	4.39E+00	
101		Tc-99m			3.02E-05	1.12E+06	9.06E-06	3.35E-01	
102		Tc-101							
103		Te-129			4.51E-01	1.67E+10	1.35E-01	5.00E+03	
104		Te-129m			7.16E-01	2.65E+10	2.15E-01	7.94E+03	
105		Te-132			8.52E-04	3.15E+07	2.55E-04	9.45E+00	
106		Th-227			4.02E-23	1.49E-12	1.21E-23	4.46E-19	
107		Th-231			4.18E-14	1.55E-03	1.25E-14	4.64E-10	

	A	B	C	D	E	F	G	H	I
108	Tl-207				2.32E-23	8.58E-13	6.95E-24	2.57E-19	
109	U-235				4.30E-14	1.59E-03	1.29E-14	4.77E-10	
110	W-187				3.59E-18	1.33E-07	1.08E-18	3.98E-14	
111	Xe-131m				1.08E-01	4.01E+09	3.25E-02	1.20E+03	
112	Xe-133				1.06E-02	3.91E+08	3.17E-03	1.17E+02	
113	Xe-133m				1.55E-08	5.74E+02	4.65E-09	1.72E-04	
114	Xe-135				4.69E-46	1.74E-35	1.41E-46	5.20E-42	
115	Xe-135m				3.05E-65	1.13E-54	9.15E-66	3.39E-61	
116	Y-90				5.31E+01	1.96E+12	1.59E+01	5.89E+05	
117	Y-90m								
118	Y-91				2.26E+01	8.37E+11	6.78E+00	2.51E+05	
119	Y-91m				7.64E-45	2.83E-34	2.29E-45	8.47E-41	
120	Y-92				3.47E-121	1.28E-110	1.04E-121	3.85E-117	
121	Zn-65				3.08E-01	1.14E+10	9.23E-02	3.41E+03	
122	Zn-69				1.08E-33	3.98E-23	3.23E-34	1.19E-29	
123	Zn-69m				1.00E-33	3.72E-23	3.01E-34	1.11E-29	
124	Zr-95				2.16E+00	7.99E+10	6.48E-01	2.40E+04	
125	Zr-97				9.48E-28	3.51E-17	2.84E-28	1.05E-23	
126	**Buildup: The material reference is Source**								
127	**Integration Parameters**								
128	Radial				30				
129	Circumferential				30				
130	Y Direction (axial)				60				
131	**Results**								
132									
133	**Energy (MeV)**				**Activity (Photons/sec)**	**Fluence Rate MeV/cm²/sec No Buildup**	**Fluence Rate MeV/cm²/sec With Buildup**	**Exposure Rate mR/hr No Buildup**	**Exposure Rate mR/hr With Buildup**
134									
135	0.0102				3.44E+12	2.96E+03	3.44E+03	8.64E+02	1.01E+03
136	0.2239				4.52E+10	1.07E+04	4.70E+04	1.93E+01	8.49E+01
137	0.3606				1.69E+11	7.62E+04	2.56E+05	1.47E+02	4.94E+02
138	0.5262				4.45E+12	3.40E+06	9.59E+06	6.68E+03	1.88E+04
139	0.681				1.77E+12	1.95E+06	4.95E+06	3.78E+03	9.58E+03
140	0.8126				1.26E+13	1.79E+07	4.25E+07	3.40E+04	8.07E+04
141	0.9418				1.54E+11	2.73E+05	6.16E+05	5.09E+02	1.15E+03
142	1.1722				4.17E+12	1.02E+07	2.14E+07	1.82E+04	3.83E+04
143	1.3333				4.24E+12	1.26E+07	2.53E+07	2.18E+04	4.39E+04
144	1.4981				5.96E+10	2.10E+05	4.09E+05	3.53E+02	6.88E+02
145	1.6079				4.02E+11	1.58E+06	3.01E+06	2.60E+03	4.97E+03
146	1.7575				9.61E+04	4.30E-01	8.02E-01	6.92E-04	1.29E-03
147	1.9599				7.37E+05	3.89E+00	7.04E+00	6.05E-03	1.10E-02
148	2.0868				7.69E+04	4.45E-01	7.94E-01	6.79E-04	1.21E-03
149	2.1857				1.63E+09	1.01E+04	1.79E+04	1.52E+01	2.68E+01
150	2.3488				3.01E+09	2.08E+04	3.60E+04	3.05E+01	5.29E+01
151	2.5224				1.26E+10	9.68E+04	1.65E+05	1.39E+02	2.36E+02
152	2.7541				1.09E-18	9.56E-24	1.59E-23	1.33E-26	2.22E-26
153	2.8086				4.78E-264	4.31E-269	7.14E-269	5.97E-272	9.89E-272
154	2.9598				8.67E-160	8.45E-165	1.38E-164	1.15E-167	1.88E-167
155	3.1706				1.23E-264	1.32E-269	2.13E-269	1.76E-272	2.84E-272
156	3.3696				4.76E-160	5.61E-165	8.90E-165	7.33E-168	1.16E-167
157	3.4328				1.59E-264	1.93E-269	3.05E-269	2.51E-272	3.97E-272
158	3.6237				4.78E-264	6.27E-269	9.79E-269	8.01E-272	1.25E-271
159	3.8236				7.01E-22	9.94E-27	1.53E-26	1.25E-29	1.92E-29
160	**Totals**				**3.15E+13**	**4.83E+07**	**1.08E+08**	**8.92E+04**	**2.00E+05**

	A	B	C	D	E	F
1	**Container Drop Event: LaSalle Isotopic: Table 11.2-5**					
2	5.400E-04	X/Q (sec/m^3)				
3	3.500E-04	Breathing Rate (m^3/sec)				
4	1.000E-02	Release Fraction				
5	3.70E+12	Conversion Factor (rem/Ci per Sv/Bq)				
6	1.00E+00	Containers/Accident				
7	2.00E+02	Container Contact - Nominal Baseline Analysis (R/hr)				
8	3.80E+02	Container Contact - Bounding Accident Value (R/hr)				
9						
10	3.889E-01	Total Inhalation Dose				
11				60 day Decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			Ac-227	1.068E-22	1.810E-03	2.57E-21
14			Ag-110	1.241E-01	0.00E+00	0.00E+00
15			Ag-110m	9.334E+00	2.170E-08	2.69E-03
16			Ba-137m	2.906E+01	0.00E+00	0.00E+00
17			Ba-139	1.7602e-312	4.640E-11	0.00E+00
18			Ba-140	8.306E+00	1.010E-09	1.11E-04
19			Ba-141	0.000E+00	2.180E-11	0.00E+00
20			Ba-142	0.000E+00	1.110E-11	0.00E+00
21			Bi-211	2.398E-23	0.00E+00	0.00E+00
22			Br-83	1.180E-181	2.410E-11	3.78E-188
23			Br-84	0.000E+00	2.610E-11	0.00E+00
24			Br-85	0.000E+00	0.00E+00	0.00E+00
25			Ce-141	1.737E+00	2.420E-09	5.59E-05
26			Ce-143	6.572E-15	9.160E-10	8.00E-20
27			Ce-144	5.698E+00	1.010E-07	7.65E-03
28			Co-58	3.047E+02	2.940E-09	1.19E-02
29			Co-60	1.108E+02	5.910E-08	8.70E-02
30			Cr-51	5.718E+00	9.030E-11	6.86E-06
31			Cs-134	1.800E+01	1.250E-08	2.99E-03
32			Cs-135	2.217E-08	1.230E-09	3.62E-13
33			Cs-136	6.290E-02	1.980E-09	1.65E-06
34			Cs-137	3.071E+01	8.630E-09	3.52E-03
35			Cs-138	0.000E+00	2.740E-11	0.00E+00
36			F-18	0.000E+00	2.260E-11	0.00E+00
37			Fe-59	2.478E+00	4.000E-09	1.32E-04
38			Fr-223	1.543E-24	1.680E-09	3.45E-29
39			I-129	4.764E-08	4.690E-08	2.97E-11
40			I-131	1.106E+00	8.890E-09	1.31E-04
41			I-132	8.776E-04	1.030E-10	1.20E-09
42			I-133	2.099E-19	1.580E-09	4.41E-24
43			I-134	0.000E+00	3.550E-11	0.00E+00
44			I-135	1.779E-64	3.320E-10	7.85E-70
45			Kr-83m	5.035E-181	0.00E+00	0.00E+00
46			Kr-85	5.001E-09	0.00E+00	0.00E+00
47			Kr-85m	8.765E-101	0.00E+00	0.00E+00
48			La-140	9.559E+00	1.310E-09	1.66E-04
49			La-141	4.072E-110	1.570E-10	8.49E-116
50			La-142	6.311E-273	6.840E-11	5.74E-279
51			Mn-54	6.679E+00	1.810E-09	1.61E-04
52			Mn-56	7.645E-168	1.020E-10	1.04E-173
53			Mo-99	3.101E-05	1.070E-09	4.41E-10
54			N-16	0.000E+00	0.00E+00	0.00E+00
55			Na-24	2.955E-29	3.270E-10	1.28E-34
56			Nb-95	3.859E+00	1.570E-09	8.05E-05
57			Nb-95m	1.832E-02	6.590E-10	1.60E-07

	A	B	C	D	E	F
58			Nb-97	1.022E-27	2.240E-11	3.04E-34
59			Nb-97m	8.988E-28	0.00E+00	0.00E+00
60			Nd-147	6.585E-03	1.850E-09	1.62E-07
61			Ni-65	5.702E-174	9.320E-11	7.06E-180
62			Np-239	2.255E-05	6.780E-10	2.03E-10
63			P-32	2.906E-02	4.190E-09	1.62E-06
64			Pa-231	6.698E-20	3.470E-04	3.09E-19
65			Pb-211	1.984E-23	2.350E-09	6.20E-28
66			Pm-147	3.426E-02	1.060E-08	4.83E-06
67			Po-211	5.359E-26	0.00E+00	0.00E+00
68			Po-215	1.888E-23	0.00E+00	0.00E+00
69			Pr-143	4.953E-02	2.190E-09	1.44E-06
70			Pr-144	5.698E+00	1.170E-11	8.86E-07
71			Pr-144m	8.148E-02	0.00E+00	0.00E+00
72			Pu-239	2.815E-04	1.160E-04	4.34E-04
73			Ra-223	1.757E-23	2.120E-06	4.95E-25
74			Re-187	3.222E-13	1.470E-11	6.29E-20
75			Rh-103m	4.671E-01	1.380E-12	8.57E-09
76			Rh-106	4.584E-01	0.00E+00	0.00E+00
77			Rn-219	2.476E-23	0.00E+00	0.00E+00
78			Ru-103	4.679E-01	2.420E-09	1.50E-05
79			Ru-106	4.584E-01	1.290E-07	7.86E-04
80			Sm-147	3.676E-14	2.020E-05	9.87E-15
81			Sr-89	1.200E+02	1.120E-08	1.79E-02
82			Sr-90	5.306E+01	3.510E-07	2.47E-01
83			Sr-91	1.215E-44	4.490E-10	7.25E-50
84			Sr-92	2.543E-159	2.180E-10	7.36E-165
85			Tc-99	3.960E-04	2.250E-09	1.18E-08
86			Tc-99m	3.023E-05	8.800E-12	3.53E-12
87			Tc-101	0.000E+00	4.840E-12	0.00E+00
88			Te-129	4.509E-01	2.420E-11	1.45E-07
89			Te-129m	7.159E-01	6.470E-09	6.15E-05
90			Te-132	8.518E-04	2.550E-09	2.89E-08
91			Th-227	4.020E-23	4.370E-06	2.33E-24
92			Th-231	4.180E-14	2.370E-10	1.32E-19
93			Tl-207	2.320E-23	0.00E+00	0.00E+00
94			U-235	4.297E-14	3.320E-05	1.90E-14
95			W-187	3.591E-18	1.670E-10	7.97E-24
96			Xe-131m	1.083E-01	0.00E+00	0.00E+00
97			Xe-133	1.057E-02	0.00E+00	0.00E+00
98			Xe-133m	1.551E-08	0.00E+00	0.00E+00
99			Xe-135	4.689E-46	0.00E+00	0.00E+00
100			Xe-135m	3.053E-65	0.00E+00	0.00E+00
101			Y-90	5.307E+01	2.280E-09	1.61E-03
102			Y-90m	0.000E+00	1.270E-10	0.00E+00
103			Y-91	2.261E+01	1.320E-08	3.97E-03
104			Y-91m	7.640E-45	9.820E-12	9.97E-52
105			Y-92	3.468E-121	2.110E-10	9.72E-127
106			Zn-65	3.078E-01	5.510E-09	2.25E-05
107			Zn-69	1.077E-33	1.060E-11	1.52E-40
108			Zn-69m	1.005E-33	2.200E-10	2.94E-39
109			Zr-95	2.160E+00	6.390E-09	1.83E-04
110			Zr-97	9.481E-28	1.170E-09	1.47E-32
111						
112						
113						
114				Dose Total (rem)		3.889E-01

	A	B	C	D	E	F
1	**Container Fire Event: LaSalle Isotopic: Table 11.2-5**					
2	5.400E-04	X/Q (sec/m^3)				
3	3.500E-04	Breathing Rate (m^3/sec)				
4	1.000E-02	Release Fraction				
5	3.70E+12	Conversion Factor (rem/Ci per Sv/Bq)				
6	6.00E+00	Containers/Accident				
7	2.00E+02	Container Contact - Nominal Baseline Analysis (R/hr)				
8	3.80E+02	Container Contact - Bounding Accident Value (R/hr)				
9						
10	2.334E+00	Total Inhalation Dose				
11				60 day Decay		
12			Isotope	Ci in Container	Inhaled DCF	Dose (rem)
13			Ac-227	1.068E-22	1.810E-03	1.541E-20
14			Ag-110	1.241E-01	0.00E+00	0.000E+00
15			Ag-110m	9.334E+00	2.170E-08	1.615E-02
16			Ba-137m	2.906E+01	0.00E+00	0.000E+00
17			Ba-139	1.7602e-312	4.640E-11	0.000E+00
18			Ba-140	8.306E+00	1.010E-09	6.688E-04
19			Ba-141	0.000E+00	2.180E-11	0.000E+00
20			Ba-142	0.000E+00	1.110E-11	0.000E+00
21			Bi-211	2.398E-23	0.00E+00	0.000E+00
22			Br-83	1.180E-181	2.410E-11	2.267E-187
23			Br-84	0.000E+00	2.610E-11	0.000E+00
24			Br-85	0.000E+00	0.00E+00	0.000E+00
25			Ce-141	1.737E+00	2.420E-09	3.351E-04
26			Ce-143	6.572E-15	9.160E-10	4.799E-19
27			Ce-144	5.698E+00	1.010E-07	4.588E-02
28			Co-58	3.047E+02	2.940E-09	7.142E-02
29			Co-60	1.108E+02	5.910E-08	5.218E-01
30			Cr-51	5.718E+00	9.030E-11	4.117E-05
31			Cs-134	1.800E+01	1.250E-08	1.794E-02
32			Cs-135	2.217E-08	1.230E-09	2.174E-12
33			Cs-136	6.290E-02	1.980E-09	9.928E-06
34			Cs-137	3.071E+01	8.630E-09	2.113E-02
35			Cs-138	0.000E+00	2.740E-11	0.000E+00
36			F-18	0.000E+00	2.260E-11	0.000E+00
37			Fe-59	2.478E+00	4.000E-09	7.903E-04
38			Fr-223	1.543E-24	1.680E-09	2.067E-28
39			I-129	4.764E-08	4.690E-08	1.781E-10
40			I-131	1.106E+00	8.890E-09	7.839E-04
41			I-132	8.776E-04	1.030E-10	7.206E-09
42			I-133	2.099E-19	1.580E-09	2.643E-23
43			I-134	0.000E+00	3.550E-11	0.000E+00
44			I-135	1.779E-64	3.320E-10	4.708E-69
45			Kr-83m	5.035E-181	0.00E+00	0.000E+00
46			Kr-85	5.001E-09	0.00E+00	0.000E+00
47			Kr-85m	8.765E-101	0.00E+00	0.000E+00
48			La-140	9.559E+00	1.310E-09	9.983E-04
49			La-141	4.072E-110	1.570E-10	5.096E-115
50			La-142	6.311E-273	6.840E-11	3.441E-278
51			Mn-54	6.679E+00	1.810E-09	9.638E-04
52			Mn-56	7.645E-168	1.020E-10	6.217E-173
53			Mo-99	3.101E-05	1.070E-09	2.645E-09
54			N-16	0.000E+00	0.00E+00	0.000E+00
55			Na-24	2.955E-29	3.270E-10	7.704E-34
56			Nb-95	3.859E+00	1.570E-09	4.830E-04
57			Nb-95m	1.832E-02	6.590E-10	9.622E-07
58			Nb-97	1.022E-27	2.240E-11	1.824E-33

	A	B	C	D	E	F
59			Nb-97m	8.988E-28	0.00E+00	0.000E+00
60			Nd-147	6.585E-03	1.850E-09	9.711E-07
61			Ni-65	5.702E-174	9.320E-11	4.237E-179
62			Np-239	2.255E-05	6.780E-10	1.219E-09
63			P-32	2.906E-02	4.190E-09	9.707E-06
64			Pa-231	6.698E-20	3.470E-04	1.853E-18
65			Pb-211	1.984E-23	2.350E-09	3.717E-27
66			Pm-147	3.426E-02	1.060E-08	2.895E-05
67			Po-211	5.359E-26	0.00E+00	0.000E+00
68			Po-215	1.888E-23	0.00E+00	0.000E+00
69			Pr-143	4.953E-02	2.190E-09	8.647E-06
70			Pr-144	5.698E+00	1.170E-11	5.314E-06
71			Pr-144m	8.148E-02	0.00E+00	0.000E+00
72			Pu-239	2.815E-04	1.160E-04	2.603E-03
73			Ra-223	1.757E-23	2.120E-06	2.969E-24
74			Re-187	3.222E-13	1.470E-11	3.776E-19
75			Rh-103m	4.671E-01	1.380E-12	5.139E-08
76			Rh-106	4.584E-01	0.00E+00	0.000E+00
77			Rn-219	2.476E-23	0.00E+00	0.000E+00
78			Ru-103	4.679E-01	2.420E-09	9.027E-05
79			Ru-106	4.584E-01	1.290E-07	4.714E-03
80			Sm-147	3.676E-14	2.020E-05	5.920E-14
81			Sr-89	1.200E+02	1.120E-08	1.071E-01
82			Sr-90	5.306E+01	3.510E-07	1.485E+00
83			Sr-91	1.215E-44	4.490E-10	4.349E-49
84			Sr-92	2.543E-159	2.180E-10	4.419E-164
85			Tc-99	3.960E-04	2.250E-09	7.103E-08
86			Tc-99m	3.023E-05	8.800E-12	2.121E-11
87			Tc-101	0.000E+00	4.840E-12	0.000E+00
88			Te-129	4.509E-01	2.420E-11	8.700E-07
89			Te-129m	7.159E-01	6.470E-09	3.692E-04
90			Te-132	8.518E-04	2.550E-09	1.731E-07
91			Th-227	4.020E-23	4.370E-06	1.400E-23
92			Th-231	4.180E-14	2.370E-10	7.898E-19
93			Tl-207	2.320E-23	0.00E+00	0.000E+00
94			U-235	4.297E-14	3.320E-05	1.137E-13
95			W-187	3.591E-18	1.670E-10	4.781E-23
96			Xe-131m	1.083E-01	0.00E+00	0.000E+00
97			Xe-133	1.057E-02	0.00E+00	0.000E+00
98			Xe-133m	1.551E-08	0.00E+00	0.000E+00
99			Xe-135	4.689E-46	0.00E+00	0.000E+00
100			Xe-135m	3.053E-65	0.00E+00	0.000E+00
101			Y-90	5.307E+01	2.280E-09	9.646E-03
102			Y-90m	0.000E+00	1.270E-10	0.000E+00
103			Y-91	2.261E+01	1.320E-08	2.379E-02
104			Y-91m	7.640E-45	9.820E-12	5.981E-51
105			Y-92	3.468E-121	2.110E-10	5.834E-126
106			Zn-65	3.078E-01	5.510E-09	1.352E-04
107			Zn-69	1.077E-33	1.060E-11	9.099E-40
108			Zn-69m	1.005E-33	2.200E-10	1.762E-38
109			Zr-95	2.160E+00	6.390E-09	1.100E-03
110			Zr-97	9.481E-28	1.170E-09	8.844E-32
111						
112						
113						
114				Dose Total (rem)		2.334E+00

	A	B	C	D	E	F
1	**Container Drop Event: LaSalle Isotopic: Table 11.2-5**					
2	0.00054	X/Q (sec/m^3)				
3	0.00035	Breathing Rate (m^3/sec)				
4	0.01	Release Fraction				
5	3700000000000	Conversion Factor (rem/Ci per Sv/Bq)				
6	1	Containers/Accident				
7	200	Container Contact - Nominal Baseline Analysis (R/hr)				
8	380	Container Contact - Bounding Accident Value (R/hr)				
9						
10	=F114	Total Inhalation Dose				
11				60 day Decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			=LSFinal!A28	=LSFinal!E28	0.00181	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D13*E13
14			=LSFinal!A29	=LSFinal!E29	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D14*E14
15			=LSFinal!A30	=LSFinal!E30	0.0000000217	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D15*E15
16			=LSFinal!A31	=LSFinal!E31	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D16*E16
17			=LSFinal!A32	=LSFinal!E32	0.0000000000464	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D17*E17
18			=LSFinal!A33	=LSFinal!E33	0.00000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D18*E18
19			=LSFinal!A34	=LSFinal!E34	0.0000000000218	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D19*E19
20			=LSFinal!A35	=LSFinal!E35	0.0000000000111	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D20*E20
21			=LSFinal!A36	=LSFinal!E36	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D21*E21
22			=LSFinal!A37	=LSFinal!E37	0.0000000000241	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D22*E22
23			=LSFinal!A38	=LSFinal!E38	0.0000000000261	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D23*E23
24			=LSFinal!A39	=LSFinal!E39	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D24*E24
25			=LSFinal!A40	=LSFinal!E40	0.00000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D25*E25
26			=LSFinal!A41	=LSFinal!E41	0.000000000916	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D26*E26
27			=LSFinal!A42	=LSFinal!E42	0.000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D27*E27
28			=LSFinal!A43	=LSFinal!E43	0.00000000294	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D28*E28
29			=LSFinal!A44	=LSFinal!E44	0.0000000591	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D29*E29
30			=LSFinal!A45	=LSFinal!E45	0.0000000000903	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D30*E30
31			=LSFinal!A46	=LSFinal!E46	0.0000000125	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D31*E31
32			=LSFinal!A47	=LSFinal!E47	0.00000000123	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D32*E32
33			=LSFinal!A48	=LSFinal!E48	0.00000000198	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D33*E33
34			=LSFinal!A49	=LSFinal!E49	0.00000000863	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D34*E34
35			=LSFinal!A50	=LSFinal!E50	0.0000000000274	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D35*E35
36			=LSFinal!A51	=LSFinal!E51	0.0000000000226	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D36*E36
37			=LSFinal!A52	=LSFinal!E52	0.000000004	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D37*E37
38			=LSFinal!A53	=LSFinal!E53	0.00000000168	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D38*E38
39			=LSFinal!A54	=LSFinal!E54	0.0000000469	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D39*E39
40			=LSFinal!A55	=LSFinal!E55	0.00000000889	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D40*E40
41			=LSFinal!A56	=LSFinal!E56	0.000000000103	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D41*E41
42			=LSFinal!A57	=LSFinal!E57	0.00000000158	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D42*E42
43			=LSFinal!A58	=LSFinal!E58	0.0000000000355	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D43*E43
44			=LSFinal!A59	=LSFinal!E59	0.000000000332	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D44*E44
45			=LSFinal!A60	=LSFinal!E60	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D45*E45
46			=LSFinal!A61	=LSFinal!E61	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D46*E46
47			=LSFinal!A62	=LSFinal!E62	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D47*E47
48			=LSFinal!A63	=LSFinal!E63	0.00000000131	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D48*E48
49			=LSFinal!A64	=LSFinal!E64	0.000000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D49*E49
50			=LSFinal!A65	=LSFinal!E65	0.0000000000684	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D50*E50
51			=LSFinal!A66	=LSFinal!E66	0.00000000181	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D51*E51
52			=LSFinal!A67	=LSFinal!E67	0.000000000102	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D52*E52
53			=LSFinal!A68	=LSFinal!E68	0.00000000107	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D53*E53
54			=LSFinal!A69	=LSFinal!E69	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D54*E54
55			=LSFinal!A70	=LSFinal!E70	0.000000000327	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D55*E55
56			=LSFinal!A71	=LSFinal!E71	0.00000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D56*E56
57			=LSFinal!A72	=LSFinal!E72	0.000000000659	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D57*E57
58			=LSFinal!A73	=LSFinal!E73	0.0000000000224	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D58*E58
59			=LSFinal!A74	=LSFinal!E74	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D59*E59
60			=LSFinal!A75	=LSFinal!E75	0.00000000185	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D60*E60
61			=LSFinal!A76	=LSFinal!E76	0.0000000000932	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D61*E61
62			=LSFinal!A77	=LSFinal!E77	0.000000000678	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D62*E62
63			=LSFinal!A78	=LSFinal!E78	0.00000000419	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D63*E63
64			=LSFinal!A79	=LSFinal!E79	0.000347	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D64*E64
65			=LSFinal!A80	=LSFinal!E80	0.00000000235	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D65*E65
66			=LSFinal!A81	=LSFinal!E81	0.0000000106	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D66*E66
67			=LSFinal!A82	=LSFinal!E82	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D67*E67
68			=LSFinal!A83	=LSFinal!E83	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D68*E68
69			=LSFinal!A84	=LSFinal!E84	0.00000000219	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D69*E69
70			=LSFinal!A85	=LSFinal!E85	0.0000000000117	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D70*E70
71			=LSFinal!A86	=LSFinal!E86	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D71*E71
72			=LSFinal!A87	=LSFinal!E87	0.000116	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D72*E72
73			=LSFinal!A88	=LSFinal!E88	0.00000212	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D73*E73
74			=LSFinal!A89	=LSFinal!E89	0.0000000000147	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D74*E74
75			=LSFinal!A90	=LSFinal!E90	0.00000000000138	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D75*E75
76			=LSFinal!A91	=LSFinal!E91	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D76*E76
77			=LSFinal!A92	=LSFinal!E92	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D77*E77
78			=LSFinal!A93	=LSFinal!E93	0.00000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D78*E78
79			=LSFinal!A94	=LSFinal!E94	0.000000129	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D79*E79
80			=LSFinal!A95	=LSFinal!E95	0.0000202	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D80*E80
81			=LSFinal!A96	=LSFinal!E96	0.0000000112	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D81*E81
82			=LSFinal!A97	=LSFinal!E97	0.000000351	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D82*E82
83			=LSFinal!A98	=LSFinal!E98	0.000000000449	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D83*E83
84			=LSFinal!A99	=LSFinal!E99	0.000000000218	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D84*E84
85			=LSFinal!A100	=LSFinal!E100	0.00000000225	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D85*E85
86			=LSFinal!A101	=LSFinal!E101	0.0000000000088	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D86*E86
87			=LSFinal!A102	=LSFinal!E102	0.00000000000484	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D87*E87
88			=LSFinal!A103	=LSFinal!E103	0.0000000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D88*E88
89			=LSFinal!A104	=LSFinal!E104	0.00000000647	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D89*E89
90			=LSFinal!A105	=LSFinal!E105	0.00000000255	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D90*E90
91			=LSFinal!A106	=LSFinal!E106	0.00000437	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D91*E91

	A	B	C	D	E	F
92			=LSFinal!A107	=LSFinal!E107	0.000000000237	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D92*E92
93			=LSFinal!A108	=LSFinal!E108	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D93*E93
94			=LSFinal!A109	=LSFinal!E109	0.0000332	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D94*E94
95			=LSFinal!A110	=LSFinal!E110	0.000000000167	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D95*E95
96			=LSFinal!A111	=LSFinal!E111	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D96*E96
97			=LSFinal!A112	=LSFinal!E112	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D97*E97
98			=LSFinal!A113	=LSFinal!E113	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D98*E98
99			=LSFinal!A114	=LSFinal!E114	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D99*E99
100			=LSFinal!A115	=LSFinal!E115	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D100*E100
101			=LSFinal!A116	=LSFinal!E116	0.00000000228	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D101*E101
102			=LSFinal!A117	=LSFinal!E117	0.000000000127	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D102*E102
103			=LSFinal!A118	=LSFinal!E118	0.0000000132	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D103*E103
104			=LSFinal!A119	=LSFinal!E119	0.00000000000982	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D104*E104
105			=LSFinal!A120	=LSFinal!E120	0.000000000211	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D105*E105
106			=LSFinal!A121	=LSFinal!E121	0.00000000551	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D106*E106
107			=LSFinal!A122	=LSFinal!E122	0.0000000000106	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D107*E107
108			=LSFinal!A123	=LSFinal!E123	0.00000000022	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D108*E108
109			=LSFinal!A124	=LSFinal!E124	0.00000000639	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D109*E109
110			=LSFinal!A125	=LSFinal!E125	0.00000000117	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D110*E110
111						
112						
113						
114				Dose Total (rem)		=SUM(F13:F110)

	A	B	C	D	E	F
1	**Container Fire Event: LaSalle Isotopic: Table 11.2-5**					
2	0.00054	X/Q (sec/m^3)				
3	0.00035	Breathing Rate (m^3/sec)				
4	0.01	Release Fraction				
5	3700000000000	Conversion Factor (rem/Ci per Sv/Bq)				
6	6	Containers/Accident				
7	200	Container Contact - Nominal Baseline Analysis (R/hr)				
8	380	Container Contact - Bounding Accident Value (R/hr)				
9						
10	=F114	Total Inhalation Dose				
11				60 day Decay		
12			Isotope	Ci in Container	Inhaled DCF	Dose (rem)
13			=LSFinal!A28	=LSFinal!E28	0.00181	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D13*E13
14			=LSFinal!A29	=LSFinal!E29	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D14*E14
15			=LSFinal!A30	=LSFinal!E30	0.0000000217	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D15*E15
16			=LSFinal!A31	=LSFinal!E31	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D16*E16
17			=LSFinal!A32	=LSFinal!E32	0.0000000000464	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D17*E17
18			=LSFinal!A33	=LSFinal!E33	0.00000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D18*E18
19			=LSFinal!A34	=LSFinal!E34	0.0000000000218	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D19*E19
20			=LSFinal!A35	=LSFinal!E35	0.0000000000111	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D20*E20
21			=LSFinal!A36	=LSFinal!E36	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D21*E21
22			=LSFinal!A37	=LSFinal!E37	0.0000000000241	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D22*E22
23			=LSFinal!A38	=LSFinal!E38	0.0000000000261	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D23*E23
24			=LSFinal!A39	=LSFinal!E39	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D24*E24
25			=LSFinal!A40	=LSFinal!E40	0.00000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D25*E25
26			=LSFinal!A41	=LSFinal!E41	0.000000000916	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D26*E26
27			=LSFinal!A42	=LSFinal!E42	0.000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D27*E27
28			=LSFinal!A43	=LSFinal!E43	0.00000000294	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D28*E28
29			=LSFinal!A44	=LSFinal!E44	0.0000000591	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D29*E29
30			=LSFinal!A45	=LSFinal!E45	0.0000000000903	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D30*E30
31			=LSFinal!A46	=LSFinal!E46	0.0000000125	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D31*E31
32			=LSFinal!A47	=LSFinal!E47	0.00000000123	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D32*E32
33			=LSFinal!A48	=LSFinal!E48	0.00000000198	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D33*E33
34			=LSFinal!A49	=LSFinal!E49	0.00000000863	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D34*E34
35			=LSFinal!A50	=LSFinal!E50	0.0000000000274	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D35*E35
36			=LSFinal!A51	=LSFinal!E51	0.0000000000226	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D36*E36
37			=LSFinal!A52	=LSFinal!E52	0.000000004	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D37*E37
38			=LSFinal!A53	=LSFinal!E53	0.00000000168	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D38*E38
39			=LSFinal!A54	=LSFinal!E54	0.0000000469	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D39*E39
40			=LSFinal!A55	=LSFinal!E55	0.00000000889	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D40*E40
41			=LSFinal!A56	=LSFinal!E56	0.000000000103	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D41*E41
42			=LSFinal!A57	=LSFinal!E57	0.00000000158	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D42*E42
43			=LSFinal!A58	=LSFinal!E58	0.0000000000355	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D43*E43
44			=LSFinal!A59	=LSFinal!E59	0.000000000332	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D44*E44
45			=LSFinal!A60	=LSFinal!E60	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D45*E45
46			=LSFinal!A61	=LSFinal!E61	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D46*E46
47			=LSFinal!A62	=LSFinal!E62	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D47*E47
48			=LSFinal!A63	=LSFinal!E63	0.00000000131	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D48*E48
49			=LSFinal!A64	=LSFinal!E64	0.000000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D49*E49
50			=LSFinal!A65	=LSFinal!E65	0.0000000000684	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D50*E50
51			=LSFinal!A66	=LSFinal!E66	0.00000000181	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D51*E51
52			=LSFinal!A67	=LSFinal!E67	0.000000000102	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D52*E52
53			=LSFinal!A68	=LSFinal!E68	0.00000000107	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D53*E53
54			=LSFinal!A69	=LSFinal!E69	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D54*E54
55			=LSFinal!A70	=LSFinal!E70	0.000000000327	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D55*E55
56			=LSFinal!A71	=LSFinal!E71	0.00000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D56*E56
57			=LSFinal!A72	=LSFinal!E72	0.000000000659	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D57*E57
58			=LSFinal!A73	=LSFinal!E73	0.0000000000224	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D58*E58
59			=LSFinal!A74	=LSFinal!E74	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D59*E59
60			=LSFinal!A75	=LSFinal!E75	0.00000000185	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D60*E60
61			=LSFinal!A76	=LSFinal!E76	0.0000000000932	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D61*E61
62			=LSFinal!A77	=LSFinal!E77	0.000000000678	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D62*E62
63			=LSFinal!A78	=LSFinal!E78	0.00000000419	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D63*E63
64			=LSFinal!A79	=LSFinal!E79	0.000347	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D64*E64
65			=LSFinal!A80	=LSFinal!E80	0.00000000235	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D65*E65
66			=LSFinal!A81	=LSFinal!E81	0.0000000106	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D66*E66
67			=LSFinal!A82	=LSFinal!E82	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D67*E67
68			=LSFinal!A83	=LSFinal!E83	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D68*E68
69			=LSFinal!A84	=LSFinal!E84	0.00000000219	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D69*E69
70			=LSFinal!A85	=LSFinal!E85	0.0000000000117	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D70*E70
71			=LSFinal!A86	=LSFinal!E86	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D71*E71
72			=LSFinal!A87	=LSFinal!E87	0.000116	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D72*E72
73			=LSFinal!A88	=LSFinal!E88	0.00000212	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D73*E73
74			=LSFinal!A89	=LSFinal!E89	0.0000000000147	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D74*E74
75			=LSFinal!A90	=LSFinal!E90	0.00000000000138	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D75*E75
76			=LSFinal!A91	=LSFinal!E91	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D76*E76
77			=LSFinal!A92	=LSFinal!E92	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D77*E77
78			=LSFinal!A93	=LSFinal!E93	0.00000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D78*E78
79			=LSFinal!A94	=LSFinal!E94	0.000000129	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D79*E79
80			=LSFinal!A95	=LSFinal!E95	0.0000202	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D80*E80
81			=LSFinal!A96	=LSFinal!E96	0.0000000112	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D81*E81
82			=LSFinal!A97	=LSFinal!E97	0.000000351	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D82*E82
83			=LSFinal!A98	=LSFinal!E98	0.000000000449	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D83*E83
84			=LSFinal!A99	=LSFinal!E99	0.000000000218	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D84*E84
85			=LSFinal!A100	=LSFinal!E100	0.00000000225	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D85*E85
86			=LSFinal!A101	=LSFinal!E101	0.0000000000088	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D86*E86
87			=LSFinal!A102	=LSFinal!E102	0.00000000000484	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D87*E87
88			=LSFinal!A103	=LSFinal!E103	0.0000000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D88*E88
89			=LSFinal!A104	=LSFinal!E104	0.00000000647	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D89*E89
90			=LSFinal!A105	=LSFinal!E105	0.00000000255	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D90*E90

	A	B	C	D	E	F
91			=LSFinal!A106	=LSFinal!E106	0.00000437	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D91*E91
92			=LSFinal!A107	=LSFinal!E107	0.000000000237	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D92*E92
93			=LSFinal!A108	=LSFinal!E108	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D93*E93
94			=LSFinal!A109	=LSFinal!E109	0.0000332	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D94*E94
95			=LSFinal!A110	=LSFinal!E110	0.000000000167	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D95*E95
96			=LSFinal!A111	=LSFinal!E111	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D96*E96
97			=LSFinal!A112	=LSFinal!E112	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D97*E97
98			=LSFinal!A113	=LSFinal!E113	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D98*E98
99			=LSFinal!A114	=LSFinal!E114	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D99*E99
100			=LSFinal!A115	=LSFinal!E115	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D100*E100
101			=LSFinal!A116	=LSFinal!E116	0.00000000228	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D101*E101
102			=LSFinal!A117	=LSFinal!E117	0.000000000127	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D102*E102
103			=LSFinal!A118	=LSFinal!E118	0.0000000132	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D103*E103
104			=LSFinal!A119	=LSFinal!E119	0.00000000000982	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D104*E104
105			=LSFinal!A120	=LSFinal!E120	0.000000000211	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D105*E105
106			=LSFinal!A121	=LSFinal!E121	0.00000000551	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D106*E106
107			=LSFinal!A122	=LSFinal!E122	0.0000000000106	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D107*E107
108			=LSFinal!A123	=LSFinal!E123	0.00000000022	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D108*E108
109			=LSFinal!A124	=LSFinal!E124	0.00000000639	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D109*E109
110			=LSFinal!A125	=LSFinal!E125	0.00000000117	=$A$2*$A$3*$A$4*$A$5*$A$6*$A$8/$A$7*D110*E110
111						
112						
113						
114				Dose Total (rem)		=SUM(F13:F110)

Attachment B: Clinton

MicroShield 2
Run #1: Based on UFSAR Table Data from 12.2-12 2
Run #2: Based on UFSAR Table Data from 12.2-12 with 60 Day Decay 4
Run #3: Based on UFSAR Table Data from 12.2-12 with 60 Day Decay and Normalized Contact Dose 6
Excel Sheets 8
Drop Accident 8
Captures the isotopic mix from Run #3 in column D, and calculates a final dose in column F.
Fire Accdent 11
Captures the isotopic mix from Run #3 in column D, and calculates a final dose in column F.
Drop Accident: Formula Version 14
Fire Accident: Formula Version 16

MicroShield 8.01
Washington Group International (8.00-0000)

Date	By	Checked

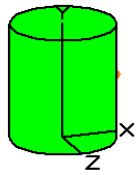
Filename	Run Date	Run Time	Duration
clinton1.msd	11-Aug-09	9:09:42 AM	0:00:07

Project Info

Case Title	Clinton 12.2-12
Description	before decay and resizing
Geometry	7 - Cylinder Volume - Side Shields

Source Dimensions

Height	182.88 cm (6 ft)
Radius	76.2 cm (2 ft 6.0 in)



Dose Points

A	X	Y	Z
#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)

Shields

Shield N	Dimension	Material	Density
Source	2.04e+05 in³	Water	0.9
Transition		Air	0.00122
Air Gap		Air	0.00122

Source Input: Grouping Method - Linear Energy
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: Grove

