Consolidated Fuel Shielding Calculations

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

ED

Approved for Public Release

LEGAL DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced from the best available copy.

Printed in the United States of America

DISCLM-2.CHP (1-91)

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

22 Sub 7

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

2. To: (Receiving Organization)

Distribution

3. From: (Originating Organization)

Nuclear Analysis and Characterization

1. EDT 130161

5. Proj/Prog/Dept/Div: 8D520

6. Cog/Proj Engr: WD Wittekind

4. Related EDT No: N/A

8. Originator Remarks:

APPROVAL / RELEASE

9. Equip/Component No: N/A

7. Purchase Order No: N/A

11. Receiver Remarks: The attached document provides revised shielding requirements for consolidated fuel storage in the 105 KE Basin. This document supports triple stacking of irradiated fuel canisters, required by irradiated fuel storage consolidation. This document is based on single canister dose rate measurements, ISOSHL-D-II calculations, and the reconstructed SCATS database.

10. System/Bldg/Facility: K Basin

12. Major Assm Dwg No: N/A

13. Permit/Permit Application No: N/A

14. Required Response Date: 10/94

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev No.	(E) Title or Description of Data Transmitted	Impact Level	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	WHC-SD-NR-ER-105	A11	0	Consolidated Fuel Shielding Calculations	2SQ	1	1	1

16. KEY		
Impact Level (F)	Reason for Transmittal (G)	Disposition (H) & (I)
1, 2, 3, or 4 see MRP 5.43 and EP-1.7	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Impact Level for required signatures)										(G)	(H)
Reason	Disp	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	Reason	Disp
1	1	Cog./Proj. Eng. WD Wittekind	<i>WD Wittekind</i>	7/27/94	HO-38						
1	1	Cog./Proj. Eng. Mgr H. Toffer	<i>H Toffer</i>	7/27/94	HO-38						
4	1	QA GM Davis	<i>QA GM Davis</i>	9/1/94	X1-80						
4	1	Safety JC Hamrick	<i>JC Hamrick</i>	10/1/94	XO-22						
4	1	RL Simons	<i>RL Simons</i>	10/1/94	HO-35						

18. WD Wittekind

WD Wittekind 7/27/94

Signature of EDT Date 1994

19. H. Toffer

H Toffer 9/1/94

Authorized Representative Date for Receiving Organization

20. H. Toffer

H Toffer 8/10/94

Cognizant/Project Engineer's Manager Date

21. DOE APPROVAL (if required)

Ltr No. _____

☐ Approved

☐ Approved w/comments

☐ Disapproved w/comments

RELEASE AUTHORIZATION

Document Number: WHC-SD-NR-ER-105

Document Title: Consolidated Fuel Shielding Calculations

Release Date: 9/7/94

* * * * *

This document was reviewed following the
procedures described in WHC-CM-3-4 and is:

APPROVED FOR PUBLIC RELEASE

* * * * *

WHC Information Release Administration Specialist:

Christine Willingham

C. Willingham
(Signature)

9/7/94
(Date)

SUPPORTING DOCUMENT		1. Total Pages 123
2. Title Consolidated Fuel Shielding Calculations	3. Number WHC-SD-NR-ER-105	4. Rev No. 0
5. Key Words Consolidated Fuel Storage, Dose Rate Calculations, ISOSHL-D-II	6. Author Name: Warren D. Wittekind <i>Warren D. Wittekind</i> Signature Organization/Charge Code 8D520/E11487	
7. Abstract Irradiated fuel radiation dose rate and radiation shielding requirements are calculated using a validated ISOSHL-D-II model. Comparisons are made to experimental measurements. ISOSHL-D-II calculations are documented.		
8. PURPOSE AND USE OF DOCUMENT - This document was prepared for use within the U.S. Department of Energy and its contractors. It is to be used only to perform, direct, or integrate work under U.S. Department of Energy contracts. This document is not approved for public release until reviewed. PATE NT STATUS - This document is not to be published in advance of patent clearance, since it is transmitted in confidence solely for use in performance of work under contracts with the U.S. Department of Energy. This document is not to be published nor its contents otherwise disseminated or used for purposes other than specified above before patent approval for such release or use has been secured, upon request, from the Patent Counsel, U.S. Department of Energy Field Office, Richland, WA. DISCLAIMER - This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.		10. RELEASE STAMP <div style="border: 1px solid black; padding: 5px; text-align: center;"> OFFICIAL RELEASE OCT-10 1994 DATE 22 station 7 </div>
9. Impact Level SQ		

**APPROVED FOR
PUBLIC RELEASE**

*CWO
9-7-94*

Consolidated Fuel Shielding Calculations

W. D. Wittekind

Date Published
September 1994

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

**Westinghouse
Hanford Company**

P.O. Box 1970
Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Approved for Public Release

EXECUTIVE SUMMARY

Consolidation of 105-KE Basin irradiated fuel into the 105-KW Basin will require double or triple stacking canisters closer to the surface of the basin water. This document calculated minimum required water shielding thickness consistent with present radiation shielding design, personnel protection requirements, and acceptable dose rate limits. The present Kaiser designs, sketches ES-N040-S03 (Option A) and ES-N040-S04 (Option B) (Kaiser 1994), indicate 227.01 cm (7 ft 5½ in.) height for triple-stacked canisters under Option B. This is acceptable according to present radiation shielding requirements. Since Option B with 4.445 cm (1½ in.) vertical spacing between canister layers is acceptable, all designs with less than 4.445 cm (1½ in.) vertical spacing are also acceptable.

This document considered gamma ray dose rates direct from irradiated fuel. This document did not consider dose rates due to radioactive isotopes, such as ¹³⁷Cs, that may have migrated away from the fuel but still remain in the basin, or localized contamination on walls, in pipes, etc.

Experimentally measured canister dose rates were compared to ISOSHL-D-II models for single canister geometry. The ISOSHL-D-II single canister model was converted into the canister storage location model, then into a larger storage array model and finally into a 1/3-basin model (storage bay). Fuel irradiation and decay were accommodated by determining the highest dose rate key from the reconstructed SCATS database as a function of irradiation and decay time. An average canister drawn from the irradiated fuel batch with the highest dose rate became the basis for the full-basin calculation.

There is routine movement of basin canisters by lifting them up and out of their array position and moving across the array to another location. The active basin calculation combined the entire static basin array with the single canister dose rate by simple addition. The only dose contribution at the dose point is from the top layer in the array; lower array levels do not contribute to this dose rate.

The following table shows the minimum required water shielding thickness for the reference date of January 31, 1995, and three subsequent decay times. The current operational limit of three canisters per storage bay out of storage and on hoists will not be affected.

ISOSHL-III Calculated Minimum Water Shield Above Storage Array.

	Reference Date +0 d	Reference +1000 d	Reference +3000 d	Reference +5000 d
Limited ¹ Access Time	210.4 cm	209.4 cm	207.6 cm	205.8 cm
	6 ft 11 in.	6 ft 11 in.	6 ft 10 in.	6 ft 10 in.
Unlimited ² Access Time	240.8 cm	239.7 cm	237.8 cm	236.0 cm
	7 ft 11 in.	7 ft 11 in.	7 ft 10 in.	7 ft 9 in.

NOTES:

Calculated distance is from top of fuel storage array to water surface.

Dose point is 152.4 cm (5 ft) air above water surface.

Situation: one canister 91.44 cm (3 ft) Above storage array.

Reference date is January 31, 1995.

¹Limited access time (1 hour/day), calculated dose rate is 2 mR/h.

²Unlimited access time, calculated dose rate is 0.2 mR/h.

The current operational level of K basin pools is 490 ± 15 cm (16.0 ± 0.5 ft) measured from the bottom of the pool to the surface of the water. The Kaiser engineering study sketches, ES-N040-S03 (Option A) and ES-N040-S04 (Option B) (Kaiser 1994), designed 227.01 cm (7 ft 5½ in.) for canisters

three high under Option B. This design would leave 260.67 ± 15.24 cm (8 ft 6 $\frac{1}{2}$ in. $\pm$ 0.5 ft) of water shielding above the top canister. At a minimum there would be 245.43 cm (8 ft $\frac{1}{2}$ in.) of water shielding above the top canister when stacked three high. Since the design minimum water shield of 245.43 cm (8 ft $\frac{1}{2}$ in.) is greater than the minimum required water shield thickness of 241.3 cm (7 ft 11 in.), this proposed design is acceptable according to the radiation shielding design, personnel protection requirements and acceptable dose rate limits.

CONTENTS

1.0	INTRODUCTION	1-1
1.1	PURPOSE	1-1
1.2	SCOPE	1-1
1.3	RESULTS	1-2
2.0	DISCUSSION	2-1
2.1	CANISTER DOSE RATE MEASUREMENTS	2-1
2.2	CANISTER SIDE ISOSHL D-II MODELS	2-2
2.3	CANISTER TOP ISOSHL D-II MODELS	2-10
2.4	STATIC STORAGE ARRAY ISOSHL D-II MODEL	2-14
2.4.1	Canister Storage Location Geometry	2-16
2.4.2	Reconstructed SCATS Database	2-18
2.4.3	Single Canister Irradiation Calculation	2-19
2.4.4	Static Storage Array Geometry	2-24
2.5	ACTIVE STORAGE ARRAY ISOSHL D-II CALCULATION	2-24
2.5.1	Active Storage Array ISOSHL D-II Model	2-28
2.5.2	Storage Array with Multiple Elevated Canisters	2-30
2.5.3	Temperature Effect on Water Density and Radiation Shielding	2-32
2.6	MINIMUM WATER SHIELD REQUIREMENT	2-33
3.0	ISOSHL D CODE COMPARISON	3-1
3.1	PURPOSE OF COMPARISON	3-1
3.2	SCOPE OF COMPARISON	3-1
3.3	RESULTS OF ISOSHL D COMPARISON	3-1
3.4	CONCLUSION OF ISOSHL D COMPARISON	3-8
4.0	CONCLUSIONS	4-1
5.0	REFERENCES	5-1
APPENDICES		
A	RECONSTRUCTED SCATS ACCOUNTABILITY DATABASE	A-1
B	DOSE RATE MEASUREMENT CANISTERS WERE STAINLESS STEEL	B-1
C	REPRESENTATIVE ISOSHL D-II INPUT FILES	C-1
	ISOSHL D-II Input for Half Canister Model 5TA, 6 wt% ^{240}Pu	C-3
	ISOSHL D-II Input for Half Canister Model 6TB, 16 wt% ^{240}Pu	C-5
	ISOSHL D-II Input for Single Canister Model B1, 16 wt% ^{240}Pu	C-7
	ISOSHL D-II Input for Static Basin Model B1800, 16 wt% ^{240}Pu	C-9
D	REPRESENTATIVE ISOSHL D-II OUTPUT	D-1
E	INDEPENDENT REVIEWER'S COMMENT	E-1

LIST OF FIGURES

1	Basin Water Shielding Geometry.	1-3
2	Active Basin ISOSHLD-II Dose Rates.	1-4
3	Static Basin ISOSHLD-II Dose Rates.	1-6
4	Canister Side ISOSHLD-II Models.	2-6
5	Canister Top ISOSHLD-II Models.	2-13
6	Storage Location ISOSHLD-II Models.	2-17
7	Static Storage Array ISOSHLD-II Models.	2-26
8	Active Basin ISOSHLD-II Model.	2-29
9	Minimum Water Thickness Basin Geometry.	2-36
10	ISOSHLD Dose Rate Comparison.	3-2
11	ISOSHLD Dose Rate Comparison-Detail.	3-3
12	ISOSHLD 4.0 to ISOSHLD-II Ratio.	3-4
13	ISO-PC 1.90 to ISOSHLD-II Ratio.	3-5
14	ISOSHLD 4.0 to ISO-PC 1.90 Ratio.	3-7

LIST OF TABLES

1	Calculated Minimum Water Shield Above Storage Array	1-2
2	Two-Region Canister Side ISOSHL-D-II Models	2-2
3	Two Region Canister Side ISOSHL-D-II Dose Rates	2-4
4	Three-Region Canister Side ISOSHL-D-II Models	2-7
5	Three-Region Canister Side ISOSHL-D-II Dose Rates	2-8
6	Four-Region Canister Top ISOSHL-D-II Models	2-11
7	Four-Region Canister Top ISOSHL-D-II Dose Rates	2-12
8	ISOSHL-D-II Gamma Ray Attenuation and Effective Penetration	2-14
9	Five-Region Canister Top ISOSHL-D-II Dose Rates	2-15
10	Five-Region Storage Location ISOSHL-D-II Models	2-16
11	Five-Region Storage Location ISOSHL-D-II Dose Rates	2-18
12	Irradiation Exposure, Decay ISOSHL-D-II Comparison	2-20
13	RIBD Calculated ¹³⁷ Cs Inventory.	2-21
14	ORIGEN2 Results for Determining ¹³⁷ Cs Activity	2-22
15	ORIGEN2 Calculated Gamma Ray Production	2-25
16	Static Storage Array ISOSHL-D-II Dose Rates	2-27
17	Active Storage Array Dose Rate Calculations	2-28
18	Active Storage Array ISOSHL-D-II Dose Rates	2-30
19	Radiation Dose Rate Increase Due to Water Temperature.	2-33
20	Shield Design Criteria	2-34
21	ISOSHL-D Dose Rate Comparisons	3-6
22	ANS-6.4.3 Water Buildup Factors (R)	3-8
23	Calculated Minimum Water Shield Above Storage Array	4-1

This page intentionally left blank.

CONSOLIDATED FUEL SHIELDING CALCULATIONS

1.0 INTRODUCTION

1.1 PURPOSE

Consolidated fuel storage considers combining irradiated N Reactor fuel from both 105-KE Basin and 105-KW Basin into just one of the basins. Since the number of canisters in the two basins is greater than the number of canister locations in a single basin, the canisters will need to be stacked two or three high. Stacking the canisters will reduce the water shielding above the upper canisters, so it is important to calculate the minimum required water shielding above the top canister in the canister storage array. The purpose of this document is to calculate this minimum required water shielding thickness above the stored irradiated uranium, consistent with Westinghouse Hanford Company policy (WHC-CM-4-9) and "as low as reasonably achievable" (ALARA) principles.

Gamma ray dose rates generated from N Reactor irradiated fuel were calculated using ISOSHLI-II (Engel et al. 1966; Mansius 1969), in support of consolidated fuel storage. This document contains the determination of the minimum water shielding above the irradiated fuel storage array, consistent with radiation shielding and acceptable dose rate practices.

1.2 SCOPE

There are three sources of gamma dose rates in the K Area fuel storage basins: (1) gamma dose rates direct from the irradiated fuel, (2) gamma ray dose rate from radioactive isotopes, such as ^{137}Cs , that have migrated away from the fuel but remain in the basin, and (3) gamma ray dose rates from surroundings, such as contamination on pipe walls. This report details the gamma ray dose rates directly from irradiated fuel.

The gamma ray dose rate direct from irradiated fuel depends on water shielding thickness. The smallest water shielding thickness consistent with radiation shielding protection practices was calculated from ISOSHLI-II models that were tested with supporting measurements.

The current operational level of K basin pools is 490 ± 15 cm (16.0 ± 0.5 ft) measured from the bottom of the pool to the surface of the water. The Kaiser engineering study sketches ES-N040-S03 and ES-N040-S04 (Kaiser 1994) designed 227.01 cm (7 ft 5 1/2 in.) for canisters stacked three high ($1\frac{1}{2}$ + 29 + $1\frac{1}{2}$ Option B + 29 + $1\frac{1}{2}$ Option B + 27 1/2 lid top = 89 1/2 in.). This design would leave only 260.67 ± 15.24 cm (8 ft 6 3/4 in. ± 0.5 ft) of water shielding above the top canister. At a minimum, this would be 245.43 cm (8 ft 1 1/4 in.) of water shielding above the top canister lid when stacked three high. Since Option B with 4.445 cm ($1\frac{1}{4}$ in.) vertical separation is being considered as the limiting case, all vertical separations between canister layers less than 4.445 cm ($1\frac{1}{4}$ in.) are also being covered. Option A has 0 cm (0 in.) between the canister layers.

The geometry considered in these shielding calculations is shown in Figure 1. There is an array of irradiated fuel storage canisters with a single canister lifted 91.44 cm (3 ft) above the array. The canisters below the top level in the array do not add to the calculated dose rate at the dose point because of the shielding of a canister; in fact, only about the upper 5 cm (2 in.) of the fuel element contribute to the dose rate at the dose point. The dose point is calculated above the floor grating, taken as 152.4 cm (5 ft) above the water surface.

1.3 RESULTS

Minimum water shielding thickness above the irradiated fuel storage array was calculated and the results are shown in Table 1. Since the minimum required water shield thicknesses calculated by ISOSHL-D-II are less than the design minimum water thickness, the proposed design is acceptable according to the radiation shielding requirement. Dose point is 152.4 cm (5 ft) of air above water surface of the calculated water shield.

Table 1. Calculated Minimum Water Shield Above Storage Array.

	Reference date +0 d	Reference +1000 d	Reference +3000 d	Reference +5000 d
Limited ¹ access time	210.4 cm 6 ft 11 in.	209.4 cm 6 ft 11 in.	207.6 cm 6 ft 11 in.	205.8 cm 6 ft 10 in.
Unlimited ² access time	240.8 cm 7 ft 11 in.	239.7 cm 7 ft 11 in.	237.8 cm 7 ft 10 in.	236.0 cm 7 ft 9 in.

NOTES:

Calculated Distance is from Top of Fuel Storage Array to Water Surface.

Dose point is 152.4 cm (5 ft) Air above water surface.

Situation: one canister 3 ft above storage array.

Reference date is January 31, 1995.

¹Limited access time (1 hour/day), calculated dose rate is 2 mR/h.

²Unlimited access time, calculated dose rate is 0.2 mR/h.

The current operational limit of three canisters per storage bay out of storage and on hoists will not be affected.

Figure 2 is a graph of the ISOSHL-D-II calculated dose rate due to an irradiated fuel storage array with one canister suspended 91.44 cm (3 ft) above the rest of the array as a function of water shielding thickness above the fuel storage array. The 91.44-cm (3-ft) distance is measured from the top of the lid in the canister array to the top of the lid of the suspended canister. A canister is 73.66 cm (29 in.) high; this allows 17.78 cm (7 in.) between the bottom of the suspended canister and the top of the canisters in the canister array. This models the situation of lifting one canister above the storage array in order to move it to another location. A 152.4-cm (5-ft) air shield is above the water surface to the calculated dose point.

**Figure 1. Basin Water Shielding Geometry.
(Single Canister 91.44 cm (3 ft) Above Triple-Stacked Array.)**

Active basin shielding calculations allowed for a single canister 91.44 cm (3 ft) above the static canister array. Dose point is calculated 152.4 cm (5 ft) above water surface.

Figure 2. Active Basin ISOSHLD-II Dose Rates.
(Single Canister 91.44 cm [3 ft] Above Array.)

Figure 3 is a graph of ISOSHL-D-II calculated dose rate due to an irradiated fuel storage array as a function of water shielding thickness above the fuel storage array. This models the situation of a static fuel storage array without any canister lifted above the fuel storage array. A 152.4-cm (5-ft) air shield is above the water surface to the calculated dose point.

1.4 METHOD

Dose rate calculations were performed for irradiated N Reactor fuel, and some single-pass reactor (SPR) fuel, presently (July 1994) stored in the 105-KE and 105-KW Basins. The calculation of dose rate incorporated the following elements:

1. Measurement of gamma dose rate on individual canisters
2. ISOSHL-D-II model dose rate calculations consistent with these single canister measurements on canister sides (Wittekind 1988b)
3. Conversion of ISOSHL-D-II canister side model to a canister top model
4. Extension of the ISOSHL-D-II canister top model to a canister storage location model
5. Accommodation of highest dose rate canister in the fuel storage basin from the ISOSHL-D-II canister models compared to measured dose rates
6. Expansion of the ISOSHL-D-II single canister storage location model to a full-basin geometry (Wittekind 1991)
7. Combination of ISOSHL-D-II full-basin results with single canister results to model single canister movement over fuel storage array
8. Consideration of additional irradiated fuel storage canisters in motion simultaneously
9. Interpolation of calculated ISOSHL-D-II dose rate results for radiation shield design requirements to determine minimum design water shield thickness requirements
10. Comparison with other ISOSHL-D versions and acceptance of a justifiable and conservative dose rate calculation.

The dose rate calculations began with establishing an ISOSHL-D-II model that would match measured dose rates. These measurements were performed on canisters from N Reactor discharges that averaged 6 wt% ^{240}Pu and 12 wt% ^{240}Pu irradiated fuel at decay times after the end of irradiation between 549 days and 5,900 days. The measurements were taken on the side of the canister, and 30.48 cm (1 ft) of water shielding away from the side of the canister. Thickness of the detector and its PVC tube holder were not considered in the ISOSHL-D-II model of the experimental measurements.

Figure 3. Static Basin ISOSILD-II Dose Rates.
(All Canisters at Same Depth in Array.)

The effect of 1 in. air attenuation was considered to be small and was neglected. Two additional measurements did not fit into this pattern: a measurement taken on the opposite canister barrel, and a canister dose rate measured on the lid. The measurement on the canister lid is most relevant to the dose rate above an irradiated fuel storage array.

The N Reactor fuel elements have a tube-in-tube geometry. There is an outer fuel cylinder and an inner fuel cylinder with a cooling hole down the center. This geometry indicates that the ISOSHL-11 model in the horizontal direction can reasonably homogenize the fuel element, zirconium, and water. This geometry also indicates that the ISOSHL-11 model in the vertical direction should not homogenize the fuel element, but rather model the fuel element as uranium, or even as uranium with a zirconium end cap. The ISOSHL-11 canister side model established the fission product gamma ray source as reasonable in magnitude and confirmed the use of the water shield for the dominant shield buildup factor for determining the deep-penetrating gamma rays at 30.48 cm (1 ft) (and greater) water shield thickness. The buildup factor accommodates the attenuation of gamma rays by absorption and by scattering. Scattered gamma rays may decrease in energy, but still contribute to the dose rate. Gamma ray scattering without absorption is accounted for by multiplying by a buildup factor. A dominant gamma ray shield must be chosen for the ISOSHL-11 calculation. At a water shield thickness of 30.48 cm (1 ft) or greater, the dominant shield is, of course, water. At canister contact, the dominant shield is the canister contents.

The ISOSHL-11 canister side model using the side of a cylinder geometry was converted to an ISOSHL-11 canister top model. The geometry was changed from the side of a cylinder to the end of a cylinder, and the homogenized canister contents were changed to pure uranium at uranium metal density. The fission product source term remained the same and the water shield buildup factor remained the same for the ISOSHL-11 canister side and canister top models.

The ISOSHL-11 canister top model was converted to a canister storage location geometry by changing from an end cylinder geometry to a rectangular geometry. A few ISOSHL-11 models were calculated to move from the end cylinder single canister model to the canister storage location rectangular model.

Another consideration was the exposure of the highest dose rate N Reactor fuel in either 105-KE or 105-KW Basin. The highest exposure N Reactor fuel is slightly over 16 wt% ^{240}Pu with a certain decay time. The shortest decay time has a lower exposure. The limiting storage basin will be composed of the highest dose rate canisters. Both situations were calculated by ISOSHL-11 with the result that the highest exposure case had the greatest calculated dose rate. The highest exposure situation was used for all subsequent calculations because this calculated the highest calculated dose rate.

The ISOSHL-11 canister storage location model was expanded to a static basin geometry by increasing the total power generated in the source region and increasing from single canister storage location rectangular geometry to a 1,800 canister storage location basin. Several ISOSHL-11 models were calculated to move from the single canister location model to the static fuel storage array rectangular model. Only the top layer of the canister array

contributes to the dose rate at the calculated dose point so lower layers in the triple-stacked canister storage array do not have to be considered in the ISOSHL-D-II calculation.

The irradiated fuel storage basin activities involve movement of canisters out of position and lifted above the fuel storage array in order to relocate the canisters. This is the active fuel storage array with one canister 91.44 cm (3 ft) (canister height is 73.66 cm [29 in.]) above the static fuel storage array. ISOSHL-D-II calculated dose results added the results for a static fuel storage array and the results for one canister with 91.44 cm (3 ft) less water shielding. The largest contribution to the active fuel storage array is due to this single canister 91.44 cm (3 ft) above the static fuel storage array. The shielding effect of the raised canister above the nearest canister in the fuel storage array was neglected.

Consideration of other nearby canisters lifted and in motion simultaneously was done by using the ISOSHL-D-II results and accommodating additional distance dispersion and increase radiation attenuation. For nearby additional raised canisters, there is a small increase in calculated radiation dose rate. There is no proposal for limiting the number of lifted canisters in the irradiated fuel storage basins.

The dose rate of 0.2 mR/h (maximum 0.5 mR/h) is the initial design level dose rate for unlimited access (WHC-CM-4-9). The dose rate of 2.0 mR/h (5.0 mR/h maximum) is the initial design level dose rate for limited access time situation, or 1 hour per day (WHC-CM-4-9). The interpolated water shielding thickness which resulted in these gamma ray dose rates became the minimum water thickness required above the irradiated fuel storage array. At this time after fuel discharge, there is very little change in radiation shielding requirements with additional decay time. There is only a small decrease of radiation shielding requirements with additional decay time after January 31, 1995. Radiation shielding requirements are dominated by the 30.17-year half-life of ^{137}Cs .

Extrapolation of contact and 30.48-cm (1-ft) water shield thickness measurements to the 152.40-cm (5-ft) and 243.84-cm (8-ft) water shield thickness ISOSHL-D-II dose rate calculations was checked by comparison with other ISOSHL-D versions. ISOSHL-D 4.0 results were accepted based on greater consistency with experimental measurements in 105-KW Basin. This is justifiable and assures a conservative calculation of dose rates. This caused an additional water shield thickness to be added to the ISOSHL-D-II dose rate calculations to account for an indicated nonconservative dose rate calculation bias in ISOSHL-D-II.

2.0 DISCUSSION

This section discusses comparison to irradiated fuel canister dose rate measurements, the ISOSHL-D-II model and extension of the ISOSHL-D-II model to, ultimately, an active (one canister in motion above the static array) fuel storage basin model with inference to a design minimum water shield thickness.

2.1 CANISTER DOSE RATE MEASUREMENTS

A gamma probe, with a stated accuracy of $\pm 10\%$ and a readout dial with smallest increment of 10 R/h on the 20,000 R/h scale used, was placed inside a PVC tube that was closed and weighted at one end. This PVC tube had a smaller, 1-ft-long tube sticking off to one side. This smaller tube was used as a fixed 1-ft distance measure. In this manner, a measurement could be made at contact and at 1-ft away from the canister side in water. The gamma ray dose rate measurements (Wittekind 1988b) were observed, and a simple two-region ISOSHL-D-II model was documented. The goal was to simulate these measurements, and to apply them to situations that were not measured because of expected high radiation dose rates.

The canisters that had their gamma dose rate measured contained Mark IA (MKIA) style fuel and Mark IV (MKIV) style N Reactor fuel, with stated exposures of 6 wt% and 12 wt% ^{240}Pu , and decay times between 549 days and 5,900 days. For simplicity in the following calculations, both MKIV and MKIA fuel was considered to be MKIV fuel. This is reasonable because MKIV and MKIA are similar. This is also conservative because this document's application will be for the gamma ray dose out of the top of the canister where the MKIV fuel, because of its longer length and consequently less vertical shielding, results in the larger gamma ray dose.

Of course the designation of 6 wt% ^{240}Pu and 12 wt% ^{240}Pu actually refers to fuel elements with a distribution of exposure that is, hopefully, centered on the 6 wt% ^{240}Pu and 12 wt% ^{240}Pu . The scatter in the dose rate measurements can easily be ascribed to this variation in the exposure of the fuel elements which happened to be closest to the gamma probe.

For simplicity in the following calculations, the measured gamma dose rate for 12 wt% ^{240}Pu exposure canisters were divided in half and considered to be a 6 wt% ^{240}Pu exposure canister. This is not entirely accurate, but is consistent with the accuracy of the canister dose rate measurements. Similarly, scaling to 16 wt% ^{240}Pu exposure canisters could be accomplished by multiplying the 6 wt% ^{240}Pu dose rate by 2.67. When the irradiation effect is calculated in Section 2.4.3, the scaling is performed more accurately, but for the purpose of comparing to experimental measurements, this scaling is reasonable.

Canister dimensions and compositions were derived from drawings H-1-36935, H-1-42793, and H-1-46215.

2.2 CANISTER SIDE ISOSHL-D-II MODELS

The 1988 ISOSHL-D-II model (Wittekind 1988b) was matched to the dose rate measurements at contact. This homogenized canister contents ISOSHL-D-II model was then considered appropriate for both the contact and the 1-ft water shielding situation. The canister contact measurement was modeled with the radiation shielding buildup factor for the homogenized canister contents, which included some water. Slight variations off of the 1988 base model included ignoring water in the homogenized canister contents, using the water buildup factor instead of the homogenized canister contents buildup factor, and solid uranium as the homogenized canister contents, also with the two different buildup factors. These various two-region models are detailed in Table 2.

Table 2. Two-Region Canister Side ISOSHL-D-II Models.

Homogenized canister contents	1988 base model	Model #2	Model #3	Model #4	Model #5
Uranium (g/cm ³)	7.3876	7.3876	7.3876	18.63	18.63
Zirconium (g/cm ³)	0.5077	0.5077	0.5077	0.00	0.00
Water (g/cm ³)	0.5300	0.0000	0.5300	0.00	0.00
Buildup factor for shield	Canister contents	Canister contents	Water	Canister	Water contents

NOTES: Canister size: 10.3251 cm radius (8.13 in. O.D.).
Fuel height: 66.294 cm (26.1 in.).