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ag-110	3.90E-01	1.44E+10	1.17E-01	4.33E+03
Ag-110m	9.40E+01	3.48E+12	2.82E+01	1.04E+06
Am-241	6.00E-02	2.22E+09	1.80E-02	6.65E+02
Ba-137m	8.50E+01	3.15E+12	2.55E+01	9.43E+05
Ba-139	8.70E-10	3.22E+01	2.61E-10	9.65E-06
Ba-140	7.20E+02	2.66E+13	2.16E+02	7.99E+06
Br-83	1.70E-06	6.29E+04	5.10E-07	1.89E-02
Ce-141	2.50E+01	9.25E+11	7.49E+00	2.77E+05
Ce-143	5.00E-02	1.85E+09	1.50E-02	5.55E+02
Ce-144	1.20E+01	4.44E+11	3.60E+00	1.33E+05
Cm-242	2.00E-03	7.40E+07	6.00E-04	2.22E+01
Co-57	2.90E+01	1.07E+12	8.69E+00	3.22E+05
Co-58	3.50E+03	1.30E+14	1.05E+03	3.88E+07
Co-60	3.00E+04	1.11E+15	8.99E+03	3.33E+08
Cr-51	1.10E+04	4.07E+14	3.30E+03	1.22E+08
Cs-134	5.90E+01	2.18E+12	1.77E+01	6.54E+05
Cs-136	8.80E+00	3.26E+11	2.64E+00	9.76E+04
Cs-137	9.30E+01	3.44E+12	2.79E+01	1.03E+06
F-18	5.00E-09	1.85E+02	1.50E-09	5.55E-05
Fe-55	2.00E+04	7.40E+14	6.00E+03	2.22E+08
Fe-59	2.80E+02	1.04E+13	8.39E+01	3.11E+06
I-131	6.50E+02	2.41E+13	1.95E+02	7.21E+06
I-132	5.30E+02	1.96E+13	1.59E+02	5.88E+06
I-133	3.30E+01	1.22E+12	9.89E+00	3.66E+05
I-135	2.60E-01	9.62E+09	7.79E-02	2.88E+03
La-140	8.40E+02	3.11E+13	2.52E+02	9.32E+06
La-141	5.40E-04	2.00E+07	1.62E-04	5.99E+00
La-142	2.00E-10	7.40E+00	6.00E-11	2.22E-06
Mn-54	1.50E+04	5.55E+14	4.50E+03	1.66E+08
Mn-56	1.30E-05	4.81E+05	3.90E-06	1.44E-01
Mo-99	1.70E+02	6.29E+12	5.10E+01	1.89E+06
Na-24	1.90E-01	7.03E+09	5.70E-02	2.11E+03
Nb-95	1.40E+01	5.18E+11	4.20E+00	1.55E+05
Nb-95m	2.10E-01	7.77E+09	6.30E-02	2.33E+03
Nb-97	6.10E-03	2.26E+08	1.83E-03	6.77E+01
Nb-97m	5.10E-03	1.89E+08	1.53E-03	5.66E+01
Nd-147	9.90E-01	3.66E+10	2.97E-01	1.10E+04
Ni-63	3.30E+02	1.22E+13	9.89E+01	3.66E+06
Ni-65	6.40E-08	2.37E+03	1.92E-08	7.10E-04

	A	B	C	D	E	F	G	H	I
67	Np-239				1.30E+03	4.81E+13	3.90E+02	1.44E+07	
68	P-32				1.80E+00	6.66E+10	5.40E-01	2.00E+04	
69	Pm-147				4.80E-02	1.78E+09	1.44E-02	5.32E+02	
70	Pr-143				3.80E+00	1.41E+11	1.14E+00	4.21E+04	
71	Pr-144				1.20E+01	4.44E+11	3.60E+00	1.33E+05	
72	Rh-103m				4.20E+00	1.55E+11	1.26E+00	4.66E+04	
73	Rh-106				9.30E-01	3.44E+10	2.79E-01	1.03E+04	
74	Ru-103				4.20E+00	1.55E+11	1.26E+00	4.66E+04	
75	Ru-106				9.30E-01	3.44E+10	2.79E-01	1.03E+04	
76	Sr-89				7.40E+02	2.74E+13	2.22E+02	8.21E+06	
77	Sr-90				8.90E+01	3.29E+12	2.67E+01	9.87E+05	
78	Sr-91				1.10E+00	4.07E+10	3.30E-01	1.22E+04	
79	Sr-92				6.40E-05	2.37E+06	1.92E-05	7.10E-01	
80	Tc-99				3.80E-01	1.41E+10	1.14E-01	4.21E+03	
81	Tc-99m				1.70E+02	6.29E+12	5.10E+01	1.89E+06	
82	Te-129				7.60E+00	2.81E+11	2.28E+00	8.43E+04	
83	Te-129m				7.60E+00	2.81E+11	2.28E+00	8.43E+04	
84	Te-132				5.20E+02	1.92E+13	1.56E+02	5.77E+06	
85	W-187				1.50E+00	5.55E+10	4.50E-01	1.66E+04	
86	Y-90				8.70E+01	3.22E+12	2.61E+01	9.65E+05	
87	Y-91				1.30E+02	4.81E+12	3.90E+01	1.44E+06	
88	Y-91m				7.30E-01	2.70E+10	2.19E-01	8.10E+03	
89	Y-92				4.30E-03	1.59E+08	1.29E-03	4.77E+01	
90	Zn-65				8.60E+02	3.18E+13	2.58E+02	9.54E+06	
91	Zn-69				2.20E-03	8.14E+07	6.59E-04	2.44E+01	
92	Zn-69m				2.00E-03	7.40E+07	6.00E-04	2.22E+01	
93	Zr-95				1.10E+01	4.07E+11	3.30E+00	1.22E+05	
94	Zr-97				5.60E-03	2.07E+08	1.68E-03	6.21E+01	
95	**Buildup: The material reference is Source**								
96	**Integration Parameters**								
97	Radial				30				
98	Circumferential				30				
99	Y Direction (axial)				60				
100	**Results**								
101						**Fluence Rate**	**Fluence Rate**	**Exposure Rate**	**Exposure Rate**
102	**Energy (MeV)**				**Activity (Photons/sec)**	**MeV/cm²/sec**	**MeV/cm²/sec**	**mR/hr**	**mR/hr**
103						**No Buildup**	**With Buildup**	**No Buildup**	**With Buildup**
104	0.015				5.93E+14	7.55E+05	8.79E+05	6.46E+04	7.52E+04
105	0.2381				3.72E+13	9.55E+06	4.05E+07	1.75E+04	7.40E+04
106	0.3378				7.10E+13	2.93E+07	1.01E+08	5.63E+04	1.95E+05
107	0.5128				6.93E+13	5.12E+07	1.46E+08	1.00E+05	2.86E+05
108	0.674				4.04E+13	4.40E+07	1.12E+08	8.51E+04	2.17E+05
109	0.8292				7.18E+14	1.06E+09	2.48E+09	2.00E+06	4.70E+06
110	0.9532				8.32E+12	1.50E+07	3.37E+07	2.79E+04	6.26E+04
111	1.172				1.13E+15	2.77E+09	5.82E+09	4.95E+06	1.04E+07
112	1.3324				1.12E+15	3.31E+09	6.66E+09	5.73E+06	1.16E+07
113	1.4307				2.30E+12	7.55E+06	1.49E+07	1.29E+04	2.54E+04
114	1.5982				3.04E+13	1.18E+08	2.26E+08	1.95E+05	3.73E+05
115	1.7576				5.93E+10	2.66E+05	4.95E+05	4.27E+02	7.96E+02
116	1.9599				4.45E+11	2.35E+06	4.25E+06	3.65E+03	6.62E+03
117	2.0867				4.65E+10	2.69E+05	4.81E+05	4.11E+02	7.33E+02
118	2.1914				6.54E+10	4.08E+05	7.18E+05	6.12E+02	1.08E+03
119	2.3534				2.97E+11	2.06E+06	3.57E+06	3.03E+03	5.24E+03
120	2.5224				1.11E+12	8.50E+06	1.45E+07	1.22E+04	2.08E+04
121	2.7541				7.02E+09	6.15E+04	1.02E+05	8.57E+01	1.43E+02
122	2.8086				1.52E-01	1.37E-06	2.26E-06	1.89E-09	3.14E-09
123	2.9598				1.48E+03	1.44E-02	2.35E-02	1.96E-05	3.20E-05
124	3.1706				3.89E-02	4.19E-07	6.75E-07	5.58E-10	8.99E-10
125	3.3696				8.09E+02	9.54E-03	1.51E-02	1.25E-05	1.98E-05
126	3.4328				5.05E-02	6.12E-07	9.68E-07	7.96E-10	1.26E-09
127	3.6237				1.52E-01	1.99E-06	3.10E-06	2.54E-09	3.97E-09
128	3.8236				4.51E+06	6.39E+01	9.85E+01	8.03E-02	1.24E-01
129	**Totals**				**3.82E+15**	**7.42E+09**	**1.57E+10**	**1.33E+07**	**2.80E+07**

MicroShield 8.01
Washington Group International (8.00-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
clinton1decay.msd	11-Aug-09	9:14:37 AM	0:00:07

Project Info

Case Title	Clinton 12.2-12
Description	before resizing
Geometry	7 - Cylinder Volume - Side Shields

Source Dimensions

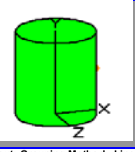
Height	182.88 cm (6 ft)
Radius	76.2 cm (2 ft 6.0 in)

Dose Points

A	X	Y	Z
#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)

Shields

Shield N	Dimension	Material	Density
Source	2.04e+05 in³	Water	0.9
Transition		Air	0.00122
Air Gap		Air	0.00122



Source Input: Grouping Method - Linear Energy
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: Grove

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ac-225	1.88E-21	6.87E-11	5.57E-22	2.06E-17
Ac-227	1.32E-22	4.88E-12	3.95E-23	1.46E-18
Ag-110	1.06E+00	3.92E+10	3.17E-01	1.17E+04
Ag-110m	7.96E+01	2.94E+12	2.39E+01	8.83E+05
Am-241	6.00E-02	2.22E+09	1.80E-02	6.65E+02
At-217				
Ba-137m	8.76E+01	3.24E+12	2.63E+01	9.72E+05
Ba-139	8.8932e-323	3.2905e-312	2.4703e-323	9.8635e-319
Ba-140	2.79E+01	1.03E+12	8.35E+00	3.09E+05
Bi-210	2.34E-24	8.66E-14	7.01E-25	2.60E-20
Bi-211	2.96E-23	1.09E-12	8.87E-24	3.28E-19
Bi-213				
Bi-214	5.49E-24	2.03E-13	1.65E-24	6.09E-20
Br-83	7.19E-188	2.66E-177	2.16E-188	7.97E-184
Ce-141	6.95E+00	2.57E+11	2.08E+00	7.71E+04
Ce-143	3.66E-15	1.35E-04	1.10E-15	4.06E-11
Ce-144	1.04E+01	3.84E+11	3.11E+00	1.15E+05
Cm-242	1.55E-03	5.74E+07	4.65E-04	1.72E+01
Co-57	2.49E+01	9.20E+11	7.46E+00	2.76E+05
Co-58	1.95E+03	7.20E+13	5.83E+02	2.16E+07
Co-60	2.94E+04	1.08E+15	8.80E+03	3.26E+08
Cr-51	2.45E+03	9.07E+13	7.35E+02	2.72E+07
Cs-134	5.58E+01	2.07E+12	1.67E+01	6.19E+05
Cs-135	8.52E-11	3.15E+00	2.56E-11	9.45E-07
Cs-136	3.73E-01	1.38E+10	1.12E-01	4.14E+03
Cs-137	9.27E+01	3.43E+12	2.78E+01	1.03E+06
F-18	4.94E-246	1.83E-235	1.48E-246	5.47E-242
Fe-55	1.92E+04	7.09E+14	5.75E+03	2.13E+08
Fe-59	1.10E+02	4.08E+12	3.31E+01	1.22E+06
Fr-221	3.56E-22	1.32E-11	1.07E-22	3.95E-18
Fr-223	1.90E-24	7.05E-14	5.71E-25	2.11E-20
I-129	3.17E-08	1.17E+03	9.49E-09	3.51E-04
I-131	3.68E+00	1.36E+11	1.10E+00	4.09E+04
I-132	1.53E-03	5.67E+07	4.60E-04	1.70E+01
I-133	4.76E-20	1.76E-09	1.43E-20	5.28E-16
I-135	6.84E-67	2.53E-56	2.05E-67	7.59E-63
Kr-83m	3.07E-187	1.14E-176	9.20E-188	3.40E-183
La-140	3.21E+01	1.19E+12	9.61E+00	3.56E+05
La-141	5.14E-114	1.90E-103	1.54E-114	5.71E-110
La-142	4.68E-283	1.73E-272	1.40E-283	5.19E-279
Mn-54	1.31E+04	4.86E+14	3.94E+03	1.46E+08
Mn-56	9.99E-174	3.70E-163	2.99E-174	1.11E-169
Mo-99	4.62E-05	1.71E+06	1.38E-05	5.12E-01
Na-24	2.40E-30	8.87E-20	7.19E-31	2.66E-26
Nb-95	9.55E+00	3.53E+11	2.86E+00	1.06E+05
Nb-95m	4.87E-02	1.80E+09	1.46E-02	5.40E+02
Nb-97	1.35E-28	5.00E-18	4.05E-29	1.50E-24
Nb-97m	1.19E-28	4.40E-18	3.56E-29	1.32E-24
Nd-147	2.24E-02	8.30E+08	6.72E-03	2.49E+02
Ni-63	3.30E+02	1.22E+13	9.88E+01	3.66E+06
Ni-65	6.15E-180	2.28E-169	1.84E-180	6.82E-176
Np-237	3.19E-09	1.18E+02	9.57E-10	3.54E-05
Np-239	2.78E-05	1.03E+06	8.34E-06	3.09E-01
P-32	9.80E-02	3.63E+09	2.94E-02	1.09E+03
Pa-231	8.26E-20	3.06E-09	2.48E-20	9.17E-16
Pa-233	1.56E-09	5.79E+01	4.69E-10	1.73E-05
Pb-209				
Pb-210	2.29E-24	8.47E-14	6.87E-25	2.54E-20
Pb-211	2.45E-23	9.06E-13	7.34E-24	2.72E-19
Pb-214	4.60E-24	1.70E-13	1.38E-24	5.10E-20
Pm-147	5.67E-02	2.10E+09	1.70E-02	6.29E+02
Po-210	1.57E-24	5.79E-14	4.69E-25	1.74E-20
Po-211	6.61E-26	2.45E-15	1.98E-26	7.33E-22
Po-213				
Po-214	5.76E-24	2.13E-13	1.73E-24	6.38E-20

	A	B	C	D	E	F	G	H	I
93		Po-215			2.33E-23	8.62E-13	6.98E-24	2.58E-19	
94		Po-218			4.55E-24	1.68E-13	1.36E-24	5.05E-20	
95		Pr-143			1.77E-01	6.56E+09	5.31E-02	1.97E+03	
96		Pr-144			1.04E+01	3.84E+11	3.11E+00	1.15E+05	
97		Pr-144m			1.48E-01	5.49E+09	4.44E-02	1.64E+03	
98		Pu-238			2.29E-06	8.47E+04	6.86E-07	2.54E-02	
99		Pu-239			3.47E-04	1.29E+07	1.04E-04	3.85E+00	
100		Ra-223			2.17E-23	8.02E-13	6.50E-24	2.40E-19	
101		Ra-225			1.03E-21	3.82E-11	3.09E-22	1.14E-17	
102		Ra-226			6.12E-24	2.27E-13	1.84E-24	6.79E-20	
103		Re-187			8.68E-14	3.21E-03	2.60E-14	9.62E-10	
104		Rh-103m			1.46E+00	5.39E+10	4.37E-01	1.62E+04	
105		Rh-106			8.31E-01	3.07E+10	2.49E-01	9.21E+03	
106		Rn-219			3.05E-23	1.13E-12	9.16E-24	3.39E-19	
107		Rn-222			4.50E-24	1.67E-13	1.35E-24	5.00E-20	
108		Ru-103			1.46E+00	5.40E+10	4.38E-01	1.62E+04	
109		Ru-106			8.31E-01	3.07E+10	2.49E-01	9.21E+03	
110		Sm-147			5.93E-14	2.20E-03	1.78E-14	6.58E-10	
111		Sr-89			3.25E+02	1.20E+13	9.74E+01	3.61E+06	
112		Sr-90			8.86E+01	3.28E+12	2.66E+01	9.83E+05	
113		Sr-91			2.58E-46	9.55E-36	7.73E-47	2.86E-42	
114		Sr-92			7.07E-165	2.62E-154	2.12E-165	7.84E-161	
115		Tc-99			3.80E-01	1.41E+10	1.14E-01	4.21E+03	
116		Tc-99m			4.50E-05	1.67E+06	1.35E-05	4.99E-01	
117		Te-129			1.39E+00	5.14E+10	4.16E-01	1.54E+04	
118		Te-129m			2.20E+00	8.16E+10	6.61E-01	2.44E+04	
119		Te-132			1.49E-03	5.51E+07	4.46E-04	1.65E+01	
120		Th-227			4.96E-23	1.84E-12	1.49E-23	5.50E-19	
121		Th-229			2.30E-21	8.50E-11	6.88E-22	2.55E-17	
122		Th-230			2.80E-19	1.04E-08	8.39E-20	3.10E-15	
123		Th-231			5.16E-14	1.91E-03	1.55E-14	5.72E-10	
124		Tl-207			2.86E-23	1.06E-12	8.58E-24	3.17E-19	
125		Tl-209			4.58E-23	1.70E-12	1.37E-23	5.08E-19	
126		U-233			4.15E-16	1.54E-05	1.25E-16	4.61E-12	
127		U-234			5.56E-13	2.06E-02	1.67E-13	6.16E-09	
128		U-235			5.30E-14	1.96E-03	1.59E-14	5.88E-10	
129		W-187			9.67E-19	3.58E-08	2.90E-19	1.07E-14	
130		Xe-131m			3.61E-01	1.33E+10	1.08E-01	4.00E+03	
131		Xe-133			2.40E-03	8.88E+07	7.20E-04	2.66E+01	
132		Xe-133m			3.52E-09	1.30E+02	1.06E-09	3.91E-05	
133		Xe-135			1.80E-48	6.67E-38	5.41E-49	2.00E-44	
134		Xe-135m			1.17E-67	4.34E-57	3.52E-68	1.30E-63	
135		Y-90			8.87E+01	3.28E+12	2.66E+01	9.83E+05	
136		Y-91			6.39E+01	2.36E+12	1.91E+01	7.08E+05	
137		Y-91m			1.62E-46	6.00E-36	4.86E-47	1.80E-42	
138		Y-92			1.59E-125	5.88E-115	4.76E-126	1.76E-121	
139		Zn-65			7.25E+02	2.68E+13	2.17E+02	8.05E+06	
140		Zn-69			6.73E-35	2.49E-24	2.02E-35	7.46E-31	
141		Zn-69m			6.28E-35	2.32E-24	1.88E-35	6.96E-31	
142		Zr-95			5.74E+00	2.13E+11	1.72E+00	6.37E+04	
143		Zr-97			1.25E-28	4.64E-18	3.76E-29	1.39E-24	
144		**Buildup: The material reference is Source**							
145		**Integration Parameters**							
146		Radial			30				
147		Circumferential			30				
148		Y Direction (axial)			60				
149					**Results**				
150						**Fluence Rate**	**Fluence Rate**	**Exposure Rate**	**Exposure Rate**
151		**Energy (MeV)**			**Activity (Photons/sec)**	**MeV/cm²/sec**	**MeV/cm²/sec**	**mR/hr**	**mR/hr**
152						**No Buildup**	**With Buildup**	**No Buildup**	**With Buildup**
153		0.0062			3.77E+14	1.97E+05	2.29E+05	9.77E+04	1.14E+05
154		0.2101			2.70E+11	5.87E+04	2.69E+05	1.05E+02	4.80E+02
155		0.3234			9.49E+12	3.69E+06	1.30E+07	7.05E+03	2.49E+04
156		0.5192			2.57E+13	1.93E+07	5.46E+07	3.78E+04	1.07E+05
157		0.6809			8.44E+12	9.33E+06	2.37E+07	1.80E+04	4.57E+04
158		0.8318			5.63E+14	8.31E+08	1.95E+09	1.57E+06	3.70E+06
159		0.9398			1.13E+12	2.00E+06	4.51E+06	3.72E+03	8.40E+03
160		1.1723			1.10E+15	2.70E+09	5.66E+09	4.82E+06	1.01E+07
161		1.3325			1.09E+15	3.22E+09	6.50E+09	5.59E+06	1.13E+07
162		1.4981			5.04E+11	1.78E+06	3.46E+06	2.99E+03	5.82E+03
163		1.6152			1.55E+12	6.13E+06	1.17E+07	1.01E+04	1.93E+04
164		1.7575			1.88E+05	7.52E-01	1.40E+00	1.21E-03	2.26E-03
165		1.9599			1.29E+06	6.79E+00	1.23E+01	1.06E-02	1.92E-02
166		2.0868			1.34E+05	7.78E-01	1.39E+00	1.19E-03	2.12E-03
167		2.1857			2.97E+09	1.84E+04	3.25E+04	2.77E+01	4.88E+01
168		2.3488			1.01E+10	6.97E+04	1.21E+05	1.02E+02	1.77E+02
169		2.5224			4.23E+10	3.25E+05	5.52E+05	4.66E+02	7.92E+02
170		2.7541			8.86E-20	7.76E-25	1.29E-24	1.08E-27	1.80E-27
171		2.8086			3.54E-274	3.19E-279	5.29E-279	4.43E-282	7.33E-282
172		2.9598			1.13E-165	1.10E-170	1.81E-170	1.50E-173	2.46E-173
173		3.1706			9.09E-275	9.80E-280	1.58E-279	1.31E-282	2.10E-282
174		3.3696			6.21E-166	7.32E-171	1.16E-170	9.58E-174	1.52E-173
175		3.4328			1.18E-274	1.43E-279	2.26E-279	1.86E-282	2.94E-282
176		3.6237			3.54E-274	4.65E-279	7.26E-279	5.94E-282	9.27E-282
177		3.8236			5.69E-23	8.07E-28	1.24E-27	1.01E-30	1.56E-30
178		**Totals**			**3.18E+15**	**6.79E+09**	**1.42E+10**	**1.22E+07**	**2.54E+07**

MicroShield 8.01
Washington Group International (8.00-0000)

Date	By	Checked

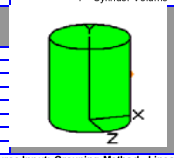
Filename	Run Date	Run Time	Duration
Clintondecay2..msd	3-Aug-09	1:47:47 PM	0:00:08

Project Info

Case Title	Clinton 12.2-12
Description	Final
Geometry	7 - Cylinder Volume - Side Shields

Source Dimensions

Height	182.88 cm (6 ft)
Radius	76.2 cm (2 ft 6.0 in)



Dose Points

A	X	Y	Z
#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)

Shields

Shield N	Dimension	Material	Density
Source	2.04e+05 in³	Water	0.9
Transition		Air	0.00122
Air Gap		Air	0.00122

Source Input: Grouping Method - Linear Energy
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: Grove

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ac-225	1.46E-23	5.41E-13	4.38E-24	1.62E-19
Ac-227	1.04E-24	3.84E-14	3.11E-25	1.15E-20
Ag-110	8.33E-03	3.08E+08	2.50E-03	9.24E+01
Ag-110m	6.26E-01	2.32E+10	1.88E-01	6.95E+03
Am-241	4.72E-04	1.75E+07	1.41E-04	5.24E+00
At-217				
Ba-137m	6.90E-01	2.55E+10	2.07E-01	7.65E+03
Ba-139				
Ba-140	2.19E-01	8.11E+09	6.57E-02	2.43E+03
Bi-210	1.84E-26	6.81E-16	5.52E-27	2.04E-22
Bi-211	2.33E-25	8.61E-15	6.98E-26	2.58E-21
Bi-213				
Bi-214	4.32E-26	1.60E-15	1.29E-26	4.79E-22
Br-83	5.66E-190	2.09E-179	1.70E-190	6.28E-186
Ce-141	5.47E-02	2.02E+09	1.64E-02	6.07E+02
Ce-143	2.88E-17	1.06E-06	8.63E-18	3.19E-13
Ce-144	8.16E-02	3.02E+09	2.45E-02	9.05E+02
Cm-242	1.22E-05	4.51E+05	3.66E-06	1.35E-01
Co-57	1.96E-01	7.24E+09	5.87E-02	2.17E+03
Co-58	1.53E+01	5.66E+11	4.59E+00	1.70E+05
Co-60	2.31E+02	8.55E+12	6.93E+01	2.56E+06
Cr-51	1.93E+01	7.14E+11	5.78E+00	2.14E+05
Cs-134	4.39E-01	1.63E+10	1.32E-01	4.87E+03
Cs-135	6.71E-13	2.48E-02	2.01E-13	7.44E-09
Cs-136	2.94E-03	1.09E+08	8.80E-04	3.26E+01
Cs-137	7.29E-01	2.70E+10	2.19E-01	8.09E+03
F-18	3.88E-248	1.44E-237	1.16E-248	4.31E-244
Fe-55	1.51E+02	5.58E+12	4.52E+01	1.67E+06
Fe-59	8.68E-01	3.21E+10	2.60E-01	9.62E+03
Fr-221	2.80E-24	1.04E-13	8.40E-25	3.11E-20
Fr-223	1.50E-26	5.54E-16	4.49E-27	1.66E-22
I-129	2.49E-10	9.22E+00	7.47E-11	2.76E-06
I-131	2.90E-02	1.07E+09	8.69E-03	3.22E+02
I-132	1.21E-05	4.47E+05	3.62E-06	1.34E-01
I-133	3.75E-22	1.39E-11	1.12E-22	4.16E-18
I-135	5.38E-69	1.99E-58	1.61E-69	5.97E-65
Kr-83m	2.41E-189	8.93E-179	7.24E-190	2.68E-185
La-140	2.52E-01	9.34E+09	7.56E-02	2.80E+03
La-141	4.05E-116	1.50E-105	1.21E-116	4.49E-112
La-142	3.68E-285	1.36E-274	1.10E-285	4.08E-281
Mn-54	1.03E+02	3.82E+12	3.10E+01	1.15E+06
Mn-56	7.88E-176	2.91E-165	2.36E-176	8.72E-172
Mo-99	3.63E-07	1.34E+04	1.09E-07	4.03E-03
Na-24	1.89E-32	6.98E-22	5.66E-33	2.09E-28
Nb-95	7.52E-02	2.78E+09	2.25E-02	8.34E+02
Nb-95m	3.83E-04	1.42E+07	1.15E-04	4.25E+00
Nb-97	1.06E-30	3.93E-20	3.19E-31	1.18E-26
Nb-97m	9.35E-31	3.46E-20	2.80E-31	1.04E-26
Nd-147	1.76E-04	6.53E+06	5.29E-05	1.96E+00
Ni-63	2.59E+00	9.60E+10	7.78E-01	2.88E+04
Ni-65	4.84E-182	1.79E-171	1.45E-182	5.37E-178
Np-237	2.51E-11	9.29E-01	7.53E-12	2.79E-07
Np-239	2.19E-07	8.10E+03	6.56E-08	2.43E-03
P-32	7.71E-04	2.85E+07	2.31E-04	8.55E+00
Pa-231	6.50E-22	2.41E-11	1.95E-22	7.21E-18
Pa-233	1.23E-11	4.55E-01	3.69E-12	1.36E-07
Pb-209				
Pb-210	1.80E-26	6.67E-16	5.40E-27	2.00E-22
Pb-211	1.93E-25	7.13E-15	5.77E-26	2.14E-21
Pb-214	3.62E-26	1.34E-15	1.09E-26	4.01E-22
Pm-147	4.46E-04	1.65E+07	1.34E-04	4.95E+00
Po-210	1.23E-26	4.56E-16	3.69E-27	1.37E-22
Po-211	5.20E-28	1.93E-17	1.56E-28	5.77E-24
Po-213				
Po-214	4.53E-26	1.68E-15	1.36E-26	5.02E-22

	A	B	C	D	E	F	G	H	I
93		Po-215			1.83E-25	6.78E-15	5.49E-26	2.03E-21	
94		Po-218			3.58E-26	1.33E-15	1.07E-26	3.97E-22	
95		Pr-143			1.39E-03	5.16E+07	4.18E-04	1.55E+01	
96		Pr-144			8.16E-02	3.02E+09	2.45E-02	9.05E+02	
97		Pr-144m			1.17E-03	4.32E+07	3.50E-04	1.29E+01	
98		Pu-238			1.80E-08	6.67E+02	5.40E-09	2.00E-04	
99		Pu-239			2.73E-06	1.01E+05	8.19E-07	3.03E-02	
100		Ra-223			1.71E-25	6.31E-15	5.11E-26	1.89E-21	
101		Ra-225			8.12E-24	3.00E-13	2.43E-24	9.00E-20	
102		Ra-226			4.82E-26	1.78E-15	1.44E-26	5.34E-22	
103		Re-187			6.83E-16	2.53E-05	2.05E-16	7.57E-12	
104		Rh-103m			1.15E-02	4.24E+08	3.44E-03	1.27E+02	
105		Rh-106			6.54E-03	2.42E+08	1.96E-03	7.25E+01	
106		Rn-219			2.40E-25	8.89E-15	7.20E-26	2.67E-21	
107		Rn-222			3.54E-26	1.31E-15	1.06E-26	3.93E-22	
108		Ru-103			1.15E-02	4.25E+08	3.44E-03	1.27E+02	
109		Ru-106			6.54E-03	2.42E+08	1.96E-03	7.25E+01	
110		Sm-147			4.67E-16	1.73E-05	1.40E-16	5.18E-12	
111		Sr-89			2.56E+00	9.46E+10	7.67E-01	2.84E+04	
112		Sr-90			6.98E-01	2.58E+10	2.09E-01	7.74E+03	
113		Sr-91			2.03E-48	7.51E-38	6.09E-49	2.25E-44	
114		Sr-92			5.56E-167	2.06E-156	1.67E-167	6.17E-163	
115		Tc-99			2.99E-03	1.11E+08	8.96E-04	3.32E+01	
116		Tc-99m			3.54E-07	1.31E+04	1.06E-07	3.93E-03	
117		Te-129			1.09E-02	4.04E+08	3.28E-03	1.21E+02	
118		Te-129m			1.73E-02	6.42E+08	5.20E-03	1.92E+02	
119		Te-132			1.17E-05	4.33E+05	3.51E-06	1.30E-01	
120		Th-227			3.90E-25	1.44E-14	1.17E-25	4.33E-21	
121		Th-229			1.81E-23	6.68E-13	5.42E-24	2.00E-19	
122		Th-230			2.20E-21	8.14E-11	6.60E-22	2.44E-17	
123		Th-231			4.06E-16	1.50E-05	1.22E-16	4.50E-12	
124		Tl-207			2.25E-25	8.33E-15	6.75E-26	2.50E-21	
125		Tl-209			3.61E-25	1.33E-14	1.08E-25	4.00E-21	
126		U-233			3.27E-18	1.21E-07	9.80E-19	3.63E-14	
127		U-234			4.37E-15	1.62E-04	1.31E-15	4.85E-11	
128		U-235			4.17E-16	1.54E-05	1.25E-16	4.63E-12	
129		W-187			7.61E-21	2.82E-10	2.28E-21	8.44E-17	
130		Xe-131m			2.84E-03	1.05E+08	8.51E-04	3.15E+01	
131		Xe-133			1.89E-05	6.99E+05	5.66E-06	2.10E-01	
132		Xe-133m			2.77E-11	1.03E+00	8.31E-12	3.07E-07	
133		Xe-135			1.42E-50	5.25E-40	4.25E-51	1.57E-46	
134		Xe-135m			9.24E-70	3.42E-59	2.77E-70	1.02E-65	
135		Y-90			6.98E-01	2.58E+10	2.09E-01	7.74E+03	
136		Y-91			5.03E-01	1.86E+10	1.51E-01	5.57E+03	
137		Y-91m			1.28E-48	4.72E-38	3.83E-49	1.42E-44	
138		Y-92			1.25E-127	4.63E-117	3.75E-128	1.39E-123	
139		Zn-65			5.71E+00	2.11E+11	1.71E+00	6.33E+04	
140		Zn-69			5.30E-37	1.96E-26	1.59E-37	5.87E-33	
141		Zn-69m			4.94E-37	1.83E-26	1.48E-37	5.48E-33	
142		Zr-95			4.52E-02	1.67E+09	1.36E-02	5.01E+02	
143		Zr-97			9.87E-31	3.65E-20	2.96E-31	1.09E-26	
144		**Buildup: The material reference is Source**							
145		**Integration Parameters**							
146		Radial			30				
147		Circumferential			30				
148		Y Direction (axial)			60				
149					**Results**				
150						**Fluence Rate**	**Fluence Rate**	**Exposure Rate**	**Exposure Rate**
151		**Energy (MeV)**			**Activity (Photons/sec)**	**MeV/cm²/sec**	**MeV/cm²/sec**	**mR/hr**	**mR/hr**
152						**No Buildup**	**With Buildup**	**No Buildup**	**With Buildup**
153		0.0062			2.96E+12	1.55E+03	1.80E+03	7.69E+02	8.95E+02
154		0.2101			2.13E+09	4.62E+02	2.12E+03	8.24E-01	3.77E+00
155		0.3234			7.47E+10	2.90E+04	1.03E+05	5.55E+01	1.98E+02
156		0.5192			2.02E+11	1.52E+05	4.30E+05	2.98E+02	8.43E+02
157		0.6809			6.84E+10	7.34E+04	1.86E+05	1.42E+02	3.60E+02
158		0.8318			4.43E+12	6.54E+06	1.54E+07	1.24E+04	2.91E+04
159		0.9398			8.92E+09	1.57E+04	3.55E+04	2.93E+01	6.61E+01
160		1.1723			8.67E+12	2.12E+07	4.45E+07	3.79E+04	7.96E+04
161		1.3325			8.57E+12	2.54E+07	5.11E+07	4.40E+04	8.87E+04
162		1.4981			3.96E+09	1.40E+04	2.72E+04	2.35E+01	4.58E+01
163		1.6152			1.22E+10	4.82E+04	9.20E+04	7.95E+01	1.52E+02
164		1.7575			1.32E+03	5.92E-03	1.10E-02	9.52E-06	1.78E-05
165		1.9599			1.01E+04	5.34E-02	9.68E-02	8.31E-05	1.51E-04
166		2.0868			1.06E+03	6.12E-03	1.09E-02	9.34E-06	1.67E-05
167		2.1857			2.34E+07	1.45E+02	2.56E+02	2.18E-01	3.84E-01
168		2.3488			7.94E+07	5.49E+02	9.30E+02	8.06E-01	1.40E+00
169		2.5224			3.32E+08	2.55E+03	4.34E+03	3.67E+00	6.23E+00
170		2.7541			6.97E-22	6.10E-27	1.02E-26	8.51E-30	1.42E-29
171		2.8086			2.79E-276	2.51E-281	4.17E-281	3.48E-284	5.77E-284
172		2.9598			8.91E-168	8.68E-173	1.42E-172	1.18E-175	1.94E-175
173		3.1706			7.15E-277	7.71E-282	1.24E-281	1.03E-284	1.66E-284
174		3.3696			4.89E-168	5.76E-173	9.15E-173	7.54E-176	1.20E-175
175		3.4328			9.30E-277	1.13E-281	1.78E-281	1.47E-284	2.32E-284
176		3.6237			2.79E-276	3.66E-281	5.71E-281	4.68E-284	7.30E-284
177		3.8236			4.48E-25	6.35E-30	9.78E-30	7.97E-33	1.23E-32
178		**Totals**			**2.50E+13**	**5.35E+07**	**1.12E+08**	**9.57E+04**	**2.00E+05**

	A	B	C	D	E	F
1	**Container Drop Event: Clinton Isotopic: Table 12.2-12**					
2	5.400E-04	X/Q (sec/m^3)				
3	3.500E-04	Breathing Rate (m^3/sec)				
4	1.000E-02	Release Fraction				
5	3.70E+12	Conversion Factor (rem/Ci per Sv/Bq)				
6	1.00E+00	Containers/Accident				
7	2.00E+02	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	1.008E-01	Total Inhalation Dose				
10						
11				60 day decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			Ac-225	1.462E-23	2.920E-06	2.985E-25
14			Ac-227	1.037E-24	1.810E-03	1.313E-23
15			Ag-110	8.329E-03	0.00E+00	0.000E+00
16			Ag-110m	6.263E-01	2.170E-08	9.503E-05
17			Am-241	4.720E-04	1.200E-04	3.961E-04
18			At-217	0.000E+00	0.00E+00	0.000E+00
19			Ba-137m	6.897E-01	0.00E+00	0.000E+00
20			Ba-139	0.000E+00	4.640E-11	0.000E+00
21			Ba-140	2.193E-01	1.010E-09	1.549E-06
22			Bi-210	1.841E-26	5.290E-08	6.812E-30
23			Bi-211	2.328E-25	0.00E+00	0.000E+00
24			Bi-213	0.000E+00	4.630E-09	0.000E+00
25			Bi-214	4.319E-26	1.780E-09	5.376E-31
26			Br-83	5.658E-190	2.410E-11	9.535E-197
27			Ce-141	5.472E-02	2.420E-09	9.259E-07
28			Ce-143	2.878E-17	9.160E-10	1.843E-22
29			Ce-144	8.158E-02	1.010E-07	5.762E-05
30			Cm-242	1.220E-05	4.670E-06	3.983E-07
31			Co-57	1.957E-01	2.450E-09	3.353E-06
32			Co-58	1.531E+01	2.940E-09	3.147E-04
33			Co-60	2.310E+02	5.910E-08	9.548E-02
34			Cr-51	1.929E+01	9.030E-11	1.218E-05
35			Cs-134	4.393E-01	1.250E-08	3.840E-05
36			Cs-135	6.707E-13	1.230E-09	5.769E-18
37			Cs-136	2.937E-03	1.980E-09	4.067E-08
38			Cs-137	7.291E-01	8.630E-09	4.400E-05
39			F-18	3.884E-248	2.260E-11	6.139E-255
40			Fe-55	1.509E+02	7.260E-10	7.660E-04
41			Fe-59	8.677E-01	4.000E-09	2.427E-05
42			Fr-221	2.804E-24	0.00E+00	0.000E+00
43			Fr-223	1.498E-26	1.680E-09	1.760E-31
44			I-129	2.492E-10	4.690E-08	8.173E-14
45			I-131	2.900E-02	8.890E-09	1.803E-06
46			I-132	1.207E-05	1.030E-10	8.692E-12
47			I-133	3.749E-22	1.580E-09	4.142E-27
48			I-135	5.382E-69	3.320E-10	1.250E-74
49			Kr-83m	2.414E-189	0.00E+00	0.000E+00
50			La-140	2.523E-01	1.310E-09	2.311E-06
51			La-141	4.048E-116	1.570E-10	4.444E-122
52			La-142	3.681E-285	6.840E-11	1.761E-291
53			Mn-54	1.033E+02	1.810E-09	1.308E-03
54			Mn-56	7.859E-176	1.020E-10	5.606E-182
55			Mo-99	3.634E-07	1.070E-09	2.719E-12
56			Na-24	1.887E-32	3.270E-10	4.315E-38
57			Nb-95	7.517E-02	1.570E-09	8.253E-07
58			Nb-95m	3.832E-04	6.590E-10	1.766E-09
59			Nb-97	1.063E-30	2.240E-11	1.666E-37
60			Nb-97m	9.354E-31	0.00E+00	0.000E+00
61			Nd-147	1.764E-04	1.850E-09	2.282E-09
62			Ni-63	2.594E+00	1.700E-09	3.084E-05
63			Ni-65	4.841E-182	9.320E-11	3.155E-188
64			Np-237	2.512E-11	1.460E-04	2.564E-11
65			Np-239	2.189E-07	6.780E-10	1.038E-12

	A	B	C	D	E	F
66			P-32	7.713E-04	4.190E-09	2.260E-08
67			Pa-231	6.503E-22	3.470E-04	1.578E-21
68			Pa-233	1.231E-11	2.580E-09	2.220E-16
69			Pb-209	0.000E+00	2.560E-11	0.000E+00
70			Pb-210	1.802E-26	3.670E-06	4.625E-28
71			Pb-211	1.927E-25	2.350E-09	3.166E-30
72			Pb-214	3.620E-26	2.110E-09	5.341E-31
73			Pm-147	4.461E-04	1.060E-08	3.307E-08
74			Po-210	1.232E-26	2.540E-06	2.188E-28
75			Po-211	5.203E-28	0.00E+00	0.000E+00
76			Po-213	0.000E+00	0.00E+00	0.000E+00
77			Po-214	4.529E-26	0.00E+00	0.000E+00
78			Po-215	1.833E-25	0.00E+00	0.000E+00
79			Po-218	3.582E-26	0.00E+00	0.000E+00
80			Pr-143	1.394E-03	2.190E-09	2.135E-08
81			Pr-144	8.158E-02	1.170E-11	6.675E-09
82			Pr-144m	1.167E-03	0.00E+00	0.000E+00
83			Pu-238	1.802E-08	1.060E-04	1.335E-08
84			Pu-239	2.733E-06	1.160E-04	2.217E-06
85			Ra-223	1.706E-25	2.120E-06	2.529E-27
86			Ra-225	8.116E-24	2.100E-06	1.192E-25
87			Ra-226	4.818E-26	2.320E-06	7.816E-28
88			Re-187	6.827E-16	1.470E-11	7.018E-23
89			Rh-103m	1.147E-02	1.380E-12	1.107E-10
90			Rh-106	6.536E-03	0.00E+00	0.000E+00
91			Rn-219	2.403E-25	0.00E+00	0.000E+00
92			Rn-222	3.544E-26	0.00E+00	0.000E+00
93			Ru-103	1.149E-02	2.420E-09	1.944E-07
94			Ru-106	6.536E-03	1.290E-07	5.896E-06
95			Sm-147	4.669E-16	2.020E-05	6.596E-17
96			Sr-89	2.558E+00	1.120E-08	2.003E-04
97			Sr-90	6.976E-01	3.510E-07	1.712E-03
98			Sr-91	2.030E-48	4.490E-10	6.374E-54
99			Sr-92	5.562E-167	2.180E-10	8.478E-173
100			Tc-99	2.990E-03	2.250E-09	4.705E-08
101			Tc-99m	3.543E-07	8.800E-12	2.180E-14
102			Te-129	1.093E-02	2.420E-11	1.849E-09
103			Te-129m	1.735E-02	6.470E-09	7.848E-07
104			Te-132	1.171E-05	2.550E-09	2.089E-10
105			Th-227	3.903E-25	4.370E-06	1.193E-26
106			Th-229	1.807E-23	5.800E-04	7.328E-23
107			Th-230	2.201E-21	8.800E-05	1.355E-21
108			Th-231	4.059E-16	2.370E-10	6.726E-22
109			Tl-207	2.252E-25	0.00E+00	0.000E+00
110			Tl-209	3.606E-25	0.00E+00	0.000E+00
111			U-233	3.269E-18	3.660E-05	8.366E-19
112			U-234	4.374E-15	3.580E-05	1.095E-15
113			U-235	4.172E-16	3.320E-05	9.685E-17
114			W-187	7.609E-21	1.670E-10	8.886E-27
115			Xe-131m	2.838E-03	0.00E+00	0.000E+00
116			Xe-133	1.889E-05	0.00E+00	0.000E+00
117			Xe-133m	2.771E-11	0.00E+00	0.000E+00
118			Xe-135	1.419E-50	0.00E+00	0.000E+00
119			Xe-135m	9.239E-70	0.00E+00	0.000E+00
120			Y-90	6.977E-01	2.280E-09	1.112E-05
121			Y-91	5.026E-01	1.320E-08	4.639E-05
122			Y-91m	1.277E-48	9.820E-12	8.766E-56
123			Y-92	1.251E-127	2.110E-10	1.845E-133
124			Zn-65	5.708E+00	5.510E-09	2.199E-04
125			Zn-69	5.296E-37	1.060E-11	3.926E-44
126			Zn-69m	4.941E-37	2.200E-10	7.601E-43
127			Zr-95	4.520E-02	6.390E-09	2.020E-06
128			Zr-97	9.868E-31	1.170E-09	8.073E-36
129						
130						

	A	B	C	D	E	F
131					Total Rem	1.008E-01

	A	B	C	D	E	F
1	**Container Fire Event: Clinton Isotopic: Table 12.2-12**					
2	5.400E-04	X/Q (sec/m^3)				
3	3.500E-04	Breathing Rate (m^3/sec)				
4	1.000E-02	Release Fraction				
5	3.70E+12	Conversion Factor (rem/Ci per Sv/Bq)				
6	6.00E+00	Containers/Accident				
7	2.00E+02	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	6.047E-01	Total Inhalation Dose				
10						
11				60 day decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			Ac-225	1.462E-23	2.920E-06	1.791E-24
14			Ac-227	1.037E-24	1.810E-03	7.877E-23
15			Ag-110	8.329E-03	0.00E+00	0.000E+00
16			Ag-110m	6.263E-01	2.170E-08	5.702E-04
17			Am-241	4.720E-04	1.200E-04	2.377E-03
18			At-217	0.000E+00	0.00E+00	0.000E+00
19			Ba-137m	6.897E-01	0.00E+00	0.000E+00
20			Ba-139	0.000E+00	4.640E-11	0.000E+00
21			Ba-140	2.193E-01	1.010E-09	9.292E-06
22			Bi-210	1.841E-26	5.290E-08	4.087E-29
23			Bi-211	2.328E-25	0.00E+00	0.000E+00
24			Bi-213	0.000E+00	4.630E-09	0.000E+00
25			Bi-214	4.319E-26	1.780E-09	3.226E-30
26			Br-83	5.658E-190	2.410E-11	5.721E-196
27			Ce-141	5.472E-02	2.420E-09	5.556E-06
28			Ce-143	2.878E-17	9.160E-10	1.106E-21
29			Ce-144	8.158E-02	1.010E-07	3.457E-04
30			Cm-242	1.220E-05	4.670E-06	2.390E-06
31			Co-57	1.957E-01	2.450E-09	2.012E-05
32			Co-58	1.531E+01	2.940E-09	1.888E-03
33			Co-60	2.310E+02	5.910E-08	5.729E-01
34			Cr-51	1.929E+01	9.030E-11	7.309E-05
35			Cs-134	4.393E-01	1.250E-08	2.304E-04
36			Cs-135	6.707E-13	1.230E-09	3.462E-17
37			Cs-136	2.937E-03	1.980E-09	2.440E-07
38			Cs-137	7.291E-01	8.630E-09	2.640E-04
39			F-18	3.884E-248	2.260E-11	3.683E-254
40			Fe-55	1.509E+02	7.260E-10	4.596E-03
41			Fe-59	8.677E-01	4.000E-09	1.456E-04
42			Fr-221	2.804E-24	0.00E+00	0.000E+00
43			Fr-223	1.498E-26	1.680E-09	1.056E-30
44			I-129	2.492E-10	4.690E-08	4.904E-13
45			I-131	2.900E-02	8.890E-09	1.082E-05
46			I-132	1.207E-05	1.030E-10	5.215E-11
47			I-133	3.749E-22	1.580E-09	2.485E-26
48			I-135	5.382E-69	3.320E-10	7.498E-74
49			Kr-83m	2.414E-189	0.00E+00	0.000E+00
50			La-140	2.523E-01	1.310E-09	1.387E-05
51			La-141	4.048E-116	1.570E-10	2.666E-121
52			La-142	3.681E-285	6.840E-11	1.057E-290
53			Mn-54	1.033E+02	1.810E-09	7.847E-03
54			Mn-56	7.859E-176	1.020E-10	3.363E-181
55			Mo-99	3.634E-07	1.070E-09	1.632E-11
56			Na-24	1.887E-32	3.270E-10	2.589E-37
57			Nb-95	7.517E-02	1.570E-09	4.952E-06
58			Nb-95m	3.832E-04	6.590E-10	1.060E-08
59			Nb-97	1.063E-30	2.240E-11	9.994E-37
60			Nb-97m	9.354E-31	0.00E+00	0.000E+00
61			Nd-147	1.764E-04	1.850E-09	1.369E-08
62			Ni-63	2.594E+00	1.700E-09	1.850E-04
63			Ni-65	4.841E-182	9.320E-11	1.893E-187
64			Np-237	2.512E-11	1.460E-04	1.539E-10
65			Np-239	2.189E-07	6.780E-10	6.228E-12

	A	B	C	D	E	F
66			P-32	7.713E-04	4.190E-09	1.356E-07
67			Pa-231	6.503E-22	3.470E-04	9.468E-21
68			Pa-233	1.231E-11	2.580E-09	1.332E-15
69			Pb-209	0.000E+00	2.560E-11	0.000E+00
70			Pb-210	1.802E-26	3.670E-06	2.775E-27
71			Pb-211	1.927E-25	2.350E-09	1.900E-29
72			Pb-214	3.620E-26	2.110E-09	3.205E-30
73			Pm-147	4.461E-04	1.060E-08	1.984E-07
74			Po-210	1.232E-26	2.540E-06	1.313E-27
75			Po-211	5.203E-28	0.00E+00	0.000E+00
76			Po-213	0.000E+00	0.00E+00	0.000E+00
77			Po-214	4.529E-26	0.00E+00	0.000E+00
78			Po-215	1.833E-25	0.00E+00	0.000E+00
79			Po-218	3.582E-26	0.00E+00	0.000E+00
80			Pr-143	1.394E-03	2.190E-09	1.281E-07
81			Pr-144	8.158E-02	1.170E-11	4.005E-08
82			Pr-144m	1.167E-03	0.00E+00	0.000E+00
83			Pu-238	1.802E-08	1.060E-04	8.012E-08
84			Pu-239	2.733E-06	1.160E-04	1.330E-05
85			Ra-223	1.706E-25	2.120E-06	1.517E-26
86			Ra-225	8.116E-24	2.100E-06	7.151E-25
87			Ra-226	4.818E-26	2.320E-06	4.690E-27
88			Re-187	6.827E-16	1.470E-11	4.211E-22
89			Rh-103m	1.147E-02	1.380E-12	6.640E-10
90			Rh-106	6.536E-03	0.00E+00	0.000E+00
91			Rn-219	2.403E-25	0.00E+00	0.000E+00
92			Rn-222	3.544E-26	0.00E+00	0.000E+00
93			Ru-103	1.149E-02	2.420E-09	1.166E-06
94			Ru-106	6.536E-03	1.290E-07	3.538E-05
95			Sm-147	4.669E-16	2.020E-05	3.958E-16
96			Sr-89	2.558E+00	1.120E-08	1.202E-03
97			Sr-90	6.976E-01	3.510E-07	1.027E-02
98			Sr-91	2.030E-48	4.490E-10	3.824E-53
99			Sr-92	5.562E-167	2.180E-10	5.087E-172
100			Tc-99	2.990E-03	2.250E-09	2.823E-07
101			Tc-99m	3.543E-07	8.800E-12	1.308E-13
102			Te-129	1.093E-02	2.420E-11	1.109E-08
103			Te-129m	1.735E-02	6.470E-09	4.709E-06
104			Te-132	1.171E-05	2.550E-09	1.253E-09
105			Th-227	3.903E-25	4.370E-06	7.156E-26
106			Th-229	1.807E-23	5.800E-04	4.397E-22
107			Th-230	2.201E-21	8.800E-05	8.127E-21
108			Th-231	4.059E-16	2.370E-10	4.036E-21
109			Tl-207	2.252E-25	0.00E+00	0.000E+00
110			Tl-209	3.606E-25	0.00E+00	0.000E+00
111			U-233	3.269E-18	3.660E-05	5.020E-18
112			U-234	4.374E-15	3.580E-05	6.570E-15
113			U-235	4.172E-16	3.320E-05	5.811E-16
114			W-187	7.609E-21	1.670E-10	5.332E-26
115			Xe-131m	2.838E-03	0.00E+00	0.000E+00
116			Xe-133	1.889E-05	0.00E+00	0.000E+00
117			Xe-133m	2.771E-11	0.00E+00	0.000E+00
118			Xe-135	1.419E-50	0.00E+00	0.000E+00
119			Xe-135m	9.239E-70	0.00E+00	0.000E+00
120			Y-90	6.977E-01	2.280E-09	6.675E-05
121			Y-91	5.026E-01	1.320E-08	2.783E-04
122			Y-91m	1.277E-48	9.820E-12	5.260E-55
123			Y-92	1.251E-127	2.110E-10	1.107E-132
124			Zn-65	5.708E+00	5.510E-09	1.320E-03
125			Zn-69	5.296E-37	1.060E-11	2.355E-43
126			Zn-69m	4.941E-37	2.200E-10	4.561E-42
127			Zr-95	4.520E-02	6.390E-09	1.212E-05
128			Zr-97	9.868E-31	1.170E-09	4.844E-35
129						
130						

	A	B	C	D	E	F
131					Total Rem	6.047E-01

	A	B	C	D	E	F
1	**Container Drop Event: Clinton Isotopic: Table 12.2-12**					
2	0.00054	X/Q (sec/m^3)				
3	0.00035	Breathing Rate (m^3/sec)				
4	0.01	Release Fraction				
5	3700000000000	Conversion Factor (rem/Ci per Sv/Bq)				
6	1	Containers/Accident				
7	200	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	=F131	Total Inhalation Dose				
10						
11				60 day decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			=CPS!A28	=CPS!E28	0.00000292	=$A$2*$A$3*$A$4*$A$5*$A$6*D13*E13
14			=CPS!A29	=CPS!E29	0.00181	=$A$2*$A$3*$A$4*$A$5*$A$6*D14*E14
15			=CPS!A30	=CPS!E30	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D15*E15
16			=CPS!A31	=CPS!E31	0.0000000217	=$A$2*$A$3*$A$4*$A$5*$A$6*D16*E16
17			=CPS!A32	=CPS!E32	0.00012	=$A$2*$A$3*$A$4*$A$5*$A$6*D17*E17
18			=CPS!A33	=CPS!E33	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D18*E18
19			=CPS!A34	=CPS!E34	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D19*E19
20			=CPS!A35	=CPS!E35	0.0000000000464	=$A$2*$A$3*$A$4*$A$5*$A$6*D20*E20
21			=CPS!A36	=CPS!E36	0.00000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*D21*E21
22			=CPS!A37	=CPS!E37	0.0000000529	=$A$2*$A$3*$A$4*$A$5*$A$6*D22*E22
23			=CPS!A38	=CPS!E38	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D23*E23
24			=CPS!A39	=CPS!E39	0.00000000463	=$A$2*$A$3*$A$4*$A$5*$A$6*D24*E24
25			=CPS!A40	=CPS!E40	0.00000000178	=$A$2*$A$3*$A$4*$A$5*$A$6*D25*E25
26			=CPS!A41	=CPS!E41	0.0000000000241	=$A$2*$A$3*$A$4*$A$5*$A$6*D26*E26
27			=CPS!A42	=CPS!E42	0.00000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*D27*E27
28			=CPS!A43	=CPS!E43	0.000000000916	=$A$2*$A$3*$A$4*$A$5*$A$6*D28*E28
29			=CPS!A44	=CPS!E44	0.000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*D29*E29
30			=CPS!A45	=CPS!E45	0.00000467	=$A$2*$A$3*$A$4*$A$5*$A$6*D30*E30
31			=CPS!A46	=CPS!E46	0.00000000245	=$A$2*$A$3*$A$4*$A$5*$A$6*D31*E31
32			=CPS!A47	=CPS!E47	0.00000000294	=$A$2*$A$3*$A$4*$A$5*$A$6*D32*E32
33			=CPS!A48	=CPS!E48	0.0000000591	=$A$2*$A$3*$A$4*$A$5*$A$6*D33*E33
34			=CPS!A49	=CPS!E49	0.0000000000903	=$A$2*$A$3*$A$4*$A$5*$A$6*D34*E34
35			=CPS!A50	=CPS!E50	0.0000000125	=$A$2*$A$3*$A$4*$A$5*$A$6*D35*E35
36			=CPS!A51	=CPS!E51	0.00000000123	=$A$2*$A$3*$A$4*$A$5*$A$6*D36*E36
37			=CPS!A52	=CPS!E52	0.00000000198	=$A$2*$A$3*$A$4*$A$5*$A$6*D37*E37
38			=CPS!A53	=CPS!E53	0.00000000863	=$A$2*$A$3*$A$4*$A$5*$A$6*D38*E38
39			=CPS!A54	=CPS!E54	0.0000000000226	=$A$2*$A$3*$A$4*$A$5*$A$6*D39*E39
40			=CPS!A55	=CPS!E55	0.000000000726	=$A$2*$A$3*$A$4*$A$5*$A$6*D40*E40
41			=CPS!A56	=CPS!E56	0.000000004	=$A$2*$A$3*$A$4*$A$5*$A$6*D41*E41
42			=CPS!A57	=CPS!E57	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D42*E42
43			=CPS!A58	=CPS!E58	0.00000000168	=$A$2*$A$3*$A$4*$A$5*$A$6*D43*E43
44			=CPS!A59	=CPS!E59	0.0000000469	=$A$2*$A$3*$A$4*$A$5*$A$6*D44*E44
45			=CPS!A60	=CPS!E60	0.00000000889	=$A$2*$A$3*$A$4*$A$5*$A$6*D45*E45
46			=CPS!A61	=CPS!E61	0.000000000103	=$A$2*$A$3*$A$4*$A$5*$A$6*D46*E46
47			=CPS!A62	=CPS!E62	0.00000000158	=$A$2*$A$3*$A$4*$A$5*$A$6*D47*E47
48			=CPS!A63	=CPS!E63	0.000000000332	=$A$2*$A$3*$A$4*$A$5*$A$6*D48*E48
49			=CPS!A64	=CPS!E64	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D49*E49
50			=CPS!A65	=CPS!E65	0.00000000131	=$A$2*$A$3*$A$4*$A$5*$A$6*D50*E50
51			=CPS!A66	=CPS!E66	0.000000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*D51*E51
52			=CPS!A67	=CPS!E67	0.0000000000684	=$A$2*$A$3*$A$4*$A$5*$A$6*D52*E52
53			=CPS!A68	=CPS!E68	0.00000000181	=$A$2*$A$3*$A$4*$A$5*$A$6*D53*E53
54			=CPS!A69	=CPS!E69	0.000000000102	=$A$2*$A$3*$A$4*$A$5*$A$6*D54*E54
55			=CPS!A70	=CPS!E70	0.00000000107	=$A$2*$A$3*$A$4*$A$5*$A$6*D55*E55
56			=CPS!A71	=CPS!E71	0.000000000327	=$A$2*$A$3*$A$4*$A$5*$A$6*D56*E56
57			=CPS!A72	=CPS!E72	0.00000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*D57*E57
58			=CPS!A73	=CPS!E73	0.000000000659	=$A$2*$A$3*$A$4*$A$5*$A$6*D58*E58
59			=CPS!A74	=CPS!E74	0.0000000000224	=$A$2*$A$3*$A$4*$A$5*$A$6*D59*E59
60			=CPS!A75	=CPS!E75	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D60*E60
61			=CPS!A76	=CPS!E76	0.00000000185	=$A$2*$A$3*$A$4*$A$5*$A$6*D61*E61
62			=CPS!A77	=CPS!E77	0.0000000017	=$A$2*$A$3*$A$4*$A$5*$A$6*D62*E62
63			=CPS!A78	=CPS!E78	0.0000000000932	=$A$2*$A$3*$A$4*$A$5*$A$6*D63*E63
64			=CPS!A79	=CPS!E79	0.000146	=$A$2*$A$3*$A$4*$A$5*$A$6*D64*E64
65			=CPS!A80	=CPS!E80	0.000000000678	=$A$2*$A$3*$A$4*$A$5*$A$6*D65*E65
66			=CPS!A81	=CPS!E81	0.00000000419	=$A$2*$A$3*$A$4*$A$5*$A$6*D66*E66
67			=CPS!A82	=CPS!E82	0.000347	=$A$2*$A$3*$A$4*$A$5*$A$6*D67*E67
68			=CPS!A83	=CPS!E83	0.00000000258	=$A$2*$A$3*$A$4*$A$5*$A$6*D68*E68
69			=CPS!A84	=CPS!E84	0.0000000000256	=$A$2*$A$3*$A$4*$A$5*$A$6*D69*E69
70			=CPS!A85	=CPS!E85	0.00000367	=$A$2*$A$3*$A$4*$A$5*$A$6*D70*E70
71			=CPS!A86	=CPS!E86	0.00000000235	=$A$2*$A$3*$A$4*$A$5*$A$6*D71*E71
72			=CPS!A87	=CPS!E87	0.00000000211	=$A$2*$A$3*$A$4*$A$5*$A$6*D72*E72
73			=CPS!A88	=CPS!E88	0.0000000106	=$A$2*$A$3*$A$4*$A$5*$A$6*D73*E73
74			=CPS!A89	=CPS!E89	0.00000254	=$A$2*$A$3*$A$4*$A$5*$A$6*D74*E74
75			=CPS!A90	=CPS!E90	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D75*E75
76			=CPS!A91	=CPS!E91	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D76*E76
77			=CPS!A92	=CPS!E92	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D77*E77
78			=CPS!A93	=CPS!E93	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D78*E78
79			=CPS!A94	=CPS!E94	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D79*E79
80			=CPS!A95	=CPS!E95	0.00000000219	=$A$2*$A$3*$A$4*$A$5*$A$6*D80*E80
81			=CPS!A96	=CPS!E96	0.0000000000117	=$A$2*$A$3*$A$4*$A$5*$A$6*D81*E81
82			=CPS!A97	=CPS!E97	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D82*E82
83			=CPS!A98	=CPS!E98	0.000106	=$A$2*$A$3*$A$4*$A$5*$A$6*D83*E83
84			=CPS!A99	=CPS!E99	0.000116	=$A$2*$A$3*$A$4*$A$5*$A$6*D84*E84
85			=CPS!A100	=CPS!E100	0.00000212	=$A$2*$A$3*$A$4*$A$5*$A$6*D85*E85

	A	B	C	D	E	F
86			=CPS!A101	=CPS!E101	0.0000021	=$A$2*$A$3*$A$4*$A$5*$A$6*D86*E86
87			=CPS!A102	=CPS!E102	0.00000232	=$A$2*$A$3*$A$4*$A$5*$A$6*D87*E87
88			=CPS!A103	=CPS!E103	0.0000000000147	=$A$2*$A$3*$A$4*$A$5*$A$6*D88*E88
89			=CPS!A104	=CPS!E104	0.00000000000138	=$A$2*$A$3*$A$4*$A$5*$A$6*D89*E89
90			=CPS!A105	=CPS!E105	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D90*E90
91			=CPS!A106	=CPS!E106	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D91*E91
92			=CPS!A107	=CPS!E107	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D92*E92
93			=CPS!A108	=CPS!E108	0.00000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*D93*E93
94			=CPS!A109	=CPS!E109	0.000000129	=$A$2*$A$3*$A$4*$A$5*$A$6*D94*E94
95			=CPS!A110	=CPS!E110	0.0000202	=$A$2*$A$3*$A$4*$A$5*$A$6*D95*E95
96			=CPS!A111	=CPS!E111	0.0000000112	=$A$2*$A$3*$A$4*$A$5*$A$6*D96*E96
97			=CPS!A112	=CPS!E112	0.000000351	=$A$2*$A$3*$A$4*$A$5*$A$6*D97*E97
98			=CPS!A113	=CPS!E113	0.000000000449	=$A$2*$A$3*$A$4*$A$5*$A$6*D98*E98
99			=CPS!A114	=CPS!E114	0.000000000218	=$A$2*$A$3*$A$4*$A$5*$A$6*D99*E99
100			=CPS!A115	=CPS!E115	0.00000000225	=$A$2*$A$3*$A$4*$A$5*$A$6*D100*E100
101			=CPS!A116	=CPS!E116	0.0000000000088	=$A$2*$A$3*$A$4*$A$5*$A$6*D101*E101
102			=CPS!A117	=CPS!E117	0.0000000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*D102*E102
103			=CPS!A118	=CPS!E118	0.00000000647	=$A$2*$A$3*$A$4*$A$5*$A$6*D103*E103
104			=CPS!A119	=CPS!E119	0.00000000255	=$A$2*$A$3*$A$4*$A$5*$A$6*D104*E104
105			=CPS!A120	=CPS!E120	0.00000437	=$A$2*$A$3*$A$4*$A$5*$A$6*D105*E105
106			=CPS!A121	=CPS!E121	0.00058	=$A$2*$A$3*$A$4*$A$5*$A$6*D106*E106
107			=CPS!A122	=CPS!E122	0.000088	=$A$2*$A$3*$A$4*$A$5*$A$6*D107*E107
108			=CPS!A123	=CPS!E123	0.000000000237	=$A$2*$A$3*$A$4*$A$5*$A$6*D108*E108
109			=CPS!A124	=CPS!E124	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D109*E109
110			=CPS!A125	=CPS!E125	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D110*E110
111			=CPS!A126	=CPS!E126	0.0000366	=$A$2*$A$3*$A$4*$A$5*$A$6*D111*E111
112			=CPS!A127	=CPS!E127	0.0000358	=$A$2*$A$3*$A$4*$A$5*$A$6*D112*E112
113			=CPS!A128	=CPS!E128	0.0000332	=$A$2*$A$3*$A$4*$A$5*$A$6*D113*E113
114			=CPS!A129	=CPS!E129	0.000000000167	=$A$2*$A$3*$A$4*$A$5*$A$6*D114*E114
115			=CPS!A130	=CPS!E130	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D115*E115
116			=CPS!A131	=CPS!E131	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D116*E116
117			=CPS!A132	=CPS!E132	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D117*E117
118			=CPS!A133	=CPS!E133	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D118*E118
119			=CPS!A134	=CPS!E134	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D119*E119
120			=CPS!A135	=CPS!E135	0.00000000228	=$A$2*$A$3*$A$4*$A$5*$A$6*D120*E120
121			=CPS!A136	=CPS!E136	0.0000000132	=$A$2*$A$3*$A$4*$A$5*$A$6*D121*E121
122			=CPS!A137	=CPS!E137	0.00000000000982	=$A$2*$A$3*$A$4*$A$5*$A$6*D122*E122
123			=CPS!A138	=CPS!E138	0.000000000211	=$A$2*$A$3*$A$4*$A$5*$A$6*D123*E123
124			=CPS!A139	=CPS!E139	0.00000000551	=$A$2*$A$3*$A$4*$A$5*$A$6*D124*E124
125			=CPS!A140	=CPS!E140	0.0000000000106	=$A$2*$A$3*$A$4*$A$5*$A$6*D125*E125
126			=CPS!A141	=CPS!E141	0.00000000022	=$A$2*$A$3*$A$4*$A$5*$A$6*D126*E126
127			=CPS!A142	=CPS!E142	0.00000000639	=$A$2*$A$3*$A$4*$A$5*$A$6*D127*E127
128			=CPS!A143	=CPS!E143	0.00000000117	=$A$2*$A$3*$A$4*$A$5*$A$6*D128*E128
129						
130						
131					Total Rem	=SUM(F13:F128)

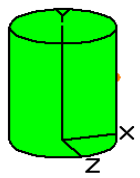
	A	B	C	D	E	F
1	**Container Fire Event: Clinton Isotopic: Table 12.2-12**					
2	0.00054	X/Q (sec/m^3)				
3	0.00035	Breathing Rate (m^3/sec)				
4	0.01	Release Fraction				
5	3700000000000	Conversion Factor (rem/Ci per Sv/Bq)				
6	6	Containers/Accident				
7	200	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	=F131	Total Inhalation Dose				
10						
11						60 day decay
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			=CPS!A28	=CPS!E28	0.00000292	=$A$2*$A$3*$A$4*$A$5*$A$6*D13*E13
14			=CPS!A29	=CPS!E29	0.00181	=$A$2*$A$3*$A$4*$A$5*$A$6*D14*E14
15			=CPS!A30	=CPS!E30	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D15*E15
16			=CPS!A31	=CPS!E31	0.0000000217	=$A$2*$A$3*$A$4*$A$5*$A$6*D16*E16
17			=CPS!A32	=CPS!E32	0.00012	=$A$2*$A$3*$A$4*$A$5*$A$6*D17*E17
18			=CPS!A33	=CPS!E33	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D18*E18
19			=CPS!A34	=CPS!E34	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D19*E19
20			=CPS!A35	=CPS!E35	0.0000000000464	=$A$2*$A$3*$A$4*$A$5*$A$6*D20*E20
21			=CPS!A36	=CPS!E36	0.00000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*D21*E21
22			=CPS!A37	=CPS!E37	0.0000000529	=$A$2*$A$3*$A$4*$A$5*$A$6*D22*E22
23			=CPS!A38	=CPS!E38	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D23*E23
24			=CPS!A39	=CPS!E39	0.00000000463	=$A$2*$A$3*$A$4*$A$5*$A$6*D24*E24
25			=CPS!A40	=CPS!E40	0.00000000178	=$A$2*$A$3*$A$4*$A$5*$A$6*D25*E25
26			=CPS!A41	=CPS!E41	0.0000000000241	=$A$2*$A$3*$A$4*$A$5*$A$6*D26*E26
27			=CPS!A42	=CPS!E42	0.00000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*D27*E27
28			=CPS!A43	=CPS!E43	0.000000000916	=$A$2*$A$3*$A$4*$A$5*$A$6*D28*E28
29			=CPS!A44	=CPS!E44	0.000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*D29*E29
30			=CPS!A45	=CPS!E45	0.00000467	=$A$2*$A$3*$A$4*$A$5*$A$6*D30*E30
31			=CPS!A46	=CPS!E46	0.00000000245	=$A$2*$A$3*$A$4*$A$5*$A$6*D31*E31
32			=CPS!A47	=CPS!E47	0.00000000294	=$A$2*$A$3*$A$4*$A$5*$A$6*D32*E32
33			=CPS!A48	=CPS!E48	0.0000000591	=$A$2*$A$3*$A$4*$A$5*$A$6*D33*E33
34			=CPS!A49	=CPS!E49	0.0000000000903	=$A$2*$A$3*$A$4*$A$5*$A$6*D34*E34
35			=CPS!A50	=CPS!E50	0.0000000125	=$A$2*$A$3*$A$4*$A$5*$A$6*D35*E35
36			=CPS!A51	=CPS!E51	0.00000000123	=$A$2*$A$3*$A$4*$A$5*$A$6*D36*E36
37			=CPS!A52	=CPS!E52	0.00000000198	=$A$2*$A$3*$A$4*$A$5*$A$6*D37*E37
38			=CPS!A53	=CPS!E53	0.00000000863	=$A$2*$A$3*$A$4*$A$5*$A$6*D38*E38
39			=CPS!A54	=CPS!E54	0.0000000000226	=$A$2*$A$3*$A$4*$A$5*$A$6*D39*E39
40			=CPS!A55	=CPS!E55	0.000000000726	=$A$2*$A$3*$A$4*$A$5*$A$6*D40*E40
41			=CPS!A56	=CPS!E56	0.000000004	=$A$2*$A$3*$A$4*$A$5*$A$6*D41*E41
42			=CPS!A57	=CPS!E57	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D42*E42
43			=CPS!A58	=CPS!E58	0.00000000168	=$A$2*$A$3*$A$4*$A$5*$A$6*D43*E43
44			=CPS!A59	=CPS!E59	0.0000000469	=$A$2*$A$3*$A$4*$A$5*$A$6*D44*E44
45			=CPS!A60	=CPS!E60	0.00000000889	=$A$2*$A$3*$A$4*$A$5*$A$6*D45*E45
46			=CPS!A61	=CPS!E61	0.000000000103	=$A$2*$A$3*$A$4*$A$5*$A$6*D46*E46
47			=CPS!A62	=CPS!E62	0.00000000158	=$A$2*$A$3*$A$4*$A$5*$A$6*D47*E47
48			=CPS!A63	=CPS!E63	0.000000000332	=$A$2*$A$3*$A$4*$A$5*$A$6*D48*E48
49			=CPS!A64	=CPS!E64	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D49*E49
50			=CPS!A65	=CPS!E65	0.00000000131	=$A$2*$A$3*$A$4*$A$5*$A$6*D50*E50
51			=CPS!A66	=CPS!E66	0.000000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*D51*E51
52			=CPS!A67	=CPS!E67	0.0000000000684	=$A$2*$A$3*$A$4*$A$5*$A$6*D52*E52
53			=CPS!A68	=CPS!E68	0.00000000181	=$A$2*$A$3*$A$4*$A$5*$A$6*D53*E53
54			=CPS!A69	=CPS!E69	0.000000000102	=$A$2*$A$3*$A$4*$A$5*$A$6*D54*E54
55			=CPS!A70	=CPS!E70	0.00000000107	=$A$2*$A$3*$A$4*$A$5*$A$6*D55*E55
56			=CPS!A71	=CPS!E71	0.000000000327	=$A$2*$A$3*$A$4*$A$5*$A$6*D56*E56
57			=CPS!A72	=CPS!E72	0.00000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*D57*E57
58			=CPS!A73	=CPS!E73	0.000000000659	=$A$2*$A$3*$A$4*$A$5*$A$6*D58*E58
59			=CPS!A74	=CPS!E74	0.0000000000224	=$A$2*$A$3*$A$4*$A$5*$A$6*D59*E59
60			=CPS!A75	=CPS!E75	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D60*E60
61			=CPS!A76	=CPS!E76	0.00000000185	=$A$2*$A$3*$A$4*$A$5*$A$6*D61*E61
62			=CPS!A77	=CPS!E77	0.0000000017	=$A$2*$A$3*$A$4*$A$5*$A$6*D62*E62
63			=CPS!A78	=CPS!E78	0.0000000000932	=$A$2*$A$3*$A$4*$A$5*$A$6*D63*E63
64			=CPS!A79	=CPS!E79	0.000146	=$A$2*$A$3*$A$4*$A$5*$A$6*D64*E64
65			=CPS!A80	=CPS!E80	0.000000000678	=$A$2*$A$3*$A$4*$A$5*$A$6*D65*E65
66			=CPS!A81	=CPS!E81	0.00000000419	=$A$2*$A$3*$A$4*$A$5*$A$6*D66*E66
67			=CPS!A82	=CPS!E82	0.000347	=$A$2*$A$3*$A$4*$A$5*$A$6*D67*E67
68			=CPS!A83	=CPS!E83	0.00000000258	=$A$2*$A$3*$A$4*$A$5*$A$6*D68*E68
69			=CPS!A84	=CPS!E84	0.0000000000256	=$A$2*$A$3*$A$4*$A$5*$A$6*D69*E69
70			=CPS!A85	=CPS!E85	0.00000367	=$A$2*$A$3*$A$4*$A$5*$A$6*D70*E70
71			=CPS!A86	=CPS!E86	0.00000000235	=$A$2*$A$3*$A$4*$A$5*$A$6*D71*E71
72			=CPS!A87	=CPS!E87	0.00000000211	=$A$2*$A$3*$A$4*$A$5*$A$6*D72*E72
73			=CPS!A88	=CPS!E88	0.0000000106	=$A$2*$A$3*$A$4*$A$5*$A$6*D73*E73
74			=CPS!A89	=CPS!E89	0.00000254	=$A$2*$A$3*$A$4*$A$5*$A$6*D74*E74
75			=CPS!A90	=CPS!E90	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D75*E75
76			=CPS!A91	=CPS!E91	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D76*E76
77			=CPS!A92	=CPS!E92	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D77*E77
78			=CPS!A93	=CPS!E93	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D78*E78
79			=CPS!A94	=CPS!E94	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D79*E79
80			=CPS!A95	=CPS!E95	0.00000000219	=$A$2*$A$3*$A$4*$A$5*$A$6*D80*E80
81			=CPS!A96	=CPS!E96	0.0000000000117	=$A$2*$A$3*$A$4*$A$5*$A$6*D81*E81
82			=CPS!A97	=CPS!E97	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D82*E82
83			=CPS!A98	=CPS!E98	0.000106	=$A$2*$A$3*$A$4*$A$5*$A$6*D83*E83
84			=CPS!A99	=CPS!E99	0.000116	=$A$2*$A$3*$A$4*$A$5*$A$6*D84*E84
85			=CPS!A100	=CPS!E100	0.00000212	=$A$2*$A$3*$A$4*$A$5*$A$6*D85*E85

	A	B	C	D	E	F
86			=CPS!A101	=CPS!E101	0.0000021	=$A$2*$A$3*$A$4*$A$5*$A$6*D86*E86
87			=CPS!A102	=CPS!E102	0.00000232	=$A$2*$A$3*$A$4*$A$5*$A$6*D87*E87
88			=CPS!A103	=CPS!E103	0.0000000000147	=$A$2*$A$3*$A$4*$A$5*$A$6*D88*E88
89			=CPS!A104	=CPS!E104	0.00000000000138	=$A$2*$A$3*$A$4*$A$5*$A$6*D89*E89
90			=CPS!A105	=CPS!E105	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D90*E90
91			=CPS!A106	=CPS!E106	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D91*E91
92			=CPS!A107	=CPS!E107	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D92*E92
93			=CPS!A108	=CPS!E108	0.00000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*D93*E93
94			=CPS!A109	=CPS!E109	0.000000129	=$A$2*$A$3*$A$4*$A$5*$A$6*D94*E94
95			=CPS!A110	=CPS!E110	0.0000202	=$A$2*$A$3*$A$4*$A$5*$A$6*D95*E95
96			=CPS!A111	=CPS!E111	0.0000000112	=$A$2*$A$3*$A$4*$A$5*$A$6*D96*E96
97			=CPS!A112	=CPS!E112	0.000000351	=$A$2*$A$3*$A$4*$A$5*$A$6*D97*E97
98			=CPS!A113	=CPS!E113	0.000000000449	=$A$2*$A$3*$A$4*$A$5*$A$6*D98*E98
99			=CPS!A114	=CPS!E114	0.000000000218	=$A$2*$A$3*$A$4*$A$5*$A$6*D99*E99
100			=CPS!A115	=CPS!E115	0.00000000225	=$A$2*$A$3*$A$4*$A$5*$A$6*D100*E100
101			=CPS!A116	=CPS!E116	0.0000000000088	=$A$2*$A$3*$A$4*$A$5*$A$6*D101*E101
102			=CPS!A117	=CPS!E117	0.0000000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*D102*E102
103			=CPS!A118	=CPS!E118	0.00000000647	=$A$2*$A$3*$A$4*$A$5*$A$6*D103*E103
104			=CPS!A119	=CPS!E119	0.00000000255	=$A$2*$A$3*$A$4*$A$5*$A$6*D104*E104
105			=CPS!A120	=CPS!E120	0.00000437	=$A$2*$A$3*$A$4*$A$5*$A$6*D105*E105
106			=CPS!A121	=CPS!E121	0.00058	=$A$2*$A$3*$A$4*$A$5*$A$6*D106*E106
107			=CPS!A122	=CPS!E122	0.000088	=$A$2*$A$3*$A$4*$A$5*$A$6*D107*E107
108			=CPS!A123	=CPS!E123	0.000000000237	=$A$2*$A$3*$A$4*$A$5*$A$6*D108*E108
109			=CPS!A124	=CPS!E124	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D109*E109
110			=CPS!A125	=CPS!E125	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D110*E110
111			=CPS!A126	=CPS!E126	0.0000366	=$A$2*$A$3*$A$4*$A$5*$A$6*D111*E111
112			=CPS!A127	=CPS!E127	0.0000358	=$A$2*$A$3*$A$4*$A$5*$A$6*D112*E112
113			=CPS!A128	=CPS!E128	0.0000332	=$A$2*$A$3*$A$4*$A$5*$A$6*D113*E113
114			=CPS!A129	=CPS!E129	0.000000000167	=$A$2*$A$3*$A$4*$A$5*$A$6*D114*E114
115			=CPS!A130	=CPS!E130	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D115*E115
116			=CPS!A131	=CPS!E131	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D116*E116
117			=CPS!A132	=CPS!E132	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D117*E117
118			=CPS!A133	=CPS!E133	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D118*E118
119			=CPS!A134	=CPS!E134	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D119*E119
120			=CPS!A135	=CPS!E135	0.00000000228	=$A$2*$A$3*$A$4*$A$5*$A$6*D120*E120
121			=CPS!A136	=CPS!E136	0.0000000132	=$A$2*$A$3*$A$4*$A$5*$A$6*D121*E121
122			=CPS!A137	=CPS!E137	0.00000000000982	=$A$2*$A$3*$A$4*$A$5*$A$6*D122*E122
123			=CPS!A138	=CPS!E138	0.000000000211	=$A$2*$A$3*$A$4*$A$5*$A$6*D123*E123
124			=CPS!A139	=CPS!E139	0.00000000551	=$A$2*$A$3*$A$4*$A$5*$A$6*D124*E124
125			=CPS!A140	=CPS!E140	0.0000000000106	=$A$2*$A$3*$A$4*$A$5*$A$6*D125*E125
126			=CPS!A141	=CPS!E141	0.00000000022	=$A$2*$A$3*$A$4*$A$5*$A$6*D126*E126
127			=CPS!A142	=CPS!E142	0.00000000639	=$A$2*$A$3*$A$4*$A$5*$A$6*D127*E127
128			=CPS!A143	=CPS!E143	0.00000000117	=$A$2*$A$3*$A$4*$A$5*$A$6*D128*E128
129						
130						
131					Total Rem	=SUM(F13:F128)

Attachment C: Byron and Braidwood

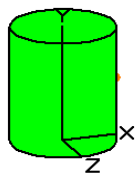
MicroShield 2
Run #1: Based on UFSAR Table Data from 11.1-10 2
Run #2: Based on UFSAR Table Data from 11.1-10 with 60 Day Decay 4
Run #3: Based on UFSAR Table Data from 11.1-10 with 60 Day Decay and Normalized Contact Dose 6
Run #4: Based on UFSAR Table Data from 12.2-13 8
Run #5: Based on UFSAR Table Data from 12.2-13 with 60 Day Decay 10
Run #6: Based on UFSAR Table Data from 12.2-13 with 60 Day Decay and Normalized Contact Dose 12
Excel Sheets 14
Drop Accident: Based on UFSAR Table 11.1-10 14
Captures the isotopic mix from Run #3 in column D, and calculates a final dose in column F.
Fire Accdent: Based on UFSAR Table 11.1-10 15
Captures the isotopic mix from Run #3 in column D, and calculates a final dose in column F.
Drop Accident: Based on UFSAR Table 12.2-13 16
Captures the isotopic mix from Run #6 in column D, and calculates a final dose in column F.
Fire Accdent: Based on UFSAR Table 12.2-13 17
Captures the isotopic mix from Run #6 in column D, and calculates a final dose in column F.
Drop Accident: Formula Version: Based on UFSAR Table 11.1-10 18
Fire Accident: Formula Version: Based on UFSAR Table 11.1-10 19
Drop Accident: Formula Version: Based on UFSAR Table 12.2-13 20
Fire Accident: Formula Version: Based on UFSAR Table 12.2-13 21