ISOSHL-D-II calculations were performed for the end of irradiation and at 500 days, 1,000 days, 3,000 days and 5,000 days decay after the end of irradiation. The physical phenomena of radioactive decay obeys the relation:

$$N(t) = N(t=0) \exp(-\lambda t) = N(t=0) \exp(-(\ln(2)/t_{1/2})t)$$

where:

- $N(t)$ = Number of atoms at time t .
- λ = Radioactive decay constant.
- $\ln(2)$ = Natural logarithm of 2.
- $t_{1/2}$ = Radioactive half-life.

The physical basis indicates that the natural logarithm of dose rate, which is proportional to the natural logarithm of the number of atoms, is proportional to decay time. Actually, the dose rate would be proportional to the sum of a number of exponentials, one for each significant isotope contributor, but at the decay times being considered, only ¹³⁷Cs is important as long as the end of irradiation ISOSHL-D-II calculated result is not used. The natural logarithm of the ISOSHL-D-II dose rate results were interpolated by

linear interpolation, using one time on one side and the other time on the other side of the decay time being interpolated, if available, otherwise the closest two ISOSHLD-II calculated times were used.

Table 3 lists the ISOSHLD-II calculated dose rates for irradiated fuel at discharge and the four specific subsequent decay times. Linear interpolation is performed to determine the ISOSHLD-II result for the decay times of the experimental measurements. The measured dose rates close to 6 wt% ^{240}Pu exposure are shown in the middle of Table 3. Finally, on the right hand side in Table 3, the ISOSHLD-II calculated result is divided by the experimental measurement.

The average of the calculated-to-measured ratio is used as the figure of merit for different ISOSHLD-II models. The homogenized canister contents model, 1988 base case, has the calculated-to-measured ratio closest to 1.0 for the canister contact measurements. For the 1-ft water shield thickness, the buildup factor for the water shield is the most appropriate ISOSHLD-II model. The ISOSHLD-II calculated results for contact geometry averaged 1.0792 (see Table 3), or about 8% high, so some modification is possible. An average result close to 1.0 was the desired result for ISOSHLD-II calculations divided by experimental measurements.

The 1988 ISOSHLD-II model was improved by explicitly including the canister barrel. This increased the number of regions from two to three and slightly reduced the homogenized canister contents radius. Accountability personnel attempted to determine whether the canisters used for experimental measurements were aluminum or stainless steel. Most of the experimentally measured canisters were stainless steel (see Appendix B). The two-region and three-region ISOSHLD-II models are depicted in Figure 4. A more detailed description of the three-region model is in Table 4.

The dose rate calculated by ISOSHLD-II for the canister side at contact was reduced about 12% in the three-region model, but because the dose rates calculated previously for the two-region ISOSHLD-II model were approximately 8% too high, the improved model is more consistent with experimental measurements on the canister side at contact. The 1988 ISOSHLD-II model calculated only the canister side at contact dose rate measurements. The three-region ISOSHLD-II model was applied to both the canister side contact dose rate measurements and the 1-ft distance dose rate measurements. The three-region canister side at contact ISOSHLD-II model used the homogenized canister contents for the dose rate buildup factor. The three-region canister side at 1 ft distance ISOSHLD-II model used water shield for the dose rate buildup factor. This is the only difference between the canister side at contact and the canister side at 1 ft distance ISOSHLD-II models.

The explanation of Table 5 is the same as the description for Table 3, except that the three-region ISOSHLD-II canister side model was calculated rather than the two-region ISOSHLD-II canister side model. The logarithm of ISOSHLD-II calculated results, were, using four different decay times after irradiation, linearly interpolated to the decay time of the measurement canisters. The average ratio of ISOSHLD-II interpolated dose rates for the eight canister measurements was calculated. An average result close to 1.0 was the desired result for ISOSHLD-II calculations divided by experimental measurements.

Table 3. Two Region Canister Side ISOSHL-D-II Dose Rates. (2 sheets)

Decay days	Calculated and interpolated dose rates (R/h)					Expt. Meas. (R/h)	ISOSHL-D-II calculated result divided by experimental measurement				
	1988 base case	Model #2	Model #3	Model #4	Model #5		1988 base case	Model #2	Model #3	Model #4	Model #5
Canister side measurements - 1 ft distance											
0*	385200.	221400.	551700.	89710.	245700.	--	--	--	--	--	--
500*	68.24	30.24	122.2	11.65	53.33	--	--	--	--	--	--
549	45.11	21.65	76.30	9.158	36.12	100	0.4511	0.2165	0.7630	0.0916	0.3612
688	34.18	15.59	60.85	6.520	28.03	60	0.5697	0.2598	1.0141	0.1087	0.4671
1000*	18.34	7.452	36.61	3.041	15.86	--	--	--	--	--	--
1838	13.69	4.970	28.93	2.050	12.48	40	0.3422	0.1242	0.7232	0.0512	0.3121
2009	12.89	4.576	27.57	1.891	11.89	25	0.5157	0.1830	1.1029	0.0756	0.4756
2034	12.78	4.521	27.38	1.869	11.80	30	0.4260	0.1507	0.9126	0.0623	0.3935
2243	11.88	4.086	25.82	1.694	11.12	25	0.4753	0.1634	1.0327	0.0678	0.4448
3000*	9.121	2.834	20.87	1.186	8.958	--	--	--	--	--	--
4353	8.214	2.534	18.85	1.062	8.092	25	0.3286	0.1014	0.7542	0.0425	0.3237
5000*	7.813	2.402	17.96	1.008	7.708	--	--	--	--	--	--
5900	7.287	2.230	16.79	0.9369	7.204	15	0.4858	0.1486	1.1191	0.0625	0.4803
Average (calculated/measured)							0.4493	0.1685	0.9277	0.0703	0.4073

Table 3. Two Region Canister Side ISOSHL-D-II Dose Rates. (2 sheets)

Decay days	Calculated and interpolated dose rates (R/h)					Expt. Meas. (R/h)	ISOSHLD-II calculated result divided by experimental measurement				
	1988 base case	Model #2	Model #3	Model #4	Model #5		1988 base case	Model #2	Model #3	Model #4	Model #5
Canister side measurements - contact											
0*	7993000.	5733000.	10930000.	2375000.	4820000.	--	--	--	---	--	--
500*	2058.	1329.	3193.	541.0	1389.	--	--	--	--	--	--
549	1818.	1167.	2847.	476.6	1237.	1760	1.0327	0.6630	1.6175	0.2708	0.7029
688	1278.	806.7	2056.	332.6	890.8	920	1.3887	0.8769	2.2346	0.3616	0.9683
1000*	579.1	352.3	990.0	148.4	426.2	--	--	--	--	--	--
1838	461.4	273.3	805.9	114.8	345.6	510	0.9047	0.5359	1.5802	0.2251	0.6776
2009	440.5	259.5	772.8	108.9	331.1	300	1.4683	0.8650	2.5759	0.3631	1.1037
2034	437.5	257.5	768.1	108.1	329.0	475	0.9211	0.5422	1.6170	0.2275	0.6927
2243	413.4	241.7	729.6	101.4	312.3	400	1.0335	0.6044	1.8241	0.2534	0.7807
3000*	336.7	192.2	605.9	80.38	258.4	--	--	--	--	--	--
4353	304.1	173.3	547.9	72.49	233.7	415	0.7327	0.4177	1.3203	0.1747	0.5631
5000*	289.6	165.0	522.2	69.00	222.7	--	--	--	--	--	--
5900	270.6	154.0	488.4	64.42	208.3	235	1.1515	0.6555	2.0783	0.2741	0.8863
Average (calculated/measured)							1.0792	0.6451	1.8560	0.2688	0.7969

*ISOSHL-D-II calculated dose rates. Other decay times were linearly interpolated using the logarithm of the dose rate (dependent variable) versus decay time (independent variable).

Figure 4. Canister Side ISOSILD-II Models.
(Two-Region and Three-Region Models for Side Dose Points.)

Two-Region Model

Homogenized canister contents buildup factor for contact geometry.

Water buildup factor for 30.48 cm (1 ft) distant dose point.

Three-Region Model.

Explicit 0.1524 cm (0.060 in.) stainless steel canister.

Homogenized canister contents buildup factor for contact geometry.

Water buildup factor for 30.48 cm (1 ft) distant dose point.

Table 4. Three-Region Canister Side ISOSHLD-II Models.

Homogenized canister contents	Model #1A	Model #2A	Model #3A	Model #4A	Model #5A
Uranium (g/cm ³)	7.3876	7.3876	7.3876	18.63	18.63
Zirconium (g/cm ³)	0.5077	0.5077	0.5077	0.00	0.00
Water (g/cm ³)	0.5300	0.0000	0.5300	0.00	0.00
Buildup factor for shield	Canister contents	Canister contents	Water	Canister contents	Water

NOTES: Canister size: 10.254 cm radius (8.074 in. O.D.).

Canister barrel thickness: 0.1524 cm (0.060 in.).

Fuel height: 66.294 cm (26.1 in.).

The three-region model with homogenized canister contents is the ISOSHLD-II side model that will be used. The buildup factor for homogenized canister contents is used for contact geometry, but the water shield buildup factor will be used for the 1-ft water shield thickness measurements.

The main conclusion to be drawn from the results calculated by ISOSHLD-II is that the irradiation that created the gamma ray source term is very reasonable. This canister side ISOSHLD-II model fixed the Mode 1 irradiation calculation to calculate a realistic quantity of fission products. Mode 1 is the computer code input option that ISOSHLD-II is coupled to the RIBD (Radioisotope Buildup and Decay) code to generate a gamma ray source from irradiation parameters and decay times to compute fission product inventories. That the fission product quantity is realistic is supported by reference to the dose rate experimental measurements (Wittekind 1988b). This same source term is also used in the canister top ISOSHLD-II model.

There is a small lack of precision in comparing the basin dose rate measurements to dose rates calculated by ISOSHLD-II because the detector was about $\frac{1}{8}$ in. in radius and centered in the 6.013-cm (2.3675-in.) outside diameter PVC tube by a lucite or polyethylene ring. In addition, there should have been about 1 in. air shield in the ISOSHLD-II modeled geometry for contact and the 30.48 cm (1 ft) distant measurements, but 1 in. air attenuation is considered a small effect in the basin dose rate measurements.

The final choice of ISOSHLD-II model for dose rate calculations on the side is the three-region model with homogenized canister contents, models #1A and #3A. The contact dose rate measurements were compared to model #1A (canister contents shield buildup factor), yet the 1 ft distance measurements were compared to model #3A (water shield buildup factor). The 1 ft water shielding situation used the radiation shielding buildup factor for water.

Table 5. Three-Region Canister Side ISOSHLD-II Dose Rates. (2 sheets)

Decay days	Calculated and interpolated dose rates (R/h)					Expt. meas. (R/h)	ISOSHLD-II calculated result divided by experimental measurement				
	Model #1A	Model #2A	Model #3A	Model #4A	Model #5A		Model #1A	Model #2A	Model #3A	Model #4A	Model #5A
Canister side measurements - 1 ft distance											
0*	280300.	158900.	399600.	64090.	177700.	--	--	--	--	--	--
500*	46.57	20.24	83.43	7.756	36.36	--	--	--	--	--	--
549	31.96	15.07	54.08	6.345	25.57	100	0.3196	0.1507	0.5408	0.0635	0.2557
688	23.85	10.70	42.43	4.455	19.52	60	0.3976	0.1784	0.7071	0.0742	0.3253
1000*	12.37	4.964	24.61	2.014	10.65	--	--	--	--	--	--
1838	9.060	3.196	19.24	1.313	8.298	40	0.2265	0.0799	0.4811	0.0328	0.2075
2009	8.502	2.921	18.30	1.203	7.886	25	0.3401	0.1168	0.7320	0.0481	0.3154
2034	8.424	2.883	18.17	1.188	7.828	30	0.2808	0.0961	0.6055	0.0396	0.2609
2243	7.794	2.583	17.08	1.067	7.355	25	0.3118	0.1033	0.6834	0.0427	0.2942
3000*	5.883	1.735	13.68	0.7250	5.871	--	--	--	--	--	--
4353	5.293	1.548	12.36	0.6483	5.301	25	0.2117	0.0619	0.4943	0.0259	0.2120
5000*	5.032	1.466	11.77	0.6145	5.048	--	--	--	--	--	--
5900	4.690	1.359	11.00	0.5704	4.716	15	0.3127	0.0906	0.7333	0.0380	0.3144
Average (calculated/measured)							0.3001	0.1097	0.6222	0.0456	0.2732

Table 5. Three-Region Canister Side ISOSHL-D-II Dose Rates. (2 sheets)

Decay days	Calculated and interpolated dose rates (R/h)					Expt. meas. (R/h)	ISOSHL-D-II calculated result divided by experimental measurement				
	Model #1A	Model #2A	Model #3A	Model #4A	Model #5A		Model #1A	Model #2A	Model #3A	Model #4A	Model #5A
Canister Side Measurements - Contact											
0*	7191000.	5017000.	9962000.	2069000.	4398000.	--	--	--	--	--	--
500*	1815.	1122.	2882.	450.4	1252.	--	--	--	--	--	--
549	1602.	983.7	2569.	396.3	1115.	1760	0.9102	0.5589	1.4697	0.2252	0.6335
688	1124.	677.4	1854.	275.6	802.4	920	1.2219	0.7363	2.0157	0.2996	0.8722
1000*	507.6	293.2	892.2	122.0	383.5	--	--	--	--	--	--
1838	404.0	226.6	726.4	94.44	311.2	510	0.7922	0.4443	1.4243	0.1852	0.6103
2009	385.6	215.0	696.5	89.63	298.3	300	1.2854	0.7166	2.3218	0.2988	0.9942
2034	383.0	213.3	692.3	88.95	296.4	475	0.8063	0.4491	1.4574	0.1873	0.6240
2243	361.8	200.0	657.7	83.44	281.4	400	0.9045	0.5001	1.6442	0.2086	0.7034
3000*	294.4	158.5	546.2	66.21	233.0	--	--	--	--	--	--
4353	265.9	142.9	494.0	59.71	210.7	415	0.6406	0.3444	1.1903	0.1439	0.5077
5000*	253.2	136.0	470.8	56.83	200.8	--	--	--	--	--	--
5900	236.6	126.9	440.4	53.05	187.8	235	1.0068	0.5402	1.8739	0.2258	0.7992
Average (calculated/measured)							0.9460	0.5362	1.6734	0.2218	0.7180

* ISOSHL-D-II calculated dose rates. Other decay times were linearly interpolated using the logarithm of the dose rate (dependent variable) versus decay time (independent variable).

This is the only difference in the ISOSHLD-II models used to simulate the dose rate measurements on the canister side. Where there is not much water shielding, canister contents is the major radiation shield, further away, water becomes the dominant radiation shield. The water shield buildup factor was used for the ISOSHLD-II canister top model for the deep shielding calculations that form the basis for the significant result of this document.

2.3 CANISTER TOP ISOSHLD-II MODELS

The canister top ISOSHLD-II model was derived from the canister side ISOSHLD-II model by changing the geometry to the end of a cylinder while retaining the same fission product gamma ray source. The ISOSHLD-II canister top models use the same irradiation exposure as the ISOSHLD-II canister side models. Different ISOSHLD-II canister side model homogenized canister contents models are compared. The end cylinder geometry included the top air space above the fuel and the $\frac{1}{2}$ -in. stainless steel lid in the shielding geometry for a four-region model.

A single canister top dose rate measurement (Wittekind 1988b) was compared to the canister top ISOSHLD-II dose rate calculations. The four-region end cylinder geometry with the same materials as the cylinder side geometry was compared to the one experimental measurement. The different ISOSHLD-II four-region canister top models are compared to the experimental measurement in Table 6. The result was that the solid uranium metal as the homogenized canister contents with the canister contents buildup factor gave ISOSHLD-II dose rate calculations closest to the experimental measurement, but ISOSHLD-II calculated dose rates were quite a bit higher than the experimental measurement.

The solid uranium model for homogenized canister contents was selected as the most realistic. This change was done because of the different gamma ray shielding for vertical tube in tube fuel geometry. ISOSHLD-II calculations for an effective water thickness were varied over a range to estimate an effective experimental detector-to-lid distance. ISOSHLD-II calculated results for the selected ISOSHLD-II canister top model are reported in Table 7. Dose rates calculated by ISOSHLD-II for a four-region canister top indicated that a 1-in. distance was necessary for canister top ISOSHLD-II dose rates to be similar to the experimental measurement. This was considered to be higher than expected, so a five-region canister top ISOSHLD-II model with an explicit zirconium endcap with the same range of effective water thickness was compared to experimental measurement. The five-region ISOSHLD-II canister top model is shown in Figure 5.

The absorption of the source gamma rays in the solid uranium fuel elements is significant. Consider the representative ISOSHLD-II calculation for 152.4 cm (5 ft) depth and the reference decay time (Appendix D). The dominant ISOSHLD-II dose comes from the 0.6500 gamma energy ($2.161\text{E}-3/2.566\text{E}-3 \times 100\% = 84.22\%$). Other contributions are listed in Table 8.

Table 6. Four-Region Canister Top ISOSHLD-II Models.

Decay days	Calculated and interpolated dose rates (R/h)					Expt. meas. (R/h)	ISOSHLD-II calculated result divided by experimental measurement				
	Model #1T	Model #2T	Model #3T	Model #4T	Model #5T		Model #1T	Model #2T	Model #3T	Model #4T	Model #5T
Canister top Measurement - contact											
0*	9393000.	5976000.	13450000.	2544000.	4388000.	--	--	--	--	--	--
500*	2233.	1192.	3781.	477.1	1000.	--	--	--	--	--	--
549	1966.	1040.	3366.	418.2	879.5	--	--	--	--	--	--
688	1369.	706.1	2421.	287.8	611.0	--	--	--	--	--	--
1000*	608.2	296.1	1155.	124.4	269.8	--	--	--	--	--	--
1838	479.5	222.1	938.8	93.31	211.1	--	--	--	--	--	--
2009	456.8	209.5	900.0	88.00	200.8	60	7.6128	3.4911	14.9997	1.4666	3.3463
2034	453.5	207.7	894.4	87.24	199.3	--	--	--	--	--	--
2243	427.4	193.3	849.4	81.20	187.5	--	--	--	--	--	--
3000*	344.8	149.1	704.4	62.63	150.2	--	--	--	--	--	--
4353	311.2	134.1	636.9	56.38	135.5	--	--	--	--	--	--
5000*	296.3	127.5	607.0	53.62	129.0	--	--	--	--	--	--
5900	276.8	118.8	567.7	50.00	120.5	--	--	--	--	--	--
Average (calculated/measured)						--	7.6128	3.4911	14.9997	1.4666	3.3463

* ISOSHLD-II calculated dose rates. Other decay times were linearly interpolated using the logarithm of the dose rate (dependent variable) versus decay time (independent variable).

Four-Region Canister Top ISOSHLD-II Model Configuration.

Fuel height:	66.29 cm	(26.1 in.)	Lid thickness:	1.270 cm	(0.50 in.)
Air thickness:	0.5588 cm	(0.22 in.)	Water thickness:	0.6350 cm	(0.25 in.)

Homogenized canister contents	Model #1T	Model #2T	Model #3T	Model #4T	Model #5T
Uranium (g/cm ³)	7.388	7.388	7.388	18.63	18.63
Zirconium (g/cm ³)	0.5077	0.5077	0.5077	0.00	0.00
Water (g/cm ³)	0.5300	0.0000	0.5300	0.00	0.00
Buildup factor for shield	Canister contents	Canister contents	Water	Canister contents	Stainless steel

Table 7. Four-Region Canister Top ISOSHL-D-II Dose Rates.

Decay days	Calculated and interpolated dose rates (R/h)					Expt. meas. (R/h)	ISOSHL-D-II calculated result divided by experimental measurement				
	+½ in. Model #4T	+½ in. Model #4T	+1 in. Model #4T	+2 in. Model #4T	+3 in. Model #4T		+½ in. Model #4T	+½ in. Model #4T	+1 in. Model #4T	+2 in. Model #4T	+3 in. Model #4T
Canister top measurement - contact											
0*	2576000.	2335000.	1943000.	1309000.	878700.	--	--	--	--	--	--
500*	483.4	436.2	360.1	237.9	155.5	--	--	--	--	--	--
549	423.8	382.4	315.7	208.5	136.3	--	--	--	--	--	--
688	291.7	263.1	217.2	143.4	93.70	--	--	--	--	--	--
1000*	126.1	113.7	93.89	61.93	40.43	--	--	--	--	--	--
1838	94.57	85.22	70.26	46.14	29.93	--	--	--	--	--	--
2009	89.18	80.35	66.22	43.45	28.15	60	1.4863	1.3392	1.1037	0.7242	0.4692
2034	88.42	79.67	65.65	43.07	27.90	--	--	--	--	--	--
2243	82.30	74.14	61.07	40.02	25.89	--	--	--	--	--	--
3000*	63.46	57.14	47.00	30.68	19.73	--	--	--	--	--	--
4353	57.14	51.45	42.31	27.62	17.75	--	--	--	--	--	--
5000*	54.34	48.93	40.24	26.26	16.88	--	--	--	--	--	--
5900	50.68	45.63	37.52	24.48	15.74	--	--	--	--	--	--
Average (calculated/measured)							1.4863	1.3392	1.1037	0.7242	0.4692

* ISOSHL-D-II calculated dose rates. Other decay times were linearly interpolated using the logarithm of the dose rate (dependent variable) versus decay time (independent variable).

Four-Region Canister Top ISOSHL-D-II Model Configuration.

Fuel height:	66.29 cm	(26.1 in.)	Lid thickness:	1.270 cm	(0.50 in.)
Air thickness:	0.5588 cm	(0.22 in.)	Water thickness:	Various	(Various)

Homogenized canister contents	+% in. Model #4T	+% in. Model #4T	+1 in. Model #4T	+2 in. Model #4T	+3 in. Model #4T
Uranium (g/cm ³)	18.63	18.63	18.63	18.63	18.63
Zirconium (g/cm ³)	0.00	0.00	0.00	0.00	0.00
Water (g/cm ³)	0.00	0.00	0.00	0.00	0.00
Buildup factor for shield	Canister contents	Canister contents	Canister contents	Canister contents	Canister contents

Figure 5. Canister Top ISOSHLD-II Models.
(Five-Region Model Adds Explicit Endcaps.)

Table 8. ISOSHL-D-II Gamma Ray Attenuation and Effective Penetration.

Gamma ray energy (MeV)	Dose rate fraction ^a	Attenuation coefficient (cm ⁻¹) ^b	Exp(-1) = 0.368 depth ^c		Exp(-7) = 0.001 depth ^d	
			cm	in.	cm	in.
0.6500	0.8422	2.552	0.39	0.15	2.74	1.08
1.2250	0.0669	1.248	0.80	0.32	5.61	2.21
1.4750	0.0361	1.043	0.96	0.38	6.71	2.64

NOTES: Representative results for 152.4 cm (5 ft) and reference decay date.

^aAppendix D, pages D-22 and D-23, were used to calculate second column.

^bAppendix D, pages D-9 and D-10, for uranium shield, were used to calculate column three.

^c1.0/attenuation coefficient.

^d7.0/attenuation coefficient.

This effective depth of penetration illustrates that the dose rate contribution comes from the top end of the irradiated fuel elements. This demonstrates that the longer fuel elements (those that reach closer to the top of the canister) would calculate the highest dose rate. The Table 8 results also demonstrate that lower layers in the triple-stacked canister array will not contribute to the ISOSHL-D-II calculated dose rate at the dose point.

Table 9 shows the five-region canister top ISOSHL-D-II result that only one-half inch of water was required for ISOSHL-D-II calculated dose rates to approximate the experimental measurement. This established the five-region canister top ISOSHL-D-II model as consistent with the canister side measurements for the gamma ray source term and the one canister top measurement. Of course in the ISOSHL-D-II canister top model, for thicker water shields, the water buildup factor would be used, similar to the ISOSHL-D-II canister side models.

2.4 STATIC STORAGE ARRAY ISOSHL-D-II MODEL

There are three stages in expanding from an ISOSHL-D-II 6 wt% ²⁴⁰Pu canister top geometry into a static storage array geometry:

1. Extension of the ISOSHL-D-II canister top model to a canister storage location model
2. Accommodation of highest dose rate canister in the fuel storage basin from the ISOSHL-D-II canister models compared to measured dose rates
3. Expansion of the ISOSHL-D-II single canister storage location model to a full-basin geometry (Wittekind 1991).

Table 9. Five-Region Canister Top ISOSHL-D-II Dose Rates.

Decay days	Calculated and interpolated dose rates (R/h)					Expt. meas. (R/h)	ISOSHL-II calculated result divided by experimental measurement				
	+½ in. Model #4TA	+½ in. Model #4TA	+1 in. Model #4TA	+2 in. Model #4TA	+3 in. Model #4TA		+½ in. Model #4TA	+½ in. Model #4TA	+1 in. Model #4TA	+2 in. Model #4TA	+3 in. Model #4TA
Canister top measurement - contact											
0*	2082000.	1893000.	1584000.	1079000.	731500.	--	--	--	--	--	--
500	372.2	337.1	280.2	187.4	123.8	--	--	--	--	--	--
549	325.8	295.1	245.3	164.0	108.4	--	--	--	--	--	--
688	223.4	202.3	168.2	112.5	74.28	--	--	--	--	--	--
1000*	95.70	86.66	72.06	48.18	31.82	--	--	--	--	--	--
1838	70.75	64.01	53.16	35.40	23.22	--	--	--	--	--	--
2009	66.52	60.18	49.96	33.24	21.77	60	1.1087	1.0030	0.8327	0.5539	0.3629
2034	65.92	59.64	49.51	32.93	21.57	--	--	--	--	--	--
2243	61.14	55.30	45.90	30.49	19.94	--	--	--	--	--	--
3000*	46.54	42.06	34.87	23.08	15.00	--	--	--	--	--	--
4353	41.87	37.84	31.37	20.76	13.49	--	--	--	--	--	--
5000*	39.80	35.97	29.82	19.73	12.82	--	--	--	--	--	--
5900	37.09	33.53	27.79	18.39	11.95	--	--	--	--	--	--
Average (calculated/measured)							1.1087	1.0030	0.8327	0.5539	0.3629

ISOSHL-D-II calculated dose rates. Other decay times were linearly interpolated using the logarithm of the dose rate (dependent variable) versus decay time (independent variable).

Five-Region Canister Top ISOSHL-D-II Model Configuration.

Fuel height:	65.33 cm	(25.72 in.)	Lid thickness:	1.270 cm	(0.50 in.)
Zirconium thickness:	0.4826 cm	(0.19 in.)	Water thickness:	Various	(Various)
Air thickness:	0.5588 cm	(0.22 in.)	NOTE: Explicit model for zirconium encaps.		

Homogenized canister contents	+½ in. Model #4TA	+½ in. Model #4TA	+1 in. Model #4TA	+2 in. Model #4TA	+3 in. Model #4TA
Uranium (g/cm ³)	18.63	18.63	18.63	18.63	18.63
Zirconium (g/cm ³)	0.00	0.00	0.00	0.00	0.00
Water (g/cm ³)	0.00	0.00	0.00	0.00	0.00
Buildup factor for shield	Canister contents	Canister contents	Canister contents	Canister contents	Canister contents

Representative ISOSHL-D-II input files are included in Appendix C, and part of an ISOSHL-D-II output is included in Appendix D.

The reconstructed SCATS (Safeguards Control and Accountability Transaction system) accountability database was used for the irradiated fuel isotopic composition and thus fuel exposure records. This accountability database is described in Section 2.4.2.

2.4.1 Canister Storage Location Geometry

The 1991 full-basin ISOSHL-D-II model was a rectangular cuboid that calculated the dose rate above the canister array (Wittekind 1991). This ISOSHL-D-II model was conservative because everything in the storage location was homogenized. The 1991 full-basin ISOSHL-D-II model was also very conservative because the dose rates were calculated at the surface of the basin water.

This 1994 static storage array ISOSHL-D-II model is built up from a single canister half model, which was referenced to experimental measurements. One extension of the five-region canister top model is to use the water shield dose buildup, which is appropriate for deep penetration through water. Another extension is from the cylinder end geometry into rectangular geometry. The detailed geometry is described in Table 10 and shown in Figure 6.

Table 10. Five-Region Storage Location ISOSHL-D-II Models.

Homogenized canister contents	Model #4TA	Model #5TA	Model #6TA	Model #6TB
Uranium (g/cm ³)	18.63	18.63	18.63	18.63
Buildup factor for shield	Canister contents	Water	Water	Water
Geometry	Cylinder	Cylinder	Canister rectangle	Storage location half-rectangle

NOTES:

Fuel height: 65.3288 cm (25.72 in.).

Zirconium endcap: 0.4826 cm (0.19 in.).

Air gap above fuel: 0.5588 cm (0.22 in.).

Stainless steel lid: 1.27 cm (0.50 in.).

Water shield thickness: various (various).

The rectangular geometry is then expanded to full fuel storage array. The same fission product gamma ray source is used in all of these storage location geometries. This storage location model is demonstrated to be consistent with the canister top geometry as far as ISOSHL-D-II dose rates are concerned. These results are listed in Table 11.

Figure 6. Storage Location ISOSILD-II Models.
(One Half-Canister Location in Irradiated Fuel Storage Array.)

Dose point on axis at
cylinder end.

Cylinder size is canister
barrel interior dimension.

Dose point on square
axis.

Square size is canister
barrel equivalent.

Dose point on rectangle
axis of symmetry.

Rectangle size is one-half
canister storage location.

WOW223

Table 11. Five-Region Storage Location ISOSHLD-II Dose Rates.

Water depth		Model #4TA (mR/h)	Model #5TA (mR/h)	Model #6TA (mR/h)	Model #6TB (mR/h)
(cm)	(ft)				
7.62	0.25	990.0	3755.	3984.	3959.
15.24	0.50	562.0	2354.	2499.	2482.
30.48	1	186.4	886.4	941.6	935.3
60.96	2	24.15	121.4	129.1	128.2
91.44	3	3.876	17.86	18.99	18.87
121.92	4	0.7171	2.970	3.157	3.140
152.40	5	1.431 E-01	5.541 E-01	5.892 E-01	5.863 E-01
182.88	6	2.966 E-02	1.123 E-01	1.194 E-01	1.189 E-01
213.36	7	6.286 E-03	2.394 E-02	2.547 E-02	2.537 E-02
243.84	8	1.352 E-03	5.257 E-03	5.597 E-03	5.575 E-03
274.32	9	2.941 E-04	1.175 E-03	1.252 E-03	1.247 E-03
304.80	10	6.461 E-05	2.660 E-04	2.834 E-04	2.824 E-04

2.4.2 Reconstructed SCATS Database

The reconstructed SCATS database (Schlosser 1990, 1992a, and 1992b) contains an inventory of the KE and KW irradiated fuel in mass and isotopic composition. The Advanced Planning organization of the United Nuclear Corporation was located in the 480 classified computing complex and had access to the then secret (now declassified) isotopic tables for calculating N Reactor fuel isotopic composition for delivery to the Plutonium-Uranium Extraction (PUREX) Plant. Two isotopic tables were used to calculate fuel composition: isotopic production tables (Wittekind 1988a) and isotopic segregation tables (Wittekind 1986).

The isotopic production tables used N Reactor measured heat generation to infer exposure and, thus, uranium and plutonium isotopics. These isotopic compositions were referenced to PUREX D-5 mass spectrometer analyses performed by Pacific Northwest Laboratory (PNL) on special dissolver batches with known N Reactor discharged fuel.

The isotopic segregation tables used neutron count rates in the fuel segregation detector (Wittekind 1984) in the 105-KE Basin. The fuel segregation program, which counted irradiated fuel elements in an underwater neutron detector, inferred the ^{240}Pu wt% for irradiated uranium. At first this was done element by element. Later, when the inners and outers were not separated, this was done by whole assemblies. The neutron counts were referenced to neutron counts in calibration elements of known ^{240}Pu wt% assay.

These standard elements were paired with other N Reactor fuel elements, which were destructively analyzed. The destructive analysis yielded isotopic compositions from about nine different mass spectrometer analyses performed by PNL on sections. These single-element analyses were used to define the burnup curve for the isotopic segregation tables.

N Reactor fuel discharges were accounted for separately from previous fuel discharges and called "keys." The keys were originally discharge keys, but with intrabasin and interbasin "heel" transfers, these keys acquired a different identity, that of a basin key based on storage locations. Heel transfers were a convenience to transfer some fuel elements from one discharge key into another discharge key because of basin transfers, canister filling, or some other reason. The basin key could maintain about 90% to 95% of the discharge key identity. The reconstructed SCATS fuel accountability tables were originally discharge key-based and depended on N Reactor production computing results. The goal of the reconstructed SCATS database was accurate isotopic quantity records. Later, Jim Schlosser made adjustments to match the accountability records for basin keys, which involved some heel transfers from one discharge key to another discharge key.

The reconstructed SCATS database formed the starting point for the maximum radiation dose rate calculations. This database resides in a spreadsheet with quantities and compositions for each separate basin key. The key date was used to calculate the decay time; this is not accurate, but it is conservative. For example, the key 14355 (or 4355B, 4355C, 4355D, and 4356D) is composed of fuel in canisters believed to contain MKIA spike column MKIV ends taken from a number of older keys, which were then designated as this new basin key 14355. Also, key 09621 contains SPR fuel elements that were discovered at different times and under different conditions and are simply combined together as this basin key. Appendix A presents a partial listing of the reconstructed SCATS database.

2.4.3 Single Canister Irradiation Calculation

The fuel storage array ISOSHL-D-II model needs to accommodate the range of fuel exposures in the 105-KE and 105-KW Basins, not just the fuel exposures used for the experimental measurements. Two possible situations would give the highest radiation dose rate: (1) the shortest decay time and (2) the highest fuel exposure. Table 12 compares these two situations for the storage location geometry. The highest fuel exposure calculates the highest gamma dose rate.

The 6 wt% ^{240}Pu irradiation input parameters are used in all ISOSHL-D-II models before this point in this document. The 16 wt% ^{240}Pu irradiation input parameters are used in all ISOSHL-D-II models after this point in this document.

The dominant isotope contributing to the gamma radiation is ^{137}Cs . The significance of uranium irradiation then is the quantity of ^{137}Cs .

Table 12. Irradiation Exposure, Decay ISOSHL-D-II Comparison.

Water depth		Model #6TB(6) (mR/h)	Model #6TB(16) (mR/h)
(cm)	(ft)		
7.62	0.25	673.5	2219.
15.24	0.50	409.1	1349.
30.48	1	141.4	466.9
60.96	2	14.88	49.38
91.44	3	1.466	4.898
121.92	4	0.1421	0.4789
152.40	5	1.391 E-02	4.740 E-02
182.88	6	1.414 E-03	4.862 E-03
213.36	7	1.546 E-04	5.318 E-04
243.84	8	1.909 E-05	6.413 E-05
274.32	9	2.758 E-06	8.759 E-06
304.80	10	4.671 E-07	1.363 E-06

The reconstructed SCATS accountability database was assembled from isotopic production tables, which converted N Reactor exposure measured in MWd/MTU into wt% ^{240}Pu , and isotopic segregation tables, which converted counts in a neutron detector into wt% ^{240}Pu . The wt% ^{240}Pu is a convenient measurement of uranium irradiation.

The RIBD code is built into ISOSHL-D-II so dose rates can be calculated from irradiated uranium. Another, more standard, isotopic calculation is ORIGEN2 (Croff 1980; Wittekind 1994c; Schmittroth 1993), which was used to calculate the decay heat of irradiated N Reactor fuel in 105-KE and 105-KW Basins. ORIGEN2 was used to calculate isotopic composition of irradiated N Reactor fuel (Hedengren 1985, 1986; Hedengren and Goldberg 1987), and to calculate decay heat for 105-KE and 105-KW Basins (Wittekind 1994a).

Consider model #6TB(6), nominally a 6 wt% ^{240}Pu irradiation calculation by RIBD in ISOSHL-D-II. The quantity of MKIV considered in one canister half, or seven elements, which are at the most 23.41 kg (51.6 lb) weight per 66.294 cm (26.1 in.) long per element. This is a calculated mass of 163.8 kg (361.2 lb). Table 13 lists the RIBD calculated ^{137}Cs inventory.

Table 13. RIBD Calculated ^{137}Cs Inventory.
(^{137}Cs Curies for Canister Half [163.8 kg] Scaled to Curies/MTU.)

6 wt% ^{240}Pu	Discharge	3,669. days (10.05 years)	4,664. days (12.77 years)	6,667. days (18.25 years)	8,669. days (23.73 years)
Ci/canister half	688.8	546.1	512.7	451.7	398.0
Ci/MTU	4,204.	3,333.	3,129.	2,757.	2,429.

16 wt% ^{240}Pu	Discharge	5,266. days (14.42 years)	6,262. days (17.14 years)	8,264. days (22.63 years)	10,266. days (28.11 years)
Ci/canister half	2,494.	1,787.	1,687.	1,478.	1,302.
Ci/MTU	15,222.	10,907.	10,297.	9,021.	7,947.

Canister half = 163.8 kg uranium inventory.

As a check, calculation of discharge ^{137}Cs from $N(t=0)=N(t)*\exp(+\ln(2)*t/t_{1/2})$, using the different decay time does reproduce discharge ^{137}Cs activity from different decay times. The half-life of ^{137}Cs is 30.17 years, but RIBD used the value 10,950 days (29.98 years), so a negligible difference (0.33% at 23.73 years decay) occurs.

From the ISOSHLI-II input, the RIBD-ISOSHLI-II specific power is:

$$1.84625 \text{ MW} / 0.1638 \text{ MT} = 11.27 \text{ MW/MT},$$

the irradiation exposure for the 16 wt% ^{240}Pu case is:

$$(1.84625 \text{ MW} / 0.1638 \text{ MT}) \times 406 \text{ d} = 4576 \text{ MWd/MT},$$

and the RIBD-ISOSHLI-II discharge ^{137}Cs is:

$$(2.494\text{E}+3 \text{ Ci } ^{137}\text{Cs} / 0.1638 \text{ MT}) = 15,222. \text{ Ci } ^{137}\text{Cs/MT}.$$

ORIGEN2 calculation for discharge ^{137}Cs for irradiation exposure of the 16.333 wt% ^{240}Pu maximum exposure key will be calculated from ORIGEN2 results tabulated in Table 14. The specific power for MKIV fuel is 11.00 MW/MT. Key 11540 at 16.333 wt% ^{240}Pu was calculated for January 31, 1992, which is Hanford Atomic Products Operations (HAPO) day 18024. The HAPO day calendar began on September 27, 1942. This decay time is 17.75 years. ([18024 days - 11540 days] $\div$ 365.25 days/year = 17.75 years.) ORIGEN2 calculation for MWd/MT and ^{137}Cs activity at discharge will use two-dimensional interpolation. The two-dimensional interpolation is for decay time and exposure. Table 14 shows slow change with decay time and more dramatic change with wt% ^{240}Pu exposure (irradiation or burnup).

Table 14. ORIGEN2 Results for Determining ^{137}Cs Activity.

Exposure case	Decay time (years)											
	0	5	10	15	20	25	30	35	40	45	50	55
	^{137}Cs (curies/MTU)											
3 wt%	1758.	1566.	1395.	1243.	1108.	986.7	879.0	783.1	697.7	621.6	553.8	493.3
6 wt%	3516.	3133.	2791.	2486.	2215.	1973.	1758.	1566.	1395.	1243.	1108.	986.7
9 wt%	5863.	5224.	4654.	4146.	3694.	3291.	2932.	2612.	2327.	2073.	1847.	1645.
12 wt%	8838.	7873.	7014.	6249.	5567.	4960.	4419.	3937.	3507.	3124.	2784.	2480.
16 wt%	12980.	11570.	10310.	9181.	8179.	7287.	6492.	5783.	5152.	4590.	4089.	3643.
	^{240}Pu (grams/MTU)											
	0	5	10	15	20	25	30	35	40	45	50	55
	^{240}Pu (grams/MTU)											
3 wt%	18.44	18.43	18.42	18.41	18.40	18.39	18.38	18.38	18.37	18.36	18.35	18.34
6 wt%	62.53	62.50	62.46	62.43	62.40	62.36	62.33	62.30	62.26	62.23	62.20	62.17
9 wt%	139.9	139.8	139.7	139.7	139.6	139.5	139.4	139.4	139.3	139.2	139.1	139.1
12 wt%	253.5	253.4	253.3	253.2	253.1	252.9	252.8	252.7	252.5	252.4	252.3	252.1
16 wt%	425.9	425.8	425.7	425.5	425.3	425.1	424.9	424.7	424.5	424.3	424.1	423.9
	Pu (grams/MTU)											
	0	5	10	15	20	25	30	35	40	45	50	55
	Pu (grams/MTU)											
3 wt%	487.0	524.1	523.8	523.6	523.4	523.2	523.0	522.9	522.7	522.6	522.5	522.4
6 wt%	931.9	966.5	965.0	963.7	962.7	961.9	961.2	960.6	960.1	959.6	959.3	958.9
9 wt%	1475.	1506.	1501.	1496.	1493.	1490.	1488.	1487.	1485.	1484.	1483.	1482.
12 wt%	2063.	2085.	2073.	2063.	2055.	2049.	2044.	2040.	2037.	2034.	2032.	2030.
16 wt%	2774.	2781.	2756.	2737.	2722.	2709.	2700.	2692.	2685.	2680.	2676.	2673.
	$\text{Wt } \%^{240}\text{Pu}$ (calculated from $^{240}\text{Pu}/\text{Pu} \times 100.0$)											
	0	5	10	15	20	25	30	35	40	45	50	55
	$\text{Wt } \%^{240}\text{Pu}$ (calculated from $^{240}\text{Pu}/\text{Pu} \times 100.0$)											
3 wt%	3.79	3.52	3.52	3.52	3.52	3.51	3.51	3.52	3.51	3.51	3.51	3.51
6 wt%	6.71	6.47	6.47	6.48	6.48	6.48	6.48	6.49	6.48	6.48	6.48	6.48
9 wt%	9.48	9.28	9.31	9.34	9.35	9.36	9.37	9.37	9.38	9.38	9.38	9.39
12 wt%	12.29	12.15	12.22	12.27	12.32	12.34	12.37	12.39	12.40	12.41	12.42	12.42
16 wt%	15.35	15.31	15.45	15.55	15.62	15.69	15.74	15.78	15.81	15.83	15.85	15.86
	ORIGEN2 calculated irradiation (MWd/MT)											
	0	5	10	15	20	25	30	35	40	45	50	55
	ORIGEN2 calculated irradiation (MWd/MT)											
3 wt%	(11.88 MW/MT outer x 0.683 outer fraction + 9.13 MW/MT inner x 0.317 inner fraction) x 50 d = 550 MWd/MT.											
6 wt%	(11.88 MW/MT outer x 0.683 outer fraction + 9.13 MW/MT inner x 0.317 inner fraction) x 100 d = 1101 MWd/MT.											
9 wt%	(11.88 MW/MT outer x 0.683 outer fraction + 9.13 MW/MT inner x 0.317 inner fraction) x 166.6 d = 1834 MWd/MT.											
12 wt%	(11.88 MW/MT outer x 0.683 outer fraction + 9.13 MW/MT inner x 0.317 inner fraction) x 250 d = 2752 MWd/MT.											
16 wt%	(11.88 MW/MT outer x 0.683 outer fraction + 9.13 MW/MT inner x 0.317 inner fraction) x 362.6 d = 3992 MWd/MT.											

NOTE: 5 Exposure cases: 3 wt%, 6 wt%, 9 wt%, 12 wt%, and 16 wt% all refer to nominal wt% ^{240}Pu .

Linear interpolation will be performed on decay time, and quadratic interpolation will be performed on the wt% ^{240}Pu exposure. First, the wt% ^{240}Pu will be calculated at 17.75 years decay. The ORIGEN2 ^{240}Pu (grams) and Pu (grams) are both linearly interpolated using the 15-year and 20-year decay values for the 9 wt%, 12 wt%, and 16 wt% cases to locate the 17.75-year decay values, division is done to determine the ORIGEN2 wt% ^{240}Pu at 17.75 years decay. Three-point lagrangian interpolation on the ^{240}Pu wt% exposure uses the following formula.

$$\frac{(16.333-12.295)(16.333-15.676)f(9)+(16.333-9.344)(16.333-15.676)f(12)+(16.333-9.344)(16.333-12.295)f(16)}{(9.344-12.295)(9.344-15.676)(12.295-9.344)(12.295-15.676)(15.676-9.344)(15.676-12.295)} =$$

$$0.1420785548 f(9 \text{ wt\%}) + -0.4604778187 f(12 \text{ wt\%}) + 1.318399264 f(16 \text{ wt\%})$$

Use exposure, Mwd/MT, and ^{137}Cs , discharge curies, at the 9, 12, and 16 wt% points to find the ORIGEN2 calculated exposure and discharge ^{137}Cs :

$$16.333 \text{ wt\% } ^{240}\text{Pu} \Rightarrow 4256 \text{ Mwd/MT \& } 13,876 \text{ Ci } ^{137}\text{Cs}.$$

Now, RIBD-ISOSHL-D-II can be compared to ORIGEN2 for exposure and ^{137}Cs content.

RIBD-ISOSHL-D irradiation compared to ORIGEN2 irradiation is:

$$4576 \text{ Mwd/MT} / 4256 \text{ Mwd/MT} = 1.075 \text{ or } 7.5\% \text{ higher in exposure and}$$

$$15,222 \text{ Ci } ^{137}\text{Cs} / 13,876 \text{ Ci } ^{137}\text{Cs} = 1.097 \text{ or } 10\% \text{ higher in } ^{137}\text{Cs}.$$

This demonstrates that the RIBD-ISOSHL-D irradiation is consistent, but about 7.5% conservative (high), with the maximum key exposure in either 105-KE or 105-KW Basin, and consistent, but conservative (high) about 2.5% (10% - 7.5% = 2.5%), with ORIGEN2-calculated ^{137}Cs content at discharge for the same Mwd/MT (or wt% ^{240}Pu). This RIBD-ISOSHL-D calculated ^{137}Cs content, which is approximately 10% higher than ORIGEN2 calculated ^{137}Cs content, is a conservative (safe) factor in this dose rate and shielding calculation.

The dose rate of interest is at the basin grating, 152.40 cm (5 ft) to 167.64 cm (5½ ft) above the water surface level, where people will be working. This increased the number of regions to six (last region is air). The ISOSHL-D-II calculated dose rate is expanded from a half canister storage location to 1,800 canister storage locations in incremental steps. The largest dose rate contribution comes from the canisters directly below the water surface, not due to the canisters further removed by angle and distance.

The 1991 ISOSHL-D-II model was very conservative and resulted in calculated dose rates which were certainly too high. The 1991 ISOSHL-D-II model homogenized the canister contents, resulting in reduced shielding material above the fuel source and reduced distance to the calculated dose points. The present improved model is consistent with experimental measurements and still provides a conservative (high) calculation of radiation dose rate.

A fine point in comparing RIBD-ISOSHL D with ORIGEN2 is that RIBD calculates only the fission product gamma rays, while ORIGEN2 calculates activation product, actinide and daughter, and fission product gamma rays.

Table 15 lists the ORIGEN2 gamma ray production for all three categories and their ratio to the total gamma production. The columns on the left are gamma photons/second. The total column sums the contributions from all three ORIGEN2 isotope categories. The columns on the right are the fraction of total gammas in each energy range due to the respective ORIGEN2 isotope category.

It is obvious that 98.96% of the total gamma photons/second are due to fission products. The higher energy gammas, which are due to actinides and daughters, are due to low-frequency spontaneous fissions that do not add significantly to the total gamma dose rate. A significant feature of the activation products is the ^{60}Co peak which occurs at 1.250 MeV. The activation products account for 11.96% of the total photons/second in this energy range. The ^{60}Co peak energy is 0.80% of the peak gamma photons/second. $(100\% * 2.088 \text{ E+12} / 2.624 \text{ E+14} = 0.80\%).$

Table 15 and these calculations are an additional supporting demonstration that the RIBD-ISOSHL D fission product gamma source calculation is a reasonable approximation of the total gamma ray source from irradiated fuel including activation products and the actinides and daughters.

2.4.4 Static Storage Array Geometry

The ISOSHL D-II single canister storage location geometry was expanded in stages to 1,800 canister storage locations. The same uranium irradiation was used, and the amount of power expended in the larger quantity of uranium was increased proportionally. The rectangular canister storage location model was increased in spatial size in stages to the entire 1,800 canister storage locations. The greatest proportional increase in calculated dose rate came at the start of the expansion, when more canisters were directly under the dose point. Figure 7 shows the expansion from a single storage location to a fuel basin geometry. The results of building up to this static fuel storage array are tabulated in Table 16.

2.5 ACTIVE STORAGE ARRAY ISOSHL D-II CALCULATION

There are three considerations in applying the static storage array ISOSHL D-II model and applying dose rate calculations to practical irradiated fuel storage basin operations:

1. A canister is lifted out of its storage location and moved over the static array to another location
2. Several canisters are lifted above the storage array simultaneously
3. Higher water temperature reduces water density that affects the radiation shielding and increases the calculated dose rate.

Table 15. ORIGEN2 Calculated Gamma Ray Production.

Average gamma ray energy (MeV)	Gamma photons/second				Fractions relative to total gamma production		
	Activation products	Actinides and daughters	Fission products	Total	Activation products (fraction)	Actinides and daughters (fraction)	Fission products (fraction)
1.500 E-02	1.016 E+10	1.546 E+12	2.875 E+13	3.031 E+13	0.0003	0.0510	0.9487
2.500 E-02	1.752 E+11	8.716 E+10	8.814 E+12	9.076 E+12	0.0193	0.0096	0.9711
3.750 E-02	4.473 E+10	8.161 E+09	2.171 E+13	2.176 E+13	0.0021	0.0004	0.9976
5.750 E-02	1.871 E+08	1.278 E+12	5.769 E+12	7.047 E+12	0.0000	0.1813	0.8186
8.500 E-02	8.119 E+07	3.211 E+09	3.817 E+12	3.820 E+12	0.0000	0.0008	0.9991
1.250 E-01	1.026 E+09	2.375 E+09	3.868 E+12	3.871 E+12	0.0003	0.0006	0.9991
2.250 E-01	1.574 E+10	1.021 E+09	3.635 E+12	3.652 E+12	0.0043	0.0003	0.9954
3.750 E-01	9.470 E+10	6.780 E+08	3.146 E+12	3.241 E+12	0.0292	0.0002	0.9706
5.750 E-01	1.217 E+11	8.343 E+07	2.624 E+14	2.625 E+14	0.0005	0.0000	0.9995
8.500 E-01	3.680 E+07	9.395 E+07	5.785 E+12	5.785 E+12	0.0000	0.0000	1.0000
1.250 E+00	2.837 E+11	7.395 E+07	2.088 E+12	2.372 E+12	0.1196	0.0000	0.8804
1.750 E+00	2.900 E+01	1.197 E+07	6.878 E+10	6.879 E+10	0.0000	0.0002	0.9998
2.250 E+00	1.504 E+06	1.930 E+05	9.688 E+09	9.690 E+09	0.0002	0.0000	0.9998
2.750 E+00	4.653 E+03	9.479 E+05	3.085 E+08	3.095 E+08	0.0000	0.0031	0.9969
3.500 E+00	1.094 E-13	9.981 E+04	4.515 E+07	4.525 E+07	0.0000	0.0022	0.9978
5.000 E+00	7.034 E-15	4.251 E+04	5.796 E-06	4.251 E+04	0.0000	1.0000	0.0000
7.000 E+00	4.558 E-16	4.872 E+03	3.761 E-07	4.872 E+03	0.0000	1.0000	0.0000
1.100 E+01	2.885 E-17	5.581 E+02	2.378 E-08	5.581 E+02	0.0000	1.0000	0.0000
Total	7.473 E+11	2.927 E+12	3.499 E+14	3.535 E+14	0.0021	0.0083	0.9896

NOTE: Situation: MKIV Fuel irradiated to 12 wt% ²⁴⁰Pu, 10 years decay.

Figure 7. Static Storage Array ISOSHLD-II Models.
(One Half-Canister Location Expanded to Static Basin.)

Table 16. Static Storage Array ISOSHL-D-II Dose Rates.
(ISOSHL-D-II Model has 152.40 cm [5 ft] Air Above Water Surface.)

Water depth		Model B $\frac{1}{2}$ ¹ (mR/h)	Model B1 ² (mR/h)	Model B4 ³ (mR/h)	Model B18 ⁴ (mR/h)	Model B50 ⁵ (mR/h)	Model B200 ⁶ (mR/h)	Model B1800 ⁷ (mR/h)
cm	ft							
7.62	0.25	2219.	4380.	16370.	58140.	107100.	159400.	172600.
15.24	0.50	1349.	2661.	9925.	34910.	62960.	89160.	93600.
30.48	1	466.9	920.6	3422.	11860.	20710.	27440.	28070.
60.96	2	49.38	97.32	360.6	1232.	2084.	2597.	2621.
91.44	3	4.898	9.656	35.80	122.2	205.1	250.6	252.1
121.92	4	0.4789	0.9446	3.510	12.06	20.34	24.82	24.95
152.92	5	4.740 E-02	9.354 E-02	3.488 E-01	1.212 E+00	2.071 E+00	2.551 E+00	2.566 E+00
182.88	6	4.862 E-03	9.603 E-03	3.596 E-02	1.267 E-01	2.207 E-01	2.774 E-01	2.794 E-01
213.36	7	5.318 E-04	1.051 E-03	3.957 E-03	1.417 E-02	2.534 E-02	3.279 E-02	3.312 E-02
243.84	8	6.413 E-05	1.269 E-04	4.802 E-04	1.753 E-03	3.232 E-03	4.345 E-03	4.407 E-03
274.32	9	8.759 E-06	1.735 E-05	6.602 E-05	2.459 E-04	4.679 E-04	6.571 E-04	6.700 E-04
304.80	10	1.363 E-06	2.704 E-06	1.034 E-05	3.919 E-05	7.683 E-05	1.125 E-04	1.154 E-04
335.28	11	2.374 E-07	4.711 E-07	1.809 E-06	6.955 E-06	1.397 E-05	2.124 E-05	2.191 E-05
365.76	12	4.483 E-08	8.902 E-08	3.428 E-07	1.333 E-06	2.731 E-06	4.283 E-06	4.444 E-06
396.24	13	8.934 E-09	1.775 E-08	6.852 E-08	2.688 E-07	5.594 E-07	9.012 E-07	9.401 E-07
426.72	14	1.843 E-09	3.663 E-09	1.417 E-08	5.600 E-08	1.180 E-07	1.948 E-07	2.043 E-07
457.20	15	3.892 E-10	7.737 E-10	2.998 E-09	1.192 E-08	2.541 E-08	4.285 E-08	4.520 E-08
487.68	16	8.350 E-11	1.661 E-10	6.443 E-10	2.575 E-09	5.547 E-09	9.547 E-09	1.013 E-08

¹Model B $\frac{1}{2}$ is one-half canister (one cylinder, barrel only), 31.75 cm (12.5 in.) x 26.67 (10.5 in.).

²Model B1 is one canister (both cylinders), 31.75 (12.5 in.) x 53.34 cm (21.0 in.).

³Model B4 is 4 canisters, 63.50 cm (25.0 in.) x 106.68 cm (42.0 in.).

⁴Model B18 is 18 canisters, 190.50 cm (75.0 in.) x 160.02 cm (63.0 in.).

⁵Model B50 is 50 canisters, 317.50 cm (125.0 in.) x 266.70 cm (105. in.).

⁶Model B200 is 200 canisters 635.00 cm (250.0 in.) x 533.40 cm (210.0 in.).

⁷Model B1800 is 1800 canisters, or a full-basin bay (about 1/3 of entire basin), 1905.00 cm (750.0 in.) x 1600.20 cm (630. in.).

The major consideration is the normal operation of lifting one irradiated fuel storage canister above the static array. The calculated dose rate increases due to a second lifted canister or water temperature change are small and are only minor considerations.

2.5.1 Active Storage Array ISOSHL-11 Model

The active storage array ISOSHL-11 dose rate is calculated by summing the dose rate for the entire static fuel storage array with that of a single canister suspended 91.44 cm (3 ft) above the array for movement and repositioning. The 91.44-cm (3-ft) distance is measured from the top of the lid in the canister array to the top of the lid of the suspended canister. A canister is 73.66 cm (29 in.) high, so 17.78 cm (7 in.) is allowed between the bottom of the suspended canister and the top of the canisters in the canister array. Figure 8 shows this situation of lifting a canister above the storage array to move it to another location.

The calculated dose rates are taken from Table 16 and reproduced in Table 17. The summing procedure is shown in Table 17. The single canister at 91.44 cm (3 ft) less water shielding than the static storage array contributes more to the dose rate than the entire static fuel storage array. Table 18 lists the active array ISOSHL-11 dose rates for all decay times.

Table 17. Active Storage Array Dose Rate Calculations (mR/h).

Array depth		Canister 91.44 cm (3 ft) above array	Static basin storage array	Total
(cm)	(ft)			
121.92	4	920.6	24.95	945.55
152.40	5	97.32	2.566	99.886
182.88	6	9.656	0.2794	9.9354
213.36	7	0.9446	0.03312	0.97772
243.84	8	0.09354	0.004407	0.097947
274.32	9	9.603 E-03	6.700 E-04	1.027 E-02
304.80	10	1.051 E-03	1.154 E-04	1.166 E-03
335.28	11	1.269 E-04	2.191 E-05	1.488 E-04
365.76	12	1.735 E-05	4.444 E-06	2.179 E-05
396.24	13	2.704 E-06	9.401 E-07	3.644 E-06
426.72	14	4.711 E-07	2.043 E-07	6.754 E-07
457.20	15	8.902 E-08	4.520 E-08	1.342 E-07
487.68	16	1.775 E-08	1.013 E-08	2.788 E-08

NOTE: Reference date is January 31, 1995.

— X —
Dose Point
Air 152.4 cm (5 ft)

Water Shield

Single canister
storage location.

— X —
Dose Point

Air 152.4 cm (5 ft)

One-third of fuel storage basin
is static storage array.

— X —
Dose Point

Air 152.4 cm (5 ft)

Active fuel storage array has
one canister above the
static fuel storage array
at 91.44 cm (3 ft) less shielding
than storage array.

Figure 8. Active Basin ISOSILD-II Model.
(One Canister 91.44 cm (3 ft) Above Static Basin Model.)

Table 18. Active Storage Array ISOSHL-D-II Dose Rates.