	A	B	C	D	E	F	G	H	I
1	MicroShield 8.01								
2	Washington Group International (8.00-0000)								
3	Date				By	Checked			
4									
5	Filename				Run Date	Run Time	Duration		
6	BB111.msd				11-Aug-09	9:20:26 AM	0:00:05		
7	Project Info								
8	Case Title				B&B 11.1-10				
9	Description				before decay and resizing				
10	Geometry				7 - Cylinder Volume - Side Shields				
11	Source Dimensions								
12	Height	182.88 cm (6 ft)							
13	Radius	76.2 cm (2 ft 6.0 in)							
14	Dose Points								
15	A	X	Y	Z					
16	#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)					
17	Shields								
18	Shield N	Dimension	Material	Density					
19	Source	2.04e+05 in³	Water	0.9					
20	Transition		Air	0.00122					
21	Air Gap		Air	0.00122					
22	Source Input: Grouping Method - Linear Energy								
23	Number of Groups: 25								
24	Lower Energy Cutoff: 0.015								
25	Photons < 0.015: Included								
26	Library: Grove								
27	Nuclide				Ci	Bq	µCi/cm³	Bq/cm³	
28	Ba-137m				6.58E+02	2.43E+13	1.97E+02	7.29E+06	
29	Ba-140				1.70E+00	6.29E+10	5.09E-01	1.88E+04	
30	Co-58				5.10E+02	1.89E+13	1.53E+02	5.65E+06	
31	Co-60				1.32E+02	4.87E+12	3.95E+01	1.46E+06	
32	Cr-51				2.80E+01	1.04E+12	8.40E+00	3.11E+05	
33	Cs-134				8.92E+02	3.30E+13	2.67E+02	9.89E+06	
34	Cs-136				5.18E+01	1.92E+12	1.55E+01	5.75E+05	
35	Cs-137				6.95E+02	2.57E+13	2.08E+02	7.71E+06	
36	Fe-55				1.02E+02	3.77E+12	3.06E+01	1.13E+06	
37	Fe-59				2.29E+01	8.49E+11	6.88E+00	2.54E+05	
38	I-133				1.85E+02	6.85E+12	5.55E+01	2.05E+06	
39	La-140				1.70E+00	6.29E+10	5.09E-01	1.88E+04	
40	Mn-54				1.70E+01	6.29E+11	5.09E+00	1.88E+05	
41	Mo-99								
42	Nb-95								
43	Rb-86				5.10E-01	1.89E+10	1.53E-01	5.65E+03	
44	Rh-103m								
45	Rh-106								
46	Ru-103								
47	Ru-106								
48	Sr-89				8.50E+00	3.14E+11	2.55E+00	9.42E+04	
49	Sr-90				6.80E-01	2.51E+10	2.04E-01	7.54E+03	
50	Y-90								
51	Y-91								
52	Zr-95								
53	Buildup: The material reference is Source								
54	Integration Parameters								
55	Radial				30				
56	Circumferential				30				
57	Y Direction (axial)				60				
58	Results								
59						Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
60	Energy (MeV)				Activity (Photons/sec)	MeV/cm²/sec	MeV/cm²/sec	mR/hr	mR/hr
61						No Buildup	With Buildup	No Buildup	With Buildup
62	0.0154				9.59E+12	1.33E+04	1.57E+04	1.06E+03	1.25E+03
63	0.1678				5.63E+11	9.08E+04	4.71E+05	1.54E+02	7.97E+02
64	0.2729				2.90E+11	8.95E+04	3.48E+05	1.68E+02	6.51E+02
65	0.3384				1.07E+12	4.43E+05	1.53E+06	8.52E+02	2.95E+03
66	0.4736				5.66E+11	3.74E+05	1.10E+06	7.33E+02	2.16E+03



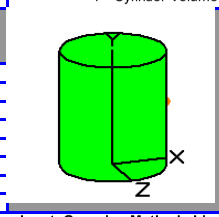
	A	B	C	D	E	F	G	H	I
67		0.58			5.18E+13	4.55E+07	1.23E+08	8.90E+04	2.41E+05
68		0.6618			2.21E+13	2.34E+07	6.01E+07	4.54E+04	1.17E+05
69		0.8018			4.99E+13	6.98E+07	1.66E+08	1.33E+05	3.16E+05
70		0.8309			3.11E+12	4.59E+06	1.08E+07	8.69E+03	2.05E+04
71		0.925			6.60E+09	1.14E+04	2.58E+04	2.13E+01	4.82E+01
72		1.0572			2.38E+12	5.00E+06	1.09E+07	9.13E+03	1.98E+04
73		1.1726			5.47E+12	1.34E+07	2.81E+07	2.39E+04	5.02E+04
74		1.2659			1.01E+12	2.76E+06	5.66E+06	4.85E+03	9.94E+03
75		1.3381			5.89E+12	1.75E+07	3.53E+07	3.04E+04	6.12E+04
76		1.5965			6.00E+10	2.33E+05	4.45E+05	3.85E+02	7.36E+02
77		1.6747			1.01E+11	4.22E+05	7.96E+05	6.88E+02	1.30E+03
78		2.3488			5.35E+08	3.70E+03	6.40E+03	5.43E+00	9.40E+00
79		2.5224			2.24E+09	1.72E+04	2.93E+04	2.47E+01	4.20E+01
80		**Totals**			**1.54E+14**	**1.84E+08**	**4.45E+08**	**3.48E+05**	**8.45E+05**

	A	B	C	D	E	F	G	H	I
1	MicroShield 8.01								
2	Washington Group International (8.00-0000)								
3	Date				By	Checked			
4									
5	Filename				Run Date	Run Time	Duration		
6	BB111decay.msd				11-Aug-09	9:21:29 AM	0:00:05		
7	Project Info								
8	Case Title				B&B 11.1-10				
9	Description				before resizing				
10	Geometry				7 - Cylinder Volume - Side Shields				
11	Source Dimensions								
12	Height	182.88 cm (6 ft)							
13	Radius	76.2 cm (2 ft 6.0 in)							
14	Dose Points								
15	A	X	Y	Z					
16	#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)					
17	Shields								
18	Shield N	Dimension	Material	Density					
19	Source	2.04e+05 in³	Water	0.9					
20	Transition		Air	0.00122					
21	Air Gap		Air	0.00122					
22	Source Input: Grouping Method - Linear Energy								
23	Number of Groups: 25								
24	Lower Energy Cutoff: 0.015								
25	Photons < 0.015: Included								
26	Library: Grove								
27	Nuclide				Ci	Bq	µCi/cm³	Bq/cm³	
28	Ba-137m				6.55E+02	2.42E+13	1.96E+02	7.26E+06	
29	Ba-140				6.58E-02	2.43E+09	1.97E-02	7.29E+02	
30	Co-58				2.83E+02	1.05E+13	8.49E+01	3.14E+06	
31	Co-60				1.29E+02	4.77E+12	3.86E+01	1.43E+06	
32	Cr-51				6.25E+00	2.31E+11	1.87E+00	6.93E+04	
33	Cs-134				8.44E+02	3.12E+13	2.53E+02	9.36E+06	
34	Cs-136				2.20E+00	8.13E+10	6.59E-01	2.44E+04	
35	Cs-137				6.92E+02	2.56E+13	2.08E+02	7.68E+06	
36	Fe-55				9.77E+01	3.62E+12	2.93E+01	1.08E+06	
37	Fe-59				9.03E+00	3.34E+11	2.71E+00	1.00E+05	
38	I-133				2.67E-19	9.89E-09	8.01E-20	2.97E-15	
39	La-140				7.57E-02	2.80E+09	2.27E-02	8.39E+02	
40	Mn-54				1.49E+01	5.50E+11	4.46E+00	1.65E+05	
41	Mo-99								
42	Nb-95								
43	Rb-86				5.49E-02	2.03E+09	1.64E-02	6.09E+02	
44	Rh-103m								
45	Rh-106								
46	Ru-103								
47	Ru-106								
48	Sr-89				3.73E+00	1.38E+11	1.12E+00	4.14E+04	
49	Sr-90				6.77E-01	2.50E+10	2.03E-01	7.51E+03	
50	Xe-133				1.35E-02	4.98E+08	4.04E-03	1.49E+02	
51	Xe-133m				1.98E-08	7.31E+02	5.92E-09	2.19E-04	
52	Y-90				6.77E-01	2.51E+10	2.03E-01	7.51E+03	
53	Y-91								
54	Zr-95								
55	Buildup: The material reference is Source								
56	Integration Parameters								
57	Radial				30				
58	Circumferential				30				
59	Y Direction (axial)				60				
60	Results								
61–63	Energy (MeV)				Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
64	0.0148				6.31E+12	7.92E+03	9.21E+03	7.07E+02	8.22E+02
65	0.1719				3.62E+10	6.03E+03	3.09E+04	1.03E+01	5.26E+01
66	0.2754				2.15E+10	6.71E+03	2.59E+04	1.26E+01	4.86E+01



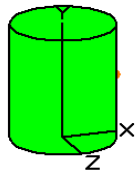
	A	B	C	D	E	F	G	H	I
67		0.333			6.41E+10	2.59E+04	9.02E+04	4.97E+01	1.73E+02
68		0.4754			4.58E+11	3.04E+05	8.96E+05	5.97E+02	1.76E+03
69		0.5908			4.11E+13	3.70E+07	9.95E+07	7.24E+04	1.94E+05
70		0.6617			2.18E+13	2.31E+07	5.93E+07	4.49E+04	1.15E+05
71		0.8002			3.98E+13	5.56E+07	1.33E+08	1.06E+05	2.52E+05
72		0.8361			7.09E+11	1.06E+06	2.48E+06	2.00E+03	4.69E+03
73		0.925			2.94E+08	5.07E+02	1.15E+03	9.47E-01	2.15E+00
74		1.0599			5.66E+11	1.19E+06	2.59E+06	2.18E+03	4.72E+03
75		1.1726			5.33E+12	1.30E+07	2.74E+07	2.33E+04	4.89E+04
76		1.2859			1.61E+11	4.51E+05	9.20E+05	7.90E+02	1.61E+03
77		1.3379			5.72E+12	1.70E+07	3.43E+07	2.95E+04	5.94E+04
78		1.5965			2.67E+09	1.04E+04	1.98E+04	1.71E+01	3.28E+01
79		1.6747			5.63E+10	2.34E+05	4.43E+05	3.82E+02	7.22E+02
80		2.3488			2.38E+07	1.65E+02	2.85E+02	2.42E-01	4.19E-01
81		2.5224			9.97E+07	7.66E+02	1.30E+03	1.10E+00	1.87E+00
82		**Totals**			**1.22E+14**	**1.49E+08**	**3.61E+08**	**2.83E+05**	**6.84E+05**

	A	B	C	D	E	F	G	H	I
1	MicroShield 8.01								
2	Washington Group International (8.00-0000)								
3	Date				By	Checked			
4									
5	Filename				Run Date	Run Time	Duration		
6	BB11decay2.msd				3-Aug-09	2:05:01 PM	0:00:05		
7	Project Info								
8	Case Title				BB 11.1-10				
9	Description				before resizing				
10	Geometry				7 - Cylinder Volume - Side Shields				
11	Source Dimensions								
12	Height	182.88 cm (6 ft)							
13	Radius	76.2 cm (2 ft 6.0 in)							
14	Dose Points								
15	A	X	Y	Z					
16	#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)					
17	Shields								
18	Shield N	Dimension	Material	Density					
19	Source	2.04e+05 in³	Water	0.9					
20	Transition		Air	0.00122					
21	Air Gap		Air	0.00122					
22	Source Input: Grouping Method - Linear Energy								
23	Number of Groups: 25								
24	Lower Energy Cutoff: 0.015								
25	Photons < 0.015: Included								
26	Library: Grove								
27	Nuclide				Ci	Bq	µCi/cm³	Bq/cm³	
28	Ba-137m				1.91E+02	7.08E+12	5.74E+01	2.12E+06	
29	Ba-140				1.92E-02	7.11E+08	5.76E-03	2.13E+02	
30	Co-58				8.28E+01	3.06E+12	2.48E+01	9.18E+05	
31	Co-60				3.77E+01	1.39E+12	1.13E+01	4.18E+05	
32	Cr-51				1.83E+00	6.76E+10	5.47E-01	2.03E+04	
33	Cs-134				2.47E+02	9.13E+12	7.39E+01	2.74E+06	
34	Cs-136				6.42E-01	2.38E+10	1.93E-01	7.12E+03	
35	Cs-137				2.02E+02	7.49E+12	6.07E+01	2.24E+06	
36	Fe-55				2.86E+01	1.06E+12	8.56E+00	3.17E+05	
37	Fe-59				2.64E+00	9.77E+10	7.91E-01	2.93E+04	
38	I-133				7.81E-20	2.89E-09	2.34E-20	8.67E-16	
39	La-140				2.21E-02	8.18E+08	6.63E-03	2.45E+02	
40	Mn-54				4.35E+00	1.61E+11	1.30E+00	4.82E+04	
41	Mo-99								
42	Nb-95								
43	Rb-86				1.60E-02	5.93E+08	4.81E-03	1.78E+02	
44	Rh-103m								
45	Rh-106								
46	Ru-103								
47	Ru-106								
48	Sr-89				1.09E+00	4.04E+10	3.27E-01	1.21E+04	
49	Sr-90				1.98E-01	7.32E+09	5.93E-02	2.19E+03	
50	Xe-133				3.94E-03	1.46E+08	1.18E-03	4.37E+01	
51	Xe-133m				5.78E-09	2.14E+02	1.73E-09	6.41E-05	
52	Y-90				1.98E-01	7.32E+09	5.93E-02	2.19E+03	
53	Y-91								
54	Zr-95								
55	Buildup: The material reference is Source								
56	Integration Parameters								
57	Radial				30				
58	Circumferential				30				
59	Y Direction (axial)				60				
60	Results								
61–63	Energy (MeV)				Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
64	0.0148				1.85E+12	2.31E+03	2.69E+03	2.07E+02	2.40E+02
65	0.1719				1.06E+10	1.76E+03	9.02E+03	3.00E+00	1.54E+01
66	0.2754				6.28E+09	1.96E+03	7.58E+03	3.67E+00	1.42E+01



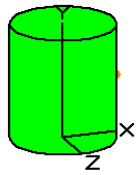
	A	B	C	D	E	F	G	H	I
67		0.333			1.87E+10	7.57E+03	2.64E+04	1.45E+01	5.06E+01
68		0.4754			1.34E+11	8.89E+04	2.62E+05	1.74E+02	5.14E+02
69		0.5908			1.20E+13	1.08E+07	2.91E+07	2.12E+04	5.68E+04
70		0.6617			6.37E+12	6.76E+06	1.73E+07	1.31E+04	3.36E+04
71		0.8002			1.16E+13	1.63E+07	3.87E+07	3.09E+04	7.37E+04
72		0.8361			2.07E+11	3.09E+05	7.24E+05	5.84E+02	1.37E+03
73		0.925			8.60E+07	1.48E+02	3.36E+02	2.77E-01	6.27E-01
74		1.0599			1.65E+11	3.49E+05	7.56E+05	6.36E+02	1.38E+03
75		1.1726			1.56E+12	3.81E+06	8.00E+06	6.81E+03	1.43E+04
76		1.2859			4.70E+10	1.32E+05	2.69E+05	2.31E+02	4.70E+02
77		1.3379			1.67E+12	4.98E+06	1.00E+07	8.62E+03	1.74E+04
78		1.5965			7.81E+08	3.03E+03	5.80E+03	5.01E+00	9.58E+00
79		1.6747			1.65E+10	6.85E+04	1.29E+05	1.12E+02	2.11E+02
80		2.3488			6.96E+06	4.81E+01	8.33E+01	7.06E-02	1.22E-01
81		2.5224			2.91E+07	2.24E+02	3.81E+02	3.21E-01	5.46E-01
82		**Totals**			**3.57E+13**	**4.36E+07**	**1.05E+08**	**8.26E+04**	**2.00E+05**

	A	B	C	D	E	F	G	H	I
1	MicroShield 8.01								
2	Washington Group International (8.00-0000)								
3	Date				By	Checked			
4									
5	Filename				Run Date	Run Time	Duration		
6	BB222.msd				11-Aug-09	9:27:01 AM	0:00:05		
7	Project Info								
8	Case Title				B&B 12.2-13				
9	Description				before decay and resizing				
10	Geometry				7 - Cylinder Volume - Side Shields				
11	Source Dimensions								
12	Height	182.88 cm (6 ft)							
13	Radius	76.2 cm (2 ft 6.0 in)							
14	Dose Points								
15	A	X	Y	Z					
16	#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)					
17	Shields								
18	Shield N	Dimension	Material	Density					
19	Source	2.04e+05 in³	Water	0.9					
20	Transition		Air	0.00122					
21	Air Gap		Air	0.00122					
22	Source Input: Grouping Method - Linear Energy								
23	Number of Groups: 25								
24	Lower Energy Cutoff: 0.015								
25	Photons < 0.015: Included								
26	Library: Grove								
27	Nuclide				Ci	Bq	µCi/cm³	Bq/cm³	
28	Ba-137m				5.27E+03	1.95E+14	1.58E+03	5.84E+07	
29	Ba-140				2.91E+01	1.08E+12	8.73E+00	3.23E+05	
30	Ce-144				1.85E+01	6.85E+11	5.55E+00	2.05E+05	
31	Co-58				5.52E+02	2.04E+13	1.66E+02	6.12E+06	
32	Co-60				7.22E+01	2.67E+12	2.16E+01	8.01E+05	
33	Cs-134				8.58E+03	3.17E+14	2.57E+03	9.52E+07	
34	Cs-136				6.29E+02	2.33E+13	1.88E+02	6.97E+06	
35	Cs-137				5.61E+03	2.07E+14	1.68E+03	6.22E+07	
36	Cs-138				1.10E+01	4.05E+11	3.29E+00	1.22E+05	
37	Fe-59				1.53E+01	5.66E+11	4.58E+00	1.70E+05	
38	I-131				1.06E+04	3.93E+14	3.18E+03	1.18E+08	
39	I-132				1.56E+03	5.78E+13	4.69E+02	1.73E+07	
40	I-133				1.85E+03	6.85E+13	5.55E+02	2.05E+07	
41	I-134				1.14E+01	4.21E+11	3.41E+00	1.26E+05	
42	I-135				3.20E+02	1.19E+13	9.60E+01	3.55E+06	
43	La-140				3.04E+01	1.13E+12	9.12E+00	3.37E+05	
44	Mn-54				4.08E+01	1.51E+12	1.22E+01	4.52E+05	
45	Mn-56				1.02E+00	3.77E+10	3.06E-01	1.13E+04	
46	Mo-99				1.11E+03	4.12E+13	3.34E+02	1.23E+07	
47	Nb-95				3.37E+01	1.25E+12	1.01E+01	3.74E+05	
48	Pr-144				1.85E+01	6.85E+11	5.55E+00	2.05E+05	
49	Rb-88				2.46E+01	9.08E+11	7.36E+00	2.72E+05	
50	Rb-89				1.10E+00	4.07E+10	3.30E-01	1.22E+04	
51	Sr-89				8.83E+01	3.27E+12	2.65E+01	9.80E+05	
52	Sr-90				1.29E+01	4.78E+11	3.87E+00	1.43E+05	
53	Sr-91				4.25E-01	1.57E+10	1.27E-01	4.71E+03	
54	Sr-92				4.42E-02	1.63E+09	1.32E-02	4.90E+02	
55	Te-132				4.59E+02	1.70E+13	1.38E+02	5.09E+06	
56	Te-134				4.59E-01	1.70E+10	1.38E-01	5.09E+03	
57	Y-90				6.37E+00	2.36E+11	1.91E+00	7.07E+04	
58	Y-91				9.17E+00	3.39E+11	2.75E+00	1.02E+05	
59	Y-92				1.02E-01	3.77E+09	3.06E-02	1.13E+03	
60	Zr-95				2.27E+01	8.39E+11	6.80E+00	2.52E+05	
61	Buildup: The material reference is Source								
62	Integration Parameters								
63	Radial				30				
64	Circumferential				30				
65	Y Direction (axial)				60				
66	Results								



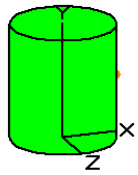
	A	B	C	D	E	F	G	H	I
67						Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
68	Energy (MeV)				Activity (Photons/sec)	MeV/cm²/sec	MeV/cm²/sec	mR/hr	mR/hr
69						No Buildup	With Buildup	No Buildup	With Buildup
70	0.053				9.48E+13	3.34E+06	1.81E+07	8.00E+03	4.33E+04
71	0.3517				3.78E+14	1.65E+08	5.59E+08	3.18E+05	1.08E+06
72	0.5419				1.67E+14	1.33E+08	3.70E+08	2.61E+05	7.25E+05
73	0.6335				6.08E+14	6.06E+08	1.58E+09	1.18E+06	3.08E+06
74	0.7974				4.06E+14	5.64E+08	1.35E+09	1.07E+06	2.56E+06
75	1.0318				4.21E+13	8.52E+07	1.86E+08	1.56E+05	3.42E+05
76	1.221				2.36E+13	6.12E+07	1.27E+08	1.08E+05	2.25E+05
77	1.3784				2.05E+13	6.37E+07	1.27E+08	1.10E+05	2.19E+05
78	1.6467				2.98E+12	1.21E+07	2.30E+07	1.99E+04	3.77E+04
79	1.7952				1.40E+12	6.47E+06	1.20E+07	1.04E+04	1.92E+04
80	1.9758				1.59E+12	8.49E+06	1.54E+07	1.32E+04	2.39E+04
81	2.2077				3.40E+11	2.14E+06	3.76E+06	3.21E+03	5.64E+03
82	2.3976				2.21E+11	1.57E+06	2.71E+06	2.29E+03	3.95E+03
83	2.5718				7.93E+10	6.27E+05	1.06E+06	8.94E+02	1.51E+03
84	2.6828				2.03E+10	1.71E+05	2.87E+05	2.41E+02	4.04E+02
85	3.0069				2.33E+09	2.33E+04	3.79E+04	3.15E+01	5.14E+01
86	3.2185				1.94E+09	2.14E+04	3.44E+04	2.84E+01	4.56E+01
87	3.3564				1.60E+09	1.87E+04	2.98E+04	2.45E+01	3.90E+01
88	3.4928				1.65E+09	2.06E+04	3.24E+04	2.66E+01	4.18E+01
89	4.7427				1.30E+09	2.52E+04	3.68E+04	2.94E+01	4.30E+01
90	**Totals**				**1.75E+15**	**1.71E+09**	**4.37E+09**	**3.26E+06**	**8.36E+06**

	A	B	C	D	E	F	G	H	I
1	MicroShield 8.01								
2	Washington Group International (8.00-0000)								
3	Date				By	Checked			
4									
5	Filename				Run Date	Run Time	Duration		
6	BB222decay.msd				11-Aug-09	9:28:06 AM	0:00:06		
7	Project Info								
8	Case Title				B&B 12.2-13				
9	Description				before resizing				
10	Geometry				7 - Cylinder Volume - Side Shields				
11	Source Dimensions								
12	Height	182.88 cm (6 ft)							
13	Radius	76.2 cm (2 ft 6.0 in)							
14	Dose Points								
15	A	X	Y	Z					
16	#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)					
17	Shields								
18	Shield N	Dimension	Material	Density					
19	Source	2.04e+05 in³	Water	0.9					
20	Transition		Air	0.00122					
21	Air Gap		Air	0.00122					
22	Source Input: Grouping Method - Linear Energy								
23	Number of Groups: 25								
24	Lower Energy Cutoff: 0.015								
25	Photons < 0.015: Included								
26	Library: Grove								
27	Nuclide				Ci	Bq	µCi/cm³	Bq/cm³	
28	Ba-137m				5.28E+03	1.96E+14	1.58E+03	5.86E+07	
29	Ba-140				1.13E+00	4.17E+10	3.38E-01	1.25E+04	
30	Ce-144				1.60E+01	5.92E+11	4.80E+00	1.77E+05	
31	Co-58				3.07E+02	1.14E+13	9.20E+01	3.40E+06	
32	Co-60				7.07E+01	2.61E+12	2.12E+01	7.84E+05	
33	Cs-134				8.12E+03	3.00E+14	2.43E+03	9.01E+07	
34	Cs-135				1.05E-07	3.88E+03	3.15E-08	1.16E-03	
35	Cs-136				2.67E+01	9.87E+11	7.99E+00	2.96E+05	
36	Cs-137				5.59E+03	2.07E+14	1.67E+03	6.20E+07	
37	Cs-138								
38	Fe-59				6.02E+00	2.23E+11	1.81E+00	6.68E+04	
39	I-131				6.02E+01	2.23E+12	1.80E+01	6.68E+05	
40	I-132				1.35E-03	5.01E+07	4.06E-04	1.50E+01	
41	I-133				2.67E-18	9.89E-08	8.01E-19	2.97E-14	
42	I-134								
43	I-135				8.43E-64	3.12E-53	2.53E-64	9.35E-60	
44	La-140				1.30E+00	4.80E+10	3.89E-01	1.44E+04	
45	Mn-54				3.57E+01	1.32E+12	1.07E+01	3.96E+05	
46	Mn-56				7.83E-169	2.90E-158	2.35E-169	8.69E-165	
47	Mo-99				3.02E-04	1.12E+07	9.06E-05	3.35E+00	
48	Nb-95				2.12E+01	7.83E+11	6.35E+00	2.35E+05	
49	Nb-95m				1.00E-01	3.72E+09	3.01E-02	1.11E+03	
50	Pr-144				1.60E+01	5.92E+11	4.80E+00	1.77E+05	
51	Pr-144m				2.29E-01	8.47E+09	6.86E-02	2.54E+03	
52	Rb-88								
53	Rb-89								
54	Sr-89				3.88E+01	1.44E+12	1.16E+01	4.30E+05	
55	Sr-90				1.29E+01	4.76E+11	3.86E+00	1.43E+05	
56	Sr-91				9.96E-47	3.69E-36	2.99E-47	1.10E-42	
57	Sr-92				4.88E-162	1.81E-151	1.46E-162	5.41E-158	
58	Tc-99				3.93E-05	1.46E+06	1.18E-05	4.36E-01	
59	Tc-99m				2.95E-04	1.09E+07	8.84E-05	3.27E+00	
60	Te-132				1.31E-03	4.86E+07	3.94E-04	1.46E+01	
61	Te-134								
62	Xe-131m				5.89E+00	2.18E+11	1.77E+00	6.54E+04	
63	Xe-133				1.35E-01	4.98E+09	4.04E-02	1.49E+03	
64	Xe-133m				1.98E-07	7.31E+03	5.92E-08	2.19E-03	
65	Xe-135				2.22E-45	8.22E-35	6.66E-46	2.46E-41	
66	Xe-135m				1.45E-64	5.35E-54	4.34E-65	1.60E-60	



	A	B	C	D	E	F	G	H	I
67	Y-90				1.29E+01	4.76E+11	3.86E+00	1.43E+05	
68	Y-91				4.51E+00	1.67E+11	1.35E+00	5.00E+04	
69	Y-91m				6.26E-47	2.32E-36	1.88E-47	6.95E-43	
70	Y-92				8.68E-124	3.21E-113	2.60E-124	9.62E-120	
71	Zr-95				1.18E+01	4.38E+11	3.55E+00	1.31E+05	
72	**Buildup: The material reference is Source**								
73	**Integration Parameters**								
74	Radial				30				
75	Circumferential				30				
76	Y Direction (axial)				60				
77					**Results**				
78						**Fluence Rate**	**Fluence Rate**	**Exposure Rate**	**Exposure Rate**
79	**Energy (MeV)**				**Activity (Photons/sec)**	**MeV/cm²/sec**	**MeV/cm²/sec**	**mR/hr**	**mR/hr**
80						**No Buildup**	**With Buildup**	**No Buildup**	**With Buildup**
81	0.0268				2.30E+13	2.08E+05	3.94E+05	2.88E+03	5.47E+03
82	0.1687				2.89E+11	4.69E+04	2.43E+05	7.96E+01	4.11E+02
83	0.3481				2.68E+12	1.15E+06	3.93E+06	2.22E+03	7.57E+03
84	0.491				7.83E+12	5.44E+06	1.58E+07	1.07E+04	3.10E+04
85	0.6183				5.41E+14	5.21E+08	1.37E+09	1.02E+06	2.67E+06
86	0.7962				2.84E+14	3.94E+08	9.40E+08	7.49E+05	1.79E+06
87	0.814				1.37E+13	1.96E+07	4.65E+07	3.72E+04	8.82E+04
88	1.0406				3.79E+12	7.77E+06	1.70E+07	1.42E+04	3.10E+04
89	1.1685				8.15E+12	1.98E+07	4.17E+07	3.55E+04	7.46E+04
90	1.3246				2.91E+12	8.52E+06	1.72E+07	1.48E+04	2.99E+04
91	1.3652				9.13E+12	2.80E+07	5.61E+07	4.83E+04	9.67E+04
92	1.5925				4.76E+10	1.84E+05	3.52E+05	3.04E+02	5.83E+02
93	1.6747				6.10E+10	2.54E+05	4.79E+05	4.14E+02	7.82E+02
94	1.7575				1.48E+05	6.64E-01	1.24E+00	1.07E-03	1.99E-03
95	1.9599				1.14E+06	5.99E+00	1.09E+01	9.32E-03	1.69E-02
96	2.0868				1.19E+05	6.86E-01	1.23E+00	1.05E-03	1.87E-03
97	2.1857				4.58E+09	2.84E+04	5.01E+04	4.27E+01	7.54E+01
98	2.3488				4.09E+08	2.82E+03	4.89E+03	4.15E+00	7.18E+00
99	2.5224				1.71E+09	1.31E+04	2.23E+04	1.89E+01	3.21E+01
100	2.6575				1.89E-160	1.57E-165	2.64E-165	2.22E-168	3.72E-168
101	2.9598				8.88E-161	8.65E-166	1.42E-165	1.18E-168	1.93E-168
102	3.3696				4.87E-161	5.74E-166	9.12E-166	7.51E-169	1.19E-168
103	**Totals**				**8.97E+14**	**1.01E+09**	**2.51E+09**	**1.93E+06**	**4.83E+06**

	A	B	C	D	E	F	G	H	I
1	MicroShield 8.01								
2	Washington Group International (8.00-0000)								
3	Date				By	Checked			
4									
5	Filename				Run Date	Run Time	Duration		
6	BB12decay2.msd				3-Aug-09	2:47:31 PM	0:00:06		
7	Project Info								
8	Case Title				BB 12.2-13				
9	Description				after				
10	Geometry				7 - Cylinder Volume - Side Shields				
11	Source Dimensions								
12	Height	182.88 cm (6 ft)							
13	Radius	76.2 cm (2 ft 6.0 in)							
14	Dose Points								
15	A	X	Y	Z					
16	#1	78.74 cm (2 ft 7.0 in)	91.44 cm (3 ft)	0.0 cm (0 in)					
17	Shields								
18	Shield N	Dimension	Material	Density					
19	Source	2.04e+05 in³	Water	0.9					
20	Transition		Air	0.00122					
21	Air Gap		Air	0.00122					
22	Source Input: Grouping Method - Linear Energy								
23	Number of Groups: 25								
24	Lower Energy Cutoff: 0.015								
25	Photons < 0.015: Included								
26	Library: Grove								
27	Nuclide				Ci	Bq	µCi/cm³	Bq/cm³	
28	Ba-137m				2.19E+02	8.10E+12	6.56E+01	2.43E+06	
29	Ba-140				4.67E-02	1.73E+09	1.40E-02	5.18E+02	
30	Ce-144				6.62E-01	2.45E+10	1.99E-01	7.35E+03	
31	Co-58				1.27E+01	4.70E+11	3.81E+00	1.41E+05	
32	Co-60				2.93E+00	1.08E+11	8.77E-01	3.25E+04	
33	Cs-134				3.36E+02	1.24E+13	1.01E+02	3.73E+06	
34	Cs-135				4.35E-09	1.61E+02	1.30E-09	4.82E-05	
35	Cs-136				1.10E+00	4.09E+10	3.31E-01	1.22E+04	
36	Cs-137				2.31E+02	8.56E+12	6.93E+01	2.57E+06	
37	Cs-138								
38	Fe-59				2.49E-01	9.23E+09	7.47E-02	2.77E+03	
39	I-131				2.49E+00	9.22E+10	7.47E-01	2.76E+04	
40	I-132				5.60E-05	2.07E+06	1.68E-05	6.21E-01	
41	I-133				1.11E-19	4.10E-09	3.32E-20	1.23E-15	
42	I-134								
43	I-135				3.49E-65	1.29E-54	1.05E-65	3.87E-61	
44	La-140				5.37E-02	1.99E+09	1.61E-02	5.96E+02	
45	Mn-54				1.48E+00	5.47E+10	4.43E-01	1.64E+04	
46	Mn-56				3.24E-170	1.20E-159	9.72E-171	3.60E-166	
47	Mo-99				1.25E-05	4.63E+05	3.75E-06	1.39E-01	
48	Nb-95				8.76E-01	3.24E+10	2.63E-01	9.72E+03	
49	Nb-95m				4.16E-03	1.54E+08	1.25E-03	4.61E+01	
50	Pr-144				6.63E-01	2.45E+10	1.99E-01	7.35E+03	
51	Pr-144m				9.47E-03	3.51E+08	2.84E-03	1.05E+02	
52	Rb-88								
53	Rb-89								
54	Sr-89				1.61E+00	5.95E+10	4.82E-01	1.78E+04	
55	Sr-90				5.33E-01	1.97E+10	1.60E-01	5.91E+03	
56	Sr-91				4.12E-48	1.53E-37	1.24E-48	4.58E-44	
57	Sr-92				2.02E-163	7.47E-153	6.06E-164	2.24E-159	
58	Tc-99				1.63E-06	6.03E+04	4.88E-07	1.81E-02	
59	Tc-99m				1.22E-05	4.52E+05	3.66E-06	1.35E-01	
60	Te-132				5.44E-05	2.01E+06	1.63E-05	6.03E-01	
61	Te-134								
62	Xe-131m				2.44E-01	9.03E+09	7.31E-02	2.71E+03	
63	Xe-133				5.58E-03	2.06E+08	1.67E-03	6.19E+01	
64	Xe-133m				8.18E-09	3.03E+02	2.45E-09	9.08E-05	
65	Xe-135				9.20E-47	3.40E-36	2.76E-47	1.02E-42	
66	Xe-135m				5.99E-66	2.22E-55	1.80E-66	6.64E-62	



	A	B	C	D	E	F	G	H	I
67	Y-90				5.33E-01	1.97E+10	1.60E-01	5.91E+03	
68	Y-91				1.87E-01	6.91E+09	5.60E-02	2.07E+03	
69	Y-91m				2.59E-48	9.60E-38	7.78E-49	2.88E-44	
70	Y-92				3.59E-125	1.33E-114	1.08E-125	3.98E-121	
71	Zr-95				4.91E-01	1.81E+10	1.47E-01	5.44E+03	
72	**Buildup: The material reference is Source**								
73	**Integration Parameters**								
74	Radial				30				
75	Circumferential				30				
76	Y Direction (axial)				60				
77					**Results**				
78						**Fluence Rate**	**Fluence Rate**	**Exposure Rate**	**Exposure Rate**
79	**Energy (MeV)**				**Activity (Photons/sec)**	**MeV/cm²/sec**	**MeV/cm²/sec**	**mR/hr**	**mR/hr**
80						**No Buildup**	**With Buildup**	**No Buildup**	**With Buildup**
81	0.0268				9.53E+11	8.60E+03	1.63E+04	1.19E+02	2.26E+02
82	0.1687				1.20E+10	1.94E+03	1.00E+04	3.29E+00	1.70E+01
83	0.3481				1.11E+11	4.77E+04	1.63E+05	9.20E+01	3.14E+02
84	0.491				3.24E+11	2.25E+05	6.53E+05	4.42E+02	1.28E+03
85	0.6183				2.24E+13	2.16E+07	5.68E+07	4.20E+04	1.11E+05
86	0.7962				1.18E+13	1.63E+07	3.89E+07	3.10E+04	7.41E+04
87	0.814				5.67E+11	8.12E+05	1.92E+06	1.54E+03	3.65E+03
88	1.0406				1.57E+11	3.22E+05	7.02E+05	5.89E+02	1.29E+03
89	1.1685				3.37E+11	8.22E+05	1.73E+06	1.47E+03	3.09E+03
90	1.3246				1.20E+11	3.53E+05	7.13E+05	6.13E+02	1.24E+03
91	1.3652				3.78E+11	1.16E+06	2.32E+06	2.00E+03	4.00E+03
92	1.5925				1.97E+09	7.62E+03	1.46E+04	1.26E+01	2.41E+01
93	1.6747				2.52E+09	1.05E+04	1.99E+04	1.72E+01	3.24E+01
94	1.7575				6.14E+03	2.75E-02	5.12E-02	4.42E-05	8.24E-05
95	1.9599				4.71E+04	2.48E-01	4.50E-01	3.86E-04	7.00E-04
96	2.0868				4.91E+03	2.84E-02	5.07E-02	4.34E-05	7.74E-05
97	2.1857				1.90E+08	1.18E+03	2.08E+03	1.77E+00	3.12E+00
98	2.3488				1.69E+07	1.17E+02	2.02E+02	1.72E-01	2.97E-01
99	2.5224				7.08E+07	5.44E+02	9.25E+02	7.81E-01	1.33E+00
100	2.6575				7.83E-162	6.50E-167	1.09E-166	9.17E-170	1.54E-169
101	2.9598				3.68E-162	3.58E-167	5.86E-167	4.88E-170	7.99E-170
102	3.3696				2.02E-162	2.38E-167	3.78E-167	3.11E-170	4.94E-170
103	**Totals**				**3.71E+13**	**4.16E+07**	**1.04E+08**	**8.00E+04**	**2.00E+05**

	A	B	C	D	E	F
1	**Container Drop Event: Byron and Braidwood Isotopic: Table 11.1.10**					
2	5.400E-04	X/Q (sec/m^3)				
3	3.500E-04	Breathing Rate (m^3/sec)				
4	1.000E-02	Release Fraction				
5	3.70E+12	Conversion Factor (rem/Ci per Sv/Bq)				
6	1.00E+00	Containers/Accident				
7	2.00E+02	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	5.190E-02	Total Inhalation Dose (rem)				
10						
11				60 day Decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			Ba-137m	1.914E+02	0.00E+00	0.000E+00
14			Ba-140	1.922E-02	1.010E-09	1.357E-07
15			Co-58	8.279E+01	2.940E-09	1.702E-03
16			Co-60	3.766E+01	5.910E-08	1.557E-02
17			Cr-51	1.826E+00	9.030E-11	1.153E-06
18			Cs-134	2.467E+02	1.250E-08	2.156E-02
19			Cs-136	6.424E-01	1.980E-09	8.895E-06
20			Cs-137	2.023E+02	8.630E-09	1.221E-02
21			Fe-55	2.856E+01	7.260E-10	1.450E-04
22			Fe-59	2.640E+00	4.000E-09	7.385E-05
23			I-133	7.814E-20	1.580E-09	8.634E-25
24			La-140	2.212E-02	1.310E-09	2.026E-07
25			Mn-54	4.347E+00	1.810E-09	5.503E-05
26			Mo-99	0.000E+00	1.070E-09	0.000E+00
27			Nb-95	0.000E+00	1.570E-09	0.000E+00
28			Rb-86	1.604E-02	1.790E-09	2.008E-07
29			Rh-103m	0.000E+00	1.380E-12	0.000E+00
30			Rh-106	0.000E+00	0.00E+00	0.000E+00
31			Ru-103	0.000E+00	2.420E-09	0.000E+00
32			Ru-106	0.000E+00	1.290E-07	0.000E+00
33			Sr-89	1.091E+00	1.120E-08	8.541E-05
34			Sr-90	1.978E-01	3.510E-07	4.856E-04
35			Xe-133	3.937E-03	0.00E+00	0.000E+00
36			Xe-133m	5.775E-09	0.00E+00	0.000E+00
37			Y-90	1.979E-01	2.280E-09	3.155E-06
38			Y-91	0.000E+00	1.320E-08	0.000E+00
39			Zr-95	0.000E+00	6.390E-09	0.000E+00
40						
41						
42					Total Rem	5.190E-02