Array depth		Reference date	+1,000 days	+3,000 days	+5,000 days
cm	ft				
121.92	4	945.55	881.66	772.11	678.38
152.40	5	99.886	93.001	81.343	71.4
182.88	6	9.9354	9.228	8.0509	7.0567
213.36	7	0.97772	0.90412	0.78537	0.68664
243.84	8	9.795 E-02	8.983 E-02	7.742 E-02	6.742 E-02
274.32	9	1.027 E-02	9.278 E-03	7.891 E-03	6.823 E-03
304.80	10	1.166 E-03	1.027 E-03	8.542 E-04	7.306 E-04
335.28	11	1.488 E-04	1.262 E-04	1.015 E-04	8.552 E-05
365.76	12	2.179 E-05	1.766 E-05	1.364 E-05	1.129 E-05
396.24	13	3.644 E-06	2.824 E-06	2.094 E-06	1.704 E-06
426.72	14	6.754 E-07	5.041 E-07	3.614 E-07	2.903 E-07
457.20	15	1.342 E-07	9.734 E-08	6.799 E-08	5.414 E-08
487.68	16	2.788 E-08	1.977 E-08	1.355 E-08	1.073 E-08

NOTES:

One canister 91.44 cm (3 ft) above static array.

Reference date is January 31, 1995.

Calculated dose rates in mR/h.

2.5.2 Storage Array with Multiple Elevated Canisters

This ISOSHL-D-II calculation was performed with only one canister of irradiated N Reactor fuel raised 91.44 cm (3 ft) above the static canister array for the maximum dose rate calculation. Other raised canisters in other basin locations would add an incremental gamma ray dose rate to this calculated maximum dose rate. Two representative calculations will be performed: (1) a second raised canister in an adjacent slot in the basin grating, and (2) a second raised canister in the next to adjacent slot. Two effects considered are increased distance and increased attenuation in the water shield.

First, the second raised canister is in the adjacent grating slot. The static basin array at 243.84 cm (8 ft) and the raised canister at 152.40 cm (5 ft) below the water surface. There is 152.40 cm (5 ft) air above the water surface to the calculated dose point for a distance of 304.80 cm (10 ft) total. (152.40 cm [5 ft] water + 152.40 cm [5 ft] air = 304.80 cm [10 ft].)

The distance between two adjacent slots in the basin grating is 100.489 cm. ($2 * [19 \frac{25}{32} \text{ in.}] = 39.5625 \text{ in.} = 100.489 \text{ cm.}$) The distance from the second raised canister will be:

$$d = \sqrt{(120. \text{ in.})^2 + (39.5625 \text{ in.})^2} = 126.35 \text{ in.}$$

The dose rate from this second canister will be diminished by distance to $(120./126.3534384)^2 = 0.9020$ of the contribution of the canister directly below the dose point. The water shielding will be increased by:

$$\Delta d = 60.0 * (126.35 / 120.0) - 60.0 = 3.175 \text{ in.} = 8.0645 \text{ cm}$$

which would diminish the dose rate because of increased water shielding by a factor of 2.577:

$$(3.175/12.0) * (0.09354/9.603E-3) = 0.26458 * 9.7407 = 2.577.$$

The combination of distance and attenuation gives $0.9020/2.577 = 0.35$ for diminishment of dose rate due to the second canister raised 91.44 cm (3 ft) above the basin array. Then a total dose rate would be:

$$0.097947 + (0.09354 * 0.35) = 0.097947 + 0.032739 = 0.130686 \text{ mR/hour.}$$

So, a second canister raised 91.44 cm (3 ft) above the static array, at closest approach in the adjacent grating slot, represents an increase to 133% of the active basin array situation. ($100\% * [0.130686/0.097947] = 133\%$.)

Next, the second raised canister is in the next to adjacent grating slot. The static array is at 243.84 cm (8 ft) and the raised canister at 152.40 cm (5 ft) below the water surface. ($[8-3] = 5 \text{ ft.}$) There is 152.40 cm (5 ft) air above the water surface to the calculated dose point for a distance of 304.80 cm (10 ft) total. (152.40 cm [5 ft] water + 152.40 cm [5 ft] air = 304.80 cm [10 ft].) The distance between next to adjacent slots in the basin grating is 200.9775 cm (79.125 in.). ($4 * [19 \frac{25}{32} \text{ in.}] = 79.125 \text{ in.}$) The distance from the second raised canister will be:

$$d = \sqrt{(120. \text{ in.})^2 + (79.125 \text{ in.})^2} = 143.74 \text{ in.}$$

The dose rate from this second canister will be diminished by distance to 0.6970 of the contribution of the canister directly below the dose point. ($120./143.7385322)^2 = 0.6970$.) The water shielding will be increased by:

$$\Delta d = 60.0 * (143.74 / 120.0) - 60.0 = 11.87 \text{ in.} = 30.15 \text{ cm}$$

which would diminish the dose rate because of increased water shielding by a factor of 9.635:

$$(11.87/12.0) * (0.09354/9.603E-3) = 0.98917 * 9.7407 = 9.635.$$

The combination of distance and attenuation gives $0.6970/9.635 = 0.072$ for diminishment of dose rate due to the second canister raised 91.44 cm (3 ft) above the basin array. Then a total dose rate would be:

$$0.097947 + (0.09354 * 0.072) = 0.097947 + 0.006735 = 0.10468 \text{ mR/hour.}$$

So, a second canister raised 91.44 cm (3 ft) above the static array, at closest approach in the next to adjacent grating slot, represents an increase to 107% of the active basin array situation. ($100\% * [0.10468/0.097947] = 107\%$.)

In conclusion, except for closest approach, which may increase the calculated dose rate by about 1/3, additional moving canisters in the basin are insignificant based on dose rate considerations.

Because of the large size of the basin compared to an expected closest approach of two canisters being moved, and that fact that an increase in gamma ray dose rate of 33% or 7% is expected for the close approach of two moving canisters suspended 91.44 cm (3 ft) above the static array, there is no proposed operational limit to the number of canisters which may be moved in the basin at one time.

2.5.3 Temperature Effect on Water Density and Radiation Shielding

Water density changes with temperature and less dense water can be expected to have diminished water shielding effect. K Basins water temperature is maintained between 5.5 °C to 32.2 °C (42 °F to 90 °F). The difference in water quantity for a fixed water depth will be used to infer radiation dose rate increase.

A calculation of change of water shielding thickness can be derived from Table 16, model B1: 4 ft dose rate 0.9446 mR/h, 5 ft dose rate 0.09354 mR/h. Water specific volume changes approximately 0.5% when the temperature changes from 5.5 °C to 32.2 °C (42 °F to 90 °F). The decrease of water mass in 152.4 cm (5 ft) of water will be converted into an equivalent decrease in linear distance while keeping the water density fixed. The equivalent decrease in water shield thickness will be converted into an increase in dose rate from using ISOSHLD-II calculated dose for two different water shield thicknesses.

An example of this increase in radiation dose rate due to temperature dependent water density decrease will be given before tabulation in Table 19. The 152.4 cm (5.0 ft) water shield thickness is used as an example because this is the water shield above the single lifted canister for the static storage array at 243.84 cm (8 ft) water shield thickness. For 5.5 °C (42 °F), the specific volume of water is 1.0000 cm³/g (0.016019 ft³/lb), and at 21.1 °C (70 °F), the specific volume of water is 1.0020 cm³/g (0.016050 ft³/lb).

Table 19. Radiation Dose Rate Increase Due to Water Temperature.

Water temperature		Water specific volume		Equivalent decrease of water shield		Increase of radiation dose rate
°C	°F	cm ³ /g	ft ³ /lb	cm	in.	
5.5	42	1.0000	0.016019	0.0000	0.0000	+0.00%
10.0	50	1.0003	0.016023	0.0380	0.0150	+1.26%
15.6	60	1.0009	0.016033	0.1331	0.0524	+4.41%
21.1	70	1.0020	0.016050	0.2944	0.1159	+9.75%
26.7	80	1.0033	0.016072	0.5026	0.1979	+16.65%
32.2	90	1.0050	0.016099	0.7573	0.2982	+25.09%

NOTES: Equivalent water shield thickness decrease calculated.
 Equivalent radiation dose rate increase calculated.
 Situation: one canister at 152.4 cm (5 ft) water depth.
 Reference water temperature is 5.5 °C (42 °F).

The equivalent decrease in water shield thickness for 152.4 cm (5 ft) of water and 5.5 °C to 21.1 °C (42 °F to 70 °F) temperature increase is:

$$(1.0 - [0.016019/0.016050]) \times 60 \text{ in.} = 0.1159 \text{ in.}$$

The effective fractional increase in ISOSHLD-II calculated dose rate is:

$$(0.1159 \text{ in.}/12.0 \text{ in.}) \times (0.9446 \text{ mR/h}/0.09354 \text{ mR/h}) = 0.0975 = 9.75\%.$$

The results of Table 19, along with the assumption that K Basins will be normally operated with water temperature less than 15 °C (60 °F) where the increase in radiation dose rate would be less than 5%. In the most extreme situation of K Basins water temperature increasing to 32 °C (90 °F), the equivalent decrease of water shield at 152.4 cm (5 ft) thickness would be only 0.76 cm (0.3 in.), which is a minor concern compared to the operational limit of water level: 490 ± 15 cm (16.0 ± 0.5 ft).

2.6 MINIMUM WATER SHIELD REQUIREMENT

The minimum water shield requirement, consistent with WHC-CM-4-9, will now be calculated. This Westinghouse company policy manual was derived from DOE Orders 5480.11 and 6430.1A.

Shielding that meets these design criteria will also meet the ALARA objectives for the Compacted Fuel Storage Facility for storing irradiated N Reactor fuel for an indefinite time. The candidate storage facility is the KW Reactor irradiated fuel storage basin.

The shield design shall be based on Table 1 from Section 8 of WHC-CM-4-9. Dose rates in all cases are at the point of exposure where an individual will actually be working.

The initial design level in Table 20 for each zone category shall be used for the design criteria. Lower levels are desirable using the ALARA principle.

Table 20. Shield Design Criteria (from Section 8 of WHC-CM-4-9).

Zone category	Access time allowed	Initial design level (mrem per hour)	Maximum (mrem per hour)
Uncontrolled Area	Full time	0.05	0.1
Controlled Area 1	Full time	0.2	0.5
Controlled Area 2	Less than 1 hour per day	2	5
Controlled Area 3	Less than 1 hour per week	10	20
Controlled Area 4	Less than 10 hours per year	50	100
Controlled Area 5	No normal access permitted	>100	--

The radiation shielding material in this calculation is basin water, although credit is taken for the uranium and zirconium in the fuel elements and the stainless steel of the Mark II canisters. The basin water surrounds the radiation source.

The canister inventory of irradiated N Reactor fuel is provided in Appendix A. The fuel is identified by fuel types (enrichments), and average fuel exposure. The radionuclide content and subsequent nuclear radiation were determined by ISOSHL-D-II. The highest exposure fuel, the key with 16.333 wt% ^{240}Pu , was used for shielding calculations.

The 2 mR/h is the radiation dose rate requirement used to calculate "Controlled Area 2" water shield thickness. The 0.2 mR/h is radiation dose rate requirement used to calculate "Controlled Area 1" water shield thickness.

Interpolation takes advantage that the ISOSHL-D-II calculated dose rate appears linear on a log-linear graph. That is the logarithm (dose rate) is linear when plotted versus the water shield thickness.

The formula for linear interpolation is:

$$f(x) = ((x-x_2)/(x_1-x_2))*f(x_1) + ((x-x_1)/(x_2-x_1))*f(x_2).$$

Using $x = \ln(2.0 \text{ mR/h})$, and choose two points on each side,

$$x_1 = \ln(9.9354 \text{ mR/h}), f(x_1) = 6 \text{ ft},$$

$$x_2 = \ln(0.97772 \text{ mR/h}), f(x_2) = 7 \text{ ft}.$$

The calculation for 2 mR/h water shield thickness is:

$$f(x) = ((\ln(2.0) - \ln(0.97772)) / (\ln(9.9354) - \ln(0.97772))) * (6 \text{ ft}) + ((\ln(2.0) - \ln(9.9354)) / (\ln(0.97772) - \ln(9.9354))) * (7 \text{ ft})$$

$$f(x) = 0.30866 * (6 \text{ ft}) + 0.69134 * (7 \text{ ft}) = 6.6913 \text{ ft} = 6 \text{ ft } 8.3 \text{ in.}$$

Finally, the result is:

2.0 mR/h controlled area 2 minimum water shield thickness = 6 ft 9 in.

Minimum water shield thickness calculations for 0.2 mR/h = 7 ft 9 in.

Similarly, minimum water shielding thicknesses can be calculated for any design level radiation dose rate and at different decay times after the reference date. These distances were measured from the top surface of the canister lid to the water surface, which is 5 ft below the calculated dose point. Figure 9 depicts these distances for minimum water shielding.

Inspecting the Mark II canister dimensions reveals the following:

Canister barrel length	26.88 in.
Bottom plate bottom to canister barrel bottom	+ 0.12 in.
Bottom plate bottom to canister barrel top	= 27.00 in.
Canister lid groove to canister lid top surface	+ 0.375 in.
Bottom plate bottom to canister lid top surface	= 27.375 in.

Inspecting the Mark II canister fuel positioning information reveals the following:

Bottom plate thickness	0.5 in.
Bottom plate dimple	0.055 in.
(minimum specification 0.03 in.)	
MKIV fuel element maximum length	26.1 in.
MKIV fuel element end cap thickness	0.19 in.
Therefore, MKIV endcap top to canister lid bottom	0.22 in.

The Kaiser engineering study considered two stacking options. Option A (ES-N040-S03) has the canisters stacked on top of each other, while the preferred option, Option B (ES-N040-S04), allows 1½ in. between the top of one layer of canisters and the bottom of the next layer of canisters. Under Option B the distance from the basin concrete surface to the top of the upper lid is:

Canister to lid top	27.375 in.	(H-1-46215 Sheets 3, 4, and 5)
Option B Spacing	+ 1.750 in.	(ES-N040-S04 Section B)
Canister full height	+29.000 in.	(H-1-46215 Sheet 1)
Option B Spacing	+ 1.750 in.	(ES-N040-S04 Section B)
Canister full height	+29.000 in.	(H-1-46215 Sheet 1)
<u>Bottom plate</u>	<u>+ 0.500 in.</u>	(ES-N040-S03 Detail 3)
Total	= 89.375 in. = 7 ft 5.375 in. = 227.0125 cm.	

NOTE: Total consists of concrete surface to lid top of third layer.

Figure 9. Minimum Water Thickness Basin Geometry.
(One Canister 91.44 cm [3 ft] Above Triple-Stacked Static Basin Model.)

Design (ES-NO40-SO3/SO4) water thickness above static array is 260.67 +/- 15.24 cm (8 ft, 6 5/8 in. +/- 6 in.). Active basin shielding calculations allowed for a single canister 91.44 cm (3 ft) above the static canister array. The active basin shielding calculations determined the minimum required water thickness above the static canister array to be 240.8 cm (7 ft, 11 in.).

3.0 ISOSHL D CODE COMPARISON

3.1 PURPOSE OF COMPARISON

This study was performed with ISOSHL D-II, yet other ISOSHL D versions exist. ISO-PC (custodian is Paul Rittman) has corrected many previous errors, some of which still exist in ISOSHL D-II. Documentation exists for ISO-PC, which is now version 1.9. ISOSHL D 4.0 (custodian is Frank Schmittroth) is undergoing major modifications with buildup and attenuation libraries derived from recently available information.

3.2 SCOPE OF COMPARISON

The basic concern in this shielding study is the attenuation of ^{137}Cs gamma rays (661.7 keV) through water shielding with deep penetration. This situation, originally calculated in mode 1 using ISOSHL D-II, then changed to mode 2 by using only 27 isotopes (550 isotopes are in the RIBD library). ISO-PC does not have RIBD for the mode 1 calculation, so both ISO-PC and ISOSHL D 4.0 were run using mode 2. The ^{137}Cs isotope is dominant, and only deep penetration in the water shield is considered, and only the rectangular geometry option is used, so this is not a comprehensive ISOSHL D comparison. The case used for comparison purposes is model B1800 for the full static fuel storage array.

3.3 RESULTS OF ISOSHL D COMPARISON

ISOSHL D calculated dose rate at 152.40 cm (5 ft) above the water surface from 1,800 canister irradiated fuel static storage array was calculated and graphed in Figure 10 covering water depths between 30.48 cm (1 ft) and 304.80 cm (10 ft). On this scale, there does not appear to be much difference between the ISOSHL D versions for calculated water shield thickness. Figure 11 shows more detail by covering only water depths between 91.44 cm (3 ft) and 228.60 cm (7.5 ft). The main feature is that ISOSHL D 4.0, with more recent build-up factors and attenuation coefficients consistently calculates higher dose rates in this geometry.

Figure 12 depicts the ratio of dose rates calculated using ISOSHL D 4.0 and ISOSHL D-II. For this document, the significant portion of this graph is the 152.40 cm (5 ft) to 243.84 cm (8 ft) depth. The 243.84 cm (8 ft) depth is significant because it is the static fuel array minimum calculated depth. The 152.40 cm (5 ft) depth is significant because it is the single canister suspended 91.44 cm (3 ft) above the static fuel array at minimum calculated depth. This figure indicates that the ISOSHL D-II calculated dose rate should be multiplied by a 2.1 factor (ratio at 152.40 cm water shield).

Figure 13 depicts the ratio of dose rates calculated using ISO-PC version 1.9 and ISOSHL D-II. Both ISO-PC and ISOSHL D-II use original 1968 or earlier vintage attenuation and buildup data. ISO-PC has undergone more significant corrections than ISOSHL D-II, and is also expected to be more correct than ISOSHL D-II. The comparison at 152.40 cm (5 ft) to 243.84 cm (8 ft) water depth is that ISOSHL D-II calculates dose rates very close to ISO-PC or is conservative in this application.

Figure 10. ISOSHLD Dose Rate Comparison.
(ISOSHLD-II, ISO-PC Version 1.90, and ISOSHLD 4.0.)

Figure 11. ISOSHLD Dose Rate Comparison-Detail.
(ISOSHLD-II, ISO-PC Version 1.90, and ISOSHLD 4.0.0.)

Figure 12. ISOSHLD 4.0 to ISOSHLD-II Ratio.
(ISOSHLD 4.0 over ISOSHLD-II.)

Figure 13. ISO-PC 1.90 to ISOSHL-D-II Ratio.
(ISO-PC 1.90 over ISOSHL-D-II.)

Figure 14 depicts the ratio of dose rates calculated using ISOSHLD 4.0 and ISO-PC version 1.90.

Table 21 tabulates various ISOSHLD results. These values were used for the comparison figures. Notice at 30.48 cm (1 ft) distance, ISOSHLD 4.0 result is 2.14 times greater than the ISOSHLD-II result. ($60030/28070 = 2.14$.) Table 5 compared experimental measurements to ISOSHLD-II adjusted to match the contact dose rate. The 30.48 cm (1 ft) water shield dose rate ratio for ISOSHLD-II/experimental measurements was 0.6222. This indicated ISOSHLD-II should calculate 1.607 higher in order to match experimental measurements more accurately. ($1/0.6222 = 1.607$.) This experimental comparison supports the accuracy of ISOSHLD 4.0 in this ^{137}Cs gamma rays through water application.

Table 21. ISOSHLD Dose Rate Comparisons.

Array depth		ISOSHLD-II		ISO-PC	ISOSHLD 4.0
cm	ft	Mode 1	Mode 2	Mode 2	Mode 2
7.62	0.25	172600.	172600.	287300.	284200.
15.24	0.50	93600.	93590.	149700.	170700.
30.48	1	28070.	28070.	42050.	60030.
60.96	2	2621.	2621.	3523.	6668.
91.44	3	252.1	252.1	307.4	660.5
121.92	4	24.95	24.95	27.78	60.83
152.40	5	2.566	2.566	2.619	5.452
182.88	6	2.794 E-01	2.794 E-01	2.618 E-01	5.009 E-01
213.36	7	3.312 E-02	3.312 E-02	2.837 E-02	4.979 E-02
243.84	8	4.407 E-03	4.407 E-03	3.404 E-03	5.582 E-03
274.32	9	6.700 E-04	6.700 E-04	4.565 E-04	7.172 E-04
304.80	10	1.154 E-04	1.154 E-04	6.802 E-05	1.045 E-04
335.28	11	2.191 E-05	2.191 E-05	1.105 E-05	1.689 E-05
365.76	12	4.444 E-06	4.444 E-06	1.917 E-06	2.960 E-06
396.24	13	9.401 E-07	9.401 E-07	3.489 E-07	5.525 E-07
426.72	14	2.043 E-07	2.043 E-07	6.592 E-08	1.087 E-07
457.20	15	4.520 E-08	4.520 E-08	1.284 E-08	2.238 E-08
487.68	16	1.013 E-08	1.013 E-08	2.567 E-09	4.817 E-09

NOTES: Static array reference date is January 31, 1995.
 Calculated dose rates in mR/h.
 Model B1800 is being considered.

Figure 14. ISOSHL D 4.0 to ISO-PC 1.90 Ratio.
(ISOSHL D 4.0 over ISO-PC 1.90.)

3.4 CONCLUSION OF ISOSHL D COMPARISON

ISOSHL D uses a point kernel method to calculate dose rates. This method adds up each point in the source, calculates the attenuation through all the intervening material and, for the dominant radiation shield, multiplies by a build-up factor. The buildup factor is used in order to accommodate the fact that the gamma rays are scattered but not absorbed. The gamma ray energy is still in the beam because it has not been absorbed. The ^{137}Cs gamma is 0.6617 MeV, and attenuation coefficient at 0.650 keV for water is 0.0832 cm^{-1} . Thus a mean free path is 12.02 cm. ($1.0/0.0832 \text{ cm}^{-1} = 12.02 \text{ cm}$.) Table 22 lists water buildup factors as a function of mean free paths.

Table 22. ANS-6.4.3 Water Buildup Factors (R).

R (mfp)*	0.6 MeV	Depth (cm)	Depth (ft)
5.0	15.6	60.1	1.972
6.0	20.8	72.1	2.366
7.0	26.7	84.1	2.760
8.0	33.5	96.2	3.155
10.0	49.3	120.2	3.943
15.0	104.	180.3	5.915
20.0	179.	240.4	7.887
25.0	276.	300.5	9.858
30.0	395.	360.6	11.830
35.0	534.	420.7	13.802
40.0	695.	480.8	15.773

Calculated Range to 487.68 cm (16 ft) Water Depth.

*Mean free paths converted to water thickness using
 $1./0.0832 \text{ cm}^{-1} = 12.02 \text{ cm}$.

Figure 12 depicts the ratio of dose rates calculated using ISOSHL D 4.0 and ISOSHL D-II. For this document, the significant portion of this graph is the 152.40 cm (5 ft) to 243.84 cm (8 ft) depth. The 152.40 cm (5 ft) depth is particularly significant because this is the depth of the single canister suspended 91.44 cm (3 ft) above the static fuel array at minimum calculated depth and the source of most of the calculated radiation dose rate for the active storage array. This figure indicates that the ISOSHL D-II calculated dose rate should be multiplied by 2.1 (ratio at 91.44 cm (5 ft) water shield).

Table 22 is a demonstration that, at 152.40 cm (5 ft) to 243.84 cm (8 ft) water shield thickness, the buildup factor is approximately 75 to 180. This amounts to a correction in the point kernel method. With this perspective, and the improvement in measured data between approximately 1960 and June 1993, a calculated dose rate ratio between ISOSHLD-II and ISOSHLD 4.0 of 2.1 is not unreasonable. The additional water shielding required to reduce calculated dose rate by approximately 2.1 for the ^{137}Cs gamma ray is 6.4 cm (2.52 in.). $\{(5 \text{ ft} - 4 \text{ ft}) \times 12 \text{ in./ft} \times [(5.452/2.566)/(0.9446/0.09354)] = 2.52 \text{ in.} = 6.4 \text{ cm.}\}$

This additional shielding is meant to accommodate the uncertainty in extrapolating from the measurements, which were made at contact or at 30.48 cm (1 ft) of water shielding, to the application to basin water depths of 152.40 cm (5 ft) to 243.84 cm (8 ft) between the irradiated fuel storage canister and the water surface.

The 6.4 cm (2.52 in.), due to the ISOSHLD 4.0 and ISOSHLD-II dose rate ratio, is added to all ISOSHLD-II calculated minimum required water shielding thickness and is reflected in the tables of minimum water shield above the storage array. Experimental measurements were interpreted to support a closer correspondence with ISOSHLD 4.0 calculated dose rates than the ISOSHLD-II or ISO-PC 1.90 calculated dose rates.

This page intentionally left blank.

4.0 CONCLUSIONS

Consolidation of 105-KE Basin irradiated fuel into the 105-KW Basin will require double or triple stacking canisters closer to the surface of the basin water. The minimum water shielding thickness consistent with radiation shielding requirements, that is 2.0 mR/h for limited access time and 0.20 mR/h for unlimited access time, were calculated.

Experimentally measured canister dose rates were consistently compared to ISOSHLD-II models of single canister geometry. The single canister model was converted into the canister storage location model. Irradiation was accommodated by determining the highest dose rate canister as a function of irradiation and decay time. The highest dose rate canister became the basis for the full-basin calculation. There is routine movement of basin canisters by lifting them up and out of their array position and moving across the array to another location. The active basin calculation logically combined the entire static basin array with the single canister dose rate by simple addition. Additional lifted and moving canisters were calculated and shown to be a minor concern. Basin water temperature was calculated and shown to be a minor concern. ISOSHLD-II calculated dose rates based on fission products only is reasonable because the contribution of ORIGEN2 calculated activation products and actinides and daughters was shown to be insignificant. The 6.4 cm (2.52 in.), due to the ISOSHLD 4.0 and ISOSHLD-II dose rate ratio, is added to all ISOSHLD-II calculated minimum required water shielding thickness and is reflected in the tables of minimum water shield above the storage array.

Table 23 shows the minimum required water shielding thickness for January 31, 1995, and three subsequent decay times.

Table 23. Calculated Minimum Water Shield Above Storage Array.

	Reference date +0 days	Reference +1,000 days	Reference +3,000 days	Reference +5,000 days
Limited ¹ Access time	210.4 cm 6 ft 11 in.	209.4 cm 6 ft 11 in.	207.6 cm 6 ft 10 in.	205.8 cm 6 ft 10 in.
Unlimited ² Access time	240.8 cm 7 ft 11 in.	239.7 cm 7 ft 11 in.	237.8 cm 7 ft 10 in.	236.0 cm 7 ft 9 in.

NOTES:

Calculated distance is from top of fuel storage array to water surface.

Dose point is 152.4 cm (5 ft) air above water surface.

Situation: one canister 91.44 cm (3 ft) above storage array.

Reference date is January 31, 1995.

¹Limited access time (1 hour/day), calculated dose rate is 2 mR/h.

²Unlimited access time, calculated dose rate is 0.2 mR/h.

The current operational level of K basin pools is $490 \text{ cm} \pm 15 \text{ cm}$ ($16.0 \pm 0.5 \text{ ft}$) measured from the bottom of the pool to the surface of the water. The Kaiser engineering study sketches ES-N040-S03 and ES-N040-S04 for Option B (Kaiser 1994) designed 227.01 cm ($7 \text{ ft } 5\frac{1}{2} \text{ in.}$) for canisters stacked three high. This design would leave only $260.67 \pm 15.24 \text{ cm}$ ($8 \text{ ft } 6\frac{1}{2} \text{ in.} \pm 0.5 \text{ ft}$) of water shielding above the top canister lid.

At a minimum there would be 245.43 cm ($8 \text{ ft } \frac{1}{2} \text{ in.}$) of water shielding above the top canister lid when stacked three high. Since these ISOSHLD-II calculated water shield minimum required thicknesses are less than the minimum design water thickness, this proposed design, Option B, is acceptable according to the radiation shielding design requirements. The current operational limit of three canisters per storage bay out of storage and on hoists will not be affected.

The most limiting design for radiation shielding concerns is the one which requires the maximum vertical spacing between canister layers. Option A requires no spacing between canister layers while Option B requires 4.445 cm ($1\frac{1}{4} \text{ in.}$) vertical spacing between canister layers. These shielding calculations showed that Option B is acceptable, and it is also true that all design vertical spacings less than 4.445 cm ($1\frac{1}{4} \text{ in.}$) are also acceptable.

These ISOSHLD-II calculations for minimum required water shielding thickness are reasonable because they were compared to single canister experimental measurements and extended by stages to the active fuel storage basin desired configuration. Comparisons were made to other ISOSHLD versions and ISOSHLD 4.0, which more consistently reproduced the experimental measurements, was used for a conservative adjustment in bridging between the experimental measurements and the active basin dose rate calculation.

The ISOSHLD-II model has a small nonconservative effect due to neglecting some PVC pipe, detector structure, and about 1 in. of air shielding present in the experimental measurements but not replicated in the ISOSHLD-II models. The effect of this simplifying assumption is believed to be small and within the accuracy of the experimental measurements and is accommodated by scaling to ISOSHLD 4.0 calculated dose rates.

The ISOSHLD-II calculations for minimum required water shielding thickness are conservative because: (1) a lifted canister was considered as the normal basin configuration, (2) the reconstructed SCATS accountability database was used for fuel exposure, and this has been shown to be 16% higher than another accountability database that did not use fuel segregation data, (3) all irradiated fuel is assumed to be maximum length MKIV fuel and to be irradiated to the maximum exposure key in 105-KE Basin, $16.3330 \text{ wt\% } ^{240}\text{Pu}$, (4) the maximum irradiated uranium is RIBD calculated to have approximately 10% more ^{137}Cs gamma source term than a similar ORIGEN2 irradiation calculation, (5) when minimum basin water level was assumed, there was no increase in the air distance to the grating dose rate point, (6) the moving canister dose rate was added to the static basin array dose rate without subtracting the contribution from the shielded canister below the suspended canister, and (7) comparison of ISOSHLD-II to other available ISOSHLD versions and acceptance of higher dose rate calculation of ISOSHLD 4.0 which used more recent dose buildup factors.

The ISOSHLI-II calculations were performed considering the base case to be the active basin situation, that is that a canister or canisters are lifted 91.44 cm (3 ft) above the top of a three-high storage array which is assumed to be vertically spaced according to Kaiser's Option B 4.445 cm (1½ in.) maximum spacing between layers.

This page intentionally left blank.

5.0 REFERENCES

- Croff, A. C., 1980, *A User's Manual for the ORIGEN2 Computer Code*, ORNL/TM-7175, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- DLC-129, 1993, "ANS643 ANS-6.4.3 Geometric Progression Gamma-Ray Buildup Factor Coefficients," Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- DOE, 1988, *Requirements for Radiation Protection*, DOE Order 5480.11, U.S. Department of Energy, Washington, D.C.
- DOE, 1989, *General Design Criteria*, DOE Order 6430.1A, U.S. Department of Energy, Washington, D.C.
- Drawing H-1-36935 sheets 1 and 2, "Irradiated Fuel Storage Canister," last updated April 18, 1980.
- Drawings H-1-42793 sheets 1 and 2, "Fuel Encapsulation Program Storage Canister," last updated July 15, 1981.
- Drawings H-1-46215 sheets 1 through 7, "Fuel Encapsulation MKII Canister Assembly," dated March 14, 1985.
- Engel, R. L., J. Greenborg, and M. M. Hendrickson, 1966, *ISOSHLD-A Computer Code for General Purpose Isotope Shielding Analysis*, BNWL-236, Pacific Northwest Laboratory, Richland, Washington.
- Hedengren, D. C., 1985, *ORIGEN2 Predictions of N Reactor Fuel Fission Product Composition*, WHC-SD-CP-TI-077, Westinghouse Hanford Company, Richland, Washington.
- Hedengren, D. C., 1986, *ORIGEN2 Predictions of N Reactor Cladding and Fuel Activation Product Composition*, WHC-SD-CP-TI-094, Westinghouse Hanford Company, Richland, Washington.
- Hedengren, D. C. and H. J. Goldberg, 1987, *ORIGEN2 Predictions of N Reactor Fuel Actinide Composition*, WHC-SD-CP-TI-105, Westinghouse Hanford Company, Richland, Washington.
- Kaiser, 1994, *Engineering Study: Spent Fuel Consolidation in the 105KW Fuel Storage Basin*, Working Outline N040ES.TD.664, Issue B, April 1994, ICF Kaiser Hanford Company, Richland, Washington.
- Mansius, C. A., 1969, *A Revised Photon Probability Library for Use with ISOSHLD-III*, BNWL-236. Sup. 2, Pacific Northwest Laboratory, Richland, Washington.
- Schlosser, J. E., 1990, *The Safeguards Control and Accountability Transactions System: SCATS, Program Documentation*, WHC-SD-NR-CSWD-047, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

- Schlosser, J. E., 1992a, *The AJAX Program, The Estimation of Isotopics of N Reactor Unsegregated Irradiated Fuels*, WHC-SD-NR-CSWD-048, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Schlosser, J. E., 1992b, *The FUELSEG Program, The Estimation of Isotopics of N Reactor Segregated Irradiated Fuels*, WHC-SD-NR-CSWD-049, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Schmittroth, F. A., 1993, *Software Certification Package for the ORIGEN2 Code*, WHC-SD-NR-SWD-006, Rev. 1, Westinghouse Hanford Company, Richland, Washington.
- WHC-CM-4-9, 1988, *Radiological Design Safety, Quality Assurance and Security*, Westinghouse Hanford Company, Richland, Washington.
- Wittekind, W. D., 1984, *PT-N-539 Calibration of N-Fuel Sort Instrumentation Final Report*, UNI-2362 A, United Nuclear Industries, Richland, Washington.
- Wittekind, W. D., 1986, *Isotopic Segregation Tables Calculated Adjustment of June 9, 1986 Using the Computer Code PTABLESEG2*, UNI-4008, United Nuclear Industries, Richland, Washington.
- Wittekind, W. D., 1988a, *N Reactor Isotopic Production Tables Calculated Adjustment of March 24, 1987 Using the Computer Code AJAX PTABLE*, WHC-00188, Westinghouse Hanford Company, Richland, Washington.
- Wittekind, W. D., 1988b, *Irradiated N Reactor Fuel Dose Rate Measurements and ISOSHL D Calculations*, WHC-SP-0306, Westinghouse Hanford Company, Richland, Washington.
- Wittekind, W.D., 1991, *Irradiated N Reactor Fuel Consolidated Storage Shielding Calculations*, WHC-SD-NR-ER-090, Westinghouse Hanford Company, Richland, Washington.
- Wittekind, W. D., 1994a, *Consolidated Fuel Decay Heat Calculations*, WHC-SD-NR-ANAL-014, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Wittekind, W. D., 1994b, *Software Certification Package for the ISOSHL D-II Code*, WHC-SD-NR-SWD-019, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Wittekind, W. D., 1994c, *Software Certification Package for the ORIGEN2 Code*, WHC-SD-NR-SWD-006, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

RECONSTRUCTED SCATS ACCOUNTABILITY DATABASE

This page intentionally left blank.

RECONSTRUCTED SCATS ACCOUNTABILITY DATABASE

Basin: "E" means 105-KE Basin, "W" means 105-KW Basin.

Key: A basin key denoted by the HAPO day number.

Decay Date: The reference date for isotopic composition calculation.

Material type: MKIA, MKIV, or Natural enrichment MKIV.

Single Pass Reactor (SPR) fuel is not well designated.

Pieces: May be assemblies, outers, or inners.

Pu: The quantity of plutonium in grams on the reference date.

U: The quantity of uranium in kilograms on the reference date.

Wt% ²⁴⁰Pu: Calculated weight percent ²⁴⁰Pu in plutonium on reference date.

This indicates the uranium exposure.

Basin	Key	Decay Date	Material type	Pieces	Pu (g)	U (kg)	Wt% ²⁴⁰ Pu
E	9621	01/31/92	MIV	75	151.17	182.53	6.0059%
E	9621	01/31/92	NAT	63	142.96	218.71	5.4636%
E	10001	01/31/92	MIV	17	171.16	139.20	9.7457%
E	10201	01/31/92	MIV	262	4212.43	2652.11	8.9414%
E	10259	01/31/92	MIV	48	891.17	534.95	9.5026%
E	10259	01/31/92	MIV	1792	35922.63	19809.02	10.2448%
E	10294	01/31/92	MIV	3024	62550.94	34667.16	10.1920%
E	10294	01/31/92	MIV	192	3551.79	2180.11	9.1668%
E	10294	01/31/92	MIV	84	2150.06	966.82	12.4467%
E	10350	01/31/92	MIV	48	857.25	528.51	9.1004%
E	10385	01/31/92	MIV	2912	66265.65	33857.17	11.0264%
E	10385	01/31/92	MIV	167	3465.38	1922.67	10.1276%
E	10456	01/31/92	MIV	2072	44066.31	23303.78	10.8237%
E	10456	01/31/92	MIV	270	6540.87	3079.31	12.1389%
E	10576	01/31/92	MIV	336	7472.42	3918.27	10.8658%
E	10602	01/31/92	MIV	624	19346.21	7161.09	15.1278% MAX
E	10602	01/31/92	MIV	924	25845.47	10733.45	13.5238%
E	10602	01/31/92	MIV	756	16699.27	8768.29	10.8991%
E	10679	01/31/92	MIV	1064	22362.47	11663.89	10.9016%
E	10679	01/31/92	MIV	1233	38251.36	14240.30	15.0223% MAX
E	10742	01/31/92	MIV	524	17052.21	6093.17	15.5346% MAX
E	10742	01/31/92	MIV	784	21300.65	8775.18	13.5581%
E	10742	01/31/92	MIV	532	10970.10	5656.47	10.9779%
E	10764	01/31/92	MIV	184	0.00	1972.00	0.0000%
E	10764	01/31/92	NAT	4	0.00	46.75	0.0000%
E	10770	01/31/92	MIV	860	26640.76	9831.86	15.0849% MAX
E	10770	01/31/92	MIV	840	17788.41	9353.97	10.8370%
E	10832	01/31/92	MIV	2296	63969.53	26344.62	13.5879%
E	10832	01/31/92	MIV	744	23853.04	8434.92	15.7130% MAX
E	10832	01/31/92	MIV	1596	33869.72	17902.13	10.7842%
E	10982	01/31/92	MIV	1328	43368.74	15338.47	15.6842% MAX
E	10982	01/31/92	MIV	896	18898.08	9815.89	10.9202%
E	11036	01/31/92	MIV	224	6386.66	2595.92	13.7577%
E	11036	01/31/92	MIV	364	7392.04	4009.62	10.5633%
E	11036	01/31/92	MIV	552	17528.96	6369.28	15.2450% MAX
E	11109	01/31/92	MIV	1380	43951.70	15877.67	15.3470% MAX
E	11109	01/31/92	MIV	840	17668.02	9329.96	10.7568%
E	11183	01/31/92	MIV	1843	59601.27	21352.39	15.4768% MAX
E	11183	01/31/92	MIV	1456	41238.88	16792.40	13.7052%
E	11183	01/31/92	MIV	1092	23550.56	12623.76	10.6101%

E	11372	01/31/92	MIV	1176	25465.36	13402.92	10.7886%	
E	11449	01/31/92	MIV	1260	28156.60	14469.78	11.0063%	
E	11449	01/31/92	MIV	1284	41281.80	14755.24	15.5218%	MAX
E	11540	01/31/92	MIV	84	2900.56	977.12	16.3330%	MAXIMUM
E	11540	01/31/92	MIV	1092	24128.54	12526.83	10.8827%	
E	11733	01/31/92	MIV	56	1358.29	644.30	11.7894%	
E	11806	01/31/92	MIV	1232	27535.62	14244.51	10.9218%	
E	11806	01/31/92	MIV	1176	38559.54	13660.31	15.5925%	MAX
E	11897	01/31/92	MIV	1176	22034.29	11718.21	10.6533%	
E	11897	01/31/92	MIV	2184	71160.12	24995.64	15.6995%	MAX
E	11979	01/31/92	MIV	1092	21739.50	11622.88	10.6084%	
E	11979	01/31/92	MIV	2239	72291.89	25342.30	15.7578%	MAX
E	12127	01/31/92	MIV	1344	43465.02	15461.22	15.5080%	MAX
E	12127	01/31/92	MIV	728	20099.93	8265.23	13.5394%	
E	12127	01/31/92	MIV	588	12638.55	6749.34	10.6265%	
E	12201	01/31/92	MIV	1060	32982.00	12083.48	15.0752%	MAX
E	12201	01/31/92	MIV	896	18818.58	10062.64	10.6335%	
E	12240	01/31/92	MIV	4	75.12	46.72	9.0329%	
E	12240	01/31/92	MIV	4	131.18	46.55	15.4862%	MAX
E	12285	01/31/92	MIV	1512	32776.71	17301.54	10.7474%	
E	12285	01/31/92	MIV	2323	66092.78	26878.65	13.6743%	
E	12285	01/31/92	MIV	1763	58577.03	20275.91	15.9224%	MAX
E	12480	01/31/92	MIV	1876	60498.04	21695.37	15.3364%	MAX
E	12480	01/31/92	MIV	1260	27095.98	14539.72	10.5801%	
E	12480	01/31/92	MIV	1540	43649.73	17814.03	13.6181%	
E	12565	01/31/92	MIV	1064	23030.59	12303.84	10.6471%	
E	12565	01/31/92	MIV	978	32799.44	11320.30	15.9162%	MAX
E	12565	01/31/92	MIV	1316	36841.09	15160.13	13.5054%	
E	12639	01/31/92	NAT	2	42.03	23.37	11.7445%	
E	12639	01/31/92	MIV	1315	28937.42	15276.44	10.7343%	
E	12639	01/31/92	MIV	1260	40282.99	14494.72	15.2881%	MAX
E	12639	01/31/92	MIV	1371	38217.64	15883.50	13.3800%	
E	12852	01/31/92	MIV	56	1270.02	653.05	12.8490%	
E	12852	01/31/92	MIV	160	3452.83	1867.50	10.4644%	
E	13015	01/31/92	MIV	84	1687.24	868.93	12.6768%	
E	13016	01/31/92	MIV	2	20.73	21.98	6.4700%	
E	13371	01/31/92	MIV	2	22.70	23.42	6.6981%	
E	13649	01/31/92	MIV	416	8629.64	4553.94	12.3933%	
E	13649	01/31/92	NAT	32	632.72	374.05	11.0612%	
E	13685	01/31/92	MIV	224	5143.26	2612.62	12.7068%	
E	14065	01/31/92	MIV	3	14.26	22.39	4.3825%	
E	14355	01/31/92	MIV	168	5225.85	1912.58	15.2730%	MAX
E	14355	01/31/92	MIV	168	4630.11	1902.04	13.5667%	
E	14355	01/31/92	MIV	504	9796.74	5883.98	9.4116%	
E	14356	01/31/92	MIV	1311	20858.23	13422.87	10.9832%	
E	14722	01/31/92	NAT	6	55.75	70.19	5.4173%	
E	15204	01/31/92	NAT	30	280.66	350.97	5.4503%	
E	15204	01/31/92	MIV	8698	82290.48	97003.40	5.8908%	
E	15240	01/31/92	NAT	32	247.55	374.47	4.5302%	
E	15240	01/31/92	MIV	11	92.78	117.52	5.4932%	
E	15316	01/31/92	MIV	1811	16271.16	19521.89	5.7812%	
E	15399	01/31/92	MIV	32	0.11	374.48	0.0000%	
E	15444	01/31/92	MIV	28	182.45	308.42	4.7221%	
E	15451	01/31/92	MIV	672	7384.76	6928.84	6.7149%	
E	15451	01/31/92	NAT	128	914.43	1496.21	4.9223%	
E	15455	01/31/92	MIV	134	902.74	1494.66	4.9003%	

E	15457	01/31/92	NAT	4	12.42	46.79	1.7028%
E	15457	01/31/92	MIV	28	198.53	290.17	4.3223%
E	15458	01/31/92	MIV	11858	72686.68	131914.03	4.2286%
E	15458	01/31/92	NAT	32	181.59	374.15	3.4295%
E	15460	01/31/92	NAT	252	971.11	2947.30	2.8092%
E	15460	01/31/92	MIV	1440	9725.90	14924.34	4.2624%
E	15461	01/31/92	MIV	1088	2473.19	12727.53	1.5482%
W	9621	01/31/92	MIA	47	102.28	105.50	6.1508%
W	9964	01/31/92	MIV	9	55.58	74.85	6.0137%
W	9964	01/31/92	MIA	42	555.04	317.85	10.6892%
W	9993	01/31/92	MIA	1062	13965.36	8448.59	10.1176%
W	10001	01/31/92	MIV	78	1109.66	902.46	9.7457%
W	10201	01/31/92	MIA	1738	20336.43	14095.26	9.0208%
W	10259	01/31/92	MIA	396	4937.24	2959.75	10.2067%
W	10294	01/31/92	MIA	2320	30055.01	19118.45	9.6313%
W	10350	01/31/92	MIA	1988	26636.21	15780.23	10.3334%
W	10385	01/31/92	MIA	1005	13762.23	8233.86	10.2122%
W	10456	01/31/92	MIA	2016	29702.50	16539.92	11.0718%
W	10602	01/31/92	MIA	1763	25818.77	14500.72	10.8561%
W	10679	01/31/92	MIA	1428	21350.66	11465.97	11.4572%
W	10742	01/31/92	MIA	840	13598.03	6643.22	12.4119%
W	10764	01/31/92	MIA	2	0.00	16.57	0.0000%
W	10764	01/31/92	MIV	26	0.00	303.86	0.0000%
W	10770	01/31/92	MIA	1008	17199.87	8167.46	12.7531%
W	10832	01/31/92	MIA	2062	34502.52	16740.73	12.5178%
W	10982	01/31/92	MIA	2100	37715.77	17205.67	13.2388%
W	11036	01/31/92	MIA	924	16486.73	7596.66	13.1223%
W	11109	01/31/92	MIA	1857	32938.33	15071.41	13.2117%
W	11183	01/31/92	MIA	1288	21976.99	10295.43	12.9001%
W	11372	01/31/92	MIA	2464	43236.77	19925.91	13.2644%
W	11449	01/31/92	MIA	2436	42676.28	19942.12	12.9521%
W	11540	01/31/92	MIV	1003	32887.93	11563.39	15.7326% MAX
W	11540	01/31/92	MIA	1512	26426.73	12460.51	12.8148%
W	11806	01/31/92	MIA	2436	44145.50	19945.00	13.3331%
W	11897	01/31/92	MIA	2488	45426.92	19665.22	13.8381%
W	11979	01/31/92	MIA	3245	57905.28	25316.56	13.7351%
W	12127	01/31/92	MIA	1974	35875.68	15749.02	13.6626%
W	12201	01/31/92	MIA	3080	52809.87	25068.61	12.7526%
W	12285	01/31/92	MIA	2406	41671.83	19722.25	12.7426%
W	12480	01/31/92	MIA	2350	42929.13	19408.82	13.2626%
W	12565	01/31/92	MIV	588	19815.17	6833.33	15.9252% MAX
W	12565	01/31/92	MIA	3051	55365.85	25194.95	13.1894%
W	12639	01/31/92	MIA	2854	49347.52	23574.21	12.6170%
W	12823	01/31/92	MIA	952	16147.30	7833.94	12.6872%
W	12852	01/31/92	MIV	5740	130130.61	66913.67	12.8490%
W	12852	01/31/92	MIV	360	12144.08	4188.92	15.8559% MAX
W	12852	01/31/92	MIA	1680	28640.58	13705.47	12.5752%
W	12942	01/31/92	MIA	2520	42506.49	20393.64	12.6096%
W	12942	01/31/92	NAT	32	672.32	373.94	11.7253%
W	12942	01/31/92	MIV	4532	95297.86	52443.23	12.2845%
W	13015	01/31/92	MIV	3972	85046.74	43798.91	12.6768%
W	13015	01/31/92	NAT	32	674.44	373.94	11.7550%
W	13016	01/31/92	MIA	2532	44046.39	20602.28	12.8199%
W	13017	01/31/92	MIV	2352	44494.20	26850.17	11.0057%
W	13371	01/31/92	MIA	616	10448.50	4984.96	12.5326%
W	13372	01/31/92	MIV	1814	36795.31	19284.08	12.3706%

W	13524	01/31/92	MIV	3416	72431.45	37578.85	12.5459%
W	13525	01/31/92	MIA	2184	38186.77	17551.51	13.0218%
W	13648	01/31/92	MIA	4	38.72	33.11	7.1663%
W	13650	01/31/92	MIA	2100	35962.19	16546.69	12.9600%
W	13686	01/31/92	MIA	2166	35800.06	17856.03	12.0334%
W	13724	01/31/92	MIA	2	14.12	15.51	5.9186%
W	13858	01/31/92	NAT	32	669.92	373.95	11.6340%
W	13858	01/31/92	MIV	4633	92534.75	52407.41	11.5760%
W	13859	01/31/92	MIA	3616	58312.78	29593.35	11.9141%
W	14055	01/31/92	MIV	28	304.23	326.33	6.3913%
W	14065	01/31/92	MIV	12	76.56	120.19	4.3825%
W	14448	01/31/92	MIV	1	13.05	14.95	6.0803%
W	14883	01/31/92	MIV	2	19.84	23.39	5.7909%
W	15204	01/31/92	MIV	1	13.49	15.91	5.8908%
W	15244	01/31/92	MIA	45	528.93	352.79	10.4053%
W	15244	01/31/92	MIV	1	8.64	7.03	9.7456%
W	15347	01/31/92	MIA	19	216.43	144.36	10.4053%
W	15445	01/31/92	MIA	242	1522.98	1965.91	5.2503%
W	15448	01/31/92	MIA	5	48.85	32.58	10.4053%
W	15451	01/31/92	MIA	56	386.34	465.45	5.2558%
W	15457	01/31/92	MIA	4	15.44	33.28	2.8178%
W	15459	01/31/92	MIA	4150	20403.56	33920.63	4.0322%
W	15460	01/31/92	MIA	252	1042.67	2096.24	3.3043%
W	15555	01/31/92	MIA	2	28.89	19.27	10.4053%

Totals (Average Wt% ²⁴⁰Pu) 207496 4013818.51 2098362.14 12.5267%

APPENDIX B

**DOSE RATE MEASUREMENT CANISTERS
WERE STAINLESS STEEL**

This page intentionally left blank.

[77] From: Karen R Morris at WHC146 7/1/94 1:36PM (745 bytes: 16 ln)
To: Warren D Wittekind at WHC71
Receipt Requested
cc: Karen R Morris, Lorie L Blehm
Subject: CANISTER INFORMATION K AREA

----- Message Contents -----

Warren;

This is the information that I could find for you.

Canister locations 5613, 6806, 0804, 1205, 0669, and 3575 are all MKII canisters. This makes them stainless steel canisters. The other two canisters 2114 and 2106, I could not get a determination if they are either were stainless or aluminum.

Thanks

Karen Morris
Specialist, NMC
3-1565

This page intentionally left blank.

APPENDIX C

REPRESENTATIVE ISOSHLD-II INPUT FILES

This page intentionally left blank.

ISOSHL-III Input for Half Canister Model 5TA, 6 wt% ²⁴⁰Pu

1 FIVE REGION TOP SHIELDING, DECAY COMPARISONS
 SEVEN ELEMENT IRRADIATION 0.90
 1.84625 112.00 0.1164 360.0 0.10 0
 4.32E+7 8.64E+7 2.59E+8 4.32E+8
 HALF CANISTER, TOP - MODEL #5TA - 1/4 FOOT
 \$INPUT
 NEXT=1,
 IGEOM=9, NSHLD=5, JBUF=5, ISPEC=3, GROUP(5)=1.,
 T(1)=65.3288, T(2)=0.4826, T(3)=0.5588, T(4)=1.27, T(5)=7.62,
 X=227.6602, SLTH=10.254, NTHETA=11, NPSI=11, DELR=0.400,
 \$END

URANUM	15	18.63	0.0	0.0	0.0	0.0
ZIRC	11	0.0	6.55	0.0	0.0	0.0
AIR	3	0.0	0.0	0.00129	0.0	0.0
IRON	9	0.0	0.0	0.0	8.030	0.0
1 WATER	1	0.0	0.0	0.0	0.0	1.0

 HALF CANISTER, TOP - MODEL #5TA - 1/2 FOOT
 \$INPUT
 NEXT=4,
 T(5)=15.24, X=235.2802,
 \$END
 HALF CANISTER, TOP - MODEL #5TA - 1 FOOT
 \$INPUT
 NEXT=4,
 T(5)=30.48, X=250.5202,
 \$END
 HALF CANISTER, TOP - MODEL #5TA - 2 FEET
 \$INPUT
 NEXT=4,
 T(5)=60.96, X=281.0002,
 \$END
 HALF CANISTER, TOP - MODEL #5TA - 3 FEET
 \$INPUT
 NEXT=4,
 T(5)=91.44, X=311.4802;
 \$END
 HALF CANISTER, TOP - MODEL #5TA - 4 FEET
 \$INPUT
 NEXT=4,
 T(5)=121.92, X=341.9602,
 \$END
 HALF CANISTER, TOP - MODEL #5TA - 5 FEET
 \$INPUT
 NEXT=4,
 T(5)=152.40, X=372.4402,
 \$END
 HALF CANISTER, TOP - MODEL #5TA - 6 FEET
 \$INPUT
 NEXT=4,
 T(5)=182.88, X=402.9202,
 \$END
 HALF CANISTER, TOP - MODEL #5TA - 7 FEET
 \$INPUT
 NEXT=4,

T(5)=213.36, X=433.4002,
\$END
HALF CANISTER, TOP - MODEL #5TA - 8 FEET
\$INPUT
NEXT=4,
T(5)=243.84, X=463.8802,
\$END
HALF CANISTER, TOP - MODEL #5TA - 9 FEET
\$INPUT
NEXT=4,
T(5)=274.32, X=494.3602,
\$END
HALF CANISTER, TOP - MODEL #5TA - 10 FEET
\$INPUT
NEXT=4,
T(5)=304.80, X=524.8402,
\$END
HALF CANISTER, TOP - 3 IN H2O, 4 FEET AIR
\$INPUT
NEXT=4,
T(5)=7.62, X=197.1802,
\$END
HALF CANISTER, TOP - 3 IN H2O, 3 FEET AIR
\$INPUT
NEXT=4,
T(5)=7.62, X=166.7002,
\$END
HALF CANISTER, TOP - 3 IN H2O, 2 FEET AIR
\$INPUT
NEXT=4,
T(5)=7.62, X=136.2202,
\$END
HALF CANISTER, TOP - 3 IN H2O, 1 FEET AIR
\$INPUT
NEXT=4,
T(5)=7.62, X=105.7402,
\$END
HALF CANISTER, TOP - 3 IN H2O, 0 FEET AIR
\$INPUT
NEXT=4,
T(5)=7.62, X=75.2602,
\$END
HALF CANISTER, TOP - 2 IN H2O, 0 FEET AIR
\$INPUT
NEXT=4,
T(5)=5.08, X=72.7202,
\$END
HALF CANISTER, TOP - 1 IN H2O, 0 FEET AIR
\$INPUT
NEXT=4,
T(5)=2.54, X=70.1802,
\$END
END OF CASE
\$INPUT
NEXT=6,
\$END

ISOSHL-D-II Input for Half Canister Model 6TB, 16 wt% ²⁴⁰Pu

```

1 16 WT. PCT. PU-240, DECAY COMPARISON
SEVEN ELEMENT IRRADIATION 0.90
1.84625 406.00 0.4221 360.0 0.10 0
4.55E+8 5.41E+8 7.14E+8 8.87E+8
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 1/4 FOOT
$INPUT
NEXT=1,
IGEOM=10, NSHLD=5, JBUF=5, ISPEC=3, GROUP(5)=1., Y=31.75,
T(1)=65.3288, T(2)=0.4826, T(3)=0.5588, T(4)=1.27, T(5)=7.62,
X=227.6602, SLTH=26.670, NTHETA=11, NPSI=11, DELR=0.400,
$END
URANUM 15 18.63 0.0 0.0 0.0 0.0
ZIRC 11 0.0 6.55 0.0 0.0 0.0
AIR 3 0.0 0.0 0.00129 0.0 0.0
IRON 9 0.0 0.0 0.0 8.030 0.0
1 WATER 1 0.0 0.0 0.0 0.0 1.0
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 1/2 FOOT
$INPUT
NEXT=4,
T(5)=15.24, X=235.2802,
$END
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 1 FOOT
$INPUT
NEXT=4,
T(5)=30.48, X=250.5202,
$END
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 2 FEET
$INPUT
NEXT=4,
T(5)=60.96, X=281.0002,
$END
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 3 FEET
$INPUT
NEXT=4,
T(5)=91.44, X=311.4802,
$END
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 4 FEET
$INPUT
NEXT=4,
T(5)=121.92, X=341.9602,
$END
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 5 FEET
$INPUT
NEXT=4,
T(5)=152.40, X=372.4402,
$END
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 6 FEET
$INPUT
NEXT=4,
T(5)=182.88, X=402.9202,
$END
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 7 FEET
$INPUT
NEXT=4,

```

T(5)=213.36, X=433.4002,
\$END
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 8 FEET
\$INPUT
NEXT=4,
T(5)=243.84, X=463.8802,
\$END
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 9 FEET
\$INPUT
NEXT=4,
T(5)=274.32, X=494.3602,
\$END
HALF CANISTER LOCATION, TOP - MODEL #6TB(16) - 10 FEET
\$INPUT
NEXT=4,
T(5)=304.80, X=524.8402,
\$END
HALF CANISTER LOCATION, TOP - 3 IN H2O, 4 FEET AIR
\$INPUT
NEXT=4,
T(5)=7.62, X=197.1802,
\$END
HALF CANISTER LOCATION, TOP - 3 IN H2O, 3 FEET AIR
\$INPUT
NEXT=4,
T(5)=7.62, X=166.7002,
\$END
HALF CANISTER LOCATION, TOP - 3 IN H2O, 2 FEET AIR
\$INPUT
NEXT=4,
T(5)=7.62, X=136.2202,
\$END
HALF CANISTER LOCATION, TOP - 3 IN H2O, 1 FEET AIR
\$INPUT
NEXT=4,
T(5)=7.62, X=105.7402,
\$END
HALF CANISTER LOCATION, TOP - 3 IN H2O, 0 FEET AIR
\$INPUT
NEXT=4,
T(5)=7.62, X=75.2602,
\$END
HALF CANISTER LOCATION, TOP - 2 IN H2O, 0 FEET AIR
\$INPUT
NEXT=4,
T(5)=5.08, X=72.7202,
\$END
HALF CANISTER LOCATION, TOP - 1 IN H2O, 0 FEET AIR
\$INPUT
NEXT=4,
T(5)=2.54, X=70.1802,
\$END
END OF CASE
\$INPUT
NEXT=6,
\$END