	A	B	C	D	E	F
1	**Container Drop Event: Byron and Braidwood Isotopic: Table 12.2.13**					
2	5.400E-04	X/Q (sec/m^3)				
3	3.500E-04	Breathing Rate (m^3/sec)				
4	1.000E-02	Release Fraction				
5	3.70E+12	Conversion Factor (rem/Ci per Sv/Bq)				
6	1.00E+00	Containers/Accident				
7	2.00E+02	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	4.697E-02	Total Inhalation Dose (rem)				
10						
11				60 day Decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			Ba-137m	2.188E+02	0.00E+00	0.000E+00
14			Ba-140	4.669E-02	1.010E-09	3.298E-07
15			Ce-144	6.625E-01	1.010E-07	4.679E-04
16			Co-58	1.271E+01	2.940E-09	2.612E-04
17			Co-60	2.926E+00	5.910E-08	1.209E-03
18			Cs-134	3.362E+02	1.250E-08	2.939E-02
19			Cs-135	4.348E-09	1.230E-09	3.740E-14
20			Cs-136	1.104E+00	1.980E-09	1.529E-05
21			Cs-137	2.313E+02	8.630E-09	1.396E-02
22			Cs-138	0.000E+00	2.740E-11	0.000E+00
23			Fe-59	2.494E-01	4.000E-09	6.975E-06
24			I-131	2.493E+00	8.890E-09	1.550E-04
25			I-132	5.602E-05	1.030E-10	4.035E-11
26			I-133	1.107E-19	1.580E-09	1.223E-24
27			I-134	0.000E+00	3.550E-11	0.000E+00
28			I-135	3.489E-65	3.320E-10	8.100E-71
29			La-140	5.373E-02	1.310E-09	4.922E-07
30			Mn-54	1.478E+00	1.810E-09	1.871E-05
31			Mn-56	3.243E-170	1.020E-10	2.313E-176
32			Mo-99	1.252E-05	1.070E-09	9.367E-11
33			Nb-95	8.765E-01	1.570E-09	9.623E-06
34			Nb-95m	4.158E-03	6.590E-10	1.916E-08
35			Pr-144	6.625E-01	1.170E-11	5.421E-08
36			Pr-144m	9.474E-03	0.00E+00	0.000E+00
37			Rb-88	0.000E+00	2.260E-11	0.000E+00
38			Rb-89	0.000E+00	1.160E-11	0.000E+00
39			Sr-89	1.607E+00	1.120E-08	1.259E-04
40			Sr-90	5.326E-01	3.510E-07	1.307E-03
41			Sr-91	4.125E-48	4.490E-10	1.295E-53
42			Sr-92	2.020E-163	2.180E-10	3.079E-169
43			Tc-99	1.629E-06	2.250E-09	2.564E-11
44			Tc-99m	1.221E-05	8.800E-12	7.511E-13
45			Te-132	5.437E-05	2.550E-09	9.696E-10
46			Te-134	0.000E+00	3.440E-11	0.000E+00
47			Xe-131m	2.440E-01	0.00E+00	0.000E+00
48			Xe-133	5.578E-03	0.00E+00	0.000E+00
49			Xe-133m	8.183E-09	0.00E+00	0.000E+00
50			Xe-135	9.198E-47	0.00E+00	0.000E+00
51			Xe-135m	5.989E-66	0.00E+00	0.000E+00
52			Y-90	5.327E-01	2.280E-09	8.493E-06
53			Y-91	1.867E-01	1.320E-08	1.723E-05
54			Y-91m	2.594E-48	9.820E-12	1.781E-55
55			Y-92	3.593E-125	2.110E-10	5.301E-131
56			Zr-95	4.905E-01	6.390E-09	2.192E-05
57						
58						
59					Total Rem	4.697E-02

	A	B	C	D	E	F
1	**Container Fire Event: Byron and Braidwood Isotopic: Table 11.1.10**					
2	5.400E-04	X/Q (sec/m^3)				
3	3.500E-04	Breathing Rate (m^3/sec)				
4	1.000E-02	Release Fraction				
5	3.70E+12	Conversion Factor (rem/Ci per Sv/Bq)				
6	6.00E+00	Containers/Accident				
7	2.00E+02	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	3.114E-01	Total Inhalation Dose (rem)				
10						
11				60 day Decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			Ba-137m	1.914E+02	0.00E+00	0.000E+00
14			Ba-140	1.922E-02	1.010E-09	8.144E-07
15			Co-58	8.279E+01	2.940E-09	1.021E-02
16			Co-60	3.766E+01	5.910E-08	9.339E-02
17			Cr-51	1.826E+00	9.030E-11	6.918E-06
18			Cs-134	2.467E+02	1.250E-08	1.294E-01
19			Cs-136	6.424E-01	1.980E-09	5.337E-05
20			Cs-137	2.023E+02	8.630E-09	7.326E-02
21			Fe-55	2.856E+01	7.260E-10	8.701E-04
22			Fe-59	2.640E+00	4.000E-09	4.431E-04
23			I-133	7.814E-20	1.580E-09	5.180E-24
24			La-140	2.212E-02	1.310E-09	1.216E-06
25			Mn-54	4.347E+00	1.810E-09	3.302E-04
26			Mo-99	0.000E+00	1.070E-09	0.000E+00
27			Nb-95	0.000E+00	1.570E-09	0.000E+00
28			Rb-86	1.604E-02	1.790E-09	1.205E-06
29			Rh-103m	0.000E+00	1.380E-12	0.000E+00
30			Rh-106	0.000E+00	0.00E+00	0.000E+00
31			Ru-103	0.000E+00	2.420E-09	0.000E+00
32			Ru-106	0.000E+00	1.290E-07	0.000E+00
33			Sr-89	1.091E+00	1.120E-08	5.125E-04
34			Sr-90	1.978E-01	3.510E-07	2.914E-03
35			Xe-133	3.937E-03	0.00E+00	0.000E+00
36			Xe-133m	5.775E-09	0.00E+00	0.000E+00
37			Y-90	1.979E-01	2.280E-09	1.893E-05
38			Y-91	0.000E+00	1.320E-08	0.000E+00
39			Zr-95	0.000E+00	6.390E-09	0.000E+00
40						
41						
42					Total Rem	3.114E-01

	A	B	C	D	E	F
1	**Container Fire Event: Byron and Braidwood Isotopic: Table 12.2.13**					
2	5.400E-04	X/Q (sec/m^3)				
3	3.500E-04	Breathing Rate (m^3/sec)				
4	1.000E-02	Release Fraction				
5	3.70E+12	Conversion Factor (rem/Ci per Sv/Bq)				
6	6.00E+00	Containers/Accident				
7	2.00E+02	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	2.818E-01	Total Inhalation Dose (rem)				
10						
11				60 day Decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			Ba-137m	2.188E+02	0.00E+00	0.000E+00
14			Ba-140	4.669E-02	1.010E-09	1.979E-06
15			Ce-144	6.625E-01	1.010E-07	2.807E-03
16			Co-58	1.271E+01	2.940E-09	1.567E-03
17			Co-60	2.926E+00	5.910E-08	7.256E-03
18			Cs-134	3.362E+02	1.250E-08	1.763E-01
19			Cs-135	4.348E-09	1.230E-09	2.244E-13
20			Cs-136	1.104E+00	1.980E-09	9.173E-05
21			Cs-137	2.313E+02	8.630E-09	8.375E-02
22			Cs-138	0.000E+00	2.740E-11	0.000E+00
23			Fe-59	2.494E-01	4.000E-09	4.185E-05
24			I-131	2.493E+00	8.890E-09	9.298E-04
25			I-132	5.602E-05	1.030E-10	2.421E-10
26			I-133	1.107E-19	1.580E-09	7.339E-24
27			I-134	0.000E+00	3.550E-11	0.000E+00
28			I-135	3.489E-65	3.320E-10	4.860E-70
29			La-140	5.373E-02	1.310E-09	2.953E-06
30			Mn-54	1.478E+00	1.810E-09	1.123E-04
31			Mn-56	3.243E-170	1.020E-10	1.388E-175
32			Mo-99	1.252E-05	1.070E-09	5.620E-10
33			Nb-95	8.765E-01	1.570E-09	5.774E-05
34			Nb-95m	4.158E-03	6.590E-10	1.150E-07
35			Pr-144	6.625E-01	1.170E-11	3.252E-07
36			Pr-144m	9.474E-03	0.00E+00	0.000E+00
37			Rb-88	0.000E+00	2.260E-11	0.000E+00
38			Rb-89	0.000E+00	1.160E-11	0.000E+00
39			Sr-89	1.607E+00	1.120E-08	7.551E-04
40			Sr-90	5.326E-01	3.510E-07	7.843E-03
41			Sr-91	4.125E-48	4.490E-10	7.771E-53
42			Sr-92	2.020E-163	2.180E-10	1.848E-168
43			Tc-99	1.629E-06	2.250E-09	1.538E-10
44			Tc-99m	1.221E-05	8.800E-12	4.506E-12
45			Te-132	5.437E-05	2.550E-09	5.818E-09
46			Te-134	0.000E+00	3.440E-11	0.000E+00
47			Xe-131m	2.440E-01	0.00E+00	0.000E+00
48			Xe-133	5.578E-03	0.00E+00	0.000E+00
49			Xe-133m	8.183E-09	0.00E+00	0.000E+00
50			Xe-135	9.198E-47	0.00E+00	0.000E+00
51			Xe-135m	5.989E-66	0.00E+00	0.000E+00
52			Y-90	5.327E-01	2.280E-09	5.096E-05
53			Y-91	1.867E-01	1.320E-08	1.034E-04
54			Y-91m	2.594E-48	9.820E-12	1.069E-54
55			Y-92	3.593E-125	2.110E-10	3.181E-130
56			Zr-95	4.905E-01	6.390E-09	1.315E-04
57						
58						
59					Total Rem	2.818E-01

	A	B	C	D	E	F
1	**Container Drop Event: Byron and Braidwood Isotopic: Table 11.1.10**					
2	0.00054	X/Q (sec/m^3)				
3	0.00035	Breathing Rate (m^3/sec)				
4	0.01	Release Fraction				
5	3700000000000	Conversion Factor (rem/Ci per Sv/Bq)				
6	1	Containers/Accident				
7	200	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	=F42	Total Inhalation Dose (rem)				
10						
11				60 day Decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			='BB11'!A28	='BB11'!E28	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D13*E13
14			='BB11'!A29	='BB11'!E29	0.00000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*D14*E14
15			='BB11'!A30	='BB11'!E30	0.00000000294	=$A$2*$A$3*$A$4*$A$5*$A$6*D15*E15
16			='BB11'!A31	='BB11'!E31	0.0000000591	=$A$2*$A$3*$A$4*$A$5*$A$6*D16*E16
17			='BB11'!A32	='BB11'!E32	0.0000000000903	=$A$2*$A$3*$A$4*$A$5*$A$6*D17*E17
18			='BB11'!A33	='BB11'!E33	0.0000000125	=$A$2*$A$3*$A$4*$A$5*$A$6*D18*E18
19			='BB11'!A34	='BB11'!E34	0.00000000198	=$A$2*$A$3*$A$4*$A$5*$A$6*D19*E19
20			='BB11'!A35	='BB11'!E35	0.00000000863	=$A$2*$A$3*$A$4*$A$5*$A$6*D20*E20
21			='BB11'!A36	='BB11'!E36	0.000000000726	=$A$2*$A$3*$A$4*$A$5*$A$6*D21*E21
22			='BB11'!A37	='BB11'!E37	0.000000004	=$A$2*$A$3*$A$4*$A$5*$A$6*D22*E22
23			='BB11'!A38	='BB11'!E38	0.00000000158	=$A$2*$A$3*$A$4*$A$5*$A$6*D23*E23
24			='BB11'!A39	='BB11'!E39	0.00000000131	=$A$2*$A$3*$A$4*$A$5*$A$6*D24*E24
25			='BB11'!A40	='BB11'!E40	0.00000000181	=$A$2*$A$3*$A$4*$A$5*$A$6*D25*E25
26			='BB11'!A41	='BB11'!E41	0.00000000107	=$A$2*$A$3*$A$4*$A$5*$A$6*D26*E26
27			='BB11'!A42	='BB11'!E42	0.00000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*D27*E27
28			='BB11'!A43	='BB11'!E43	0.00000000179	=$A$2*$A$3*$A$4*$A$5*$A$6*D28*E28
29			='BB11'!A44	='BB11'!E44	0.00000000000138	=$A$2*$A$3*$A$4*$A$5*$A$6*D29*E29
30			='BB11'!A45	='BB11'!E45	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D30*E30
31			='BB11'!A46	='BB11'!E46	0.00000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*D31*E31
32			='BB11'!A47	='BB11'!E47	0.000000129	=$A$2*$A$3*$A$4*$A$5*$A$6*D32*E32
33			='BB11'!A48	='BB11'!E48	0.0000000112	=$A$2*$A$3*$A$4*$A$5*$A$6*D33*E33
34			='BB11'!A49	='BB11'!E49	0.000000351	=$A$2*$A$3*$A$4*$A$5*$A$6*D34*E34
35			='BB11'!A50	='BB11'!E50	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D35*E35
36			='BB11'!A51	='BB11'!E51	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D36*E36
37			='BB11'!A52	='BB11'!E52	0.00000000228	=$A$2*$A$3*$A$4*$A$5*$A$6*D37*E37
38			='BB11'!A53	='BB11'!E53	0.0000000132	=$A$2*$A$3*$A$4*$A$5*$A$6*D38*E38
39			='BB11'!A54	='BB11'!E54	0.00000000639	=$A$2*$A$3*$A$4*$A$5*$A$6*D39*E39
40						
41						
42					Total Rem	=SUM(F13:F39)

	A	B	C	D	E	F
1	**Container Drop Event: Byron and Braidwood Isotopic: Table 12.2.13**					
2	0.00054	X/Q (sec/m^3)				
3	0.00035	Breathing Rate (m^3/sec)				
4	0.01	Release Fraction				
5	3700000000000	Conversion Factor (rem/Ci per Sv/Bq)				
6	1	Containers/Accident				
7	200	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	=F59	Total Inhalation Dose (rem)				
10						
11				60 day Decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			='BB12'!A28	='BB12'!E28	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D13*E13
14			='BB12'!A29	='BB12'!E29	0.00000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*D14*E14
15			='BB12'!A30	='BB12'!E30	0.000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*D15*E15
16			='BB12'!A31	='BB12'!E31	0.00000000294	=$A$2*$A$3*$A$4*$A$5*$A$6*D16*E16
17			='BB12'!A32	='BB12'!E32	0.0000000591	=$A$2*$A$3*$A$4*$A$5*$A$6*D17*E17
18			='BB12'!A33	='BB12'!E33	0.0000000125	=$A$2*$A$3*$A$4*$A$5*$A$6*D18*E18
19			='BB12'!A34	='BB12'!E34	0.00000000123	=$A$2*$A$3*$A$4*$A$5*$A$6*D19*E19
20			='BB12'!A35	='BB12'!E35	0.00000000198	=$A$2*$A$3*$A$4*$A$5*$A$6*D20*E20
21			='BB12'!A36	='BB12'!E36	0.00000000863	=$A$2*$A$3*$A$4*$A$5*$A$6*D21*E21
22			='BB12'!A37	='BB12'!E37	0.0000000000274	=$A$2*$A$3*$A$4*$A$5*$A$6*D22*E22
23			='BB12'!A38	='BB12'!E38	0.000000004	=$A$2*$A$3*$A$4*$A$5*$A$6*D23*E23
24			='BB12'!A39	='BB12'!E39	0.00000000889	=$A$2*$A$3*$A$4*$A$5*$A$6*D24*E24
25			='BB12'!A40	='BB12'!E40	0.000000000103	=$A$2*$A$3*$A$4*$A$5*$A$6*D25*E25
26			='BB12'!A41	='BB12'!E41	0.00000000158	=$A$2*$A$3*$A$4*$A$5*$A$6*D26*E26
27			='BB12'!A42	='BB12'!E42	0.0000000000355	=$A$2*$A$3*$A$4*$A$5*$A$6*D27*E27
28			='BB12'!A43	='BB12'!E43	0.000000000332	=$A$2*$A$3*$A$4*$A$5*$A$6*D28*E28
29			='BB12'!A44	='BB12'!E44	0.00000000131	=$A$2*$A$3*$A$4*$A$5*$A$6*D29*E29
30			='BB12'!A45	='BB12'!E45	0.00000000181	=$A$2*$A$3*$A$4*$A$5*$A$6*D30*E30
31			='BB12'!A46	='BB12'!E46	0.000000000102	=$A$2*$A$3*$A$4*$A$5*$A$6*D31*E31
32			='BB12'!A47	='BB12'!E47	0.00000000107	=$A$2*$A$3*$A$4*$A$5*$A$6*D32*E32
33			='BB12'!A48	='BB12'!E48	0.00000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*D33*E33
34			='BB12'!A49	='BB12'!E49	0.000000000659	=$A$2*$A$3*$A$4*$A$5*$A$6*D34*E34
35			='BB12'!A50	='BB12'!E50	0.0000000000117	=$A$2*$A$3*$A$4*$A$5*$A$6*D35*E35
36			='BB12'!A51	='BB12'!E51	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D36*E36
37			='BB12'!A52	='BB12'!E52	0.0000000000226	=$A$2*$A$3*$A$4*$A$5*$A$6*D37*E37
38			='BB12'!A53	='BB12'!E53	0.0000000000116	=$A$2*$A$3*$A$4*$A$5*$A$6*D38*E38
39			='BB12'!A54	='BB12'!E54	0.0000000112	=$A$2*$A$3*$A$4*$A$5*$A$6*D39*E39
40			='BB12'!A55	='BB12'!E55	0.000000351	=$A$2*$A$3*$A$4*$A$5*$A$6*D40*E40
41			='BB12'!A56	='BB12'!E56	0.000000000449	=$A$2*$A$3*$A$4*$A$5*$A$6*D41*E41
42			='BB12'!A57	='BB12'!E57	0.000000000218	=$A$2*$A$3*$A$4*$A$5*$A$6*D42*E42
43			='BB12'!A58	='BB12'!E58	0.00000000225	=$A$2*$A$3*$A$4*$A$5*$A$6*D43*E43
44			='BB12'!A59	='BB12'!E59	0.0000000000088	=$A$2*$A$3*$A$4*$A$5*$A$6*D44*E44
45			='BB12'!A60	='BB12'!E60	0.00000000255	=$A$2*$A$3*$A$4*$A$5*$A$6*D45*E45
46			='BB12'!A61	='BB12'!E61	0.0000000000344	=$A$2*$A$3*$A$4*$A$5*$A$6*D46*E46
47			='BB12'!A62	='BB12'!E62	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D47*E47
48			='BB12'!A63	='BB12'!E63	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D48*E48
49			='BB12'!A64	='BB12'!E64	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D49*E49
50			='BB12'!A65	='BB12'!E65	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D50*E50
51			='BB12'!A66	='BB12'!E66	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D51*E51
52			='BB12'!A67	='BB12'!E67	0.00000000228	=$A$2*$A$3*$A$4*$A$5*$A$6*D52*E52
53			='BB12'!A68	='BB12'!E68	0.0000000132	=$A$2*$A$3*$A$4*$A$5*$A$6*D53*E53
54			='BB12'!A69	='BB12'!E69	0.00000000000982	=$A$2*$A$3*$A$4*$A$5*$A$6*D54*E54
55			='BB12'!A70	='BB12'!E70	0.000000000211	=$A$2*$A$3*$A$4*$A$5*$A$6*D55*E55
56			='BB12'!A71	='BB12'!E71	0.00000000639	=$A$2*$A$3*$A$4*$A$5*$A$6*D56*E56
57						
58						
59					Total Rem	=SUM(F13:F56)

	A	B	C	D	E	F
1	**Container Fire Event: Byron and Braidwood Isotopic: Table 11.1.10**					
2	0.00054	X/Q (sec/m^3)				
3	0.00035	Breathing Rate (m^3/sec)				
4	0.01	Release Fraction				
5	3700000000000	Conversion Factor (rem/Ci per Sv/Bq)				
6	6	Containers/Accident				
7	200	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	=F42	Total Inhalation Dose (rem)				
10						
11				60 day Decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			='BB11'!A28	='BB11'!E28	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D13*E13
14			='BB11'!A29	='BB11'!E29	0.00000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*D14*E14
15			='BB11'!A30	='BB11'!E30	0.00000000294	=$A$2*$A$3*$A$4*$A$5*$A$6*D15*E15
16			='BB11'!A31	='BB11'!E31	0.0000000591	=$A$2*$A$3*$A$4*$A$5*$A$6*D16*E16
17			='BB11'!A32	='BB11'!E32	0.0000000000903	=$A$2*$A$3*$A$4*$A$5*$A$6*D17*E17
18			='BB11'!A33	='BB11'!E33	0.0000000125	=$A$2*$A$3*$A$4*$A$5*$A$6*D18*E18
19			='BB11'!A34	='BB11'!E34	0.00000000198	=$A$2*$A$3*$A$4*$A$5*$A$6*D19*E19
20			='BB11'!A35	='BB11'!E35	0.00000000863	=$A$2*$A$3*$A$4*$A$5*$A$6*D20*E20
21			='BB11'!A36	='BB11'!E36	0.000000000726	=$A$2*$A$3*$A$4*$A$5*$A$6*D21*E21
22			='BB11'!A37	='BB11'!E37	0.000000004	=$A$2*$A$3*$A$4*$A$5*$A$6*D22*E22
23			='BB11'!A38	='BB11'!E38	0.00000000158	=$A$2*$A$3*$A$4*$A$5*$A$6*D23*E23
24			='BB11'!A39	='BB11'!E39	0.00000000131	=$A$2*$A$3*$A$4*$A$5*$A$6*D24*E24
25			='BB11'!A40	='BB11'!E40	0.00000000181	=$A$2*$A$3*$A$4*$A$5*$A$6*D25*E25
26			='BB11'!A41	='BB11'!E41	0.00000000107	=$A$2*$A$3*$A$4*$A$5*$A$6*D26*E26
27			='BB11'!A42	='BB11'!E42	0.00000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*D27*E27
28			='BB11'!A43	='BB11'!E43	0.00000000179	=$A$2*$A$3*$A$4*$A$5*$A$6*D28*E28
29			='BB11'!A44	='BB11'!E44	0.00000000000138	=$A$2*$A$3*$A$4*$A$5*$A$6*D29*E29
30			='BB11'!A45	='BB11'!E45	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D30*E30
31			='BB11'!A46	='BB11'!E46	0.00000000242	=$A$2*$A$3*$A$4*$A$5*$A$6*D31*E31
32			='BB11'!A47	='BB11'!E47	0.000000129	=$A$2*$A$3*$A$4*$A$5*$A$6*D32*E32
33			='BB11'!A48	='BB11'!E48	0.0000000112	=$A$2*$A$3*$A$4*$A$5*$A$6*D33*E33
34			='BB11'!A49	='BB11'!E49	0.000000351	=$A$2*$A$3*$A$4*$A$5*$A$6*D34*E34
35			='BB11'!A50	='BB11'!E50	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D35*E35
36			='BB11'!A51	='BB11'!E51	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D36*E36
37			='BB11'!A52	='BB11'!E52	0.00000000228	=$A$2*$A$3*$A$4*$A$5*$A$6*D37*E37
38			='BB11'!A53	='BB11'!E53	0.0000000132	=$A$2*$A$3*$A$4*$A$5*$A$6*D38*E38
39			='BB11'!A54	='BB11'!E54	0.00000000639	=$A$2*$A$3*$A$4*$A$5*$A$6*D39*E39
40						
41						
42					Total Rem	=SUM(F13:F39)

	A	B	C	D	E	F
1	**Container Fire Event: Byron and Braidwood Isotopic: Table 12.2.13**					
2	0.00054	X/Q (sec/m^3)				
3	0.00035	Breathing Rate (m^3/sec)				
4	0.01	Release Fraction				
5	3700000000000	Conversion Factor (rem/Ci per Sv/Bq)				
6	6	Containers/Accident				
7	200	Container Contact - Nominal Baseline Analysis (R/hr)				
8						
9	=F59	Total Inhalation Dose (rem)				
10						
11				60 day Decay		
12			Isotope	Ci in container	InhaleDCF	Dose (rem)
13			='BB12'!A28	='BB12'!E28	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D13*E13
14			='BB12'!A29	='BB12'!E29	0.00000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*D14*E14
15			='BB12'!A30	='BB12'!E30	0.000000101	=$A$2*$A$3*$A$4*$A$5*$A$6*D15*E15
16			='BB12'!A31	='BB12'!E31	0.00000000294	=$A$2*$A$3*$A$4*$A$5*$A$6*D16*E16
17			='BB12'!A32	='BB12'!E32	0.0000000591	=$A$2*$A$3*$A$4*$A$5*$A$6*D17*E17
18			='BB12'!A33	='BB12'!E33	0.0000000125	=$A$2*$A$3*$A$4*$A$5*$A$6*D18*E18
19			='BB12'!A34	='BB12'!E34	0.00000000123	=$A$2*$A$3*$A$4*$A$5*$A$6*D19*E19
20			='BB12'!A35	='BB12'!E35	0.00000000198	=$A$2*$A$3*$A$4*$A$5*$A$6*D20*E20
21			='BB12'!A36	='BB12'!E36	0.00000000863	=$A$2*$A$3*$A$4*$A$5*$A$6*D21*E21
22			='BB12'!A37	='BB12'!E37	0.0000000000274	=$A$2*$A$3*$A$4*$A$5*$A$6*D22*E22
23			='BB12'!A38	='BB12'!E38	0.000000004	=$A$2*$A$3*$A$4*$A$5*$A$6*D23*E23
24			='BB12'!A39	='BB12'!E39	0.00000000889	=$A$2*$A$3*$A$4*$A$5*$A$6*D24*E24
25			='BB12'!A40	='BB12'!E40	0.000000000103	=$A$2*$A$3*$A$4*$A$5*$A$6*D25*E25
26			='BB12'!A41	='BB12'!E41	0.00000000158	=$A$2*$A$3*$A$4*$A$5*$A$6*D26*E26
27			='BB12'!A42	='BB12'!E42	0.0000000000355	=$A$2*$A$3*$A$4*$A$5*$A$6*D27*E27
28			='BB12'!A43	='BB12'!E43	0.000000000332	=$A$2*$A$3*$A$4*$A$5*$A$6*D28*E28
29			='BB12'!A44	='BB12'!E44	0.00000000131	=$A$2*$A$3*$A$4*$A$5*$A$6*D29*E29
30			='BB12'!A45	='BB12'!E45	0.00000000181	=$A$2*$A$3*$A$4*$A$5*$A$6*D30*E30
31			='BB12'!A46	='BB12'!E46	0.000000000102	=$A$2*$A$3*$A$4*$A$5*$A$6*D31*E31
32			='BB12'!A47	='BB12'!E47	0.00000000107	=$A$2*$A$3*$A$4*$A$5*$A$6*D32*E32
33			='BB12'!A48	='BB12'!E48	0.00000000157	=$A$2*$A$3*$A$4*$A$5*$A$6*D33*E33
34			='BB12'!A49	='BB12'!E49	0.000000000659	=$A$2*$A$3*$A$4*$A$5*$A$6*D34*E34
35			='BB12'!A50	='BB12'!E50	0.0000000000117	=$A$2*$A$3*$A$4*$A$5*$A$6*D35*E35
36			='BB12'!A51	='BB12'!E51	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D36*E36
37			='BB12'!A52	='BB12'!E52	0.0000000000226	=$A$2*$A$3*$A$4*$A$5*$A$6*D37*E37
38			='BB12'!A53	='BB12'!E53	0.0000000000116	=$A$2*$A$3*$A$4*$A$5*$A$6*D38*E38
39			='BB12'!A54	='BB12'!E54	0.0000000112	=$A$2*$A$3*$A$4*$A$5*$A$6*D39*E39
40			='BB12'!A55	='BB12'!E55	0.000000351	=$A$2*$A$3*$A$4*$A$5*$A$6*D40*E40
41			='BB12'!A56	='BB12'!E56	0.000000000449	=$A$2*$A$3*$A$4*$A$5*$A$6*D41*E41
42			='BB12'!A57	='BB12'!E57	0.000000000218	=$A$2*$A$3*$A$4*$A$5*$A$6*D42*E42
43			='BB12'!A58	='BB12'!E58	0.00000000225	=$A$2*$A$3*$A$4*$A$5*$A$6*D43*E43
44			='BB12'!A59	='BB12'!E59	0.0000000000088	=$A$2*$A$3*$A$4*$A$5*$A$6*D44*E44
45			='BB12'!A60	='BB12'!E60	0.00000000255	=$A$2*$A$3*$A$4*$A$5*$A$6*D45*E45
46			='BB12'!A61	='BB12'!E61	0.0000000000344	=$A$2*$A$3*$A$4*$A$5*$A$6*D46*E46
47			='BB12'!A62	='BB12'!E62	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D47*E47
48			='BB12'!A63	='BB12'!E63	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D48*E48
49			='BB12'!A64	='BB12'!E64	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D49*E49
50			='BB12'!A65	='BB12'!E65	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D50*E50
51			='BB12'!A66	='BB12'!E66	0.00E+00	=$A$2*$A$3*$A$4*$A$5*$A$6*D51*E51
52			='BB12'!A67	='BB12'!E67	0.00000000228	=$A$2*$A$3*$A$4*$A$5*$A$6*D52*E52
53			='BB12'!A68	='BB12'!E68	0.0000000132	=$A$2*$A$3*$A$4*$A$5*$A$6*D53*E53
54			='BB12'!A69	='BB12'!E69	0.00000000000982	=$A$2*$A$3*$A$4*$A$5*$A$6*D54*E54
55			='BB12'!A70	='BB12'!E70	0.000000000211	=$A$2*$A$3*$A$4*$A$5*$A$6*D55*E55
56			='BB12'!A71	='BB12'!E71	0.00000000639	=$A$2*$A$3*$A$4*$A$5*$A$6*D56*E56
57						
58						
59					Total Rem	=SUM(F13:F56)

Computer Disclosure Sheet

Discipline Nuclear

Client: Exelon Corporation
Project: LaSalle Generating Station
IRSF Design Basis Event Dose Assessment

Date: August 2009
Job No. NCS0097

Program(s) used	Rev No.	Rev Date
Excel for Attachment Spreadsheets	N/A	N/A

Calculation Set No.: L-003430, Rev. 0

Status [ ] Prelim.
[X] Final
[ ] Void

URS Prequalification [ ] Yes
[X] No

Run No. Description:

Analysis Description: Spreadsheets were used to execute arithmetic manipulations of numbers, for various applications within the attachments of this analysis. As a first step, it was verified that the spreadsheets duplicated the calculated values. All of the inputs were checked for consistency with their source and their use, and all results were checked for consistency with expected values. Spreadsheet formula pages are included with the calculations.

The attached computer output has been reviewed, the input data checked,
And the results approved for release. Input criteria for this analysis were established.

By: On: 8/2009

Run by: W. Golden

Checked by: H. Rothstein

Approved by: D. Gardner

Remarks:
These spreadsheets were applied in a straight-forward manner and were hand checked.

Computer Disclosure Sheet

Discipline Nuclear

Client: Exelon Corporation
Project: LaSalle Generating Station
IRSF Design Basis Event Dose Assessment

Date: August 2009
Job No. NCS0097

Program(s) used	Rev No.	Rev Date
Microshield 8.01 (MC-201)	0	4/2009

Calculation Set No.: L-003430, Rev. 0

Status [ ] Prelim.
[X] Final
[ ] Void

URS Prequalification [X] Yes
[ ] No

Run No. Description:

Analysis Description: MicroShield was used to develop HIC isotope mixes and adjust them for decay and to produce a 200 R/hr HIC contact dose rate, for use of the resulting Curie levels for each isotope in the Excel spreadsheet. All of the inputs were checked for consistency with their source and their use, and all results were checked for consistency with expected values.

The attached computer output has been reviewed, the input data checked,
And the results approved for release. Input criteria for this analysis were established.

By: On: 8/2009

Run by: W. Golden

Checked by: H. Rothstein

Approved by: D. Gardner

Remarks:
The program was applied in a straight-forward manner and was hand checked.

ATTACHMENT 5

Calculation No. L-003429

LaSalle IRSF Storage Bay HIC Spacing to Prevent Spread of a Postulated HIC Fire

CC-AA-309-1001
Revision 5
Page 27 of 66

ATTACHMENT 1
Page 1 of 5

Design Analysis Major Revision Cover Sheet

Page 1 of 18

Design Analysis (Major Revision)		**Last Page No.** *18 / Att. J-1	
Analysis No.: [1]	L-003429	**Revision:** [2]	000
Title: [3]	IRSF Storage Bay HIC Spacing to Prevent Spread of a Postulated HIC Fire		
EC/ECR No.: [4]	375636	**Revision:** [5]	0
Station(s): [7]	LaSalle County Station	**Component(s):** [14]	
Unit No.: [8]	00	N/A	
Discipline: [9]	Mech		
Descrip. Code/Keyword: [10]	F02/F03 IRSF		
Safety/QA Class: [11]	Non-Safety		
System Code: [12]	N/A		
Structure: [13]	N/A		

CONTROLLED DOCUMENT REFERENCES [16]

Document No.:	From/To	Document No.:	From/To
EC 375636	~~From~~ To		~~From~~
	~~To~~		~~From~~
	~~From~~		~~From~~
	~~From~~		~~From~~

Is this Design Analysis Safeguards Information? [15] Yes ☐ No ☒ If yes, see SY-AA-101-106

Does this Design Analysis contain Unverified Assumptions? [17] Yes ☐ No ☒ If yes, ATI/AR#:

This Design Analysis SUPERCEDES: [18] None

Description of Revision (list affected pages for partials): [19] Initial Issue

Preparer: [20] Noani Propst (Print Name) — Noani Propst (Sign Name) — 09/28/09 (Date)

Method of Review: [21] **Detailed Review** ☒ **Alternate Calculations (attached)** ☐ **Testing** ☐

Reviewer: [22] Sam Dawoud, Licensed Fire Protection Engineer (Print Name) — (Sign Name) AL-22172 — 09.28.09 (Date)

Review Notes: [23] Independent review ☒ Peer review ☐ All inputs, assumptions, approaches, numerical analyses, and results were independently reviewed and checked.

(For External Analyses Only)

External Approver: [24] Donald Gardner (Print Name) — (Sign Name) — 09.28.09 (Date)

Exelon Reviewer: [25] Eric Ballou (Print Name) — Eric Ballou (Sign Name) — 11/13/09 (Date) **

Independent 3rd Party Review Reqd? [26] Yes ☒* No ☐

Exelon Approver: [27] DAN SCHMIT (Print Name) — D Schmit (Sign Name) — 11/19/09 (Date)

*Combined Independent 3rd Party Review / Chief Engineer Design Review provided by Gaines Bruce, Licensed Fire Protection Engineer

** Note: This cover sheet matches that in CC-AA-309-1001 rev. 5 (contains all the form information)

ATTACHMENT 1
Owners Acceptance Review Checklist for External Design Analysis
Page 1 of 1

DESIGN ANALYSIS NO. L-003429 **REV:** 0

		Yes	No	N/A
1.	Do assumptions have sufficient rationale?	☒	☐	☐
2.	Are assumptions compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
3.	Do the design inputs have sufficient rationale?	☒	☐	☐
4.	Are design inputs correct and reasonable with critical parameters identified, if appropriate?	☒	☐	☐
5.	Are design inputs compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
6.	Are Engineering Judgments clearly documented and justified?	☒	☐	☐
7.	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
8.	Do the results and conclusions satisfy the purpose and objective of the Design Analysis?	☒	☐	☐
9.	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
10.	Does the Design Analysis include the applicable design basis documentation?	☒	☐	☐
11.	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?	☒	☐	☐
12.	Are there any unverified assumptions?	☐	☒	☐
13.	Do all unverified assumptions have a tracking and closure mechanism in place?	☐	☐	☒
14.	Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change?	☒	☐	☐
15.	Do the sources of inputs **and** analysis methodology used meet current technical requirements and regulatory commitments? (If the input sources **or** analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent code)	☒	☐	☐
16.	Have vendor supporting technical documents and references (including GE DRFs) been reviewed when necessary?	☒	☐	☐
17.	Have margin impacts been identified and documented appropriately for any negative impacts (Reference ER-AA-2007)?	☐	☐	☒

EXELON REVIEWER: Eric Barron / [signature] **DATE:** 11/13/09
Print / Sign

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1. PURPOSE AND OBJECTIVE

This calculation was prepared for the Exelon Interim Radwaste Storage Facility (IRSF) at the LaSalle County Station, but it also applies to similar Exelon IRSFs such as at the Dresden and Quad Cities Stations. These IRSFs serve as the interim storage facility for Low Level Radioactive Waste (LLRW). These facilities are not safety-related and have no safe-shutdown function for the nuclear plants they are associated with. Currently, the IRSFs have several High-Density Polyethylene (HDPE) High-Integrity Containers (HICs) intended for long term storage. HDPE is considered a combustible material. Stored within these HDPE HICs are Class B and C radwaste resins, which contain approximately 40-50 percent water within the resin structure. The pure resin is also a combustible material.

A fire scenario in the IRSF storage area is not considered to be a realistic event, as there is no source for sustained ignition of the HDPE as would be required to initiate a fire in a HIC or group of stacked HICS. A stray spark landing on a HIC would be expected to self-extinguish rather than initiate a HIC fire. The HIC contents, with at least 40 percent water content, would be expected to smother the fire if it could reach them, rather than dry out and heat sufficiently from the energy release from a HDPE fire to reach the Auto-Ignition Temperature (AIT) and add to the fire loading. Sustainable ignition sources such as diesel fuel cannot be brought into the vicinity of the IRSF storage area; the adjacent truck bay is isolated from the storage area by thick concrete walls, with the only openings high above the floors of the truck bay and storage area. Any fire in the truck bay while manned for truck movement and unloading/loading due to the presence of transient combustibles would be extinguished by manual actions before the storage area could be affected. However, a fire is postulated to occur in the IRSF storage area for a group of HICS and their contents as a conservative measure. Currently, no automatic detection or suppression system is installed in the IRSF storage bay, and manual suppression systems are not credited because the postulated fire could be beyond the reach of human response due to storage area inaccessibility from the truck bay area. The purpose of this analysis is to determine a minimum horizontal separation distance between stored HICs to prevent spreading any postulated fire to another HIC or group of HICs in the IRSF storage area.

The postulated fire considered is conservatively of 3 bare (i.e., HDPE with no steel shell) double-stacked containers, for a total of 6 containers on fire. These containers are assumed to all be exposed to the fire simultaneously to form a pool fire diameter of 13.1 feet, according to the configuration layout as shown in Figures 1 and 2.

2. METHODOLOGY AND ACCEPTANCE CRITERIA

This calculation is based on the methodology developed under Fire Dynamics Tools (FDT) Quantitative Fire Hazard Analysis Method for U.S. Nuclear Regulatory Commission Fire Inspection Program (NUREG – 1805, October 2004), Reference [1]. The NRC Section 5.3.2 method for *Solid Flame Radiation Model equations for horizontal and vertical target orientations at ground level with no-wind conditions,,*is the method that was applied, as the target HICs have exactly the same elevation as the HICs assumed to be on fire.

As mentioned above, no details of potential ignition sources are provided since the existing IRSFs have no possible fire exposure due to the isolation from humans or equipment failures, but the worst-case scenario is postulated with the assumption that a HIC group fire occurs. Radiative heat flux on a target HIC decreases with distance from burning HIC(s). The criteria for preventing ignition of the adjacent HIC is to specify the minimum distance that results in a maximum exposing radiative heat flux at a level below which ignition cannot occur. According to Janssens' definition, "the minimum heat flux for ignition, q''_{min}(dot) is the heat flux below which the ignition under practical conditions (in bench scale test or a real fire) cannot occur" (Reference [5] *page 2)*.

The group of 6 HDPE HICs and their contained resin is assumed to be the combustible material involved in the fire.