ISOSHL-D-II Input for Single Canister Model B1, 16 wt% ²⁴⁰Pu

```

1 BUILD UP TO FULL 1800 CANISTER BASIN
ONE CANISTER IRRADIATION 0.90
3.69250 406.00 0.4221 360.0 0.10 0
4.55E+8 5.41E+8 7.14E+8 8.87E+8
ONE CANISTER LOCATION, TOP - MODEL B1 - 1/4 FOOT
$INPUT
NEXT=1,
IGEOM=10, NSHLD=5, JBUF=5, ISPEC=3, GROUP(5)=1., Y=31.75,
T(1)=65.3288, T(2)=0.4826, T(3)=0.5588, T(4)=1.27, T(5)=7.62,
X=227.6602, SLTH=53.34, NTHETA=22, NPSI=11, DELR=0.400,
$END
URANUM 15 18.63 0.0 0.0 0.0 0.0
ZIRC 11 0.0 6.55 0.0 0.0 0.0
AIR 3 0.0 0.0 0.00129 0.0 0.0
IRON 9 0.0 0.0 0.0 8.030 0.0
1 WATER 1 0.0 0.0 0.0 0.0 1.0
ONE CANISTER LOCATION, TOP - MODEL B1 - 1/2 FOOT
$INPUT
NEXT=4,
T(5)=15.24, X=235.2802,
$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 1 FOOT
$INPUT
NEXT=4,
T(5)=30.48, X=250.5202,
$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 2 FEET
$INPUT
NEXT=4,
T(5)=60.96, X=281.0002,
$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 3 FEET
$INPUT
NEXT=4,
T(5)=91.44, X=311.4802,
$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 4 FEET
$INPUT
NEXT=4,
T(5)=121.92, X=341.9602,
$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 5 FEET
$INPUT
NEXT=4,
T(5)=152.40, X=372.4402,
$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 6 FEET
$INPUT
NEXT=4,
T(5)=182.88, X=402.9202,
$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 7 FEET
$INPUT
NEXT=4,

```

T(5)=213.36, X=433.4002,
\$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 8 FEET
\$INPUT
NEXT=4,
T(5)=243.84, X=463.8802,
\$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 9 FEET
\$INPUT
NEXT=4,
T(5)=274.32, X=494.3602,
\$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 10 FEET
\$INPUT
NEXT=4,
T(5)=304.80, X=524.8402,
\$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 11 FEET
\$INPUT
NEXT=4,
T(5)=335.28, X=555.3202,
\$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 12 FEET
\$INPUT
NEXT=4,
T(5)=365.76, X=585.8002,
\$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 13 FEET
\$INPUT
NEXT=4,
T(5)=396.24, X=616.2802,
\$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 14 FEET
\$INPUT
NEXT=4,
T(5)=426.72, X=646.7602,
\$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 15 FEET
\$INPUT
NEXT=4,
T(5)=457.20, X=677.2402,
\$END
ONE CANISTER LOCATION, TOP - MODEL B1 - 16 FEET
\$INPUT
NEXT=4,
T(5)=487.68, X=707.7202,
\$END
END OF CASE
\$INPUT
NEXT=6,
\$END

ISOSHL-11 Input for Static Basin Model B1800, 16 wt% ²⁴⁰Pu

```

1 BUILD UP TO FULL 1800 CANISTER BASIN
1800 CANISTER IRRADIATION 0.90
6646.50 406.00 0.4221 360.0 0.10 0
4.55E+8 5.41E+8 7.14E+8 8.87E+8
1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 1/4 FOOT
$INPUT
NEXT=1,
IGEOM=10, NSHLD=5, JBUF=5, ISPEC=3, GROUP(5)=1., Y=1905.00,
T(1)=65.3288, T(2)=0.4826, T(3)=0.5588, T(4)=1.27, T(5)=7.62,
X=227.6602, SLTH=1600.20, NTHETA=44, NPSI=22, DELR=0.400,
$END
URANUM 15 18.63 0.0 0.0 0.0 0.0
ZIRC 11 0.0 6.55 0.0 0.0 0.0
AIR 3 0.0 0.0 0.00129 0.0 0.0
IRON 9 0.0 0.0 0.0 8.030 0.0
1 WATER 1 0.0 0.0 0.0 0.0 1.0
1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 1/2 FOOT
$INPUT
NEXT=4,
T(5)=15.24, X=235.2802,
$END
1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 1 FOOT
$INPUT
NEXT=4,
T(5)=30.48, X=250.5202,
$END
1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 2 FEET
$INPUT
NEXT=4,
T(5)=60.96, X=281.0002,
$END
1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 3 FEET
$INPUT
NEXT=4,
T(5)=91.44, X=311.4802,
$END
1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 4 FEET
$INPUT
NEXT=4,
T(5)=121.92, X=341.9602,
$END
1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 5 FEET
$INPUT
NEXT=4,
T(5)=152.40, X=372.4402,
$END
1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 6 FEET
$INPUT
NEXT=4,
T(5)=182.88, X=402.9202,
$END
1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 7 FEET
$INPUT
NEXT=4,

```

T(5)=213.36, X=433.4002,
 \$END
 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 8 FEET
 \$INPUT
 NEXT=4,
 T(5)=243.84, X=463.8802,
 \$END
 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 9 FEET
 \$INPUT
 NEXT=4,
 T(5)=274.32, X=494.3602,
 \$END
 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 10 FEET
 \$INPUT
 NEXT=4,
 T(5)=304.80, X=524.8402,
 \$END
 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 11 FEET
 \$INPUT
 NEXT=4,
 T(5)=335.28, X=555.3202,
 \$END
 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 12 FEET
 \$INPUT
 NEXT=4,
 T(5)=365.76, X=585.8002,
 \$END
 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 13 FEET
 \$INPUT
 NEXT=4,
 T(5)=396.24, X=616.2802,
 \$END
 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 14 FEET
 \$INPUT
 NEXT=4,
 T(5)=426.72, X=646.7602,
 \$END
 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 15 FEET
 \$INPUT
 NEXT=4,
 T(5)=457.20, X=677.2402,
 \$END
 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 16 FEET
 \$INPUT
 NEXT=4,
 T(5)=487.68, X=707.7202,
 \$END
 END OF CASE
 \$INPUT
 NEXT=6,
 \$END

APPENDIX D

REPRESENTATIVE ISOSHL D-II OUTPUT

(Output is from Full-Basin Model B1800.)

This page intentionally left blank.

[illegible]

```

*****
*
*      Wed Jun 22 19:02:38 1994
*
*NUCLEAR ANALYSIS & CHARACTERIZATION
*
*CODE CUSTODIAN: W D WITTEKIND HO-38
*
*****

```

BUILD UP TO FULL 1800 CANISTER BASIN

```

POWER = 6.64650E+03 MEGAWATTS
IRRADIATION TIME = 4.06000E+02 DAYS
PHI*SIG25*TIME = 4.22100E-01 N/CM2-S * CM2 * SEC
U-235 ABSORPTION CROSS-SECTION 360.000 BARNs
NEUTRON FLUX = 3.343E+13 NEUTRONS/(CM**2 - SEC)
1800 CANISTER IRRADIATION

```

```
CON 9.0000E-01, PO 6.6465E+03, TIME 4.0600E+02, T 4.2210E-01, SIGA25 3.6000E+02, DEL 1.0000E-01.
AG*108 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 2
AG*108 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 2
0 0.000E+00 4.550E+08 5.410E+08 7.140E+08 8.870E+08 DECAY POINTS - SECONDS
```

ZN	72	3.242E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA	72	3.239E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE	72	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN	73	3.275E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA	73	3.343E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE	73	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA	74	1.170E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE	74	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA	75	1.337E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE*	75	1.337E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE	75	2.675E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00

AS	75	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA	76	3.342E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE	76	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS	76	1.745E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	76	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE*	77	1.805E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE	77	1.888E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS	77	3.050E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE*	77	2.321E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	77	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE	78	6.016E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS	78	6.685E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	78	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS	79	1.337E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE*	79	1.337E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	79	1.832E+01	1.832E+01	1.831E+01	1.831E+01	1.831E+01
BR	79	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS	80	2.674E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	80	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR*	80	3.085E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR	80	1.235E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	80	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS	81	4.178E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE*	81	2.811E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	81	4.461E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR	81	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	81	6.996E-10	6.995E-10	6.995E-10	6.995E-10	6.995E-10
SE	82	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR	82	1.940E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	82	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE*	83	1.274E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	83	7.964E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR	83	2.261E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR*	83	2.261E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	83	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	84	2.718E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR*	84	8.615E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR	84	4.321E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	84	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS	85	2.124E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	85	4.247E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR	85	5.946E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR*	85	5.948E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	85	1.015E+06	4.010E+05	3.364E+05	2.363E+05	1.659E+05
RB	85	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	86	4.236E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR	86	8.472E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	86	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB*	86	6.544E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB	86	6.302E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR	86	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	87	1.111E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR	87	1.111E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	87	1.111E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB	87	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR*	87	2.944E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR	87	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR	88	1.218E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	88	1.558E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB	88	1.559E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR	88	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR	89	8.270E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	89	1.925E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB	89	1.992E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR	89	2.066E+08	9.820E-24	0.000E+00	0.000E+00	0.000E+00
Y*	89	4.132E+04	1.964E-27	0.000E+00	0.000E+00	0.000E+00
Y	89	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR	90	1.091E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	90	2.182E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB	90	2.481E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR	90	7.334E+06	5.182E+06	4.853E+06	4.253E+06	3.727E+06
Y*	90	2.282E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y	90	7.555E+06	5.184E+06	4.854E+06	4.254E+06	3.728E+06
ZR	90	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	91	1.522E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB*	91	8.437E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB	91	1.679E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR	91	2.526E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Y*	91	1.490E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y	91	2.609E+08	3.598E-19	3.010E-24	0.000E+00	0.000E+00
ZR	91	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	92	1.249E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB	92	2.533E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR	92	2.750E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y	92	2.751E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR	92	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	93	6.089E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB	93	2.057E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR	93	3.025E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y	93	3.072E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR	93	2.650E+02	2.653E+02	2.653E+02	2.653E+02	2.653E+02
NB*	93	6.578E+00	6.232E+01	6.393E+01	6.547E+01	6.603E+01
NB	93	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	94	3.364E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB	94	1.445E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR	94	2.785E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y	94	3.187E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR	94	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB*	94	1.216E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB	94	1.718E-06	1.717E-06	1.717E-06	1.717E-06	1.717E-06
MO	94	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	95	1.726E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB	95	3.453E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR	95	3.453E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y	95	3.453E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR	95	3.427E+08	1.416E-16	3.486E-21	0.000E+00	0.000E+00
NB*	95	6.851E+06	3.006E-18	7.399E-23	0.000E+00	0.000E+00
NB	95	3.382E+08	3.072E-16	7.563E-21	0.000E+00	0.000E+00
MO	95	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y	96	1.655E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR	96	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB	96	4.456E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO	96	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR	97	1.303E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB	97	2.605E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR	97	2.605E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y	97	2.605E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR	97	3.352E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB*	97	3.017E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB	97	3.352E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO	97	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR	98	8.949E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB*	98	1.647E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB	98	1.781E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO	98	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR	99	1.710E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB	99	3.420E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO	99	3.421E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC*	99	3.147E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC	99	1.226E+03	1.240E+03	1.240E+03	1.240E+03	1.240E+03
RU	99	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB	100	3.714E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO	100	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC	100	8.618E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU	100	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB	101	1.504E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO	101	3.008E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC	101	3.008E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU	101	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO	102	2.760E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC	102	2.760E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU	102	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC	103	1.160E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU	103	2.232E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH*	103	2.221E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH	103	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO	104	1.945E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC	104	1.945E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU	104	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH*	104	2.091E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH	104	2.864E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD	104	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO	105	7.894E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC	105	1.184E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU	105	1.185E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH*	105	3.188E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00

RH 105	1.046E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD 105	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU 106	4.656E+07	2.117E+03	3.199E+02	7.144E+00	1.595E-01
RH*106	9.801E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH 106	5.049E+07	2.117E+03	3.199E+02	7.144E+00	1.595E-01
PD 106	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC 107	8.688E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU 107	8.823E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH 107	8.823E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD 107	6.660E+00	6.661E+00	6.661E+00	6.661E+00	6.661E+00
AG 107	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU 108	5.024E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH 108	5.024E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD 108	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG*108	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG 108	1.128E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD 108	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH 109	3.264E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD*109	3.265E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD 109	3.309E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG*109	3.309E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG 109	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD 110	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG*110	2.713E+04	2.175E-02	1.532E-03	7.370E-06	3.546E-08
AG 110	2.123E+06	4.350E-04	3.064E-05	1.474E-07	7.091E-10
CD 110	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD*111	2.598E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD 111	5.761E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG*111	5.761E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG 111	5.766E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD*111	1.030E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD 111	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD 112	3.081E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG 112	3.080E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD 112	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD 113	5.941E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG*113	5.941E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG 113	5.347E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD*113	1.768E+00	8.655E-01	7.562E-01	5.764E-01	4.393E-01
CD 113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN 113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD 114	5.607E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG 114	5.607E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD 114	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN*114	2.840E-03	5.681E-35	0.000E+00	0.000E+00	0.000E+00
IN 114	4.726E-03	5.681E-35	0.000E+00	0.000E+00	0.000E+00
PD 115	4.203E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG*115	1.177E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG 115	3.261E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD*115	3.042E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD 115	4.166E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN*115	4.166E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN 115	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 115	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD 116	3.342E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG 116	3.342E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD 116	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN*116	7.765E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN 116	2.190E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 116	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG 117	6.168E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD*117	3.091E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD 117	3.084E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN*117	3.084E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN 117	3.707E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN*117	1.181E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 117	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD 118	3.569E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN 118	3.569E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 118	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD*119	4.248E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD 119	4.248E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN*119	4.248E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN 119	4.207E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN*119	3.106E+04	1.420E-02	8.997E-04	3.496E-06	1.358E-08
SN 119	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN 120	1.784E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 120	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

CD 121	6.498E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN*121	6.498E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN 121	2.017E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN*121	2.837E+03	1.902E+03	1.763E+03	1.515E+03	1.301E+03
SN 121	1.413E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 121	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN 122	2.286E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 122	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB*122	8.521E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 122	8.422E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE 122	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN 123	3.138E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN*123	4.679E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 123	5.668E+04	2.931E-08	1.396E-10	2.973E-15	6.334E-20
SB 123	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE*123	2.138E+00	6.073E-14	1.671E-16	1.181E-21	8.348E-27
TE 123	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 124	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB*124	3.279E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 124	1.394E+03	6.551E-24	6.919E-29	0.000E+00	0.000E+00
TE 124	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN*125	3.904E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 125	1.980E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 125	4.811E+05	1.234E+04	6.128E+03	1.499E+03	3.667E+02
TE*125	5.070E+04	1.770E+03	8.790E+02	2.150E+02	5.260E+01
TE 125	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 126	5.439E+01	5.438E+01	5.438E+01	5.438E+01	5.438E+01
SB*126	5.439E+01	5.438E+01	5.438E+01	5.438E+01	5.438E+01
SB 126	3.765E+04	5.384E+01	5.384E+01	5.384E+01	5.383E+01
TE 126	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 127	1.685E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 127	1.738E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE*127	3.106E+06	2.607E-09	3.657E-12	6.665E-18	1.215E-23
TE 127	1.696E+07	2.578E-09	3.615E-12	6.589E-18	1.201E-23
I 127	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 128	2.143E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB*128	2.315E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 128	2.572E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE 128	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 128	1.125E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 128	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 129	5.607E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE*129	2.018E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE 129	5.607E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 129	2.541E+00	2.661E+00	2.661E+00	2.661E+00	2.661E+00
XE 129	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN 130	1.121E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 130	1.121E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE 130	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 130	1.863E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 130	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 131	1.604E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE*131	2.834E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE 131	1.601E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 131	1.887E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE*131	1.539E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 131	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 132	2.291E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE 132	2.665E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 132	2.665E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 132	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 133	1.949E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE*133	1.998E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE 133	1.400E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 133	3.351E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE*133	6.711E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 133	3.720E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 133	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 134	1.795E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE 134	3.938E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 134	4.239E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 134	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS*134	1.081E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 134	1.940E+06	1.660E+04	6.750E+03	1.104E+03	1.807E+02
BA 134	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB 135	1.686E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE 135	1.686E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 135	3.612E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00

XE*135	9.754E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 135	7.190E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 135	2.719E+01	2.737E+01	2.737E+01	2.737E+01	2.737E+01
BA*135	1.217E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA 135	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 136	1.512E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 136	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 136	3.336E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA 136	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 137	2.793E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 137	3.576E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 137	8.979E+06	6.434E+06	6.041E+06	5.322E+06	4.689E+06
BA*137	8.261E+06	5.919E+06	5.558E+06	4.897E+06	4.314E+06
BA 137	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 138	1.974E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 138	3.177E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 138	3.368E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA 138	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 139	9.866E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 139	2.590E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 139	3.270E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA 139	3.336E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA 139	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 140	1.984E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 140	3.228E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA 140	3.332E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA 140	3.413E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE 140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 141	8.507E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 141	2.658E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA 141	3.265E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA 141	3.298E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE 141	3.292E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR 141	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 142	1.872E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 142	1.857E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA 142	3.006E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA 142	3.107E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE 142	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR 142	4.083E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND 142	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 143	1.636E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 143	3.272E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA 143	3.272E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA 143	3.272E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE 143	3.277E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR 143	3.266E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND 143	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE 144	1.332E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS 144	2.663E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA 144	2.663E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA 144	2.663E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE 144	1.915E+08	5.258E+02	4.674E+01	3.591E-01	2.759E-03
PR 144	1.963E+08	5.259E+02	4.674E+01	3.591E-01	2.759E-03
ND 144	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE 145	2.115E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR 145	2.115E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND 145	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE 146	1.658E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR 146	1.692E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND 146	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE 147	3.418E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR 147	6.836E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND 147	1.374E+08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM 147	3.075E+07	6.920E+05	3.345E+05	7.752E+04	1.796E+04
SM 147	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE 148	9.633E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR 148	9.633E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND 148	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM*148	2.142E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM 148	1.579E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM 148	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND 149	7.379E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM 149	8.541E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM 149	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND 150	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM 150	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND 151	3.424E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00

PM 151	3.489E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM 151	2.084E+04	1.977E+04	1.936E+04	1.856E+04	1.779E+04
EU 151	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM 152	1.203E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM 152	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU*152	7.126E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU 152	1.289E+02	5.754E+01	4.941E+01	3.636E+01	2.676E+01
GD 152	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM 153	6.697E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM 153	2.551E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU 153	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM 154	4.788E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM 154	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU 154	7.416E+04	3.970E+04	3.527E+04	2.781E+04	2.193E+04
GD 154	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM 155	6.292E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU 155	2.279E+05	8.823E+02	3.088E+02	3.736E+01	4.520E+00
GD 155	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM 156	2.924E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU 156	1.057E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD 156	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU 157	1.921E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD 157	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU 158	9.727E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD 158	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU 159	2.562E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD 159	5.198E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB 159	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU 160	6.346E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD 160	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB 160	1.156E+04	1.122E-18	7.747E-23	0.000E+00	0.000E+00
DY 160	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD 161	3.558E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB 161	3.590E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
DY 161	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD 162	1.509E+04	6.859E-01	1.036E-01	2.314E-03	5.169E-05
TB 162	1.508E+04	6.860E-01	1.037E-01	2.315E-03	5.170E-05
DY 162	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB 163	9.054E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
DY 163	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
DY 164	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
DY*165	7.703E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
DY 165	9.202E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
HO 165	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
DY 166	1.546E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
HO 166	1.909E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ER 166	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ER*167	4.143E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ER 167	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0	3.085E+10	2.391E+07	2.205E+07	1.909E+07	1.668E+07
1					
0					

TOTAL CURIES

ISOTOPE SELECTION DATA

ISOTOPES CONSIDERED ARE		VALUES REPRESENT A WEIGHTING FACTOR					
ALL		1.000E+00					
0	SHIELD COMPOSITION GR/CC	1	2	3	4	5	
	URANIUM	1.863E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	
	ZR	0.000E+00	6.550E+00	0.000E+00	0.000E+00	0.000E+00	
	AIR	0.000E+00	0.000E+00	1.290E-03	0.000E+00	0.000E+00	
	IRON	0.000E+00	0.000E+00	0.000E+00	8.030E+00	0.000E+00	
	H2O	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+00	
MASS ABSORPTION COEFFICIENTS (LAST REGION IS AIR)							
	0.0150	1.786E+03	3.096E+02	4.414E-03	3.546E+02	3.569E+00	4.424E-03
	0.0250	9.604E+02	7.984E+01	6.527E-04	9.858E+01	5.280E-01	6.542E-04
	0.0350	4.304E+02	7.015E+01	3.496E-04	4.565E+01	2.900E-01	3.504E-04
	0.0450	2.059E+02	4.809E+01	2.709E-04	2.116E+01	2.280E-01	2.715E-04
	0.0550	1.166E+02	2.986E+01	2.399E-04	1.168E+01	2.040E-01	2.405E-04
	0.0650	7.648E+01	1.964E+01	2.242E-04	7.797E+00	1.910E-01	2.247E-04
	0.0750	5.310E+01	1.364E+01	2.132E-04	5.565E+00	1.828E-01	2.137E-04
	0.0850	3.704E+01	9.891E+00	2.045E-04	4.033E+00	1.723E-01	2.049E-04

0.0950	2.800E+01	7.434E+00	1.980E-04	3.202E+00	1.698E-01	1.985E-04
0.1500	3.942E+01	2.476E+00	1.721E-04	1.638E+00	1.500E-01	1.725E-04
0.2500	1.337E+01	1.277E+00	1.471E-04	1.100E+00	1.275E-01	1.474E-04
0.3500	7.228E+00	7.860E-01	1.309E-04	8.014E-01	1.130E-01	1.312E-04
0.4750	4.238E+00	5.928E-01	1.180E-04	7.026E-01	1.015E-01	1.183E-04
0.6500	2.552E+00	4.913E-01	1.116E-04	5.782E-01	8.320E-02	1.118E-04
0.8250	1.854E+00	4.192E-01	8.966E-05	5.115E-01	7.750E-02	8.986E-05
1.0000	1.518E+00	3.792E-01	8.192E-05	4.722E-01	7.050E-02	8.210E-05
1.2250	1.248E+00	3.537E-01	7.392E-05	4.119E-01	6.350E-02	7.408E-05
1.4750	1.043E+00	3.065E-01	6.644E-05	3.774E-01	5.080E-02	6.658E-05
1.7000	9.594E-01	2.882E-01	6.166E-05	3.581E-01	5.370E-02	6.180E-05
1.9000	8.998E-01	2.784E-01	5.805E-05	3.332E-01	5.050E-02	5.818E-05
2.1000	8.607E-01	2.653E-01	5.483E-05	3.228E-01	4.800E-02	5.495E-05
2.3000	8.383E-01	2.620E-01	5.250E-05	3.059E-01	4.570E-02	5.262E-05
2.5000	8.216E-01	2.587E-01	4.992E-05	3.035E-01	4.360E-02	5.004E-05
2.7000	8.123E-01	2.489E-01	4.773E-05	2.939E-01	4.180E-02	4.784E-05
3.0000	8.048E-01	2.378E-01	4.373E-05	2.851E-01	3.950E-02	4.383E-05

1	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 1 FOOT					
0	SOURCE SHIELDS DIST TO DETECTOR 2.505E+02 CM.					
0	SLAB	SLAB				VOL.=1.991E+08 CC
0	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH =1.600E+03 CM			
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05		
0	1800 CANISTER IRRADIATION					
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 0.000E+00 SEC AFTER SHUTDOWN					
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED					
0	SHIELD THICKNESS,CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	3.048E+01
0	GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX	DOSE RATE
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT	AT DOSE POINT
		PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR
	1	4.033E+19	2.818E+19	0.0150	0.000E+00	0.000E+00
	2	3.155E+19	1.602E+19	0.0250	0.000E+00	0.000E+00
	3	3.786E+19	1.050E+19	0.0350	0.000E+00	0.000E+00
	4	1.175E+19	7.652E+18	0.0450	1.632E-15	5.354E-21
	5	9.453E+18	5.915E+18	0.0550	6.689E-06	1.532E-11
	6	6.010E+18	4.773E+18	0.0650	1.622E-01	3.067E-07
	7	9.239E+18	3.999E+18	0.0750	1.094E+02	1.875E-04
	8	1.374E+19	3.446E+18	0.0850	2.020E+04	3.266E-02
	9	5.119E+18	3.044E+18	0.0950	1.049E+05	1.681E-01
	10	8.803E+19	1.794E+19	0.1500	1.155E+07	1.995E+01
	11	8.427E+19	7.496E+18	0.2500	1.145E+08	2.244E+02
	12	7.169E+19	3.811E+18	0.3500	4.540E+08	9.353E+02
	13	1.288E+20	3.048E+18	0.4750	2.858E+09	5.831E+03
	14	1.656E+20	2.050E+18	0.6500	1.103E+10	2.295E+04
	15	1.150E+20	8.891E+17	0.8250	1.295E+10	2.589E+04
	16	5.567E+19	7.269E+17	1.0000	9.690E+09	1.870E+04
	17	6.084E+19	5.269E+17	1.2250	1.832E+10	3.371E+04
	18	6.151E+19	2.972E+17	1.4750	3.751E+10	6.602E+04
	19	1.270E+19	1.469E+17	1.7000	9.439E+09	1.614E+04
	20	1.104E+19	9.763E+16	1.9000	1.063E+10	1.764E+04
	21	1.319E+19	6.607E+16	2.1000	1.536E+10	2.457E+04
	22	6.050E+18	4.491E+16	2.3000	8.189E+09	1.261E+04
	23	1.249E+19	3.097E+16	2.5000	1.949E+10	2.963E+04
	24	4.405E+18	2.154E+16	2.7000	7.801E+09	1.155E+04
	25	1.527E+19	2.527E+16	3.0000	3.183E+10	4.552E+04
0	TOTAL	1.072E+21	1.208E+20		1.957E+11	3.319E+05

GAMMA ATTENUATION CALCULATION										1800 CANISTER LOCATIONS, TOP - MODEL B1800 -										1 FOOT																			
SOURCE										SHIELDS										DIST TO DETECTOR 2.505E+02 CM.																			
SLAB										SLAB										VOL.=1.991E+08 CC																			
THICKNESS = 6.533E+01 CM										HEIGHT = 1.905E+03 CM										WIDTH =1.600E+03 CM																			
INTEGRATION SPECS NTHETA = 45										NPSI = 23										DELR = 4.0000E-01										NTHETA X NPSI X T(1) / DELR = 1.6904E+05									
1800 CANISTER IRRADIATION																																							
REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.443E+01 YRS AFTER SHUTDOWN																																							
TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED																																							

0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	3.048E+01	
0	GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX	DOSE RATE	
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT	AT DOSE POINT	
		PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR	
	1	6.754E+15	6.725E+15	0.0150	0.000E+00	0.000E+00	
	2	3.923E+15	3.786E+15	0.0250	0.000E+00	0.000E+00	
	3	1.104E+16	2.262E+15	0.0350	0.000E+00	0.000E+00	
	4	1.539E+15	1.532E+15	0.0450	2.137E-19	7.009E-25	
	5	1.102E+15	1.102E+15	0.0550	7.798E-10	1.786E-15	
	6	9.277E+14	9.258E+14	0.0650	2.503E-05	4.733E-11	
	7	8.281E+14	8.281E+14	0.0750	9.804E-03	1.680E-08	
	8	7.484E+14	7.377E+14	0.0850	1.100E+00	1.779E-06	
	9	6.575E+14	6.568E+14	0.0950	1.347E+01	2.160E-05	
	10	3.557E+15	2.960E+15	0.1500	4.666E+02	8.063E-04	
	11	1.072E+15	9.663E+14	0.2500	1.456E+03	2.854E-03	
	12	4.774E+14	4.695E+14	0.3500	3.023E+03	6.227E-03	
	13	6.270E+14	3.502E+14	0.4750	1.391E+04	2.838E-02	
	14	1.965E+17	2.077E+14	0.6500	1.309E+07	2.724E+01	
	15	8.996E+14	7.676E+13	0.8250	1.013E+05	2.026E-01	
	16	5.102E+14	5.171E+13	1.0000	8.879E+04	1.714E-01	
	17	6.003E+14	2.633E+13	1.2250	1.808E+05	3.326E-01	
	18	4.102E+13	8.635E+12	1.4750	2.502E+04	4.403E-02	
	19	3.522E+13	1.978E+12	1.7000	2.618E+04	4.477E-02	
	20	4.352E+11	4.195E+11	1.9000	4.188E+02	6.952E-04	
	21	1.865E+11	2.875E+10	2.1000	2.171E+02	3.474E-04	
	22	1.041E+10	2.580E+09	2.3000	1.409E+01	2.170E-05	
	23	1.693E+10	1.269E+09	2.5000	2.642E+01	4.016E-05	
	24	8.387E+09	5.548E+08	2.7000	1.486E+01	2.199E-05	
	25	2.312E+08	2.312E+08	3.0000	4.819E-01	6.891E-07	
0	TOTAL	2.318E+17	2.367E+16		1.354E+07	2.807E+01	

1
0
GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS; TOP - MODEL B1800 - 1 FOOT
0 SOURCE SHIELDS DIST TO DETECTOR 2.505E+02 CM.
+ SLAB SLAB
0 THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM VOL.=1.991E+08 CC
0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05
0 1800 CANISTER IRRADIATION
0 REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.715E+01 YRS AFTER SHUTDOWN
0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED

0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	3.048E+01	
0	GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX	DOSE RATE	
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT	AT DOSE POINT	
		PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR	
	1	6.301E+15	6.274E+15	0.0150	0.000E+00	0.000E+00	
	2	3.630E+15	3.535E+15	0.0250	0.000E+00	0.000E+00	
	3	1.035E+16	2.111E+15	0.0350	0.000E+00	0.000E+00	
	4	1.433E+15	1.431E+15	0.0450	1.990E-19	6.529E-25	
	5	1.030E+15	1.030E+15	0.0550	7.285E-10	1.668E-15	
	6	8.668E+14	8.652E+14	0.0650	2.339E-05	4.423E-11	
	7	7.742E+14	7.742E+14	0.0750	9.166E-03	1.571E-08	
	8	6.935E+14	6.898E+14	0.0850	1.019E+00	1.648E-06	
	9	6.150E+14	6.143E+14	0.0950	1.260E+01	2.020E-05	
	10	3.282E+15	2.769E+15	0.1500	4.306E+02	7.440E-04	
	11	9.968E+14	9.039E+14	0.2500	1.354E+03	2.654E-03	
	12	4.433E+14	4.392E+14	0.3500	2.807E+03	5.783E-03	
	13	4.870E+14	3.277E+14	0.4750	1.080E+04	2.204E-02	
	14	1.840E+17	1.943E+14	0.6500	1.226E+07	2.551E+01	
	15	5.219E+14	7.180E+13	0.8250	5.876E+04	1.175E-01	
	16	4.522E+14	4.835E+13	1.0000	7.871E+04	1.519E-01	
	17	5.285E+14	2.460E+13	1.2250	1.592E+05	2.929E-01	
	18	2.637E+13	8.060E+12	1.4750	1.608E+04	2.830E-02	
	19	3.174E+13	1.841E+12	1.7000	2.359E+04	4.034E-02	
	20	3.884E+11	3.861E+11	1.9000	3.738E+02	6.206E-04	
	21	3.809E+10	2.310E+10	2.1000	4.435E+01	7.097E-05	

22	1.565E+09	3.816E+08	2.3000	2.118E+00	3.262E-06
23	2.556E+09	1.893E+08	2.5000	3.988E+00	6.062E-06
24	1.267E+09	8.337E+07	2.7000	2.244E+00	3.321E-06
25	3.493E+07	3.493E+07	3.0000	7.281E-02	1.041E-07
0 TOTAL	2.164E+17	2.211E+16		1.261E+07	2.617E+01
0					
0	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 1 FOOT				
0	SOURCE SHIELDS DIST TO DETECTOR 2.505E+02 CM.				
+	SLAB	SLAB	VOL.=1.991E+08 CC		
0	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH =1.600E+03 CM		
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.264E+01 YRS AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS,CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00 3.048E+01
0	GROUP	TOTAL GROUP	GROUP	GROUP	DOSE RATE
	PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	ENERGY FLUX	AT DOSE POINT
	PHOTONS	PHOTONS	MEV	AT DOSE POINT	ROENTGENS/HOUR
				MEV/CMS/SEC	
1	5.504E+15	5.479E+15	0.0150	0.000E+00	0.000E+00
2	3.149E+15	3.089E+15	0.0250	0.000E+00	0.000E+00
3	9.097E+15	1.845E+15	0.0350	0.000E+00	0.000E+00
4	1.251E+15	1.251E+15	0.0450	1.737E-19	5.699E-25
5	9.005E+14	9.005E+14	0.0550	6.371E-10	1.459E-15
6	7.582E+14	7.568E+14	0.0650	2.046E-05	3.869E-11
7	6.774E+14	6.774E+14	0.0750	8.020E-03	1.375E-08
8	6.043E+14	6.038E+14	0.0850	8.881E-01	1.436E-06
9	5.384E+14	5.377E+14	0.0950	1.103E+01	1.768E-05
10	2.820E+15	2.424E+15	0.1500	3.699E+02	6.391E-04
11	8.641E+14	7.916E+14	0.2500	1.174E+03	2.301E-03
12	3.860E+14	3.847E+14	0.3500	2.444E+03	5.035E-03
13	3.548E+14	2.871E+14	0.4750	7.872E+03	1.606E-02
14	1.618E+17	1.702E+14	0.6500	1.078E+07	2.243E+01
15	2.697E+14	6.290E+13	0.8250	3.036E+04	6.072E-02
16	3.591E+14	4.236E+13	1.0000	6.250E+04	1.206E-01
17	4.157E+14	2.155E+13	1.2250	1.252E+05	2.304E-01
18	1.600E+13	7.059E+12	1.4750	9.756E+03	1.717E-02
19	2.581E+13	1.611E+12	1.7000	1.919E+04	3.281E-02
20	3.373E+11	3.373E+11	1.9000	3.246E+02	5.389E-04
21	1.978E+10	1.963E+10	2.1000	2.304E+01	3.686E-05
22	3.478E+07	8.348E+06	2.3000	4.707E-02	7.249E-08
23	5.704E+07	4.177E+06	2.5000	8.899E-02	1.353E-07
24	2.828E+07	1.852E+06	2.7000	5.009E-02	7.414E-08
25	7.802E+05	7.802E+05	3.0000	1.626E-03	2.325E-09
0 TOTAL	1.898E+17	1.933E+16		1.104E+07	2.291E+01
1					
0					

GAMMA ATTENUATION CALCULATION		1800 CANISTER LOCATIONS, TOP - MODEL B1800 -		1 FOOT	
0	SOURCE	SHIELDS DIST TO DETECTOR 2.505E+02 CM.			
0	SLAB	SLAB	VOL.=1.991E+08 CC		
+	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH =1.600E+03 CM		
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.813E+01 YRS AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS,CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00 3.048E+01
0	GROUP	TOTAL GROUP	GROUP	GROUP	DOSE RATE
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT
		PHOTONS	PHOTONS	MEV	ROENTGENS/HOUR
	1	4.817E+15	4.795E+15	0.0150	0.000E+00
	2	2.750E+15	2.704E+15	0.0250	0.000E+00
	3	8.003E+15	1.614E+15	0.0350	0.000E+00
	4	1.095E+15	1.094E+15	0.0450	1.520E-19 4.986E-25
	5	7.883E+14	7.883E+14	0.0550	5.578E-10 1.277E-15
	6	6.639E+14	6.625E+14	0.0650	1.791E-05 3.388E-11
	7	5.932E+14	5.932E+14	0.0750	7.022E-03 1.204E-08
	8	5.288E+14	5.288E+14	0.0850	7.772E-01 1.257E-06

9	4.716E+14	4.709E+14	0.0950	9.663E+00	1.549E-05
10	2.433E+15	2.123E+15	0.1500	3.192E+02	5.515E-04
11	7.505E+14	6.935E+14	0.2500	1.019E+03	1.998E-03
12	3.376E+14	3.371E+14	0.3500	2.138E+03	4.404E-03
13	2.895E+14	2.516E+14	0.4750	6.423E+03	1.310E-02
14	1.425E+17	1.492E+14	0.6500	9.494E+06	1.975E+01
15	1.939E+14	5.512E+13	0.8250	2.183E+04	4.366E-02
16	2.866E+14	3.712E+13	1.0000	4.988E+04	9.627E-02
17	3.292E+14	1.889E+13	1.2250	9.913E+04	1.824E-01
18	1.232E+13	6.186E+12	1.4750	7.516E+03	1.323E-02
19	2.105E+13	1.412E+12	1.7000	1.565E+04	2.675E-02
20	2.955E+11	2.955E+11	1.9000	2.844E+02	4.721E-04
21	1.719E+10	1.719E+10	2.1000	2.002E+01	3.203E-05
22	7.754E+05	1.851E+05	2.3000	1.050E-03	1.616E-09
23	1.274E+06	9.288E+04	2.5000	1.987E-03	3.020E-09
24	6.316E+05	4.130E+04	2.7000	1.119E-03	1.656E-09
25	1.743E+04	1.743E+04	3.0000	3.632E-05	5.193E-11
0 TOTAL	1.668E+17	1.692E+16		9.699E+06	2.013E+01
1					
0	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 2 FEET				
0	SOURCE SHIELDS DIST TO DETECTOR 2.810E+02 CM.				
+	SLAB	SLAB	VOL.=1.991E+08 CC		
0	THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM				
0	INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05				
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 0.000E+00 SEC AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS, CM. 6.533E+01 4.826E-01 5.588E-01 1.270E+00 6.096E+01				
0	GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT
		PHOTONS	PHOTONS	MEV	MEV/CMS/SEC
					DOSE RATE
					AT DOSE POINT
					ROENTGENS/HOUR
1	4.033E+19	2.818E+19	0.0150	0.000E+00	0.000E+00
2	3.155E+19	1.602E+19	0.0250	0.000E+00	0.000E+00
3	3.786E+19	1.050E+19	0.0350	0.000E+00	0.000E+00
4	1.175E+19	7.652E+18	0.0450	1.458E-18	4.782E-24
5	9.453E+18	5.915E+18	0.0550	1.162E-08	2.661E-14
6	6.010E+18	4.773E+18	0.0650	3.961E-04	7.491E-10
7	9.239E+18	3.999E+18	0.0750	3.218E-01	5.516E-07
8	1.374E+19	3.446E+18	0.0850	3.210E+01	5.190E-05
9	5.119E+18	3.044E+18	0.0950	1.716E+02	2.750E-04
10	8.803E+19	1.794E+19	0.1500	1.765E+05	3.050E-01
11	8.427E+19	7.496E+18	0.2500	3.218E+06	6.308E+00
12	7.169E+19	3.811E+18	0.3500	1.902E+07	3.918E+01
13	1.288E+20	3.048E+18	0.4750	1.648E+08	3.361E+02
14	1.656E+20	2.050E+18	0.6500	1.017E+09	2.115E+03
15	1.150E+20	8.891E+17	0.8250	1.370E+09	2.740E+03
16	5.567E+19	7.269E+17	1.0000	1.197E+09	2.310E+03
17	6.084E+19	5.269E+17	1.2250	2.669E+09	4.911E+03
18	6.151E+19	2.972E+17	1.4750	7.772E+09	1.368E+04
19	1.270E+19	1.469E+17	1.7000	1.777E+09	3.039E+03
20	1.104E+19	9.763E+16	1.9000	2.180E+09	3.619E+03
21	1.319E+19	6.607E+16	2.1000	3.363E+09	5.381E+03
22	6.050E+18	4.491E+16	2.3000	1.905E+09	2.934E+03
23	1.249E+19	3.097E+16	2.5000	4.805E+09	7.304E+03
24	4.405E+18	2.154E+16	2.7000	2.020E+09	2.989E+03
25	1.527E+19	2.527E+16	3.0000	8.778E+09	1.255E+04
0 TOTAL	1.072E+21	1.208E+20		3.904E+10	6.396E+04
1					
0	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 2 FEET				
0	SOURCE SHIELDS DIST TO DETECTOR 2.810E+02 CM.				
+	SLAB	SLAB	VOL.=1.991E+08 CC		
0	THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM				
0	INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05				
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.443E+01 YRS AFTER SHUTDOWN				

WHC-SD-NR-ER-105 Rev. 0

0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED

0	GROUP	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	6.096E+01	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
0	GROUP	TOTAL GROUP PRODUCTION RATE PHOTONS	GROUP BREMSSTRAHLUNG PHOTONS	GROUP AVERAGE ENERGY MEV	GROUP ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR		
1		6.754E+15	6.725E+15	0.0150	0.000E+00	0.000E+00		
2		3.923E+15	3.786E+15	0.0250	0.000E+00	0.000E+00		
3		1.104E+16	2.262E+15	0.0350	0.000E+00	0.000E+00		
4		1.539E+15	1.532E+15	0.0450	1.909E-22	6.261E-28		
5		1.102E+15	1.102E+15	0.0550	1.355E-12	3.102E-18		
6		9.277E+14	9.258E+14	0.0650	6.114E-08	1.156E-13		
7		8.281E+14	8.281E+14	0.0750	2.884E-05	4.944E-11		
8		7.484E+14	7.377E+14	0.0850	1.748E-03	2.827E-09		
9		6.575E+14	6.568E+14	0.0950	2.204E-02	3.533E-08		
10		3.557E+15	2.960E+15	0.1500	7.133E+00	1.233E-05		
11		1.072E+15	9.663E+14	0.2500	4.094E+01	8.025E-05		
12		4.774E+14	4.695E+14	0.3500	1.266E+02	2.609E-04		
13		6.270E+14	3.502E+14	0.4750	8.019E+02	1.636E-03		
14		1.965E+17	2.077E+14	0.6500	1.207E+06	2.510E+00		
15		8.996E+14	7.676E+13	0.8250	1.072E+04	2.144E-02		
16		5.102E+14	5.171E+13	1.0000	1.097E+04	2.117E-02		
17		6.003E+14	2.633E+13	1.2250	2.633E+04	4.845E-02		
18		4.102E+13	8.635E+12	1.4750	5.184E+03	9.124E-03		
19		3.522E+13	1.978E+12	1.7000	4.930E+03	8.430E-03		
20		4.352E+11	4.195E+11	1.9000	8.592E+01	1.426E-04		
21		1.865E+11	2.875E+10	2.1000	4.755E+01	7.608E-05		
22		1.041E+10	2.580E+09	2.3000	3.279E+00	5.050E-06		
23		1.693E+10	1.269E+09	2.5000	6.514E+00	9.901E-06		
24		8.387E+09	5.548E+08	2.7000	3.846E+00	5.691E-06		
25		2.312E+08	2.312E+08	3.0000	1.329E-01	1.900E-07		
0	TOTAL	2.318E+17	2.367E+16		1.266E+06	2.621E+00		

GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 2 FEET
SOURCE SHIELDS DIST TO DETECTOR 2.810E+02 CM.

+ SLAB SLAB THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM VOL.=1.991E+08 CC
0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05

0 1800 CANISTER IRRADIATION REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.715E+01 YRS AFTER SHUTDOWN

0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED

0	GROUP	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	6.096E+01	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
0	GROUP	TOTAL GROUP PRODUCTION RATE PHOTONS	GROUP BREMSSTRAHLUNG PHOTONS	GROUP AVERAGE ENERGY MEV	GROUP ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR		
1		6.301E+15	6.274E+15	0.0150	0.000E+00	0.000E+00		
2		3.630E+15	3.535E+15	0.0250	0.000E+00	0.000E+00		
3		1.035E+16	2.111E+15	0.0350	0.000E+00	0.000E+00		
4		1.433E+15	1.431E+15	0.0450	1.778E-22	5.832E-28		
5		1.030E+15	1.030E+15	0.0550	1.265E-12	2.898E-18		
6		8.668E+14	8.652E+14	0.0650	5.713E-08	1.080E-13		
7		7.742E+14	7.742E+14	0.0750	2.697E-05	4.622E-11		
8		6.935E+14	6.898E+14	0.0850	1.620E-03	2.619E-09		
9		6.150E+14	6.143E+14	0.0950	2.061E-02	3.304E-08		
10		3.282E+15	2.769E+15	0.1500	6.582E+00	1.137E-05		
11		9.968E+14	9.039E+14	0.2500	3.807E+01	7.461E-05		
12		4.433E+14	4.392E+14	0.3500	1.176E+02	2.423E-04		
13		4.870E+14	3.277E+14	0.4750	6.228E+02	1.271E-03		
14		1.840E+17	1.943E+14	0.6500	1.130E+06	2.350E+00		
15		5.219E+14	7.180E+13	0.8250	6.219E+03	1.244E-02		
16		4.522E+14	4.835E+13	1.0000	9.721E+03	1.876E-02		
17		5.285E+14	2.460E+13	1.2250	2.319E+04	4.266E-02		
18		2.637E+13	8.060E+12	1.4750	3.332E+03	5.864E-03		
19		3.174E+13	1.841E+12	1.7000	4.442E+03	7.596E-03		
20		3.884E+11	3.861E+11	1.9000	7.669E+01	1.273E-04		

WHC-SD-NR-ER-105 Rev. 0

21	3.809E+10	2.310E+10	2.1000	9.714E+00	1.554E-05
22	1.565E+09	3.816E+08	2.3000	4.928E-01	7.589E-07
23	2.556E+09	1.893E+08	2.5000	9.833E-01	1.495E-06
24	1.267E+09	8.337E+07	2.7000	5.808E-01	8.596E-07
25	3.493E+07	3.493E+07	3.0000	2.008E-02	2.871E-08
0 TOTAL	2.164E+17	2.211E+16		1.178E+06	2.439E+00
1					
0					
0	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 2 FEET				
0	SOURCE SHIELDS DIST TO DETECTOR 2.810E+02 CM.				
+	SLAB	SLAB	VOL.=1.991E+08 CC		
0	THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH =1.600E+03 CM				
0	INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05				
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.264E+01 YRS AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS, CM. 6.533E+01 4.826E-01 5.588E-01 1.270E+00 6.096E+01				
0	GROUP	TOTAL GROUP PRODUCTION RATE PHOTONS	GROUP BREMSSTRAHLUNG PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC
					DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	5.504E+15	5.479E+15	0.0150	0.000E+00	0.000E+00
2	3.149E+15	3.089E+15	0.0250	0.000E+00	0.000E+00
3	9.097E+15	1.845E+15	0.0350	0.000E+00	0.000E+00
4	1.251E+15	1.251E+15	0.0450	1.552E-22	5.090E-28
5	9.005E+14	9.005E+14	0.0550	1.107E-12	2.534E-18
6	7.582E+14	7.568E+14	0.0650	4.997E-08	9.450E-14
7	6.774E+14	6.774E+14	0.0750	2.360E-05	4.045E-11
8	6.043E+14	6.038E+14	0.0850	1.411E-03	2.282E-09
9	5.384E+14	5.377E+14	0.0950	1.805E-02	2.893E-08
10	2.820E+15	2.424E+15	0.1500	5.654E+00	9.771E-06
11	8.641E+14	7.916E+14	0.2500	3.300E+01	6.468E-05
12	3.860E+14	3.847E+14	0.3500	1.024E+02	2.109E-04
13	3.548E+14	2.871E+14	0.4750	4.538E+02	9.257E-04
14	1.618E+17	1.702E+14	0.6500	9.937E+05	2.067E+00
15	2.697E+14	6.290E+13	0.8250	3.213E+03	6.426E-03
16	3.591E+14	4.236E+13	1.0000	7.719E+03	1.490E-02
17	4.157E+14	2.155E+13	1.2250	1.824E+04	3.356E-02
18	1.600E+13	7.059E+12	1.4750	2.021E+03	3.558E-03
19	2.581E+13	1.611E+12	1.7000	3.613E+03	6.178E-03
20	3.373E+11	3.373E+11	1.9000	6.659E+01	1.105E-04
21	1.978E+10	1.963E+10	2.1000	5.045E+00	8.072E-06
22	3.478E+07	8.348E+06	2.3000	1.095E-02	1.687E-08
23	5.704E+07	4.177E+06	2.5000	2.194E-02	3.335E-08
24	2.828E+07	1.852E+06	2.7000	1.297E-02	1.919E-08
25	7.802E+05	7.802E+05	3.0000	4.484E-04	6.412E-10
0 TOTAL	1.898E+17	1.933E+16		1.029E+06	2.133E+00
1					
0					

GAMMA ATTENUATION CALCULATION		1800 CANISTER LOCATIONS, TOP - MODEL B1800 -		2 FEET	
0	SOURCE	SHIELDS DIST TO DETECTOR 2.810E+02 CM.			
+	SLAB	SLAB	VOL.=1.991E+08 CC		
0	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH =1.600E+03 CM		
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.813E+01 YRS AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS,CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00 6.096E+01
0	GROUP	TOTAL GROUP	GROUP	GROUP	DOSE RATE
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT
		PHOTONS	PHOTONS	MEV	ROENTGENS/HOUR
	1	4.817E+15	4.795E+15	0.0150	0.000E+00
	2	2.750E+15	2.704E+15	0.0250	0.000E+00
	3	8.003E+15	1.614E+15	0.0350	0.000E+00
	4	1.095E+15	1.094E+15	0.0450	4.454E-28
	5	7.883E+14	7.883E+14	0.0550	2.219E-18
	6	6.639E+14	6.625E+14	0.0650	8.275E-14
	7	5.932E+14	5.932E+14	0.0750	3.541E-11
	8	5.288E+14	5.288E+14	0.0850	1.997E-09

WHC-SD-NR-ER-105 Rev. 0

9	4.716E+14	4.709E+14	0.0950	1.581E-02	2.534E-08
10	2.433E+15	2.123E+15	0.1500	4.879E+00	8.431E-06
11	7.505E+14	6.935E+14	0.2500	2.866E+01	5.617E-05
12	3.376E+14	3.371E+14	0.3500	8.956E+01	1.845E-04
13	2.895E+14	2.516E+14	0.4750	3.703E+02	7.554E-04
14	1.425E+17	1.492E+14	0.6500	8.749E+05	1.820E+00
15	1.939E+14	5.512E+13	0.8250	2.311E+03	4.621E-03
16	2.866E+14	3.712E+13	1.0000	6.161E+03	1.189E-02
17	3.292E+14	1.889E+13	1.2250	1.444E+04	2.657E-02
18	1.232E+13	6.186E+12	1.4750	1.557E+03	2.741E-03
19	2.105E+13	1.412E+12	1.7000	2.946E+03	5.038E-03
20	2.955E+11	2.955E+11	1.9000	5.834E+01	9.685E-05
21	1.719E+10	1.719E+10	2.1000	4.385E+00	7.016E-06
22	7.754E+05	1.851E+05	2.3000	2.442E-04	3.760E-10
23	1.274E+06	9.288E+04	2.5000	4.899E-04	7.446E-10
24	6.316E+05	4.130E+04	2.7000	2.896E-04	4.286E-10
25	1.743E+04	1.743E+04	3.0000	1.001E-05	1.432E-11
0 TOTAL	1.668E+17	1.692E+16		9.029E+05	1.872E+00

0 GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 3 FEET
 0 SOURCE SHIELDS DIST TO DETECTOR 3.115E+02 CM.
 + SLAB SLAB THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM VOL.=1.991E+08 CC
 0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05
 0 1800 CANISTER IRRADIATION
 0 REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 0.000E+00 SEC AFTER SHUTDOWN
 0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED
 0 SHIELD THICKNESS, CM. 6.533E+01 4.826E-01 5.588E-01 1.270E+00 9.144E+01

0 GROUP	TOTAL GROUP PRODUCTION RATE PHOTONS	GROUP BREMSSTRAHLUNG PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.033E+19	2.818E+19	0.0150	0.000E+00	0.000E+00
2	3.155E+19	1.602E+19	0.0250	0.000E+00	0.000E+00
3	3.786E+19	1.050E+19	0.0350	0.000E+00	0.000E+00
4	1.175E+19	7.652E+18	0.0450	1.298E-21	4.258E-27
5	9.453E+18	5.915E+18	0.0550	2.045E-11	4.682E-17
6	6.010E+18	4.773E+18	0.0650	9.974E-07	1.886E-12
7	9.239E+18	3.999E+18	0.0750	1.008E-03	1.728E-09
8	1.374E+19	3.446E+18	0.0850	1.350E-01	2.184E-07
9	5.119E+18	3.044E+18	0.0950	2.517E-01	4.034E-07
10	8.803E+19	1.794E+19	0.1500	2.792E+03	4.825E-03
11	8.427E+19	7.496E+18	0.2500	9.322E+04	1.827E-01
12	7.169E+19	3.811E+18	0.3500	8.182E+05	1.685E+00
13	1.288E+20	3.048E+18	0.4750	9.719E+06	1.983E+01
14	1.656E+20	2.050E+18	0.6500	9.563E+07	1.989E+02
15	1.150E+20	8.891E+17	0.8250	1.485E+08	2.969E+02
16	5.567E+19	7.269E+17	1.0000	1.519E+08	2.933E+02
17	6.084E+19	5.269E+17	1.2250	4.008E+08	7.374E+02
18	6.151E+19	2.972E+17	1.4750	1.660E+09	2.921E+03
19	1.270E+19	1.469E+17	1.7000	3.450E+08	5.899E+02
20	1.104E+19	9.763E+16	1.9000	4.613E+08	7.657E+02
21	1.319E+19	6.607E+16	2.1000	7.603E+08	1.217E+03
22	6.050E+18	4.491E+16	2.3000	4.580E+08	7.052E+02
23	1.249E+19	3.097E+16	2.5000	1.224E+09	1.861E+03
24	4.405E+18	2.154E+16	2.7000	5.405E+08	8.000E+02
25	1.527E+19	2.527E+16	3.0000	2.504E+09	3.581E+03
0 TOTAL	1.072E+21	1.208E+20		8.760E+09	1.399E+04

0 GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 3 FEET
 0 SOURCE SHIELDS DIST TO DETECTOR 3.115E+02 CM.
 + SLAB SLAB THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM VOL.=1.991E+08 CC
 0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05
 0 1800 CANISTER IRRADIATION
 0 REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.443E+01 YRS AFTER SHUTDOWN

0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED

0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	9.144E+01
0	GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX	DOSE RATE
0		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT	AT DOSE POINT
		PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR
1		6.754E+15	6.725E+15	0.0150	0.000E+00	0.000E+00
2		3.923E+15	3.786E+15	0.0250	0.000E+00	0.000E+00
3		1.104E+16	2.262E+15	0.0350	0.000E+00	0.000E+00
4		1.539E+15	1.532E+15	0.0450	1.700E-25	5.575E-31
5		1.102E+15	1.102E+15	0.0550	2.384E-15	5.459E-21
6		9.277E+14	9.258E+14	0.0650	1.539E-10	2.911E-16
7		8.281E+14	8.281E+14	0.0750	9.036E-08	1.549E-13
8		7.484E+14	7.377E+14	0.0850	7.354E-06	1.189E-11
9		6.575E+14	6.568E+14	0.0950	3.233E-05	5.182E-11
10		3.557E+15	2.960E+15	0.1500	1.128E-01	1.950E-07
11		1.072E+15	9.663E+14	0.2500	1.186E+00	2.324E-06
12		4.774E+14	4.695E+14	0.3500	5.448E+00	1.122E-05
13		6.270E+14	3.502E+14	0.4750	4.730E+01	9.650E-05
14		1.965E+17	2.077E+14	0.6500	1.135E+05	2.361E-01
15		8.996E+14	7.676E+13	0.8250	1.162E+03	2.323E-03
16		5.102E+14	5.171E+13	1.0000	1.392E+03	2.687E-03
17		6.003E+14	2.633E+13	1.2250	3.954E+03	7.276E-03
18		4.102E+13	8.635E+12	1.4750	1.107E+03	1.948E-03
19		3.522E+13	1.978E+12	1.7000	9.568E+02	1.636E-03
20		4.352E+11	4.195E+11	1.9000	1.818E+01	3.018E-05
21		1.865E+11	2.875E+10	2.1000	1.075E+01	1.720E-05
22		1.041E+10	2.580E+09	2.3000	7.882E-01	1.214E-06
23		1.693E+10	1.269E+09	2.5000	1.660E+00	2.523E-06
24		8.387E+09	5.548E+08	2.7000	1.029E+00	1.523E-06
25		2.312E+08	2.312E+08	3.0000	3.791E-02	5.421E-08
0	TOTAL	2.318E+17	2.367E+16		1.221E+05	2.521E-01

1

0

GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 3 FEET
SOURCE SHIELDS DIST TO DETECTOR 3.115E+02 CM.