3. ASSUMPTION

- The proposed HIC storage arrangement is shown in Figure 2.
- The area of fuel on fire is assumed to be a circular pool involving horizontal, upward facing, combustible fuel, which will form a dike or curing geometry. See Figures 1 and 2.
- The postulated fire is assumed to freely burn due to the configuration space available (there are no fire barriers to contain the fire). Oxygen depletion is not considered in this storage area. In addition, the HIC fire scenario is far from the storage area wall. Moisture effects on the fire are disregarded for conservatism.
- Although the IRFS is ventilated by a Heating, Ventilation, and Air Conditioning (HVAC) system to maintain a temperature range of approximately 45-120°F (see LaSalle IRSF LAR Support Technical Report Supporting EC DCR No. 375636, section 4.6 of Attachment E), the air flow rate in the vicinity of the HICs is low so the HVAC system is considered to not participate in the fire growth rate and a wind-free storage environment is assumed.
- A postulated piloted fire (i.e., with the presence of an ignition source) will start uniformly in one (1) bare HDPE HIC and then spread uniformly to five (5) other bare HICs, resulting in a fire configuration as shown on Figures 2 and 3 of three double-stacked HICs stored adjacent to each other. The pool fire diameter is assumed to form a circular area with all containers enclosed.
- There is conservatively no fire growth period; i.e., the maximum heat release rate (HRR) occurs instantaneously.
- The HICs are HDPE PL8-120B containers assumed to weight 950 lbs, per the manufacturer (although part of this weight includes internal dewatering legs that will be surrounded by resin, for conservatism, the calculation includes the dewatering legs participation in the fire analysis). See Attachment B- Empty HIC Weight Energy Solutions Memo.
- The HDPE empirical constant $k\beta$ is assumed to have a value of 100 m^{-1} as a conservative estimate since the exact values are not defined according to Reference [1]. The Attachment C- Polypropylene Material Property value is utilized, as the most similar to HDPE of those listed. This empirical constant is used to calculate the Heat Release Rate.
- The heat dissipated vertically (convection energy release rate) is conservatively assumed to be 40% of the total heat generated; the heat dissipated by radiation to the surrounding HICs is conservatively assumed to be 30% of the total heat generated; furthermore, 30% of the total heat generated is assumed to sustain the combustion reaction, Reference [2].

4. DESIGN INPUT

4.1 HIC Dimension

A standard HDPE PL8-120 container dimension is 61 inches (1.55 meter) diameter, 74.5 inches (1.90 meter) high, and ½ inch (12.7 mm) thick (see Attachment B). The HDPE HIC total weight is 950 lbs (430.91 kg). These containers are equipped with grapple-able lifting steel elements that support the weight when the container is lifted. A steel stacking plate is used for the two-high stackable basket support.

The container is determined to be a thermally thick inert solid, as per the following formula, Reference [5]:

$L_o / \sqrt{(\alpha t_{ig})} \geq 4$

α = thermal diffusivity, evaluated at the ignition
t_{ig} = ignition temperature (^oC)
L_o = thickness of the solid (m)

Where
$\alpha = k/\rho c$

The thermal inertia, $k\rho c$, is 1.57 kW^2s/m^4K^2 (see Attachment D – Compilation of Experimental Data).

4.2 Pool Fire Diameter

It is assumed that HDPE will melt and burn forming a pool fire. See Figure 1, extracted from Reference [8].

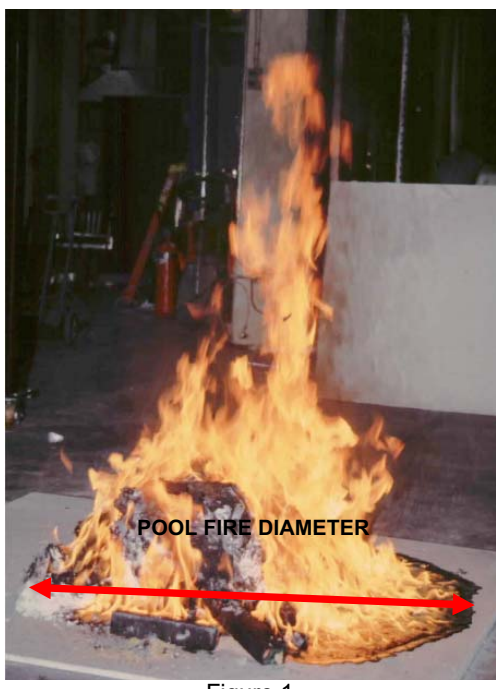


Figure 1

A combined pool fire diameter for three double-stacked adjacent HICs simultaneously burning is 13.1 ft. See Figure 2.

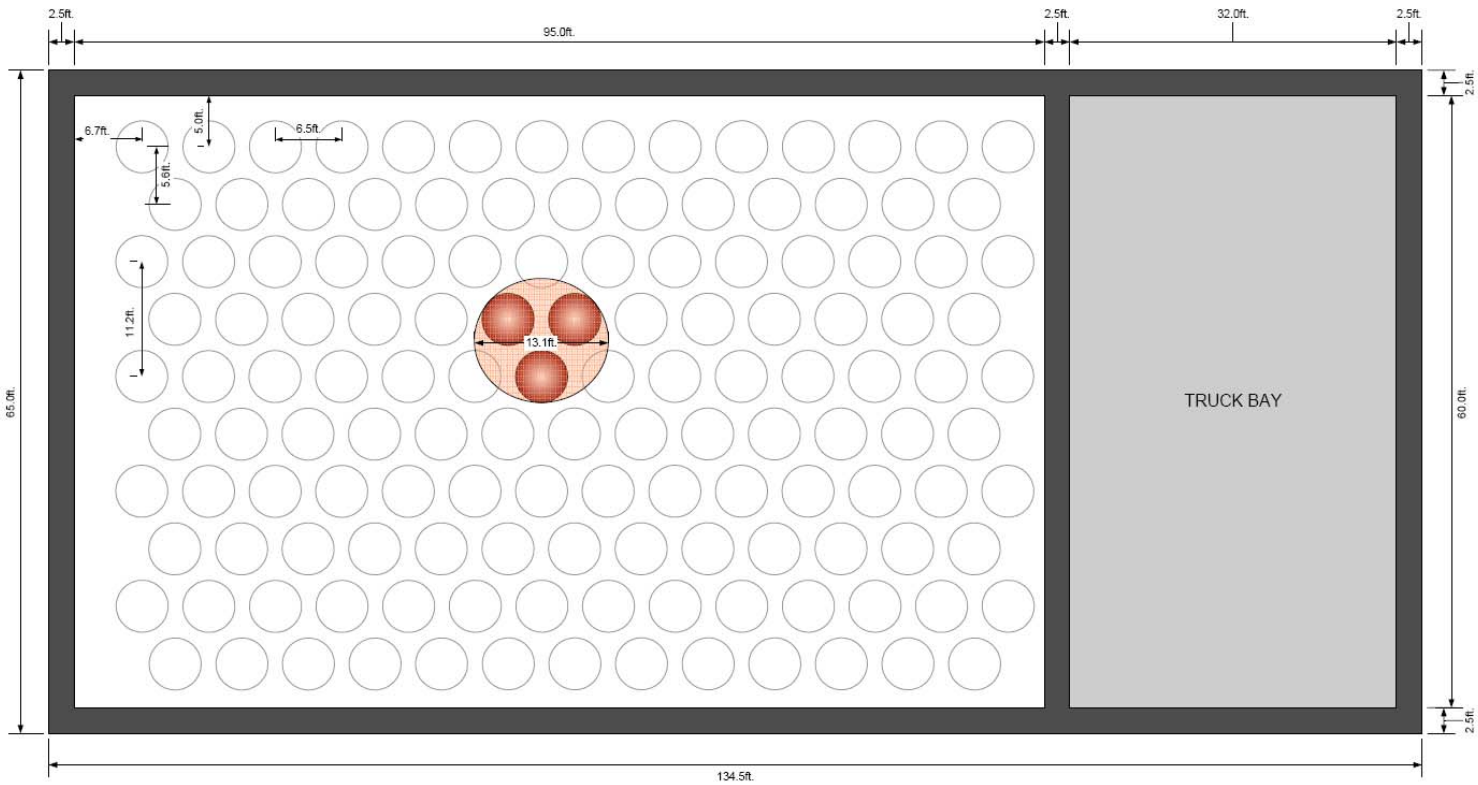


Figure 2 – HIC Configuration on IRSF Storage Bay

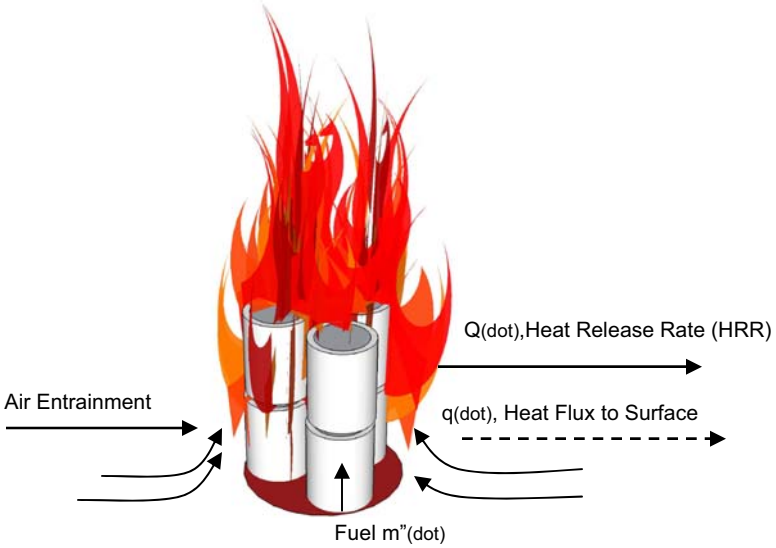


Figure 3 –Features of a Pool Fire
Reference [1], section 3-7

4.3 HDPE Properties

HDPE material properties are obtained from multiple references, and multiple values of the same material property can change the results of this calculation. For this reason, a safety factor is included in the calculations and for some material property values to provide a conservative value of the minimum safe distance required to prevent ignition by radiative heat in the adjacent uninsulated HIC.

- The specific gravity of HDPE is approximately 0.965, Reference [3]. See Attachment E- HDPE Physical and Chemical Data.

- The flash point temperature obtained experimentally is 608°F (320°C), Reference [5]. See Attachment D- Compilation of Experimental Data.

- The mass burning rate of fuel, m", is 0.018 kg/m^{2}sec, Reference [1] , See Attachment C, *Table 3-2 Large-Pool Fire Burning Rate Data*. This value for HDPE is based on polypropylene similar properties.

- The complete heat of combustion of polyethylene is 46,500 kJ/kg, Reference [1], *Table 8-1 Thermal Properties of Common Solid Combustible Material*. See Attachment F- Thermal Properties of Common Solid Combustible Materials. This value is conservatively used as the effective heat of combustion of polyethylene. The difference between the complete heat of combustion and effective heat of combustion according to Reference [1], page 3-5, is that the complete heat of "combustion leaves no residual fuel and releasing all of the chemical energy of the material" ,instead of the effective heat of combustion, the measured of energy released when "combustion is not necessarily complete and some residue remains".

- The empirical constant kβ is assumed to be 100 m^{-1} for conservatism based on polypropylene similar properties, Reference [1] *Table 3-2 Large-Pool Burning Rate Data (Babrauskas, 2002, © SFPE*). See Attachment C –Polypropylene Material Property.

- Material properties values are based on tests from a quiescent environment using a blackened material surface to maximize the surface absorptivity, thus minimizing the ignition temperature and the minimum heat flux for ignition, Reference [5]. Therefore, these values obtained by Reference [5] are considered conservative. According to SFPE, Reference [5] pg 2, the values used in this calculation are considered conservative, and "no additional safety factor is necessary for the minimum allowable radiation to prevent ignition"

- The lowest thermal load per unit area of initiating a combustion reaction on the HDPE is given by the critical heat flux, q''_{crit}(dot), and this value is 6.2 kW/m^2 , Reference [1] *table 3*. See Attachment D- Results from Several Different Materials Correlated Using the Flux Time Product.

- The minimum heat flux for ignition, q''_{min}(dot), is 15 kW/m^2, Reference [5] *table 1*. See Attachment H- Collection of Data by Tewarson Giving Minimum Heat Flux and Thermal Response Parameter Values.

- One-dimensional heat transfer through the solid with radiant heating on the surface.

- The radiative fraction, $\chi\rho$, is 0.3, Reference [2].

- The thermal conductivity is 0.45 W/m K, and the specific heat is 1,900J/ K kg, reference [6].

- The thermal inertia is 1.57 (kW/m^2 K)^2, Reference [5]. See Attachment D.

4.4 Resins Properties

For conservatism, the resins material properties are assumed to be the same as HDPE material properties. The maximum mass of resins stored in a HIC is approximately 6,500 lb.

5. REFERENCES

[1] Fire Dynamics Tools (FDTs): Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program, NUREG-1805, NRC, N. Iqbal, M.H. Salley, October 2004.

[2] Introduction to Fire Dynamics 2nd edition, Dougal Drysdale 1999.

[3] High Density Polyethylene Material Safety Data Sheet, National Petochemical Company, Edit No. 01, ET/HSE/050.

[4] Fire Protection Handbook edition 19, A. Cote, C. Grant, J. Raymond Hall. NFPA, 2003.

[5] Engineering Guide: Piloted Ignition Solid Materials Under Radiant Exposure, SFPE, January 2002.

[6] Test on Flammability of Polyethylene, P.S. Flower, December 21, 2004.

[7] Powdex PCM Material Safety Data Sheet, Graver Technologies.

[8] Heat Release Rate Test of Plastic Trash Containers, D.W. Stroup and D. Madrzykowski, U.S. Department of Commerce National Institute of Standards and Technology, April 24, 2003.

[9] Waste Containers for Extended Storage of Class A, B and C Wastes, EPRI, Rev 1.

6. CALCULATIONS

Note:
The values determined in this analysis were calculated using a Microsoft™ Excel™ spreadsheet, and are calculated to a greater number of significant figures than presented in this document. Full details of the equations and analysis can be seen by referring to the spreadsheet included as Attachment A.

Conversion Factors

Table 7.1

To Convert from	To		Multiply by
Feet	Meter	=	0.3048
Pounds Mass	Kilogram	=	0.45359
^oF	^oC	=	$5/9^oF - 32$
BTU/lb	kJ/kg	=	2.325
kW	BTU/sec	=	0.94782
kW/m^2	BTU/ft^2 sec	=	0.08805

Estimating Radiant Heat Flux from Fire to a Target Fuel at Ground Level under Wind-Free Condition Point Source Radiant Model (Reference [1], *Spreadsheet 05.1 Heat Flux Calculation Wind Free, Solid Flame 1*)

The following methods are carefully selected using professional judgment to ensure both conservatism in results and industry-expert and NRC acceptability.

6.1 HIC Surface Area

Cylinder Surface Area

$$A_{HIC} = (2\pi r^2 + 2\pi r h_c)$$

Where,
A_{HIC} = surface area of pool fire of one HIC (m^2)
r = d/2 = radius of the container (m)
h_c = height of the container (m)

$$A_{HIC} = (2\pi (1.55\ m/2)^2 + 2\pi (1.55\ m/2) * (1.89\ m)) = 12.97\ m^2$$

6.2 HDPE HIC Material Volume

Volume of an empty cylinder

V = volume of sides + volume of top and bottom
$= (\pi (r^2 - r_o^2) h_c) + (2 \pi r^2 T)$

Where,
V = volume of the container (m^3)
r = d/2 = radius of the container (m)
r_o = (r – T)= empty radius of the container (m)
T = thickness of the container (m)
h_c = height of the container (m)

$V = \pi ((0.77\ m)^2 - (0.77\ m - 0.0127\ m)^2) * (1.89\ m) + 2\pi (0.77\ m)^2 * (0.0127\ m)$
$= 0.16\ m^3$

6.3 Pool Fire Diameter

A pool fire diameter based on a circular shape is determined assuming that all 6 HICs burn together forming a large dike diameter on the floor. See Figure 2.

$D = 3.99\ m$

6.4 Surface Area of Pool Fire

HDPE material decomposes in a manner similar to liquids forming a horizontal, upward-facing pool fire. Since in this case six containers are simultaneously burning, it is predicted that an addition of all the containers will form a single combined cylinder area of pool fire.

$A_{dike} = 2\pi R^2$

Where,
A_{dike} = surface area of pool fire of combined HICs (m^2)
R = D/2 = radius of circle formed by all the containers (m), see Figure [2].

$A_{dike} = (2\pi (3.99\ m/2)^2 = 12.52\ m^2$

6.5 Heat Release Rate Calculation (HHR)

The average burning rate of combustible materials has been experimentally determined in free-burning tests. The burning rate is reported as horizontal burning area in units of kg/m^2-sec.

$Q_{(dot)} = m'' \Delta H_{c,eff} (1 - e^{-k\beta D}) A_{dike}$

Where,
$Q_{(dot)}$ = pool fire heat release rate (kW)
m" = mass burning rate of fuel per unit surface area (kg/m^2-sec)
$\Delta H_{c,eff}$ = effective heat of combustion of fuel (kJ/kg)
A_{dike} = surface area of pool fire (area involved in vaporization) (m^2)
$k\beta$ = empirical constant (m^{-1})
D = diameter of pool fire (diameter involved in vaporization, circular pool is assumed) (m)

$Q_{(dot)} = (0.018\ kg/m^2 sec) * (46{,}500\ kJ/kg) * (1 - e^{-100\ m_{-1} * 3.99\ m}) * (12.52\ m^2) =$
$10{,}480.64\ kW * 0.94782 = 9{,}934\ Btu/sec$

The HDPE container HHR is 10,480.64 kW (~10.5 *MW*).

6.6 Heat Release Rate per Unit Length of Fire Calculation

The HHR per unit length can be calculated assuming the horizontal fire source length.

$l \times w = A_{dike} = 12.52\ m^2$

$l = \sqrt{(12.52\ m^2)} = 3.54\ m$

$Q' = Q_{(dot)} / l$

$Q' = 10{,}480.64\ kW / 3.54\ m = 2{,}961.81\ kW/m$

6.7 Flame Height Calculation

The flame height depends on whether the flame is laminar or turbulent. Laminar flames are shorter than turbulent flames. As a plume of hot gases rises above a flame, the temperature, velocity and width of the plume changes as the plume mixes with the surroundings. The height and temperature of the flame are important in estimating the ignition of adjacent combustibles. Flame height is defined as the flame observed at least 50 percent of the time. See Figure 3, extracted from Reference [8].

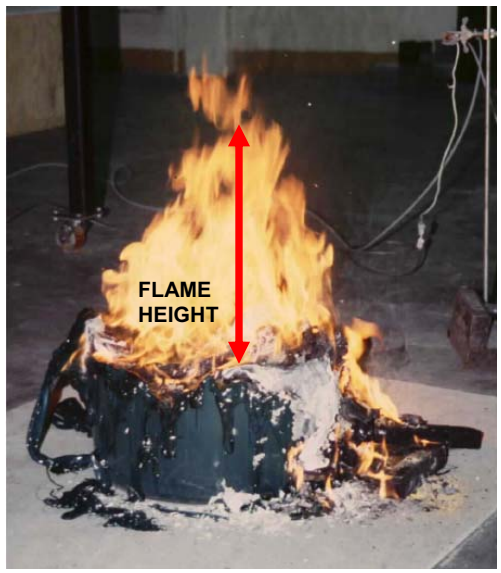


Figure 3

Several calculation methods are available for determining this flame height; the Heskestad method is used in this calculation as evaluation shows that it provides conservative results.

Heskestad Method (1995)

$H_f = 0.235\ Q_{(dot)}^{2/5} - 1.02\ D$

Where,
H_f = flame height (m)
$Q_{(dot)}$ = heat release rate of the fire (kW)
D = Diameter of pool fire (m)

$H_f = 0.235\ (10{,}480.64\ kW)^{2/5} - 1.02\ (3.99\ m) = 5.46\ m * 3.281 = 13.98$ ft

6.8 Emissive Power

Emissive Power is the total radiative power leaving the surface of the fire per unit area per unit time based on Stefan's law. Since the temperature is not well defined, Shokri and Beyler (1989) correlated experimental data of flame radiation to external targets in terms of an average power of the flame. For conservatism, the HDPE container is assumed to be a black body, having a cylindrical flame, acting as a homogeneous radiator with an average emissive power. Emissive power is inversely dependent on the pool diameter only, as follows:

$E = 58\ (10^{-0.00823D})$

Where,
E = Flame emissive power (kW/m^2)
D= diameter of pool fire (m)

$E = 58\ (10^{-0.00823 \times 3.99\ m}) = 53.77\ kW/m^2 * 0.08805 = 4.74\ Btu/ft^2 sec$

The flame emissive power is calculated to be 4.74 $Btu/ft^2 sec$ (53.77 kW/m^2) and represents the average emissive power over the whole flame.

6.9 Minimum Spacing Calculation

6.9.1 View Factor

The configuration factor is a geometrical value that provides the fraction of the radiation leaving one surface that strikes another surface directly. The value varies between 0 and 1 according to the target location, flame height, and pool fire diameter. When a target approaches the flame, the configuration factor approaches 1. The flame is based on a cylindrical shape (see Figure 4). The target containers are at the same ground level as the burning containers, therefore the following are considered:

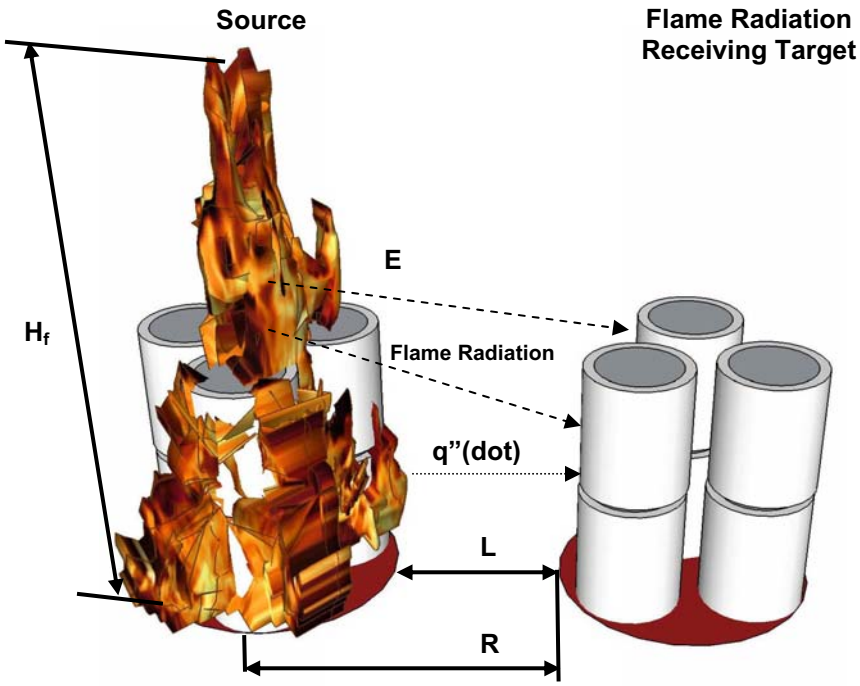


Figure 4

$q''(dot) = E*F_{1\rightarrow 2,\ Max\ (no\ wind)}$ or $F_{1\rightarrow 2,\ Max\ (no\ wind)} = q''(dot)/E$

Where,
q"(dot) = incident radiative heat flux or critical heat flux (kW/m^2)
E = average emissive power at flame surface (kW/m^2)
$F_{1\rightarrow 2,\ Max\ (no\ wind)}$ = configuration factor

$F_{1\rightarrow 2,\ Max\ (no\ wind)} = 15\ kW/m^2 / 53.77\ kW/m^2 = 0.279$

Since the configuration factor is considered a 2-dimensional value, the following equations describe the horizontal and vertical behavior of the configuration fraction.

$$F_{1\rightarrow 2,\ Max\ (no\ wind)} = \sqrt{(F_{1\rightarrow 2,\ H}^2 + F_{1\rightarrow 2,\ V}^2)}$$

$$F_{1\rightarrow 2,\ H} = \frac{(B-1/S)}{\pi\sqrt{(B^2-1)}} \tan^{-1}\sqrt{\frac{(B+1)*(S-1)}{(B-1)*(S+1)}} - \frac{(A-1/S)}{\pi\sqrt{(A^2-1)}} \tan^{-1}\sqrt{\frac{(A+1)*(S-1)}{(A-1)*(S+1)}}$$

$$F_{1\rightarrow 2,\ V} = \frac{1}{\pi S}\tan^{-1}\left(\frac{h}{\sqrt{(S^2-1)}}\right) - \frac{h}{\pi S}\tan^{-1}\sqrt{\frac{(S-1)}{(S+1)}} + \frac{Ah}{\pi S\sqrt{(A^2-1)}}\tan^{-1}\sqrt{\frac{(A+1)*(S-1)}{(A-1)*(S+1)}}$$

Where A, B, S, and h are mathematical constants and calculated as follows:

$$A = \frac{h^2 + S^2 + 1}{2S},\quad B = \frac{1 + S^2}{2S},\quad S = \frac{2R}{D},\quad h = \frac{2H_f}{D}$$

R = the distance between the center of the cylinder (flame) to the target (m)

H_f = the height of the cylinder (flame) (m)
D = the cylinder (flame) diameter (m)

These values are determined when the distance between the center of the cylinder flame to the target, R, is known. The following describes the relation between R and L according to Figure 4.

R = L + D/2

Where,

R= distance from center of the pool fire to edge of the target (m)
L = distance between pool fire and target (m)
D = pool fire diameter (m)

In this case, these values are unknown; therefore, due to the complexity of this mathematical equation, Excel "goal seeking" is used to calculate both vectors $F_{1\to2,\ H}$ and $F_{1\to2,\ V}$, and the minimum distance R. The following are the results obtained (see Attachment A):

L= 2.022*m* / 0.3048 = 6.64 ft

R = 2.022 *m* + 3.99*m*/2 = 4.019*m* /0.3048 = 13.19 *ft*

h= (2*(5.46*m*))/3.99 m = 2.735

S= 2* (4.019 *m*) /3.99 *m* = 2.013

A = ($(2.013)^2$ +($2.735)^2$ + 1)/ (2* 2.013) = 3.113
B= (1 + 2.013^2)/ (2 * 2.013) = 1.255

$$F_{1\to2,\ H} = \frac{(1.255-1/2.013)}{\pi\sqrt{(1.255^2-1)}}\tan^{-1}\sqrt{\frac{(1.255+1)*(2.013-1)}{(1.255-1)*(2.013+1)}} - \frac{(3.113-1/2.013)}{\pi\sqrt{(3.113^2-1)}}\tan^{-1}\sqrt{\frac{(3.113+1)*(1.255-1)}{(3.113-1)*(1.255+1)}}$$

= 0.141

$$F_{1\to2,\ V} = \frac{1}{\pi*2.013}\tan^{-1}\left(\frac{2.735}{\sqrt{(2.013^2-1)}}\right) - \frac{(2.735)}{\pi*2.013}\tan^{-1}\sqrt{\frac{(2.013-1)}{(2.013+1)}} + \frac{3.113*(2.735)}{\pi*2.013\sqrt{(3.113^2-1)}}\tan^{-1}\sqrt{\frac{(3.113+1)*(2.013-1)}{(3.113-1)*(2.013+1)}}$$

= 0.242

$F_{1\to2,\ Max\ (no\ wind)} = \sqrt{(0.141^2 + 0.242^2)} = 0.280$

The results indicate that the minimum safe distance from the edge of a container to the edge of the other container is 6.64 ft (2.022 m).

Following the spreadsheet and its formula version, Attachment A also contains this minimum spacing calculation and other calculated fire parameters of interest.

7. SUMMARY OF RESULTS AND CONCLUSIONS

This analysis determined a conservative spacing of bare HDPE HICs such that a postulated fire burning the containers for 3 HICs double-stacked would not spread to adjacent bare HDPE HICs. The methodology selected is based on the *Fire Dynamics Tools (FDT^s)-NUREG 1805,* Reference [1], ***Spreadsheet 05.1 Heat Flux Calculation Wind Free, Solid Flame 1*, based on the cylindrical configuration of the fire and same elevation level as the target**. The level of conservatism includes significant safety factors for these geometrical configuration calculated values, since conservative material properties, design layout and method of approach are taken into account. The following list summarizes some of the conservative numbers in this calculation:

- The postulated fire consists of 6 HICs with all of their HDPE considered to be included as the fire source
- The value of the minimum heat flux for ignition is obtained from the SFPE Engineering Guide for piloted ignition and based on a blackened surface to maximize the surface absorptivity, which, per the Guide, is conservative and therefore “no additional safety factor is necessary for the minimum allowable radiation to prevent ignition”.
- No fire growth period.
- Use of the 100 m^{-1} as the empirical constant.
- One dimensional heat transfer through the solid with radiant heating on the surface.
- Effective Heat of Combustion 46,500 kJ/kg.
- Diameter of pool fire is 13.1 feet.

The result is that maintaining a minimum distance of approximately 6.64 *feet* (2.0222 *m*) between adjacent bare HDPE HICs should ensure that even an incredible fire completely consuming a group of 3 HICs double-stacked would not spread to adjacent bare HDPE HICs in an IRSF.

ATTACHMENT A- CALCULATION SPREADSHEETS

Excel Spreadsheet Calculation (Separate File)

Exelon IRSF

August 6, 2009

ESTIMATING RADIANT HEAT FLUX FROM FIRE TO A TARGET FUEL AT GROUND LEVEL UNDER WIND-FREE CONDITION POINT SOURCE RADIATION MODEL
3 CONTAINERS ON FIRE - DOUBLE-STACKED

Entered by User
Fuel Properties
Calculated

INPUT PARAMETERS

HIC Diameter	5.08	ft	1.55	m
Pool of Fire Diameter (6 HICs)	13.1	ft	3.99	m
HIC Height	6.21	ft	1.89	m
Thickness of Container	0.0417	ft	0.013	m
Radiatice Fraction χ_r	0.3			
Initial Temperature (T_o)	77	°F	25	°C

THERMAL PROPERTIES

Fuel	Mass Burning Rate m"(kg/m^2-sec)	Heat of Combustion $\Delta H_{c,eff}$ (kJ/kg)	Empirical Constant kβ (m^{-1})	Critical Heat Flux (kW/m^2)	Density (kg/m^3)	Thermal Conductivity (Wm^{-1} ^{o} K^{-1})	Specific Heat (J^{o}K^{-1}kg^{-1})	Ignition Temp (^{o}C)	Minimum Heat Flux for Ignition q"$_{min}$(dot) (kW/m^2)	Thermal inertia (kW/m^2 K)^2	TRP (kW/m^{2}s$^{1/2}$)(flamm)	Flux Time Product Index (n)
High Density Polyethylene	0.018	46500	100	6.2	965	0.45	1900	320	15	1.57	321	1
Resins	0.018	46500	100	6.2	965	0.45	1900	320	15	1.57	321	1

Radius of the Container	2.5	ft	0.77	m
Radius of the Pool Fire	6.6	ft	2.00	m
HIC Surface Area(A_{HIC})	139.64	ft^2	12.97	m^2
Fuel Area or Dike Area (A_{dike})	134.78	ft^2	12.52	m^2
Volume of the Container	5.79	ft^3	0.16	m^3

Mass Burning Rate of Fuel (m")	0.018	kg/m^2-sec
Effective Heat of Combustion of Fuel ($\Delta H_{c,eff}$)	46,500	kJ/kg
Empirical Constant (kβ)	100	m^{-1}
Air Density at 25 ^{o}C	1.184	kg/m^3

ESTIMATING RADIATIVE HEAT FLUX TO A TARGET FUEL

Pool Fire Diameter Calculation

D = 3.99 m 13.10 ft

Heat Release Rate Calculation

$Q_{(dot)} = m''\Delta H_{c,eff}(1 - e^{-k\beta D}) A_{dike}$

Where
$Q_{(dot)}$ = pool fire heat release rate (kW)
m" = mass burning rate of fuel per unit surface area (kg/m ^{2}-sec)
ΔH_c = effective heat of combustion of fuel (kJ/kg)
A_{dike} = surface area of pool fire (area involved in vaporization) (m ^{2})
kβ = empirical constant (m^{-1})
D = diameter of pool fire (diameter involved in vaporization, circular pool is assumed) (m)

HRR

$Q_{(dot)}$ = 10,480.64 kW 9,934 Btu/sec

Heat Release Rate Per Unit Length of Fire Calculation

Q'= Q/l

Where
Q' = heat release rate per unit leght (KW/m)
$Q_{(dot)}$ = fire heat release rate of the fire (kW)
l = length of the fire source (m)

Fire Source Length Calculation

l x w = A_{dike}

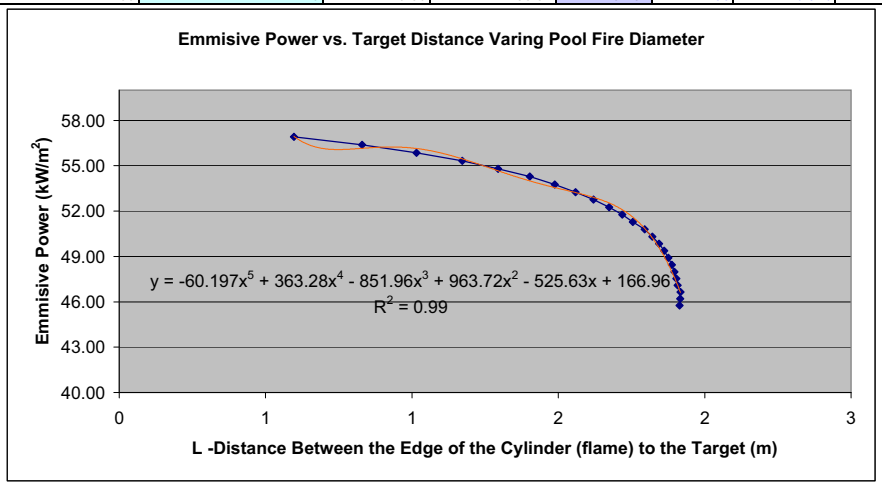
l= 3.54 m

Q' = 2,961.81 kW/m

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
72		**Flame Height Calculation**												
73														
74			**Heskestad Method (1995)**											
75														
76			$H_f = 0.235\ Q_{(dot)}^{2/5} - 1.02\ D$											
77														
78			Where,											
79			H_f = flame height (m)											
80			$Q_{(dot)}$ = heat release rate of the fire (kW)											
81			D =Diameter of pool fire(m)											
82														
83		H_f	5.46 m			17.91 ft								
84														
85														
86			**Thomas Method (1962)**											
87														
88			$H_f = 42 \times D[\ m''/\ (\rho_a\ \sqrt{(g \times D)})]^{0.61}$											
89														
90			Where,											
91			H_f = flame height (m)											
92			D = Diameter of pool fire (m)											
93			g= gravitational acceleration (m/sec^2)											
94			ρ_a = ambient air density (kg/m^3)											
95														
96		H_f	4.26 m			13.98 ft								
97														
98		**Emissive Power**												
99		$E = 58\ (10^{-0.00823D})$												
100		Where,	E = Flame emissive power (kW/m^2)											
101			D= diameter of pool fire (m)											
102														
103		E =	53.77 kW/m^2			4.74 Btu/ft^2-sec								
104														
105														
106		**Distance from the Center of the Pool Fire to Edge of the Target Calculation**												
107														
108		R = L + D/2												
109		Where	R = distance from center of the pool fire to edge of the target (m)											
110			L = distance between pool fire and target (m)											
111			D = pool fire diameter (m)											
112														
113		R =	4.019 m			13.19 ft		→	Goal seek method					
114														
115		L =	2.022 m			6.64 ft			R is obtained by manually inserting the view factor calculated value (C155 cell has to be equal to C129 cell) in the "goal seek" under tools by varing the R (C133)					
116														
117		**View Factor**												
118														
119		$q'' = E^*F_{1\text{->}2,Max}$												
120		or												
121		$F_{1\text{->}2,H} = q''/E$												
122			Where,											
123			$F_{1\text{->}2,H}$ = configuration factor											
124			q'' = incident radiative heat flux or critical heat flux (kW/m^2)											
125			E = emissive power											
126														
127		$F_{1\text{->}2,Max}$	0.279											
128														
129		$F_{1\text{->}2,H}$ =	$(B-1/S)/\pi(B^2-1)^{1/2} \tan^{-1}((B+1)(S-1)/(B-1)(S+1))^{1/2} - (A-1/S)/(\pi(A^2-1)^{1/2}) \tan^{-1}((A+1)(S-1)/(A-1)(S+1))^{1/2}$											
130		$F_{1\text{->}2,V}$ =	$1/(\pi S) \tan^{-1}(h/(S^2-1)^{1/2}) - (h/\pi S) \tan^{-1}((S-1)/(S+1))^{1/2} + Ah/\pi S(A^2-1)^{1/2} \tan^{-1}((A+1)(S-1)/(A-1)(S+1))^{1/2}$											
131		A =	$(h^2+S^2+1)/2S$											
132		B =	$(1+S^2)/2S$											
133		S =	2R/D											
134		h =	$2H_f/D$											
135		$F_{1\text{->}2,max}$ =	$\sqrt{(F^2_{1\text{->}2,H} + F^2_{1\text{->}2,V})}$											
136														
137		Where	$F_{1\text{->}2,H}$ = horizontal view factor											
138			$F_{1\text{->}2,V}$ = vertical view factor											
139			$F_{1\text{->}2,max}$ = maximum view factor											
140			R = distance from center of the pool fire to edge of the target (m)											
141			H_f = height of the pool fire flame (m)											
142			D = pool fire diameter (m)											
143														
144														
145														
146		S =	2.013											
147		h =	2.735											
148		A =	3.113											
149		B =	1.255											
150														
151		$F_{1\text{->}2,H}$ =	0.141											
152		$F_{1\text{->}2,V}$ =	0.242											
153		$F_{1\text{->}2,Max}$ =	0.280	Check Value. Proceed if value is in the +/-5% error range										
154														

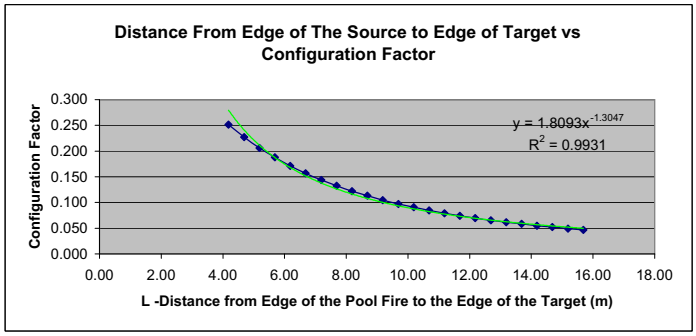
Table of Distance vs Emissive Power Where the Pool Diameter Varies

Pool Fire Diameter (m)	R	L	Emmisive Power (kW/m^2)	View Factor	S	h	A	B	$F_{1->2,H}$	$F_{1->2,V}$	$F_{1->2,Max}$
12.50	8.16	1.91	45.77	0.328	1.306	0.874	1.328	1.036	0.231	0.371	0.437
12.00	7.92	1.92	46.20	0.325	1.319	0.910	1.352	1.039	0.228	0.367	0.432
11.50	7.67	1.92	46.64	0.322	1.333	0.950	1.380	1.042	0.225	0.364	0.428
11.00	7.41	1.91	47.09	0.319	1.347	0.993	1.411	1.045	0.223	0.360	0.424
10.50	7.15	1.90	47.53	0.316	1.362	1.040	1.445	1.048	0.220	0.356	0.419
10.00	6.90	1.90	47.99	0.313	1.379	1.092	1.484	1.052	0.217	0.352	0.414
9.50	6.64	1.89	48.44	0.310	1.397	1.149	1.529	1.057	0.214	0.348	0.409
9.00	6.38	1.88	48.91	0.307	1.417	1.213	1.581	1.061	0.211	0.343	0.403
8.50	6.11	1.86	49.37	0.304	1.438	1.285	1.641	1.067	0.208	0.339	0.397
8.00	5.84	1.84	49.84	0.301	1.461	1.365	1.710	1.073	0.205	0.334	0.392
7.50	5.57	1.82	50.32	0.298	1.486	1.456	1.793	1.079	0.202	0.329	0.385
7.00	5.29	1.79	50.79	0.295	1.513	1.560	1.891	1.087	0.198	0.323	0.379
6.50	5.00	1.75	51.28	0.293	1.540	1.680	2.011	1.095	0.196	0.318	0.373
6.00	4.72	1.72	51.77	0.290	1.573	1.820	2.157	1.104	0.192	0.312	0.366
5.50	4.42	1.67	52.26	0.287	1.609	1.985	2.340	1.115	0.188	0.305	0.359
5.00	4.12	1.62	52.76	0.284	1.648	2.184	2.575	1.127	0.185	0.298	0.351
4.50	3.81	1.56	53.26	0.282	1.693	2.427	2.881	1.142	0.181	0.291	0.343
4.00	3.49	1.49	53.77	0.279	1.744	2.730	3.296	1.159	0.176	0.283	0.334
3.50	3.15	1.40	54.28	0.276	1.801	3.120	3.880	1.178	0.172	0.275	0.324
3.00	2.79	1.29	54.79	0.274	1.863	3.640	4.756	1.200	0.168	0.266	0.315
2.50	2.42	1.17	55.32	0.271	1.937	4.368	6.151	1.227	0.163	0.257	0.304
2.00	2.02	1.02	55.84	0.269	2.015	5.460	8.652	1.256	0.158	0.247	0.293
1.50	1.58	0.83	56.37	0.266	2.107	7.280	13.870	1.291	0.153	0.237	0.282
1.00	1.10	0.60	56.91	0.264	2.193	10.920	28.511	1.325	0.148	0.228	0.272



Evaluation of the Distance Impact in Terms of Configuration Factor

Pool Fire Diameter (m)	R	L	Emmisive Power (kW/m^2)	S	h	A	B	$F_{1->2,H}$	$F_{1->2,V}$	$F_{1->2,Max}$
9.63	20.50	15.69	48.33	4.258	1.134	2.397	2.246	0.007	0.046	0.047
9.63	20.00	15.19	48.33	4.154	1.134	2.352	2.197	0.008	0.049	0.049
9.63	19.50	14.69	48.33	4.050	1.134	2.307	2.148	0.009	0.051	0.052
9.63	19.00	14.19	48.33	3.946	1.134	2.263	2.100	0.010	0.054	0.055
9.63	18.50	13.69	48.33	3.842	1.134	2.219	2.051	0.010	0.057	0.058
9.63	18.00	13.19	48.33	3.738	1.134	2.175	2.003	0.011	0.061	0.062
9.63	17.50	12.69	48.33	3.634	1.134	2.132	1.955	0.013	0.064	0.065
9.63	17.00	12.19	48.33	3.531	1.134	2.089	1.907	0.014	0.068	0.070
9.63	16.50	11.69	48.33	3.427	1.134	2.047	1.859	0.015	0.073	0.074
9.63	16.00	11.19	48.33	3.323	1.134	2.005	1.812	0.017	0.077	0.079
9.63	15.50	10.69	48.33	3.219	1.134	1.965	1.765	0.019	0.083	0.085
9.63	15.00	10.19	48.33	3.115	1.134	1.925	1.718	0.021	0.088	0.091
9.63	14.50	9.69	48.33	3.011	1.134	1.885	1.672	0.023	0.095	0.097
9.63	14.00	9.19	48.33	2.908	1.134	1.847	1.626	0.026	0.101	0.105
9.63	13.50	8.69	48.33	2.804	1.134	1.810	1.580	0.029	0.109	0.113
9.63	13.00	8.19	48.33	2.700	1.134	1.773	1.535	0.033	0.118	0.122
9.63	12.50	7.69	48.33	2.596	1.134	1.738	1.491	0.038	0.127	0.132
9.63	12.00	7.19	48.33	2.492	1.134	1.705	1.447	0.043	0.137	0.144
9.63	11.50	6.69	48.33	2.388	1.134	1.673	1.404	0.049	0.149	0.157
9.63	11.00	6.19	48.33	2.285	1.134	1.643	1.361	0.056	0.162	0.171
9.63	10.50	5.69	48.33	2.181	1.134	1.614	1.320	0.065	0.176	0.188
9.63	10.00	5.19	48.33	2.077	1.134	1.589	1.279	0.075	0.192	0.206
9.63	9.50	4.69	48.33	1.973	1.134	1.566	1.240	0.087	0.210	0.227
9.63	9.00	4.19	48.33	1.869	1.134	1.546	1.202	0.102	0.230	0.251



ESTIMATING BURNING DURATION OF SOLID COMBUSTIBLES

The following calculations provides an approximation of the burning duration of solid combustibles based on free burning rate with a given surface area.
Green boxes are inputs

INPUT PARAMETERS

Mass of Solid Fuel (m_{solid})	950	lb	430.91	kg
Mass of Resins(m_{solid})	6500	lb	2,948.3	kg
HIC exposed Floor Area of F	137.6	ft^2	12.78	m^2
IRSF Storage Area	5700	ft^2	529.55	m^2

THERMAL PROPERTIES OF SOLID COMBUSTIBLE MATERIALS

	HHR per Unit Floor Area Q"	Heat of Combustion ΔH_c	Density ~ρ	Flash Pt Temp $T_{flash\ pt}$	Auto Ignition Temp $T_{igniton}$
Polyethylene (PE)	1408 kW/m^2	46500 kJ/kg	930 kg/m^3	341 C	349
Resins	1408 kW/m^2	46500 kJ/kg	930 kg/m^3	341 C	349

BURNING DURATION OF SOLID COMBUSTIBLES

Reference: Buchanan, A. H., "Structural Design for Fire Safety," 2001, Page 38.
The burning duration of a solid fuel can be calculated if the total energy contained in the fuel and HRR are known.
The burning duration is given by:

$Q = E / t_{solid}$
or
$t_{solid} = (E) / (Q''\ A_{Fuel})$

Where
t_{solid} = burning duration of solid combustible (sec)
$E = m_{Fuel}\ \Delta H_c$ = total energy contained in the fuel (kJ)
Q = heat releare rate of fire (kW)
Q" = heat release rate per unit floor area of fuel (kW/m^2)
A_{Fuel} = exposed floor area of fuel (m^2)

$t_{solid} = (m_{Fuel}\ \Delta H_c) / (Q''\ A_{Fuel})$
Where
m_{Fuel} = mass of solid fuel (kg)
ΔH_c = fuel effective heat of combustion (kJ/kg)

$t_{solid} = (m_{solid}\ \Delta H_c) / (Q''\ A_{solid})$

t_{solid} =	8,730	sec	145.50	min	2.43	hr

Case I

Method I

Total Numbers of containers of PolyHICs	6

Mass of Solid Fuel (m_{solid})	5,700	lb	2.59E+03	kg
Mass of Resin (m_{solid})	39,000	lb	1.77E+04	kg
Exposed Floor Area of Fuel	140	ft^2	13.0	m^2
Heat Release Rate per Unit	1408	kW/m^2		
Effective Heat of Combustio	46500	kJ/kg		

t_{solid} =	51,615	sec	860.24	min	14.34	hr

Method II

25,981.88

Case II

Method I

Total Numbers of containers of PolyHICs	270

Mass of Solid Fuel (m_{solid})	256,500	lb	1.16E+05	kg
Mass of Resin (m_{solid})	1,755,000	lb	7.96E+05	kg
Exposed Floor Area of Fuel	6,284	ft^2	583.8	m^2
Heat Release Rate per Unit	1408	kW/m^2		
Effective Heat of Combustio	46500	kJ/kg		

t_{solid} =	51,615	sec	860.24	min	14.34	hr

Time of Ignition of HIC Exposed to a Constant Radiative Heat Flux

Method of Mikkola and Wichman (for thermally thick)

$t_{ig} = \pi/4\ k\rho c\ (T_{ig} - T_a)^2 / (q_e'' - q_{critical}'')^2$

Where t_{ig} = material ignition time (sec)

$k\rho c$ = material thermal inertia $(kW/m^2\text{-}K)^2$-sec

T_{ig} = material ignition temperature (°C)

T_a = ambient air temperature (°C)

q_e'' = exposure or external radiative heat flux (kW/m^2)

$q''_{critical}$ = material critical heat flux for ignition (kW/m^2)

t_{ig} = **1385.70** sec **23.09** min

Spreadsheet Formulas:
(Separate File)

Exelon IR

ESTIMA

3 CONTAINERS ON FIRE - DOUBLE-STACKED

3

Entered by User
Fuel Properties
Calculated

INPUT PARAMETERS

HIC Diameter	5.08	ft	=D16*0.3048	m
Pool of Fire Diameter (6 HICs)	=13.1	ft	=D17*0.3048	m
HIC Height	6.21	ft	=D18*0.3048	m
Thickness of Container	0.0417	ft	=D19*0.3048	m
Radiatice Fraction χ_r	0.3			
Initial Temperature (T_∞)	77	°F	=(D21-32)/1.8	°C

THERMAL PROPERTIES

Fuel	Mass Burning Rate m''(kg/m²-sec)	Heat of Combustion $\Delta H_{c,eff}$(kJ/kg)	Empirical Constant k(β (m^{-1})	Critical Heat Flux (kW/m²)	Density (kg/m³)	Thermal Conductivity (Wm^{-1}K^{-1})	Specific Heat (J^{-1}K^{-1}kg^{-1})
High Density Polyethylene	0.018	46500	100	6.2	=0.965*1000	0.45	1900
Resins	0.018	46500	100	6.2	=0.965*1000	0.45	1900

Radius of the Container	=D16/2	ft	=D32*0.3048	m
Radius of the Pool Fire	=D17/2	ft	=D33*0.3048	m
HIC Surface Area(A_{HIC})	=2*PI()*(D16/2)^2+(D16/2)*D18)	ft²	=D31*(0.3048)^2	m²
Fuel Area or Dike Area (A_{fire})	=PI()*D17^2/4	ft²	=D32*(0.3048)^2	m²
Volume of the Container	=PI()*((D29)^2-(D29-D19)^2)*D18+2*PI()*(D29)^2*D19	ft³	=D33*(0.3048)^3	m³
Mass Burning Rate of Fuel (m'')	=C25	kg/m²-sec		
Effective Heat of Combustion of Fuel ($\Delta H_{c,eff}$)	=D25	kJ/kg		
Empirical Constant (kβ)	=E25	m^{-1}		
Air Density at 25 °C	1.184	kg/m³		

ESTIMATING RADIATIVE HEAT FLUX TO A TARGET

Pool Fire Diameter Calculation

D = =F17 m =C46*3.281 ft

Heat Release Rate Calculation

$Q_{f(t)} = m''\Delta H_{c,eff}(1 - e^{-k\beta D})\, A_{fire}$

Where

$Q_{f(t)}$ = pool fire heat release rate (kW)
m'' = mass burning rate of fuel per unit surface area (kg/m²sec)
ΔH_c = effective heat of combustion of fuel (kJ/kg)
A_{fire} = surface area of pool fire (area involved in vaporization) (m²)
kβ = empirical constant (m^{-1})
D = diameter of pool fire (diameter involved in vaporization, circular pool is assumed) (m)

HRR

$Q_{f(t)}$ = =D35*D36*F32*(1-EXP(-D37*C46)) kW =C57*0.94782 Btu/sec

Heat Release Rate Per Unit Length of Fire Calculation

Q' = Q/l

Where

Q' = heat release rate per unit leght (KW/m)
$Q_{f(t)}$ = fire heat release rate of the fire (kW)
l = length of the fire source (m)

Fire Source Length Calculation

l x w = A_{fire}

l= =(F32)^(1/2) m

Q' = =C57/C68 kW/m

Flame Height Calculation

Heskestad Method (1995)

$H_f = 0.235\, Q_{f(t)}^{2/5} - 1.02\, D$

Where,
H_f = flame height (m)
$Q_{f(t)}$ = heat release rate of the fire (kW)
D =Diameter of pool fire(m)

H_f =0.235*C57^(2/5)-1.02*F17 m =C83*3.281 ft

Thomas Method (1962)

$H_f = 42 \times D[\, m''/(\rho_\infty \sqrt{g} \times D)]^{0.61}$

Where,
H_f = flame height (m)
D = Diameter of pool fire (m)
g= gravitational acceleration (m/sec²)
ρ_∞ = ambient air density (kg/m³)

H_f =42*C46*(C25/(D38*(9.81*C46)^(1/2)))^(0.61) m =C96*3.281 ft

Emissive Power

$E = 58\ (10^{(-0.00823D)})$

Where,

E = Flame emissive power (kW/m^2)

D= diameter of pool fire (m)

E = =58*(10^(-0.00823*C46)) kW/m^2 =(C103*317)/(60*60) Btu/ft^2-sec

Distance from the Center of the Pool Fire to Edge of t

R = L + D/2

Where

R = distance from center of the pool fire to edge of the target (m)

L = distance between pool fire and target (m)

D = pool fire diameter (m)

R = 4.018713865592411 m =C113*3.281 ft

Goal seek method

$F_{1\to2H}$ = view factor calculated value (C155 cell)

R is obtained by manually inverting the view factor calculated value (C155 cell has to be equal to C129 cell) the "goal seek" under tools by varing the R (C103)

L = =C113-C46/2 m =C115*3.281 ft

View Factor

$q''_r = E*F_{1\to2Max}$

or

$F_{1\to2H} = q''_r/E$

Where,

$F_{1\to2H}$ = configuration factor

q''_r = incident radiative heat flux or critical heat flux (kW/m^2)

E = emissive power

$F_{1\to2Max}$ =K2/S/(C103)

$F_{1\to2H}$ = $(B-1/S)/\pi(B^2-1)^{1/2}\tan^{-1}((B+1)(S-1)/(B-1)(S+1))^{1/2}-(A-1/S)/(\pi(A^2-1)^{1/2})\tan^{-1}((A+1)(S-1)/(A-1)(S+1))^{1/2}$

$F_{1\to2V}$ = $1/(\pi S)\tan^{-1}(h/(S^2-1)^{1/2})+(h/\pi S)\tan^{-1}((S-1)/(S+1))^{1/2}+A/\pi S(A^2-1)^{1/2}\tan^{-1}((A+1)(S-1)/(A-1)(S+1))^{1/2}$

A = $(h^2+S^2+1)/2S$

B = $(1+S^2)/2S$

S = 2R/D

h = 2H/D

$F_{1\to2Max}$ = $\sqrt{(F^2_{1\to2H}+F^2_{1\to2V})}$

Where

$F_{1\to2H}$ = horizontal view factor

$F_{1\to2V}$ = vertical view factor

$F_{1\to2max}$ = maximum view factor

R = distance from center of the pool fire to edge of the target (m)

H_f = height of the pool fire flame (m)

D = pool fire diameter (m)

S = =2*C113/C46

h = =2*C83/C46

A = =(C147^2+C146^2+1)/(2*C146)

B = =(1+C146^2)/(2*C146)

$F_{1\to2H}$ = =((C149-1/C146)/(Pi()*SQRT(C149^2-1))*ATAN(SQRT((C149+1)*(C146-1)/((C149-1)*(C146+1)))-(C148-1/C146)/(Pi()*SQRT(C148^2-1))*ATAN(SQRT((C148+1)*(C146-1)/((C148-1)*(C146+1))

$F_{1\to2V}$ = =1/(Pi()*C146)*ATAN(C147/SQRT(C146^2-1))-C147/(Pi()*C146)*ATAN(SQRT((C146-1)/(C146+1)))+C148*C147/(Pi()*C146*SQRT(C148^2-1))*ATAN(SQRT((C148+1)*(C146-1)/((C148-1)*(C146+1))

$F_{1\to2Max}$ = =SQRT(C151^2+C152^2) =IF(C153=C127,"Results match, see cell C130","Check Value. Proceed if

Table of Distance vs Emissive Power Where the Pool

Pool Fire Diameter (m)	R	L	Emmisive Power (kW/m^2)	View Factor	S	h	A
12.5	8.163905.302671511	=C158-B158/2	=58*1*(-0.00823*B158)	=$K$25/E158	=2*C158/B158	=2*$C$83/B158	=(H158^2+G158^2+1)/(2*G158
12	7.916173202031288	=C159-B159/2	=58*1*(-0.00823*B159)	=$K$25/E159	=2*C159/B159	=2*$C$83/B159	=(H159^2+G159^2+1)/(2*G159
11.5	7.669961057242412	=C160-B160/2	=58*1*(-0.00823*B160)	=$K$25/E160	=2*C160/B160	=2*$C$83/B160	=(H160^2+G160^2+1)/(2*G160
11	7.407102726621139	=C161-B161/2	=58*1*(-0.00823*B161)	=$K$25/E161	=2*C161/B161	=2*$C$83/B161	=(H161^2+G161^2+1)/(2*G161
10.5	7.153004931843372	=C162-B162/2	=58*1*(-0.00823*B162)	=$K$25/E162	=2*C162/B162	=2*$C$83/B162	=(H162^2+G162^2+1)/(2*G162
10	6.896653049790002	=C163-B163/2	=58*1*(-0.00823*B163)	=$K$25/E163	=2*C163/B163	=2*$C$83/B163	=(H163^2+G163^2+1)/(2*G163
9.5	6.637790180989267	=C164-B164/2	=58*1*(-0.00823*B164)	=$K$25/E164	=2*C164/B164	=2*$C$83/B164	=(H164^2+G164^2+1)/(2*G164
9	6.376348810456862	=C165-B165/2	=58*1*(-0.00823*B165)	=$K$25/E165	=2*C165/B165	=2*$C$83/B165	=(H165^2+G165^2+1)/(2*G165
8.5	6.111903720054874	=C166-B166/2	=58*1*(-0.00823*B166)	=$K$25/E166	=2*C166/B166	=2*$C$83/B166	=(H166^2+G166^2+1)/(2*G166
8	5.84362315973297	=C167-B167/2	=58*1*(-0.00823*B167)	=$K$25/E167	=2*C167/B167	=2*$C$83/B167	=(H167^2+G167^2+1)/(2*G167
7.5	5.571159194766075	=C168-B168/2	=58*1*(-0.00823*B168)	=$K$25/E168	=2*C168/B168	=2*$C$83/B168	=(H168^2+G168^2+1)/(2*G168
7	5.294788699665268	=C169-B169/2	=58*1*(-0.00823*B169)	=$K$25/E169	=2*C169/B169	=2*$C$83/B169	=(H169^2+G169^2+1)/(2*G169
6.5	5.004504464432836	=C170-B170/2	=58*1*(-0.00823*B170)	=$K$25/E170	=2*C170/B170	=2*$C$83/B170	=(H170^2+G170^2+1)/(2*G170
6	4.711966502867776	=C171-B171/2	=58*1*(-0.00823*B171)	=$K$25/E171	=2*C171/B171	=2*$C$83/B171	=(H171^2+G171^2+1)/(2*G171
5.5	4.423766117091138	=C172-B172/2	=58*1*(-0.00823*B172)	=$K$25/E172	=2*C172/B172	=2*$C$83/B172	=(H172^2+G172^2+1)/(2*G172
5	4.120177278372421	=C173-B173/2	=58*1*(-0.00823*B173)	=$K$25/E173	=2*C173/B173	=2*$C$83/B173	=(H173^2+G173^2+1)/(2*G173
4.5	3.809238449117601	=C174-B174/2	=58*1*(-0.00823*B174)	=$K$25/E174	=2*C174/B174	=2*$C$83/B174	=(H174^2+G174^2+1)/(2*G174
4	3.487410805351668	=C175-B175/2	=58*1*(-0.00823*B175)	=$K$25/E175	=2*C175/B175	=2*$C$83/B175	=(H175^2+G175^2+1)/(2*G175
3.5	3.152235171417927	=C176-B176/2	=58*1*(-0.00823*B176)	=$K$25/E176	=2*C176/B176	=2*$C$83/B176	=(H176^2+G176^2+1)/(2*G176
3	2.794074472481193	=C177-B177/2	=58*1*(-0.00823*B177)	=$K$25/E177	=2*C177/B177	=2*$C$83/B177	=(H177^2+G177^2+1)/(2*G177
2.5	2.421681760082249	=C178-B178/2	=58*1*(-0.00823*B178)	=$K$25/E178	=2*C178/B178	=2*$C$83/B178	=(H178^2+G178^2+1)/(2*G178
2	2.015375355223333	=C179-B179/2	=58*1*(-0.00823*B179)	=$K$25/E179	=2*C179/B179	=2*$C$83/B179	=(H179^2+G179^2+1)/(2*G179
1.5	1.580040474272233	=C180-B180/2	=58*1*(-0.00823*B180)	=$K$25/E180	=2*C180/B180	=2*$C$83/B180	=(H180^2+G180^2+1)/(2*G180
1	1.096616926780227	=C181-B181/2	=58*1*(-0.00823*B181)	=$K$25/E181	=2*C181/B181	=2*$C$83/B181	=(H181^2+G181^2+1)/(2*G181

Evaluation of the Distance Impact in Terms of Config

Pool Fire Diameter (m)	R	L	Emmisive Power (kW/m²)	S	h	A	B
9.63	20.5	=C212-B212/2	=58*1*(1-0.00823*B212)	=2*C212/B212	=2*$C$83/B212	=(G212*2+F212*2+1)/(2*F2	=(1+F212*2)/(2*F212)
9.63	20	=C213-B213/2	=58*1*(1-0.00823*B213)	=2*C213/B213	=2*$C$83/B213	=(G213*2+F213*2+1)/(2*F2	=(1+F213*2)/(2*F213)
9.63	19.5	=C214-B214/2	=58*1*(1-0.00823*B214)	=2*C214/B214	=2*$C$83/B214	=(G214*2+F214*2+1)/(2*F2	=(1+F214*2)/(2*F214)
9.63	19	=C215-B215/2	=58*1*(1-0.00823*B215)	=2*C215/B215	=2*$C$83/B215	=(G215*2+F215*2+1)/(2*F2	=(1+F215*2)/(2*F215)
9.63	18.5	=C216-B216/2	=58*1*(1-0.00823*B216)	=2*C216/B216	=2*$C$83/B216	=(G216*2+F216*2+1)/(2*F2	=(1+F216*2)/(2*F216)
9.63	18	=C217-B217/2	=58*1*(1-0.00823*B217)	=2*C217/B217	=2*$C$83/B217	=(G217*2+F217*2+1)/(2*F2	=(1+F217*2)/(2*F217)
9.63	17.5	=C218-B218/2	=58*1*(1-0.00823*B218)	=2*C218/B218	=2*$C$83/B218	=(G218*2+F218*2+1)/(2*F2	=(1+F218*2)/(2*F218)
9.63	17	=C219-B219/2	=58*1*(1-0.00823*B219)	=2*C219/B219	=2*$C$83/B219	=(G219*2+F219*2+1)/(2*F2	=(1+F219*2)/(2*F219)
9.63	16.5	=C220-B220/2	=58*1*(1-0.00823*B220)	=2*C220/B220	=2*$C$83/B220	=(G220*2+F220*2+1)/(2*F2	=(1+F220*2)/(2*F220)
9.63	16	=C221-B221/2	=58*1*(1-0.00823*B221)	=2*C221/B221	=2*$C$83/B221	=(G221*2+F221*2+1)/(2*F2	=(1+F221*2)/(2*F221)
9.63	15.5	=C222-B222/2	=58*1*(1-0.00823*B222)	=2*C222/B222	=2*$C$83/B222	=(G222*2+F222*2+1)/(2*F2	=(1+F222*2)/(2*F222)
9.63	15	=C223-B223/2	=58*1*(1-0.00823*B223)	=2*C223/B223	=2*$C$83/B223	=(G223*2+F223*2+1)/(2*F2	=(1+F223*2)/(2*F223)
9.63	14.5	=C224-B224/2	=58*1*(1-0.00823*B224)	=2*C224/B224	=2*$C$83/B224	=(G224*2+F224*2+1)/(2*F2	=(1+F224*2)/(2*F224)
9.63	14	=C225-B225/2	=58*1*(1-0.00823*B225)	=2*C225/B225	=2*$C$83/B225	=(G225*2+F225*2+1)/(2*F2	=(1+F225*2)/(2*F225)
9.63	13.5	=C226-B226/2	=58*1*(1-0.00823*B226)	=2*C226/B226	=2*$C$83/B226	=(G226*2+F226*2+1)/(2*F2	=(1+F226*2)/(2*F226)
9.63	13	=C227-B227/2	=58*1*(1-0.00823*B227)	=2*C227/B227	=2*$C$83/B227	=(G227*2+F227*2+1)/(2*F2	=(1+F227*2)/(2*F227)
9.63	12.5	=C228-B228/2	=58*1*(1-0.00823*B228)	=2*C228/B228	=2*$C$83/B228	=(G228*2+F228*2+1)/(2*F2	=(1+F228*2)/(2*F228)
9.63	12	=C229-B229/2	=58*1*(1-0.00823*B229)	=2*C229/B229	=2*$C$83/B229	=(G229*2+F229*2+1)/(2*F2	=(1+F229*2)/(2*F229)
9.63	11.5	=C230-B230/2	=58*1*(1-0.00823*B230)	=2*C230/B230	=2*$C$83/B230	=(G230*2+F230*2+1)/(2*F2	=(1+F230*2)/(2*F230)
9.63	11	=C231-B231/2	=58*1*(1-0.00823*B231)	=2*C231/B231	=2*$C$83/B231	=(G231*2+F231*2+1)/(2*F2	=(1+F231*2)/(2*F231)
9.63	10.5	=C232-B232/2	=58*1*(1-0.00823*B232)	=2*C232/B232	=2*$C$83/B232	=(G232*2+F232*2+1)/(2*F2	=(1+F232*2)/(2*F232)
9.63	10	=C233-B233/2	=58*1*(1-0.00823*B233)	=2*C233/B233	=2*$C$83/B233	=(G233*2+F233*2+1)/(2*F2	=(1+F233*2)/(2*F233)
9.63	9.5	=C234-B234/2	=58*1*(1-0.00823*B234)	=2*C234/B234	=2*$C$83/B234	=(G234*2+F234*2+1)/(2*F2	=(1+F234*2)/(2*F234)
9.63	9	=C235-B235/2	=58*1*(1-0.00823*B235)	=2*C235/B235	=2*$C$83/B235	=(G235*2+F235*2+1)/(2*F2	=(1+F235*2)/(2*F235)

ESTIMATING BURNING DURATION OF SOLID COMB

The following calculations provides an approximation of t
burning rate with a given surface area.
Green boxes are inputs

INPUT PARAMETERS

Mass of Solid Fuel (m_{solid})	950	lb	=C266*0.453592	kg
Mass of Resins(m_{resin})	6500	lb	=C267*0.453592	kg
HIC exposed Floor Area of Fuel (A_{fuel})	=(2*Pi()*(2.5)*2+2*Pi()*(2.5)*(6.26)	ft²	=C268*0.092903	m²
IRSF Storage Area	5700	ft²	=C269*0.092903	m²

THERMAL PROPERTIES OF

	HHR per Unit Floor Area Q''		Heat of Combustion ΔH_c		Density $\sim\rho$		Flash Pt Temp $T_{flash\,pt}$
Polyethylene (PE)	1408	kW/m²	46500	kJ/kg	930	kg/m³	341
Resins	1408	kW/m²	46500	kJ/kg	930	kg/m³	341

BURNING DURATION OF SOLID COMBUSTIBLES

Reference: Buchanan, A. H., "Structural Design for Fire S
The burning duration of a solid fuel can be calculated if th
The burning duration is given by:

$Q = E / t_{solid}$

or

$t_{solid} = (E) / (Q'' A_{fuel})$

Where

t_{solid} = burning duration of solid combustible (sec)
$E = m_{fuel}\,\Delta H_c$ = total energy contained in the fuel (kJ)
Q = heat releaseraterate of fire (kW)
Q'' = heat release rate per unit floor area of fuel (kW/m²)
A_{fuel} = exposed floor area of fuel (m²)

$t_{solid} = (m_{fuel}\,\Delta H_c) / (Q''\,A_{fuel})$

Where

m_{fuel} = mass of solid fuel (kg)
ΔH_c = fuel effective heat of combustion (kJ/kg)

$t_{solid} = (m_{solid}\,\Delta H_c) / (Q''\,A_{solid})$

t_{solid} =			=((E266+E267)/E276)/(C276*E268)	sec	=E298/60	min =G298/60

Case I

Method I

Total Numbers of containers of PolyHICs: **6**

Mass of Solid Fuel (m_{solid})	=E301*C266	lb	=D303*0.453592	kg
Mass of Resin (m_{fuel})	=E301*C267	lb	=D304*0.453592	kg
Exposed Floor Area of Fuel (A_{fuel})	=D31	ft²	=D305*0.092903	m²
Heat Release Rate per Unit Floor Area (Q'')	=C276	kW/m²		
Effective Heat of Combustion ($\Delta H_{c,eff}$)	=E276	kJ/kg		
t_{solid} =		=((F303+F304)/D307)/(D306*F305)	sec	=E308/60 min =G308/60

Case II

Method I

Total Numbers of containers of PolyHICs: **270**

Mass of Solid Fuel (m_{solid})	=E311*C266	lb	=D313*0.453592	kg
Mass of Resin (m_{fuel})	=E311*C267	lb	=D314*0.453592	kg
Exposed Floor Area of Fuel (A_{fuel})	=D3145	ft²	=D315*0.092903	m²
Heat Release Rate per Unit Floor Area (Q'')	=C276	kW/m²		
Effective Heat of Combustion ($\Delta H_{c,eff}$)	=E276	kJ/kg		
t_{solid} =		=((F313+F314)/D317)/(D316*F315)	sec	=E318/60 min =G318/60

Time of Ignition of HIC Exposed to a Constant Radiat

Method of Mikkola and Wichman (for thermally thick)

$t_{ig} = \pi/4\ k\rho c\ (T_{ig} - T_a)^2 / (q_e'' - q''_{critical})^2$

Where

t_{ig} = material ignition time (sec)
$k\rho c$ = material thermal inertia (kW/m²-K)²-sec
T_{ig} = material ignition temperature (°C)
T_a = ambient air temperature (°C)
q_e'' = exposure or external radiative heat flux (kW/m²)
$q''_{critical}$ = material critical heat flux for ignition (kW/m²)

t_{ig} =	=Pi()*L25/(4)*(J25-F21)^2)/(K25-F25)^2)	sec	=C336/60	min

	J	K
2	=TODAY()	
24	Ignition Temp (°C)	Minimum Heat Flux for Ignition $\dot{q}''_{ign}$ (dot) (kW/m^2)
25	320	15
26	320	15

	J	K
157	B	$F_{1=0\pm\pi}$
158	=(1+G158*2)/(2*G158)	=((J158-1/G158)/(PI()*SQRT(J158*2-1)*ATAN(SQRT((J158+1)*(G158-1)/((J158-1)*(G158+1))))-(J158-1/G158)/(PI()*SQRT(J158*2-1)*ATAN(SQRT((J158+1)*(G158-1)/((J158-1)*(G158+1)))))
159	=(1+G159*2)/(2*G159)	=((J159-1/G159)/(PI()*SQRT(J159*2-1)*ATAN(SQRT((J159+1)*(G159-1)/((J159-1)*(G159+1))))-(J159-1/G159)/(PI()*SQRT(J159*2-1)*ATAN(SQRT((J159+1)*(G159-1)/((J159-1)*(G159+1)))))
160	=(1+G160*2)/(2*G160)	=((J160-1/G160)/(PI()*SQRT(J160*2-1)*ATAN(SQRT((J160+1)*(G160-1)/((J160-1)*(G160+1))))-(J160-1/G160)/(PI()*SQRT(J160*2-1)*ATAN(SQRT((J160+1)*(G160-1)/((J160-1)*(G160+1)))))
161	=(1+G161*2)/(2*G161)	=((J161-1/G161)/(PI()*SQRT(J161*2-1)*ATAN(SQRT((J161+1)*(G161-1)/((J161-1)*(G161+1))))-(J161-1/G161)/(PI()*SQRT(J161*2-1)*ATAN(SQRT((J161+1)*(G161-1)/((J161-1)*(G161+1)))))
162	=(1+G162*2)/(2*G162)	=((J162-1/G162)/(PI()*SQRT(J162*2-1)*ATAN(SQRT((J162+1)*(G162-1)/((J162-1)*(G162+1))))-(J162-1/G162)/(PI()*SQRT(J162*2-1)*ATAN(SQRT((J162+1)*(G162-1)/((J162-1)*(G162+1)))))
163	=(1+G163*2)/(2*G163)	=((J163-1/G163)/(PI()*SQRT(J163*2-1)*ATAN(SQRT((J163+1)*(G163-1)/((J163-1)*(G163+1))))-(J163-1/G163)/(PI()*SQRT(J163*2-1)*ATAN(SQRT((J163+1)*(G163-1)/((J163-1)*(G163+1)))))
164	=(1+G164*2)/(2*G164)	=((J164-1/G164)/(PI()*SQRT(J164*2-1)*ATAN(SQRT((J164+1)*(G164-1)/((J164-1)*(G164+1))))-(J164-1/G164)/(PI()*SQRT(J164*2-1)*ATAN(SQRT((J164+1)*(G164-1)/((J164-1)*(G164+1)))))
165	=(1+G165*2)/(2*G165)	=((J165-1/G165)/(PI()*SQRT(J165*2-1)*ATAN(SQRT((J165+1)*(G165-1)/((J165-1)*(G165+1))))-(J165-1/G165)/(PI()*SQRT(J165*2-1)*ATAN(SQRT((J165+1)*(G165-1)/((J165-1)*(G165+1)))))
166	=(1+G166*2)/(2*G166)	=((J166-1/G166)/(PI()*SQRT(J166*2-1)*ATAN(SQRT((J166+1)*(G166-1)/((J166-1)*(G166+1))))-(J166-1/G166)/(PI()*SQRT(J166*2-1)*ATAN(SQRT((J166+1)*(G166-1)/((J166-1)*(G166+1)))))
167	=(1+G167*2)/(2*G167)	=((J167-1/G167)/(PI()*SQRT(J167*2-1)*ATAN(SQRT((J167+1)*(G167-1)/((J167-1)*(G167+1))))-(J167-1/G167)/(PI()*SQRT(J167*2-1)*ATAN(SQRT((J167+1)*(G167-1)/((J167-1)*(G167+1)))))
168	=(1+G168*2)/(2*G168)	=((J168-1/G168)/(PI()*SQRT(J168*2-1)*ATAN(SQRT((J168+1)*(G168-1)/((J168-1)*(G168+1))))-(J168-1/G168)/(PI()*SQRT(J168*2-1)*ATAN(SQRT((J168+1)*(G168-1)/((J168-1)*(G168+1)))))
169	=(1+G169*2)/(2*G169)	=((J169-1/G169)/(PI()*SQRT(J169*2-1)*ATAN(SQRT((J169+1)*(G169-1)/((J169-1)*(G169+1))))-(J169-1/G169)/(PI()*SQRT(J169*2-1)*ATAN(SQRT((J169+1)*(G169-1)/((J169-1)*(G169+1)))))
170	=(1+G170*2)/(2*G170)	=((J170-1/G170)/(PI()*SQRT(J170*2-1)*ATAN(SQRT((J170+1)*(G170-1)/((J170-1)*(G170+1))))-(J170-1/G170)/(PI()*SQRT(J170*2-1)*ATAN(SQRT((J170+1)*(G170-1)/((J170-1)*(G170+1)))))
171	=(1+G171*2)/(2*G171)	=((J171-1/G171)/(PI()*SQRT(J171*2-1)*ATAN(SQRT((J171+1)*(G171-1)/((J171-1)*(G171+1))))-(J171-1/G171)/(PI()*SQRT(J171*2-1)*ATAN(SQRT((J171+1)*(G171-1)/((J171-1)*(G171+1)))))
172	=(1+G172*2)/(2*G172)	=((J172-1/G172)/(PI()*SQRT(J172*2-1)*ATAN(SQRT((J172+1)*(G172-1)/((J172-1)*(G172+1))))-(J172-1/G172)/(PI()*SQRT(J172*2-1)*ATAN(SQRT((J172+1)*(G172-1)/((J172-1)*(G172+1)))))
173	=(1+G173*2)/(2*G173)	=((J173-1/G173)/(PI()*SQRT(J173*2-1)*ATAN(SQRT((J173+1)*(G173-1)/((J173-1)*(G173+1))))-(J173-1/G173)/(PI()*SQRT(J173*2-1)*ATAN(SQRT((J173+1)*(G173-1)/((J173-1)*(G173+1)))))
174	=(1+G174*2)/(2*G174)	=((J174-1/G174)/(PI()*SQRT(J174*2-1)*ATAN(SQRT((J174+1)*(G174-1)/((J174-1)*(G174+1))))-(J174-1/G174)/(PI()*SQRT(J174*2-1)*ATAN(SQRT((J174+1)*(G174-1)/((J174-1)*(G174+1)))))
175	=(1+G175*2)/(2*G175)	=((J175-1/G175)/(PI()*SQRT(J175*2-1)*ATAN(SQRT((J175+1)*(G175-1)/((J175-1)*(G175+1))))-(J175-1/G175)/(PI()*SQRT(J175*2-1)*ATAN(SQRT((J175+1)*(G175-1)/((J175-1)*(G175+1)))))
176	=(1+G176*2)/(2*G176)	=((J176-1/G176)/(PI()*SQRT(J176*2-1)*ATAN(SQRT((J176+1)*(G176-1)/((J176-1)*(G176+1))))-(J176-1/G176)/(PI()*SQRT(J176*2-1)*ATAN(SQRT((J176+1)*(G176-1)/((J176-1)*(G176+1)))))
177	=(1+G177*2)/(2*G177)	=((J177-1/G177)/(PI()*SQRT(J177*2-1)*ATAN(SQRT((J177+1)*(G177-1)/((J177-1)*(G177+1))))-(J177-1/G177)/(PI()*SQRT(J177*2-1)*ATAN(SQRT((J177+1)*(G177-1)/((J177-1)*(G177+1)))))
178	=(1+G178*2)/(2*G178)	=((J178-1/G178)/(PI()*SQRT(J178*2-1)*ATAN(SQRT((J178+1)*(G178-1)/((J178-1)*(G178+1))))-(J178-1/G178)/(PI()*SQRT(J178*2-1)*ATAN(SQRT((J178+1)*(G178-1)/((J178-1)*(G178+1)))))
179	=(1+G179*2)/(2*G179)	=((J179-1/G179)/(PI()*SQRT(J179*2-1)*ATAN(SQRT((J179+1)*(G179-1)/((J179-1)*(G179+1))))-(J179-1/G179)/(PI()*SQRT(J179*2-1)*ATAN(SQRT((J179+1)*(G179-1)/((J179-1)*(G179+1)))))
180	=(1+G180*2)/(2*G180)	=((J180-1/G180)/(PI()*SQRT(J180*2-1)*ATAN(SQRT((J180+1)*(G180-1)/((J180-1)*(G180+1))))-(J180-1/G180)/(PI()*SQRT(J180*2-1)*ATAN(SQRT((J180+1)*(G180-1)/((J180-1)*(G180+1)))))
181	=(1+G181*2)/(2*G181)	=((J181-1/G181)/(PI()*SQRT(J181*2-1)*ATAN(SQRT((J181+1)*(G181-1)/((J181-1)*(G181+1))))-(J181-1/G181)/(PI()*SQRT(J181*2-1)*ATAN(SQRT((J181+1)*(G181-1)/((J181-1)*(G181+1)))))

	J	K
208		
209		
210		
211	$F_{i->j2k}$	$F_{i->j2v}$
212	=(G212-I/F212)/(PI()*SQRT(I212^2-1))*ATAN(SQRT((G212+1)*(F212-1)/(G12-1)*(F212+1)))-(H212-I/F212)/(PI()*SQRT(I212^2-1)*ATAN(SQRT((H212+1)*(F212-1)/(H212-1)*(F212+1))))	=1/(PI()*F212)*ATAN(G212/SQRT(F212^2-1))-G212/(PI()*F212)*ATAN(SQRT((F212-1)/(F212+1)))+H212*G212/(PI()*F212*SQRT(H212^2-1))*ATAN(SQRT((H212+1)*(F212-1)/(H212-1)*(F212+1)))
213	=(G213-I/F213)/(PI()*SQRT(I213^2-1))*ATAN(SQRT((G213+1)*(F213-1)/(G13-1)*(F213+1)))-(H213-I/F213)/(PI()*SQRT(I213^2-1)*ATAN(SQRT((H213+1)*(F213-1)/(H213-1)*(F213+1)))	=1/(PI()*F213)*ATAN(G213/SQRT(F213^2-1))-G213/(PI()*F213)*ATAN(SQRT((F213-1)/(F213+1)))+H213*G213/(PI()*F213*SQRT(H213^2-1))*ATAN(SQRT((H213+1)*(F213-1)/(H213-1)*(F213+1)))
214	=(G214-I/F214)/(PI()*SQRT(I214^2-1))*ATAN(SQRT((G214+1)*(F214-1)/(G14-1)*(F214+1)))-(H214-I/F214)/(PI()*SQRT(I214^2-1)*ATAN(SQRT((H214+1)*(F214-1)/(H214-1)*(F214+1)))	=1/(PI()*F214)*ATAN(G214/SQRT(F214^2-1))-G214/(PI()*F214)*ATAN(SQRT((F214-1)/(F214+1)))+H214*G214/(PI()*F214*SQRT(H214^2-1))*ATAN(SQRT((H214+1)*(F214-1)/(H214-1)*(F214+1)))
215	=(G215-I/F215)/(PI()*SQRT(I215^2-1))*ATAN(SQRT((G215+1)*(F215-1)/(G15-1)*(F215+1)))-(H215-I/F215)/(PI()*SQRT(I215^2-1)*ATAN(SQRT((H215+1)*(F215-1)/(H215-1)*(F215+1)))	=1/(PI()*F215)*ATAN(G215/SQRT(F215^2-1))-G215/(PI()*F215)*ATAN(SQRT((F215-1)/(F215+1)))+H215*G215/(PI()*F215*SQRT(H215^2-1))*ATAN(SQRT((H215+1)*(F215-1)/(H215-1)*(F215+1)))
216	=(G216-I/F216)/(PI()*SQRT(I216^2-1))*ATAN(SQRT((G216+1)*(F216-1)/(G16-1)*(F216+1)))-(H216-I/F216)/(PI()*SQRT(I216^2-1)*ATAN(SQRT((H216+1)*(F216-1)/(H216-1)*(F216+1)))	=1/(PI()*F216)*ATAN(G216/SQRT(F216^2-1))-G216/(PI()*F216)*ATAN(SQRT((F216-1)/(F216+1)))+H216*G216/(PI()*F216*SQRT(H216^2-1))*ATAN(SQRT((H216+1)*(F216-1)/(H216-1)*(F216+1)))
217	=(G217-I/F217)/(PI()*SQRT(I217^2-1))*ATAN(SQRT((G217+1)*(F217-1)/(G17-1)*(F217+1)))-(H217-I/F217)/(PI()*SQRT(I217^2-1)*ATAN(SQRT((H217+1)*(F217-1)/(H217-1)*(F217+1)))	=1/(PI()*F217)*ATAN(G217/SQRT(F217^2-1))-G217/(PI()*F217)*ATAN(SQRT((F217-1)/(F217+1)))+H217*G217/(PI()*F217*SQRT(H217^2-1))*ATAN(SQRT((H217+1)*(F217-1)/(H217-1)*(F217+1)))
218	=(G218-I/F218)/(PI()*SQRT(I218^2-1))*ATAN(SQRT((G218+1)*(F218-1)/(G18-1)*(F218+1)))-(H218-I/F218)/(PI()*SQRT(I218^2-1)*ATAN(SQRT((H218+1)*(F218-1)/(H218-1)*(F218+1)))	=1/(PI()*F218)*ATAN(G218/SQRT(F218^2-1))-G218/(PI()*F218)*ATAN(SQRT((F218-1)/(F218+1)))+H218*G218/(PI()*F218*SQRT(H218^2-1))*ATAN(SQRT((H218+1)*(F218-1)/(H218-1)*(F218+1)))
219	=(G219-I/F219)/(PI()*SQRT(I219^2-1))*ATAN(SQRT((G219+1)*(F219-1)/(G19-1)*(F219+1)))-(H219-I/F219)/(PI()*SQRT(I219^2-1)*ATAN(SQRT((H219+1)*(F219-1)/(H219-1)*(F219+1)))	=1/(PI()*F219)*ATAN(G219/SQRT(F219^2-1))-G219/(PI()*F219)*ATAN(SQRT((F219-1)/(F219+1)))+H219*G219/(PI()*F219*SQRT(H219^2-1))*ATAN(SQRT((H219+1)*(F219-1)/(H219-1)*(F219+1)))
220	=(G220-I/F220)/(PI()*SQRT(I220^2-1))*ATAN(SQRT((G220+1)*(F220-1)/(G20-1)*(F220+1)))-(H220-I/F220)/(PI()*SQRT(I220^2-1)*ATAN(SQRT((H220+1)*(F220-1)/(H220-1)*(F220+1)))	=1/(PI()*F220)*ATAN(G220/SQRT(F220^2-1))-G220/(PI()*F220)*ATAN(SQRT((F220-1)/(F220+1)))+H220*G220/(PI()*F220*SQRT(H220^2-1))*ATAN(SQRT((H220+1)*(F220-1)/(H220-1)*(F220+1)))
221	=(G221-I/F221)/(PI()*SQRT(I221^2-1))*ATAN(SQRT((G221+1)*(F221-1)/(G21-1)*(F221+1)))-(H221-I/F221)/(PI()*SQRT(I221^2-1)*ATAN(SQRT((H221+1)*(F221-1)/(H221-1)*(F221+1)))	=1/(PI()*F221)*ATAN(G221/SQRT(F221^2-1))-G221/(PI()*F221)*ATAN(SQRT((F221-1)/(F221+1)))+H221*G221/(PI()*F221*SQRT(H221^2-1))*ATAN(SQRT((H221+1)*(F221-1)/(H221-1)*(F221+1)))
222	=(G222-I/F222)/(PI()*SQRT(I222^2-1))*ATAN(SQRT((G222+1)*(F222-1)/(G22-1)*(F222+1)))-(H222-I/F222)/(PI()*SQRT(I222^2-1)*ATAN(SQRT((H222+1)*(F222-1)/(H222-1)*(F222+1)))	=1/(PI()*F222)*ATAN(G222/SQRT(F222^2-1))-G222/(PI()*F222)*ATAN(SQRT((F222-1)/(F222+1)))+H222*G222/(PI()*F222*SQRT(H222^2-1))*ATAN(SQRT((H222+1)*(F222-1)/(H222-1)*(F222+1)))
223	=(G223-I/F223)/(PI()*SQRT(I223^2-1))*ATAN(SQRT((G223+1)*(F223-1)/(G23-1)*(F223+1)))-(H223-I/F223)/(PI()*SQRT(I223^2-1)*ATAN(SQRT((H223+1)*(F223-1)/(H223-1)*(F223+1)))	=1/(PI()*F223)*ATAN(G223/SQRT(F223^2-1))-G223/(PI()*F223)*ATAN(SQRT((F223-1)/(F223+1)))+H223*G223/(PI()*F223*SQRT(H223^2-1))*ATAN(SQRT((H223+1)*(F223-1)/(H223-1)*(F223+1)))
224	=(G224-I/F224)/(PI()*SQRT(I224^2-1))*ATAN(SQRT((G224+1)*(F224-1)/(G24-1)*(F224+1)))-(H224-I/F224)/(PI()*SQRT(I224^2-1)*ATAN(SQRT((H224+1)*(F224-1)/(H224-1)*(F224+1)))	=1/(PI()*F224)*ATAN(G224/SQRT(F224^2-1))-G224/(PI()*F224)*ATAN(SQRT((F224-1)/(F224+1)))+H224*G224/(PI()*F224*SQRT(H224^2-1))*ATAN(SQRT((H224+1)*(F224-1)/(H224-1)*(F224+1)))
225	=(G225-I/F225)/(PI()*SQRT(I225^2-1))*ATAN(SQRT((G225+1)*(F225-1)/(G25-1)*(F225+1)))-(H225-I/F225)/(PI()*SQRT(I225^2-1)*ATAN(SQRT((H225+1)*(F225-1)/(H225-1)*(F225+1)))	=1/(PI()*F225)*ATAN(G225/SQRT(F225^2-1))-G225/(PI()*F225)*ATAN(SQRT((F225-1)/(F225+1)))+H225*G225/(PI()*F225*SQRT(H225^2-1))*ATAN(SQRT((H225+1)*(F225-1)/(H225-1)*(F225+1)))
226	=(G226-I/F226)/(PI()*SQRT(I226^2-1))*ATAN(SQRT((G226+1)*(F226-1)/(G26-1)*(F226+1)))-(H226-I/F226)/(PI()*SQRT(I226^2-1)*ATAN(SQRT((H226+1)*(F226-1)/(H226-1)*(F226+1)))	=1/(PI()*F226)*ATAN(G226/SQRT(F226^2-1))-G226/(PI()*F226)*ATAN(SQRT((F226-1)/(F226+1)))+H226*G226/(PI()*F226*SQRT(H226^2-1))*ATAN(SQRT((H226+1)*(F226-1)/(H226-1)*(F226+1)))
227	=(G227-I/F227)/(PI()*SQRT(I227^2-1))*ATAN(SQRT((G227+1)*(F227-1)/(G27-1)*(F227+1)))-(H227-I/F227)/(PI()*SQRT(I227^2-1)*ATAN(SQRT((H227+1)*(F227-1)/(H227-1)*(F227+1)))	=1/(PI()*F227)*ATAN(G227/SQRT(F227^2-1))-G227/(PI()*F227)*ATAN(SQRT((F227-1)/(F227+1)))+H227*G227/(PI()*F227*SQRT(H227^2-1))*ATAN(SQRT((H227+1)*(F227-1)/(H227-1)*(F227+1)))
228	=(G228-I/F228)/(PI()*SQRT(I228^2-1))*ATAN(SQRT((G228+1)*(F228-1)/(G28-1)*(F228+1)))-(H228-I/F228)/(PI()*SQRT(I228^2-1)*ATAN(SQRT((H228+1)*(F228-1)/(H228-1)*(F228+1)))	=1/(PI()*F228)*ATAN(G228/SQRT(F228^2-1))-G228/(PI()*F228)*ATAN(SQRT((F228-1)/(F228+1)))+H228*G228/(PI()*F228*SQRT(H228^2-1))*ATAN(SQRT((H228+1)*(F228-1)/(H228-1)*(F228+1)))
229	=(G229-I/F229)/(PI()*SQRT(I229^2-1))*ATAN(SQRT((G229+1)*(F229-1)/(G29-1)*(F229+1)))-(H229-I/F229)/(PI()*SQRT(I229^2-1)*ATAN(SQRT((H229+1)*(F229-1)/(H229-1)*(F229+1)))	=1/(PI()*F229)*ATAN(G229/SQRT(F229^2-1))-G229/(PI()*F229)*ATAN(SQRT((F229-1)/(F229+1)))+H229*G229/(PI()*F229*SQRT(H229^2-1))*ATAN(SQRT((H229+1)*(F229-1)/(H229-1)*(F229+1)))
230	=(G230-I/F230)/(PI()*SQRT(I230^2-1))*ATAN(SQRT((G230+1)*(F230-1)/(G30-1)*(F230+1)))-(H230-I/F230)/(PI()*SQRT(I230^2-1)*ATAN(SQRT((H230+1)*(F230-1)/(H230-1)*(F230+1)))	=1/(PI()*F230)*ATAN(G230/SQRT(F230^2-1))-G230/(PI()*F230)*ATAN(SQRT((F230-1)/(F230+1)))+H230*G230/(PI()*F230*SQRT(H230^2-1))*ATAN(SQRT((H230+1)*(F230-1)/(H230-1)*(F230+1)))
231	=(G231-I/F231)/(PI()*SQRT(I231^2-1))*ATAN(SQRT((G231+1)*(F231-1)/(G31-1)*(F231+1)))-(H231-I/F231)/(PI()*SQRT(I231^2-1)*ATAN(SQRT((H231+1)*(F231-1)/(H231-1)*(F231+1)))	=1/(PI()*F231)*ATAN(G231/SQRT(F231^2-1))-G231/(PI()*F231)*ATAN(SQRT((F231-1)/(F231+1)))+H231*G231/(PI()*F231*SQRT(H231^2-1))*ATAN(SQRT((H231+1)*(F231-1)/(H231-1)*(F231+1)))
232	=(G232-I/F232)/(PI()*SQRT(I232^2-1))*ATAN(SQRT((G232+1)*(F232-1)/(G32-1)*(F232+1)))-(H232-I/F232)/(PI()*SQRT(I232^2-1)*ATAN(SQRT((H232+1)*(F232-1)/(H232-1)*(F232+1)))	=1/(PI()*F232)*ATAN(G232/SQRT(F232^2-1))-G232/(PI()*F232)*ATAN(SQRT((F232-1)/(F232+1)))+H232*G232/(PI()*F232*SQRT(H232^2-1))*ATAN(SQRT((H232+1)*(F232-1)/(H232-1)*(F232+1)))
233	=(G233-I/F233)/(PI()*SQRT(I233^2-1))*ATAN(SQRT((G233+1)*(F233-1)/(G33-1)*(F233+1)))-(H233-I/F233)/(PI()*SQRT(I233^2-1)*ATAN(SQRT((H233+1)*(F233-1)/(H233-1)*(F233+1)))	=1/(PI()*F233)*ATAN(G233/SQRT(F233^2-1))-G233/(PI()*F233)*ATAN(SQRT((F233-1)/(F233+1)))+H233*G233/(PI()*F233*SQRT(H233^2-1))*ATAN(SQRT((H233+1)*(F233-1)/(H233-1)*(F233+1)))
234	=(G234-I/F234)/(PI()*SQRT(I234^2-1))*ATAN(SQRT((G234+1)*(F234-1)/(G34-1)*(F234+1)))-(H234-I/F234)/(PI()*SQRT(I234^2-1)*ATAN(SQRT((H234+1)*(F234-1)/(H234-1)*(F234+1)))	=1/(PI()*F234)*ATAN(G234/SQRT(F234^2-1))-G234/(PI()*F234)*ATAN(SQRT((F234-1)/(F234+1)))+H234*G234/(PI()*F234*SQRT(H234^2-1))*ATAN(SQRT((H234+1)*(F234-1)/(H234-1)*(F234+1)))
235	=(G235-I/F235)/(PI()*SQRT(I235^2-1))*ATAN(SQRT((G235+1)*(F235-1)/(G35-1)*(F235+1)))-(H235-I/F235)/(PI()*SQRT(I235^2-1)*ATAN(SQRT((H235+1)*(F235-1)/(H235-1)*(F235+1)))	=1/(PI()*F235)*ATAN(G235/SQRT(F235^2-1))-G235/(PI()*F235)*ATAN(SQRT((F235-1)/(F235+1)))+H235*G235/(PI()*F235*SQRT(H235^2-1))*ATAN(SQRT((H235+1)*(F235-1)/(H235-1)*(F235+1)))
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271		
272		
273		
274		**Auto Ignition Temp**
275		$T_{ignition}$
276	G	349
277	G	349
278		
279		
280		
281		
282		
283		
284		
285		
286		
287		
288		
289		
290		
291		
292		
293		
294		
295		
296		
297		
298	hr	
299		**Method II**
300		=D3.07*(D303+D304)/60000
301		
302		
303		
304		
305		
306		
307		
308	hr	
309		
310		
311		
312		
313		
314		
315		
316		
317		
318	hr	
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L	M	N
Thermal inertia $(kW/m^2 K)^2$	TRP $(kW/m^2s^{1/2})(fs\cdot mm)$	Flux Time Product Index (n)
1.57	321	1
1.57	321	1

	L	M	N
157	$F_{L-2,y}$	$F_{L-2,Mx}$	
158	=1/(PI()*G158*ATAN(H158/SQRT(G158^2-1))-H158/(PI()*G158*ATAN(SQRT((G158-1)/(G158+1))*H158*H158/(PI()*G158*SQRT(H158^2-1)*ATAN(SQRT((H158+1)*(G158-1)/(H158-1))*(G158+1))))	=SQRT(K158^2+L158^2)	
159	=1/(PI()*G159*ATAN(H159/SQRT(G159^2-1))-H159/(PI()*G159*ATAN(SQRT((G159-1)/(G159+1))*H159*H159/(PI()*G159*SQRT(H159^2-1)*ATAN(SQRT((H159+1)*(G159-1)/(H159-1))*(G159+1)))	=SQRT(K159^2+L159^2)	
160	=1/(PI()*G160*ATAN(H160/SQRT(G160^2-1))-H160/(PI()*G160*ATAN(SQRT((G160-1)/(G160+1))*H160*H160/(PI()*G160*SQRT(H160^2-1)*ATAN(SQRT((H160+1)*(G160-1)/(H160-1))*(G160+1)))	=SQRT(K160^2+L160^2)	
161	=1/(PI()*G161*ATAN(H161/SQRT(G161^2-1))-H161/(PI()*G161*ATAN(SQRT((G161-1)/(G161+1))*H161*H161/(PI()*G161*SQRT(H161^2-1)*ATAN(SQRT((H161+1)*(G161-1)/(H161-1))*(G161+1)))	=SQRT(K161^2+L161^2)	
162	=1/(PI()*G162*ATAN(H162/SQRT(G162^2-1))-H162/(PI()*G162*ATAN(SQRT((G162-1)/(G162+1))*H162*H162/(PI()*G162*SQRT(H162^2-1)*ATAN(SQRT((H162+1)*(G162-1)/(H162-1))*(G162+1)))	=SQRT(K162^2+L162^2)	
163	=1/(PI()*G163*ATAN(H163/SQRT(G163^2-1))-H163/(PI()*G163*ATAN(SQRT((G163-1)/(G163+1))*H163*H163/(PI()*G163*SQRT(H163^2-1)*ATAN(SQRT((H163+1)*(G163-1)/(H163-1))*(G163+1)))	=SQRT(K163^2+L163^2)	
164	=1/(PI()*G164*ATAN(H164/SQRT(G164^2-1))-H164/(PI()*G164*ATAN(SQRT((G164-1)/(G164+1))*H164*H164/(PI()*G164*SQRT(H164^2-1)*ATAN(SQRT((H164+1)*(G164-1)/(H164-1))*(G164+1)))	=SQRT(K164^2+L164^2)	
165	=1/(PI()*G165*ATAN(H165/SQRT(G165^2-1))-H165/(PI()*G165*ATAN(SQRT((G165-1)/(G165+1))*H165*H165/(PI()*G165*SQRT(H165^2-1)*ATAN(SQRT((H165+1)*(G165-1)/(H165-1))*(G165+1)))	=SQRT(K165^2+L165^2)	
166	=1/(PI()*G166*ATAN(H166/SQRT(G166^2-1))-H166/(PI()*G166*ATAN(SQRT((G166-1)/(G166+1))*H166*H166/(PI()*G166*SQRT(H166^2-1)*ATAN(SQRT((H166+1)*(G166-1)/(H166-1))*(G166+1)))	=SQRT(K166^2+L166^2)	
167	=1/(PI()*G167*ATAN(H167/SQRT(G167^2-1))-H167/(PI()*G167*ATAN(SQRT((G167-1)/(G167+1))*H167*H167/(PI()*G167*SQRT(H167^2-1)*ATAN(SQRT((H167+1)*(G167-1)/(H167-1))*(G167+1)))	=SQRT(K167^2+L167^2)	
168	=1/(PI()*G168*ATAN(H168/SQRT(G168^2-1))-H168/(PI()*G168*ATAN(SQRT((G168-1)/(G168+1))*H168*H168/(PI()*G168*SQRT(H168^2-1)*ATAN(SQRT((H168+1)*(G168-1)/(H168-1))*(G168+1)))	=SQRT(K168^2+L168^2)	
169	=1/(PI()*G169*ATAN(H169/SQRT(G169^2-1))-H169/(PI()*G169*ATAN(SQRT((G169-1)/(G169+1))*H169*H169/(PI()*G169*SQRT(H169^2-1)*ATAN(SQRT((H169+1)*(G169-1)/(H169-1))*(G169+1)))	=SQRT(K169^2+L169^2)	
170	=1/(PI()*G170*ATAN(H170/SQRT(G170^2-1))-H170/(PI()*G170*ATAN(SQRT((G170-1)/(G170+1))*H170*H170/(PI()*G170*SQRT(H170^2-1)*ATAN(SQRT((H170+1)*(G170-1)/(H170-1))*(G170+1)))	=SQRT(K170^2+L170^2)	
171	=1/(PI()*G171*ATAN(H171/SQRT(G171^2-1))-H171/(PI()*G171*ATAN(SQRT((G171-1)/(G171+1))*H171*H171/(PI()*G171*SQRT(H171^2-1)*ATAN(SQRT((H171+1)*(G171-1)/(H171-1))*(G171+1)))	=SQRT(K171^2+L171^2)	
172	=1/(PI()*G172*ATAN(H172/SQRT(G172^2-1))-H172/(PI()*G172*ATAN(SQRT((G172-1)/(G172+1))*H172*H172/(PI()*G172*SQRT(H172^2-1)*ATAN(SQRT((H172+1)*(G172-1)/(H172-1))*(G172+1)))	=SQRT(K172^2+L172^2)	
173	=1/(PI()*G173*ATAN(H173/SQRT(G173^2-1))-H173/(PI()*G173*ATAN(SQRT((G173-1)/(G173+1))*H173*H173/(PI()*G173*SQRT(H173^2-1)*ATAN(SQRT((H173+1)*(G173-1)/(H173-1))*(G173+1)))	=SQRT(K173^2+L173^2)	
174	=1/(PI()*G174*ATAN(H174/SQRT(G174^2-1))-H174/(PI()*G174*ATAN(SQRT((G174-1)/(G174+1))*H174*H174/(PI()*G174*SQRT(H174^2-1)*ATAN(SQRT((H174+1)*(G174-1)/(H174-1))*(G174+1)))	=SQRT(K174^2+L174^2)	
175	=1/(PI()*G175*ATAN(H175/SQRT(G175^2-1))-H175/(PI()*G175*ATAN(SQRT((G175-1)/(G175+1))*H175*H175/(PI()*G175*SQRT(H175^2-1)*ATAN(SQRT((H175+1)*(G175-1)/(H175-1))*(G175+1)))	=SQRT(K175^2+L175^2)	
176	=1/(PI()*G176*ATAN(H176/SQRT(G176^2-1))-H176/(PI()*G176*ATAN(SQRT((G176-1)/(G176+1))*H176*H176/(PI()*G176*SQRT(H176^2-1)*ATAN(SQRT((H176+1)*(G176-1)/(H176-1))*(G176+1)))	=SQRT(K176^2+L176^2)	
177	=1/(PI()*G177*ATAN(H177/SQRT(G177^2-1))-H177/(PI()*G177*ATAN(SQRT((G177-1)/(G177+1))*H177*H177/(PI()*G177*SQRT(H177^2-1)*ATAN(SQRT((H177+1)*(G177-1)/(H177-1))*(G177+1)))	=SQRT(K177^2+L177^2)	
178	=1/(PI()*G178*ATAN(H178/SQRT(G178^2-1))-H178/(PI()*G178*ATAN(SQRT((G178-1)/(G178+1))*H178*H178/(PI()*G178*SQRT(H178^2-1)*ATAN(SQRT((H178+1)*(G178-1)/(H178-1))*(G178+1)))	=SQRT(K178^2+L178^2)	
179	=1/(PI()*G179*ATAN(H179/SQRT(G179^2-1))-H179/(PI()*G179*ATAN(SQRT((G179-1)/(G179+1))*H179*H179/(PI()*G179*SQRT(H179^2-1)*ATAN(SQRT((H179+1)*(G179-1)/(H179-1))*(G179+1)))	=SQRT(K179^2+L179^2)	
180	=1/(PI()*G180*ATAN(H180/SQRT(G180^2-1))-H180/(PI()*G180*ATAN(SQRT((G180-1)/(G180+1))*H180*H180/(PI()*G180*SQRT(H180^2-1)*ATAN(SQRT((H180+1)*(G180-1)/(H180-1))*(G180+1)))	=SQRT(K180^2+L180^2)	
181	=1/(PI()*G181*ATAN(H181/SQRT(G181^2-1))-H181/(PI()*G181*ATAN(SQRT((G181-1)/(G181+1))*H181*H181/(PI()*G181*SQRT(H181^2-1)*ATAN(SQRT((H181+1)*(G181-1)/(H181-1))*(G181+1)))	=SQRT(K181^2+L181^2)	

	L	M	N
208			
209			
210			
211	$F_{i=2,Max}$		
212	=SQRT(J212^2+K212^2)		
213	=SQRT(J213^2+K213^2)		
214	=SQRT(J214^2+K214^2)		
215	=SQRT(J215^2+K215^2)		
216	=SQRT(J216^2+K216^2)		
217	=SQRT(J217^2+K217^2)		
218	=SQRT(J218^2+K218^2)		
219	=SQRT(J219^2+K219^2)		
220	=SQRT(J220^2+K220^2)		
221	=SQRT(J221^2+K221^2)		
222	=SQRT(J222^2+K222^2)		
223	=SQRT(J223^2+K223^2)		
224	=SQRT(J224^2+K224^2)		
225	=SQRT(J225^2+K225^2)		
226	=SQRT(J226^2+K226^2)		
227	=SQRT(J227^2+K227^2)		
228	=SQRT(J228^2+K228^2)		
229	=SQRT(J229^2+K229^2)		
230	=SQRT(J230^2+K230^2)		
231	=SQRT(J231^2+K231^2)		
232	=SQRT(J232^2+K232^2)		
233	=SQRT(J233^2+K233^2)		
234	=SQRT(J234^2+K234^2)		
235	=SQRT(J235^2+K235^2)		

Other calculated fire parameters of interest:

- **Burning Duration of Solids Combustibles (HDPE HIC)**

  Fuel load per unit floor area, material burning rate, and the available ventilation define the intensity and the duration of the fire.

  Buchanan Method (2001)

  $Q_{(dot)} = E_{total}/t_{solid}$
  or
  $t_{solid} = E_{total}/ (Q'' A_{fuel})$

  Where,
  t_{solid} = burning duration of solid combustible (sec)
  $E_{total} = m_{fuel}\ \Delta H_{c,eff}$ = total energy contained in the fuel (kJ)
  $Q_{(dot)}$ = heat release rate of fire (kW)
  Q" = heat release rate per unit floor area of fuel (kW/m^2)
  A_{fuel} = exposed floor area (m^2)

  $E_{total} = (430.91\ kg + 2948.35\ kg)*(46{,}500 kJ/kg) = 1.5713 \times 10^8\ kJ$

  $t_{solid} = (1.5713 \times 10^8\ kJ\ ) / (\ (1{,}408\ kW/m^2)*(12.78\ m^2)) = 8{,}730\ sec$

  Thus, the burning time of one HIC with the resins is approximately **145.50 *minutes* (2.43 *hours*)**.

  6 Containers Burning Duration

  A scenario where 3 uninsulated HDPE HICs double-stacked is evaluated (total of 6 containers).

  Total mass of solid fuel = 950 lbs * 6 containers = 5,700 lbs * 0.453592 = 2.59 x10^3 kg

  Total mass of resin = 6,500 lbs * 6 containers = 39,000 lbs * 0.453592 = 1.77 x10^4 kg

  Exposed floor area of fuel = 139.64 ft^2 = 12.97 m^2 [see section 7.4]

  $T_{solid} = [\ (2.59\times10^3\ kg + 1.77\times10^4\ kg\ )*46{,}500\ kJ/kg\ /\ (1{,}408\ kW/m^2 * 12.97\ m^2\ )] = 51{,}615\ sec$

  This evaluation does not include values that prolong the burning time such as spreading the fire in the IRSF storage bay. It is calculated that 6 containers can burn for 14.34 hours (51,615 sec).

- **Time of Ignition of HDPE HIC Exposed to a Constant Radiative Heat Flux**

  The time of ignition is calculated for HDPE considering a constant external radiative heat flux using multiple methods, Reference [5]. The methods below are differentiated by the parameters used to obtain the time of ignition and the procedure.

  Method of Mikkola and Wichman *(Reference [5])*

  Mikkola and Wichman use the critical temperature to solve the one-dimensional conduction equation with linearized radiative and convective boundary condition. The time of ignition is derived based on thermally thick method.

  $t_{ig} = \pi/4 * k\rho c\ (T_{ig} - T_a)^2/(q_e'' - q_{crit}'')^2$

  Where,

t_{ig} = material ignition time (sec)
$k\rho c$ = material thermal inertia (kW/m^2-K^2)-sec
T_{ig} = material ignition temperature (^{o}C)
T_a = ambient air temperature (^{o}C)
q_e" = exposure or external radiative heat flux (kW/m^2)
q"$_{crit}$ = material critical heat flux for ignition (kW/m^2)

$$t_{ig} = \pi/4 * 1.57\ (kW/m^2K)^2 * (320^oC - 25^oC)^2/(15\ kW/m^2 - 6.2\ kW/m^2)^2 = 1385.7\ sec\ /60 = 23.09\ min$$

ATTACHMENT B – EMPTY HIC WEIGHT BASIS (ENERGY SOLUTIONS MEMO)

ENERGYSOLUTIONS
We're part of the solution

Date: November 7th 2008

To: Tom Britt, Exelon – Dresden Station

From: Carly Jackson – Energy*Solutions* Engineering

Subject: PL8-120 FR Liners

C/C: Darold Morris, Sean Rigby, Mark Dempsey, Sam Pearson

Please see the following table for information regarding 8-120 size polyethylene High Integrity Containers with bead resin internals and grapple-able lifting arrangements. Empty weights are the best estimable value. Weights vary due to inconsistencies in container thickness and internal materials. Maximum gross weights are based on Certificate of Compliance DHEC-HIC-PL-001 for dewatered (non-solidified) liners.

Lifting Arrangement	Ht (in)	Max Dia (in)	Empty Weight (lb)	Usable Volume (ft3)	Maximum Gross Weight (lb)	Stacking Plate Weight (lb)
Standard Basket	74.5	61	950	101	10,000	N/A
2-High Stackable	74.5	61.5	1,125	101	10,000	510
4-High Stackable (GRSB) Steel Shell	74.5	61.5	2,150	101	10,000	N/A

ATTACHMENT C – POLYPROPYLENE MATERIAL PROPERTIES

These tables were extracted from NUREG-1805- Fire Dynamics Tools (FDTs).

Table 3-2. Large-Pool Fire Burning Rate Data
(Babrauskas, 2002, © SFPE. With permission.)

Material	Mass Loss Rate $\dot{m}''$ (kg/m^2-sec)	Heat of Combustion $\Delta H_{c,\,eff}$ (kJ/kg)	Density ρ (kg/m^3)	Empirical Constant $k\beta$ (m^{-1})
Cryogenics				
Liquid H_2	0.017	12,000	70	6.1
LNG (mostly CH_4)	0.078	50,000	415	1.1
LPG (mostly C_3H_8)	0.099	46,000	585	1.4
Alcohols				
Methanol (CH_3OH)	0.017	20,000	796	100 **
Ethanol (C_2H_5OH)	0.015	26,800	794	100 **
Simple Organic Fuels				
Butane (C_4H_{10})	0.078	45,700	573	2.7
Benzene (C_6H_6)	0.085	40,100	874	2.7
Hexane (C_6H_{14})	0.074	44,700	650	1.9
Heptane (C_7H_{16})	0.101	44,600	675	1.1
Xylene (C_8H_{10})	0.090	40,800	870	1.4
Acetone (C_3H_6O)	0.041	25,800	791	1.9
Dioxane ($C_4H_8O_2$)	0.018	26,200	1,035	5.4
Diethyl ether ($C_4H_{10}O$)	0.085	34,200	714	0.7
Petroleum Products				
Benzine	0.048	44,700	740	3.6
Gasoline	0.055	43,700	740	2.1
Kerosene	0.039	43,200	820	3.5
JP-4	0.051	43,500	760	3.6
JP-5	0.054	43,000	810	1.6
Transformer Oil, hydrocarbon	0.039	46,400	760	0.7
Fuel Oil, heavy	0.035	39,700	940–1,000	1.7
Crude Oil	0.022–0.045	42,500–42,700	830–880	2.8
Solids				
Polymethylmethacrylate $(C_5H_8O_2)_n$	0.020	24,900	1,184	3.3
Polypropylene $(C_3H_6)_n$	0.018	43,200	905	100 **
Polystyrene $(C_8H_8)_n$	0.034	39,700	1,050	100 **
Miscellaneous				
561® Silicon Transformer Fluid	0.005	28,100	960	100 **

** these values are to be used only for computation purposes; the true values are unknown.

Table 3-4. Burning Rates of Some Common Combustible Materials Found in Nuclear Power Plants*

Fuel	Mass Burning Rate $\dot{m}''$ (kg/m^2-sec)	Heat of Combustion $\Delta H_{c,eff}$ (kJ/kg)	Density ρ (kg/m^3)
Cable Materials			
PE/PVC	0.0044	25,100	-
XPE/FRXPE	0.0037	28,300	-
XPE/Neoprene	0.0043	10,300	-
PE, PP/Cl.S.PE	0.0026	26,800	-
FRXPE/Cl.S.PE	0.0033	17,300	-
PE, Nylon/PVC, Nylon	0.0034	10,200	-
Silicone, glass braid, asbestos	0.0045	24,000	-
XPE/XPE	0.0044	12,500	-
FEP - Teflon™	0.007	3,200	-
ETFE - Tefzel™	0.014	12,600	-
Flammable/Combustible Liquid			
Diesel Oil	0.044	44,400	918
Gasoline	0.055	43,700	740
Kerosene	0.039	43,200	820
Transformer Oil	0.039	46,000	760
Lube Oil (used in RCP motors and turbine lubrication)**	-	-	-
Cellulose Material			
Wood	0.055	13,000–15,000	420–640

*Empirical constants ($k\beta$) are unknown. Use $k\beta = 100 m^{-1}$ as a conservative estimate.

**For lubricating oil, use properties of transformer oil (has similar burning characteristics).

CL.S.PE-Chlorosulfonated Polyethylene; FR-Fire Retardant; PE-Polyethylene; PP-Polypropylene; PVC-Polyvinylchloride; Teflon™ - FEP-Fluorinated Polyethylene- Propylene; Tefzel™- ETFE-Ethylenetetrafluoroethylene; XLPE-Crosslinked Polyethylene.

ATTACHMENT D – COMPILATION OF EXPERIMENTAL DATA

Extracted from Reference [5].

TABLE 3. Compilation of Experimental Data Given in the Appendix. Data are correlated using the thermally thick analysis of Mikkola and Wichman17 as given in Equation 4. Data included in this table are for sample thickness greater than 15 mm.

Material	**Thickness** (mm)	$\dot{q}''_{crit}$ (kW/m²)	T_{ig} (°C)[a]	$k\rho c$ (kW²s/m⁴K²)	**Ref. #**
Basswood	64	10.4	298	0.122	30
Softwood	20	13.1	369[b]	0.175	35
Redwood	64	14.8	363	0.0418	30
Redwood	19	14.8	410	0.0323	36
Red Oak	64	11.9	315	0.268	30
Red Oak	32	4	310	0.614	36
Southern Pine	64	13.5	320	0.112	30
Radiata Pine	38	7.6	340	0.273	37
Nylon 6/6	25	20.4	380	0.384	36
Polyethylene	25	6.2	320	1.57	36
Polypropylene	25	10.1	315	0.362	36

[a]Ignition temperature measured experimentally unless otherwise noted.
[b]Ignition temperature calculated from critical heat flux and Equation 6.

ATTACHMENT E – HDPE PHYSICAL AND CHEMICAL DATA – MSDS EXTRACT

NATIONAL PETOCHEMICAL COMPANY	MATERIAL SAFETY DATA SHEET (MSDS)
NAME: High density Polyethylene	**COLLECTION:** Essential Polymers

10- PHYSICAL & CHEMICAL DATA

PHYSICAL STATE	solid
PHYSICAL SHAPE	partially crystalline solid
COLOUR	Colourless
ODOUR	odourless
PH	Not applicable
WATER SOLUBILITY	Insoluble
ORGANIC SOLVENT SOLUBILITY	Insoluble in almost all solvents at room temperature; soluble in many organic solvents above 93 deg C; may "swell" by absorption of solvents below 60 deg C.
SPECIFIC GRAVITY	0.941-0.965
LEL	Dust can explode violently above 390 deg C at airborne levels above 20 g/m3
AUTOIGNITION TEMP	349 deg C (660 deg F)
FLASH POINT	Polyethylene can burn if strongly heated. Flash ignition temperature is 341 deg C (646 deg F)
MELTING POINT	126-136 deg C
BOILING POINT	Not available
VAPOR PRESSURE	Zero
VISCOSITY	Not available
REMAINDER DATA	

ATTACHMENT F – THERMAL PROPERTIES OF COMMON SOLID COMBUSTIBLE MATERIALS

Extracted from NUREG-1805, see Reference [1].

Table 8-1. Thermal Properties of Common Solid Combustible Materials
(Tewarson, 1995, © SFPE. With permission.)

Materials	HRR per Unit Floor Area $\dot{Q}''$ (kW/m^2)	Heat of Combustion ΔH_c (kJkg)
PE/PVC	589	24,000
XPE/FRXPE	475	28,300
XPE/Neoprene	354	10,300
PE, Nylon/PVC, Nylon	231	9,200
Teflon	98	3,200
Douglas fir plywood	124	13,000–15,000
Fire-retardant treated plywood	81	13,500
Particle board, 19 mm thick	1,900	17,500
Nylon 6/6	1,313	32,000
Polymethlmethacrylate (PMMA)	665	26,000
Polypropylene (PP)	1,509	43,200
Polystyrene (PS)	1,101	42,000
Polyethylene (PE)	1,408	46,500
Polycarbonate	420	24,400
Polyurethene	710	45,000
Polyvinyl Chloride (PVC) Flexible	237	15,700
Strene-butadiene Copolymers (SBR)	163	44,000
Ethylene Propylene Dien Rubber	956	28,800
Empty Cartons 15 ft high	1700	12,700
Wood pallets, stacked 1.5 ft high	1,420	13,000–15,000
Wood pallets, stacked 5 ft high	3,970	13,000–15,000
Wood pallets, stacked 10 ft high	6,800	13,000–15,000

ATTACHMENT G – RESULTS FOR SEVERAL DIFFERENT MATERIALS CORRELATING THE FLUX TIME PRODUCT

TABLE 6. Results for Several Different Materials Correlated Using the Flux Time Product Method Given in Equation 21

Sample Material	FTP (kW s/m^2)^n	$\dot{q}''_{crit}$ (kW/m^2)	n	Ref. #
Chipboard	5,370	6.4	1.49	31
Chipboard (Horizontal) (15 mm)	9,921	9.0	1.70	35
Chipboard (Vertical) (15 mm)	11,071	10.0	1.70	35
Fiberboard	3,981	8.3	1.66	31
Hardboard	8,127	8.1	1.49	31
Hardboard (Painted Gloss)	9,332	8.1	1.51	31
Hardwood	2,818	8.1	1.50	31
Plywood	6,164	10.6	1.51	31
Plywood (Horizontal) (12 mm)	5,409	8.5	1.50	35
Plywood (Vertical) (12 mm)	42,025	10.0	2.00	35
Plywood (Painted Gloss)	6,761	11.4	1.50	31
PMMA (cast) (3 mm)	3,100	5.0	1.25	33
PMMA (extruded) (2 mm)	1,290	9.0	1.00	33
Polyethylene (2 mm)	2,220	12.5	1.00	33
Polypropylene (3.3 mm)	8,110	6.5	1.50	33
PVC (Extruded Gray) (3 mm)	5,130	15.0	1.50	33
PVC (Pressed White) (3 mm)	95,000	8.0	2.00	33
Softwood	5,130	13.7	1.53	31
Softwood (Horizontal) (20 mm)	44,079	10.0	2.20	31
Softwood (Vertical) (20 mm)	16,502	12.0	1.90	35
Softwood Intumescent Paint	4,569	13.0	1.50	31

ATTACHMENT H – COLLECTION OF DATA BY TEWARSON GIVING MINIMUM HEAT FLUX AND THERMAL RESPONSE PARAMETER VALUES

TABLE 1. Collection of Data by Tewarson Giving Minimum Heat Flux and Thermal Response Parameter Values for a Multitude of Samples[15]

Materials	$\dot{q}''_{min}$ (kW/m^2) Flammability Apparatus	TRP (kW-s$^{1/2}$/m^2) Flammability Apparatus	TRP (kW-s$^{1/2}$/m^2) Cone Calorimeter
Natural Materials			
Flour	10	218	-
Sugar	10	255	-
Tissue paper	10	95	-
Newspaper	10	108	-
Wood (red oak)	10	134	-
Wood (Douglas fir)	10	138	-
Corrugated paper (light)	10	152	-
Corrugated paper (heavy)			
No coating	10	189	-
Coating (10% by weight)	15	435	-
Coating (15% by weight)	15	526	-
Coating (20% by weight)	15	714	-
Wood (hemlock)	-	-	175
Wool 100%	-	-	252
Wood (Douglas fir/fire retardant, FR)	10	251	-
Synthetic Materials			
Epoxy resin	-	-	457
Polystyrene (PS)	13	162	-
Acrylic fiber 100%	-	-	180
Polypropylene (PP)	15	193	291
PP/FR panel	15	315	-
Styrene-butadiene (SB)	10	198	-
Cross-linked polyethylenes (XLPE)	15	224-301	-
Polyvinyl ester	-	-	263
Polyoxymethylene	13	269	-
Nylon	15	270	-
Polyamide-6	-	-	379
Polymethylmethacrylate (PMMA)	11	274	-
Isophtalic polyester	-	-	296
Acrylonitrile-butadiene-styrene (ABS)	-	-	317
Polyethylene (high-density) (PE)	15	321	364
PE/nonhalogenated fire retardants	15	652-705	-
Polyvinyl ester panels	13-15	440-700	-
Modified acrylic (FR)	-	-	526
Polycarbonate	15	331	-
Polycarbonate panel	16	420	-

ATTACHMENT J – COMPUTER DISCLOSURE SHEET

Computer Disclosure Sheet
Discipline Nuclear

Client: Exelon Nuclear Power Plants — Date: July, 2009
Project: IRSF Storage Bay Fire Spacing Assessment — Job No.

Program(s) used	Rev No.	Rev Date
Calculation Set No.: L-003429, Rev. 000		
Attachment A Spreadsheets	N/A	N/A
	Status	[ ] Prelim [X] Final [ ] Void

URS Prequalification [ ] Yes
[X] No

Run No. Description:

Analysis Description: Spreadsheets were used to execute arithmetic manipulations of numbers, for various applications within the attachments of this analysis.

The attached computer output has been reviewed, the input data checked,
And the results approved for release. Input criteria for this analysis were established.

By: On: 7/2009

Run by:

Checked by: N. Propst

Approved by: S. Dawoud

Remarks:

These spreadsheets were applied in a straight-forward manner and were hand checked.