+ SLAB SLAB THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM VOL.=1.991E+08 CC
0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05

0 1800 CANISTER IRRADIATION

REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.715E+01 YRS AFTER SHUTDOWN
0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED

0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	9.144E+01
0	GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX	DOSE RATE
0		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT	AT DOSE POINT
		PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR
1		6.301E+15	6.274E+15	0.0150	0.000E+00	0.000E+00
2		3.630E+15	3.535E+15	0.0250	0.000E+00	0.000E+00
3		1.035E+16	2.111E+15	0.0350	0.000E+00	0.000E+00
4		1.433E+15	1.431E+15	0.0450	1.583E-25	5.193E-31
5		1.030E+15	1.030E+15	0.0550	2.227E-15	5.100E-21
6		8.668E+14	8.652E+14	0.0650	1.438E-10	2.720E-16
7		7.742E+14	7.742E+14	0.0750	8.448E-08	1.448E-13
8		6.935E+14	6.898E+14	0.0850	6.814E-06	1.102E-11
9		6.150E+14	6.143E+14	0.0950	3.024E-05	4.847E-11
10		3.282E+15	2.769E+15	0.1500	1.041E-01	1.799E-07
11		9.968E+14	9.039E+14	0.2500	1.103E+00	2.161E-06
12		4.433E+14	4.392E+14	0.3500	5.060E+00	1.042E-05
13		4.870E+14	3.277E+14	0.4750	3.674E+01	7.495E-05
14		1.840E+17	1.943E+14	0.6500	1.063E+05	2.211E-01
15		5.219E+14	7.180E+13	0.8250	6.738E+02	1.348E-03
16		4.522E+14	4.835E+13	1.0000	1.234E+03	2.382E-03
17		5.285E+14	2.460E+13	1.2250	3.481E+03	6.406E-03
18		2.637E+13	8.060E+12	1.4750	7.114E+02	1.252E-03
19		3.174E+13	1.841E+12	1.7000	8.622E+02	1.474E-03
20		3.884E+11	3.861E+11	1.9000	1.623E+01	2.694E-05

WHC-SD-NR-ER-105 Rev. 0

21	3.809E+10	2.310E+10	2.1000	2.196E+00	3.514E-06
22	1.565E+09	3.816E+08	2.3000	1.185E-01	1.824E-07
23	2.556E+09	1.893E+08	2.5000	2.505E-01	3.808E-07
24	1.267E+09	8.337E+07	2.7000	1.555E-01	2.301E-07
25	3.493E+07	3.493E+07	3.0000	5.728E-03	8.190E-09
0 TOTAL	2.164E+17	2.211E+16		1.133E+05	2.340E-01
1					
0					
0	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 3 FEET				
0	SOURCE SHIELDS DIST TO DETECTOR 3.115E+02 CM.				
0					
0	SLAB	SLAB			VOL.=1.991E+08 CC
0	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH = 1.600E+03 CM		
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.264E+01 YRS AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS, CM. 6.533E+01 4.826E-01 5.588E-01 1.270E+00 9.144E+01				
0	GROUP	TOTAL GROUP	GROUP	GROUP	DOSE RATE
		PRODUCTION RATE	BREMSSTRAHLUNG	ENERGY FLUX	AT DOSE POINT
		PHOTONS	PHOTONS	AT DOSE POINT	ROENTGENS/HOUR
			AVERAGE ENERGY	MEV/CMS/SEC	
			MEV		
1	5.504E+15	5.479E+15	0.0150	0.000E+00	0.000E+00
2	3.149E+15	3.089E+15	0.0250	0.000E+00	0.000E+00
3	9.097E+15	1.845E+15	0.0350	0.000E+00	0.000E+00
4	1.251E+15	1.251E+15	0.0450	1.382E-25	4.533E-31
5	9.005E+14	9.005E+14	0.0550	1.948E-15	4.460E-21
6	7.582E+14	7.568E+14	0.0650	1.258E-10	2.379E-16
7	6.774E+14	6.774E+14	0.0750	7.392E-08	1.267E-13
8	6.043E+14	6.038E+14	0.0850	5.937E-06	9.600E-12
9	5.384E+14	5.377E+14	0.0950	2.647E-05	4.244E-11
10	2.820E+15	2.424E+15	0.1500	8.944E-02	1.546E-07
11	8.641E+14	7.916E+14	0.2500	9.559E-01	1.874E-06
12	3.860E+14	3.847E+14	0.3500	4.405E+00	9.074E-06
13	3.548E+14	2.871E+14	0.4750	2.677E+01	5.460E-05
14	1.618E+17	1.702E+14	0.6500	9.345E+04	1.944E-01
15	2.697E+14	6.290E+13	0.8250	3.482E+02	6.964E-04
16	3.591E+14	4.236E+13	1.0000	9.800E+02	1.891E-03
17	4.157E+14	2.155E+13	1.2250	2.738E+03	5.039E-03
18	1.600E+13	7.059E+12	1.4750	4.317E+02	7.597E-04
19	2.581E+13	1.611E+12	1.7000	7.013E+02	1.199E-03
20	3.373E+11	3.373E+11	1.9000	1.409E+01	2.339E-05
21	1.978E+10	1.963E+10	2.1000	1.141E+00	1.825E-06
22	3.478E+07	8.348E+06	2.3000	2.633E-03	4.054E-09
23	5.704E+07	4.177E+06	2.5000	5.590E-03	8.496E-09
24	2.828E+07	1.852E+06	2.7000	3.471E-03	5.137E-09
25	7.802E+05	7.802E+05	3.0000	1.279E-04	1.829E-10
0 TOTAL	1.898E+17	1.933E+16		9.870E+04	2.041E-01
1					
0					
0	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 3 FEET				
0	SOURCE SHIELDS DIST TO DETECTOR 3.115E+02 CM.				
0					
0	SLAB	SLAB			VOL.=1.991E+08 CC
0	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH = 1.600E+03 CM		
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.813E+01 YRS AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS, CM. 6.533E+01 4.826E-01 5.588E-01 1.270E+00 9.144E+01				
0	GROUP	TOTAL GROUP	GROUP	GROUP	DOSE RATE
		PRODUCTION RATE	BREMSSTRAHLUNG	ENERGY FLUX	AT DOSE POINT
		PHOTONS	PHOTONS	AT DOSE POINT	ROENTGENS/HOUR
			AVERAGE ENERGY	MEV/CMS/SEC	
			MEV		
1	4.817E+15	4.795E+15	0.0150	0.000E+00	0.000E+00
2	2.750E+15	2.704E+15	0.0250	0.000E+00	0.000E+00
3	8.003E+15	1.614E+15	0.0350	0.000E+00	0.000E+00
4	1.095E+15	1.094E+15	0.0450	1.209E-25	3.966E-31
5	7.883E+14	7.883E+14	0.0550	1.705E-15	3.905E-21
6	6.639E+14	6.625E+14	0.0650	1.102E-10	2.083E-16
7	5.932E+14	5.932E+14	0.0750	6.472E-08	1.109E-13
8	5.288E+14	5.288E+14	0.0850	5.196E-06	8.402E-12

9	4.716E+14	4.709E+14	0.0950	2.319E-05	3.717E-11
10	2.433E+15	2.123E+15	0.1500	7.718E-02	1.334E-07
11	7.505E+14	6.935E+14	0.2500	8.302E-01	1.627E-06
12	3.376E+14	3.371E+14	0.3500	3.853E+00	7.936E-06
13	2.895E+14	2.516E+14	0.4750	2.184E+01	4.456E-05
14	1.425E+17	1.492E+14	0.6500	8.229E+04	1.712E-01
15	1.939E+14	5.512E+13	0.8250	2.504E+02	5.008E-04
16	2.866E+14	3.712E+13	1.0000	7.821E+02	1.510E-03
17	3.292E+14	1.889E+13	1.2250	2.168E+03	3.990E-03
18	1.232E+13	6.186E+12	1.4750	3.325E+02	5.853E-04
19	2.105E+13	1.412E+12	1.7000	5.718E+02	9.778E-04
20	2.955E+11	2.955E+11	1.9000	1.235E+01	2.049E-05
21	1.719E+10	1.719E+10	2.1000	9.913E-01	1.586E-06
22	7.754E+05	1.851E+05	2.3000	5.869E-05	9.039E-11
23	1.274E+06	9.288E+04	2.5000	1.248E-04	1.897E-10
24	6.316E+05	4.130E+04	2.7000	7.751E-05	1.147E-10
25	1.743E+04	1.743E+04	3.0000	2.857E-06	4.085E-12
0 TOTAL	1.668E+17	1.692E+16		8.643E+04	1.788E-01

1	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 4 FEET				
0	SOURCE SHIELDS DIST TO DETECTOR 3.420E+02 CM.				
+	SLAB	SLAB	VOL.=1.991E+08 CC		
0	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH =1.600E+03 CM		
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 0.000E+00 SEC AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00 1.219E+02
0	GROUP	TOTAL GROUP	GROUP	GROUP	DOSE RATE
	PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	ENERGY FLUX	AT DOSE POINT
	PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR
	1	4.033E+19	2.818E+19	0.0150	0.000E+00 0.000E+00
	2	3.155E+19	1.602E+19	0.0250	0.000E+00 0.000E+00
	3	3.786E+19	1.050E+19	0.0350	0.000E+00 0.000E+00
	4	1.175E+19	7.652E+18	0.0450	1.160E-24 3.804E-30
	5	9.453E+18	5.915E+18	0.0550	3.650E-14 8.358E-20
	6	6.010E+18	4.773E+18	0.0650	2.571E-09 4.861E-15
	7	9.239E+18	3.999E+18	0.0750	3.261E-06 5.590E-12
	8	1.374E+19	3.446E+18	0.0850	5.913E-04 9.562E-10
	9	5.119E+18	3.044E+18	0.0950	1.172E-03 1.879E-09
	10	8.803E+19	1.794E+19	0.1500	4.541E+01 7.848E-05
	11	8.427E+19	7.496E+18	0.2500	2.763E+03 5.416E-03
	12	7.169E+19	3.811E+18	0.3500	3.589E+04 7.394E-02
	13	1.288E+20	3.048E+18	0.4750	5.829E+05 1.189E+00
	14	1.656E+20	2.050E+18	0.6500	9.107E+06 1.894E+01
	15	1.150E+20	8.891E+17	0.8250	1.630E+07 3.259E+01
	16	5.567E+19	7.269E+17	1.0000	1.958E+07 3.779E+01
	17	6.084E+19	5.269E+17	1.2250	6.118E+07 1.126E+02
	18	6.151E+19	2.972E+17	1.4750	3.601E+08 6.337E+02
	19	1.270E+19	1.469E+17	1.7000	6.805E+07 1.164E+02
	20	1.104E+19	9.763E+16	1.9000	9.921E+07 1.647E+02
	21	1.319E+19	6.607E+16	2.1000	1.747E+08 2.796E+02
	22	6.050E+18	4.491E+16	2.3000	1.120E+08 1.724E+02
	23	1.249E+19	3.097E+16	2.5000	3.172E+08 4.822E+02
	24	4.405E+18	2.154E+16	2.7000	1.472E+08 2.178E+02
	25	1.527E+19	2.527E+16	3.0000	7.269E+08 1.039E+03
0	TOTAL	1.072E+21	1.208E+20		2.112E+09 3.309E+03

1	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 4 FEET				
0	SOURCE SHIELDS DIST TO DETECTOR 3.420E+02 CM.				
0	SLAB	SLAB	VOL.=1.991E+08 CC		
0	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH = 1.600E+03 CM		
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.443E+01 YRS AFTER SHUTDOWN				

WHC-SD-NR-ER-105 Rev. 0

0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED

0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	1.219E+02
0	GROUP	TOTAL GROUP PRODUCTION RATE PHOTONS	GROUP BREMSSTRAHLUNG PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1		6.754E+15	6.725E+15	0.0150	0.000E+00	0.000E+00
2		3.923E+15	3.786E+15	0.0250	0.000E+00	0.000E+00
3		1.104E+16	2.262E+15	0.0350	0.000E+00	0.000E+00
4		1.539E+15	1.532E+15	0.0450	1.518E-28	4.980E-34
5		1.102E+15	1.102E+15	0.0550	4.255E-18	9.744E-24
6		9.277E+14	9.258E+14	0.0650	3.968E-13	7.503E-19
7		8.281E+14	8.281E+14	0.0750	2.923E-10	5.011E-16
8		7.484E+14	7.377E+14	0.0850	3.220E-08	5.207E-14
9		6.575E+14	6.568E+14	0.0950	1.506E-07	2.414E-13
10		3.557E+15	2.960E+15	0.1500	1.835E-03	3.171E-09
11		1.072E+15	9.663E+14	0.2500	3.515E-02	6.890E-08
12		4.774E+14	4.695E+14	0.3500	2.390E-01	4.923E-07
13		6.270E+14	3.502E+14	0.4750	2.837E+00	5.788E-06
14		1.965E+17	2.077E+14	0.6500	1.081E+04	2.248E-02
15		8.996E+14	7.676E+13	0.8250	1.275E+02	2.550E-04
16		5.102E+14	5.171E+13	1.0000	1.794E+02	3.463E-04
17		6.003E+14	2.633E+13	1.2250	6.037E+02	1.111E-03
18		4.102E+13	8.635E+12	1.4750	2.402E+02	4.227E-04
19		3.522E+13	1.978E+12	1.7000	1.888E+02	3.228E-04
20		4.352E+11	4.195E+11	1.9000	3.910E+00	6.491E-06
21		1.865E+11	2.875E+10	2.1000	2.471E+00	3.953E-06
22		1.041E+10	2.580E+09	2.3000	1.927E-01	2.967E-07
23		1.693E+10	1.269E+09	2.5000	4.300E-01	6.537E-07
24		8.387E+09	5.548E+08	2.7000	2.803E-01	4.148E-07
25		2.312E+08	2.312E+08	3.0000	1.100E-02	1.573E-08
0	TOTAL	2.318E+17	2.367E+16		1.216E+04	2.495E-02

0 GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 4 FEET
0 SOURCE SHIELDS DIST TO DETECTOR 3.420E+02 CM.

+ SLAB SLAB
0 THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM VOL.=1.991E+08 CC
0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05
0 1800 CANISTER IRRADIATION

REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.715E+01 YRS AFTER SHUTDOWN
0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED

0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	1.219E+02
0	GROUP	TOTAL GROUP PRODUCTION RATE PHOTONS	GROUP BREMSSTRAHLUNG PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1		6.301E+15	6.274E+15	0.0150	0.000E+00	0.000E+00
2		3.630E+15	3.535E+15	0.0250	0.000E+00	0.000E+00
3		1.035E+16	2.111E+15	0.0350	0.000E+00	0.000E+00
4		1.433E+15	1.431E+15	0.0450	1.414E-28	4.639E-34
5		1.030E+15	1.030E+15	0.0550	3.975E-18	9.103E-24
6		8.668E+14	8.652E+14	0.0650	3.707E-13	7.011E-19
7		7.742E+14	7.742E+14	0.0750	2.733E-10	4.685E-16
8		6.935E+14	6.898E+14	0.0850	2.984E-08	4.825E-14
9		6.150E+14	6.143E+14	0.0950	1.408E-07	2.258E-13
10		3.282E+15	2.769E+15	0.1500	1.693E-03	2.926E-09
11		9.968E+14	9.039E+14	0.2500	3.268E-02	6.406E-08
12		4.433E+14	4.392E+14	0.3500	2.219E-01	4.572E-07
13		4.870E+14	3.277E+14	0.4750	2.204E+00	4.495E-06
14		1.840E+17	1.943E+14	0.6500	1.012E+04	2.105E-02
15		5.219E+14	7.180E+13	0.8250	7.396E+01	1.479E-04
16		4.522E+14	4.835E+13	1.0000	1.591E+02	3.070E-04
17		5.285E+14	2.460E+13	1.2250	5.315E+02	9.780E-04
18		2.637E+13	8.060E+12	1.4750	1.544E+02	2.717E-04
19		3.174E+13	1.841E+12	1.7000	1.701E+02	2.908E-04
20		3.884E+11	3.861E+11	1.9000	3.490E+00	5.794E-06

WHC-SD-NR-ER-105 Rev. 0

	21	3.809E+10	2.310E+10	2.1000	5.047E-01	8.075E-07
	22	1.565E+09	3.816E+08	2.3000	2.896E-02	4.460E-08
	23	2.556E+09	1.893E+08	2.5000	6.492E-02	9.867E-08
	24	1.267E+09	8.337E+07	2.7000	4.233E-02	6.265E-08
	25	3.493E+07	3.493E+07	3.0000	1.663E-03	2.377E-09
0	TOTAL	2.164E+17	2.211E+16		1.122E+04	2.306E-02
1						
0	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 4 FEET					
0	SOURCE SHIELDS DIST TO DETECTOR 3.420E+02 CM.					
+	SLAB	SLAB				VOL.=1.991E+08 CC
0	THICKNESS = 6.533E+01 CM		HEIGHT = 1.905E+03 CM	WIDTH = 1.600E+03 CM		
0	INTEGRATION SPECS	NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION					
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.264E+01 YRS AFTER SHUTDOWN					
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED					
0	SHIELD THICKNESS, CM. 6.533E+01 4.826E-01 5.588E-01 1.270E+00 1.219E+02					
0	GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX	DOSE RATE
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT	AT DOSE POINT
		PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR
	1	5.504E+15	5.479E+15	0.0150	0.000E+00	0.000E+00
	2	3.149E+15	3.089E+15	0.0250	0.000E+00	0.000E+00
	3	9.097E+15	1.845E+15	0.0350	0.000E+00	0.000E+00
	4	1.251E+15	1.251E+15	0.0450	1.234E-28	4.049E-34
	5	9.005E+14	9.005E+14	0.0550	3.476E-18	7.961E-24
	6	7.582E+14	7.568E+14	0.0650	3.243E-13	6.132E-19
	7	6.774E+14	6.774E+14	0.0750	2.392E-10	4.099E-16
	8	6.043E+14	6.038E+14	0.0850	2.600E-08	4.204E-14
	9	5.384E+14	5.377E+14	0.0950	1.233E-07	1.977E-13
	10	2.820E+15	2.424E+15	0.1500	1.455E-03	2.514E-09
	11	8.641E+14	7.916E+14	0.2500	2.833E-02	5.553E-08
	12	3.860E+14	3.847E+14	0.3500	1.932E-01	3.981E-07
	13	3.548E+14	2.871E+14	0.4750	1.605E+00	3.275E-06
	14	1.618E+17	1.702E+14	0.6500	8.899E+03	1.851E-02
	15	2.697E+14	6.290E+13	0.8250	3.822E+01	7.643E-05
	16	3.591E+14	4.236E+13	1.0000	1.263E+02	2.438E-04
	17	4.157E+14	2.155E+13	1.2250	4.181E+02	7.692E-04
	18	1.600E+13	7.059E+12	1.4750	9.365E+01	1.648E-04
	19	2.581E+13	1.611E+12	1.7000	1.383E+02	2.366E-04
	20	3.373E+11	3.373E+11	1.9000	3.031E+00	5.031E-06
	21	1.978E+10	1.963E+10	2.1000	2.621E-01	4.194E-07
	22	3.478E+07	8.348E+06	2.3000	6.436E-04	9.911E-10
	23	5.704E+07	4.177E+06	2.5000	1.448E-03	2.202E-09
	24	2.828E+07	1.852E+06	2.7000	9.451E-04	1.399E-09
	25	7.802E+05	7.802E+05	3.0000	3.713E-05	5.310E-11
0	TOTAL	1.898E+17	1.933E+16		9.719E+03	2.001E-02
1						
0	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 4 FEET					
0	SOURCE SHIELDS DIST TO DETECTOR 3.420E+02 CM.					
+	SLAB	SLAB				VOL.=1.991E+08 CC
0	THICKNESS = 6.533E+01 CM		HEIGHT = 1.905E+03 CM	WIDTH = 1.600E+03 CM		
0	INTEGRATION SPECS	NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION					
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.264E+01 YRS AFTER SHUTDOWN					
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED					
0	SHIELD THICKNESS, CM. 6.533E+01 4.826E-01 5.588E-01 1.270E+00 1.219E+02					

9	4.716E+14	4.709E+14	0.0950	1.080E-07	1.731E-13
10	2.433E+15	2.123E+15	0.1500	1.255E-03	2.169E-09
11	7.505E+14	6.935E+14	0.2500	2.461E-02	4.823E-08
12	3.376E+14	3.371E+14	0.3500	1.690E-01	3.481E-07
13	2.895E+14	2.516E+14	0.4750	1.310E+00	2.672E-06
14	1.425E+17	1.492E+14	0.6500	7.836E+03	1.630E-02
15	1.939E+14	5.512E+13	0.8250	2.748E+01	5.496E-05
16	2.866E+14	3.712E+13	1.0000	1.008E+02	1.945E-04
17	3.292E+14	1.889E+13	1.2250	3.310E+02	6.091E-04
18	1.232E+13	6.186E+12	1.4750	7.215E+01	1.270E-04
19	2.105E+13	1.412E+12	1.7000	1.128E+02	1.929E-04
20	2.955E+11	2.955E+11	1.9000	2.655E+00	4.408E-06
21	1.719E+10	1.719E+10	2.1000	2.278E-01	3.645E-07
22	7.754E+05	1.851E+05	2.3000	1.435E-05	2.210E-11
23	1.274E+06	9.288E+04	2.5000	3.234E-05	4.916E-11
24	6.316E+05	4.130E+04	2.7000	2.110E-05	3.123E-11
25	1.743E+04	1.743E+04	3.0000	8.293E-07	1.186E-12
0 TOTAL	1.668E+17	1.692E+16		8.485E+03	1.748E-02

1
0
GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 5 FEET
0 SOURCE SHIELDS DIST TO DETECTOR 3.724E+02 CM.
+ SLAB SLAB VOL.=1.991E+08 CC
0 THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH =1.600E+03 CM
0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05
0 1800 CANISTER IRRADIATION
REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 0.000E+00 SEC AFTER SHUTDOWN
0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED
0 SHIELD THICKNESS,CM. 6.533E+01 4.826E-01 5.588E-01 1.270E+00 1.524E+02
0 GROUP TOTAL GROUP GROUP GROUP ENERGY FLUX DOSE RATE
PRODUCTION RATE BREMSSTRAHLUNG AVERAGE ENERGY AT DOSE POINT AT DOSE POINT
PHOTONS PHOTONS MEV MEV/CMS/SEC ROENTGENS/HOUR

1	4.033E+19	2.818E+19	0.0150	0.000E+00	0.000E+00
2	3.155E+19	1.602E+19	0.0250	0.000E+00	0.000E+00
3	3.786E+19	1.050E+19	0.0350	0.000E+00	0.000E+00
4	1.175E+19	7.652E+18	0.0450	0.000E+00	0.000E+00
5	9.453E+18	5.915E+18	0.0550	6.577E-17	1.506E-22
6	6.010E+18	4.773E+18	0.0650	6.737E-12	1.274E-17
7	9.239E+18	3.999E+18	0.0750	1.079E-08	1.850E-14
8	1.374E+19	3.446E+18	0.0850	2.661E-06	4.303E-12
9	5.119E+18	3.044E+18	0.0950	5.635E-06	9.033E-12
10	8.803E+19	1.794E+19	0.1500	7.557E-01	1.306E-06
11	8.427E+19	7.496E+18	0.2500	8.350E+01	1.637E-04
12	7.169E+19	3.811E+18	0.3500	1.601E+03	3.297E-03
13	1.288E+20	3.048E+18	0.4750	3.546E+04	7.234E-02
14	1.656E+20	2.050E+18	0.6500	8.756E+05	1.821E+00
15	1.150E+20	8.891E+17	0.8250	1.805E+06	3.610E+00
16	5.567E+19	7.269E+17	1.0000	2.551E+06	4.922E+00
17	6.084E+19	5.269E+17	1.2250	9.450E+06	1.739E+01
18	6.151E+19	2.972E+17	1.4750	7.896E+07	1.390E+02
19	1.270E+19	1.469E+17	1.7000	1.357E+07	2.321E+01
20	1.104E+19	9.763E+16	1.9000	2.157E+07	3.581E+01
21	1.319E+19	6.607E+16	2.1000	4.060E+07	6.496E+01
22	6.050E+18	4.491E+16	2.3000	2.767E+07	4.261E+01
23	1.249E+19	3.097E+16	2.5000	8.311E+07	1.263E+02
24	4.405E+18	2.154E+16	2.7000	4.051E+07	5.996E+01
25	1.527E+19	2.527E+16	3.0000	2.133E+08	3.050E+02
0 TOTAL	1.072E+21	1.208E+20		5.340E+08	8.247E+02

1
0
GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 5 FEET
0 SOURCE SHIELDS DIST TO DETECTOR 3.724E+02 CM.
+ SLAB SLAB VOL.=1.991E+08 CC
0 THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH =1.600E+03 CM
0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05
0 1800 CANISTER IRRADIATION
REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.443E+01 YRS AFTER SHUTDOWN

0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED

0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	1.524E+02	
0	GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX	DOSE RATE	
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT	AT DOSE POINT	
		PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR	
1		6.754E+15	6.725E+15	0.0150	0.000E+00	0.000E+00	
2		3.923E+15	3.786E+15	0.0250	0.000E+00	0.000E+00	
3		1.104E+16	2.262E+15	0.0350	0.000E+00	0.000E+00	
4		1.539E+15	1.532E+15	0.0450	0.000E+00	0.000E+00	
5		1.102E+15	1.102E+15	0.0550	7.668E-21	1.756E-26	
6		9.277E+14	9.258E+14	0.0650	1.040E-15	1.966E-21	
7		8.281E+14	8.281E+14	0.0750	9.673E-13	1.658E-18	
8		7.484E+14	7.377E+14	0.0850	1.449E-10	2.343E-16	
9		6.575E+14	6.568E+14	0.0950	7.238E-10	1.160E-15	
10		3.557E+15	2.960E+15	0.1500	3.053E-05	5.276E-11	
11		1.072E+15	9.663E+14	0.2500	1.062E-03	2.082E-09	
12		4.774E+14	4.695E+14	0.3500	1.066E-02	2.195E-08	
13		6.270E+14	3.502E+14	0.4750	1.726E-01	3.521E-07	
14		1.965E+17	2.077E+14	0.6500	1.039E+03	2.161E-03	
15		8.996E+14	7.676E+13	0.8250	1.412E+01	2.824E-05	
16		5.102E+14	5.171E+13	1.0000	2.337E+01	4.511E-05	
17		6.003E+14	2.633E+13	1.2250	9.323E+01	1.716E-04	
18		4.102E+13	8.635E+12	1.4750	5.266E+01	9.269E-05	
19		3.522E+13	1.978E+12	1.7000	3.765E+01	6.437E-05	
20		4.352E+11	4.195E+11	1.9000	8.502E-01	1.411E-06	
21		1.865E+11	2.875E+10	2.1000	5.740E-01	9.184E-07	
22		1.041E+10	2.580E+09	2.3000	4.762E-02	7.334E-08	
23		1.693E+10	1.269E+09	2.5000	1.127E-01	1.712E-07	
24		8.387E+09	5.548E+08	2.7000	7.714E-02	1.142E-07	
25		2.312E+08	2.312E+08	3.0000	3.229E-03	4.618E-09	
0	TOTAL	2.318E+17	2.367E+16		1.262E+03	2.566E-03	

0 GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 5 FEET

0 SOURCE SHIELDS DIST TO DETECTOR 3.724E+02 CM.
+ SLAB SLAB VOL.=1.991E+08 CC
0 THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM
0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05
0 1800 CANISTER IRRADIATION
0 REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.715E+01 YRS AFTER SHUTDOWN

0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED

0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	1.524E+02	
0	GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX	DOSE RATE	
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT	AT DOSE POINT	
		PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR	
1		6.301E+15	6.274E+15	0.0150	0.000E+00	0.000E+00	
2		3.630E+15	3.535E+15	0.0250	0.000E+00	0.000E+00	
3		1.035E+16	2.111E+15	0.0350	0.000E+00	0.000E+00	
4		1.433E+15	1.431E+15	0.0450	0.000E+00	0.000E+00	
5		1.030E+15	1.030E+15	0.0550	7.163E-21	1.640E-26	
6		8.668E+14	8.652E+14	0.0650	9.716E-16	1.837E-21	
7		7.742E+14	7.742E+14	0.0750	9.044E-13	1.550E-18	
8		6.935E+14	6.898E+14	0.0850	1.343E-10	2.171E-16	
9		6.150E+14	6.143E+14	0.0950	6.770E-10	1.085E-15	
10		3.282E+15	2.769E+15	0.1500	2.818E-05	4.869E-11	
11		9.968E+14	9.039E+14	0.2500	9.876E-04	1.936E-09	
12		4.433E+14	4.392E+14	0.3500	9.897E-03	2.039E-08	
13		4.870E+14	3.277E+14	0.4750	1.340E-01	2.734E-07	
14		1.840E+17	1.943E+14	0.6500	9.730E+02	2.024E-03	
15		5.219E+14	7.180E+13	0.8250	8.192E+00	1.638E-05	
16		4.522E+14	4.835E+13	1.0000	2.072E+01	3.998E-05	
17		5.285E+14	2.460E+13	1.2250	8.209E+01	1.510E-04	
18		2.637E+13	8.060E+12	1.4750	3.385E+01	5.957E-05	
19		3.174E+13	1.841E+12	1.7000	3.392E+01	5.800E-05	
20		3.884E+11	3.861E+11	1.9000	7.589E-01	1.260E-06	

21	3.809E+10	2.310E+10	2.1000	1.173E-01	1.876E-07
22	1.565E+09	3.816E+08	2.3000	7.158E-03	1.102E-08
23	2.556E+09	1.893E+08	2.5000	1.701E-02	2.585E-08
24	1.267E+09	8.337E+07	2.7000	1.165E-02	1.724E-08
25	3.493E+07	3.493E+07	3.0000	4.879E-04	6.977E-10
0 TOTAL	2.164E+17	2.211E+16		1.153E+03	2.351E-03
1	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 5 FEET				
0	SOURCE SHIELDS DIST TO DETECTOR 3.724E+02 CM.				
+	SLAB	SLAB			VOL.=1.991E+08 CC
0	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH = 1.600E+03 CM		
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.264E+01 YRS AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00 1.524E+02
0	GROUP	TOTAL GROUP	GROUP	GROUP	DOSE RATE
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT
		PHOTONS	PHOTONS	MEV	ROENTGENS/HOUR
1	5.504E+15	5.479E+15	0.0150	0.000E+00	0.000E+00
2	3.149E+15	3.089E+15	0.0250	0.000E+00	0.000E+00
3	9.097E+15	1.845E+15	0.0350	0.000E+00	0.000E+00
4	1.251E+15	1.251E+15	0.0450	0.000E+00	0.000E+00
5	9.005E+14	9.005E+14	0.0550	6.265E-21	1.435E-26
6	7.582E+14	7.568E+14	0.0650	8.499E-16	1.607E-21
7	6.774E+14	6.774E+14	0.0750	7.913E-13	1.356E-18
8	6.043E+14	6.038E+14	0.0850	1.170E-10	1.892E-16
9	5.384E+14	5.377E+14	0.0950	5.927E-10	9.501E-16
10	2.820E+15	2.424E+15	0.1500	2.420E-05	4.182E-11
11	8.641E+14	7.916E+14	0.2500	8.562E-04	1.678E-09
12	3.860E+14	3.847E+14	0.3500	8.617E-03	1.775E-08
13	3.548E+14	2.871E+14	0.4750	9.765E-02	1.992E-07
14	1.618E+17	1.702E+14	0.6500	8.556E+02	1.780E-03
15	2.697E+14	6.290E+13	0.8250	4.233E+00	8.466E-06
16	3.591E+14	4.236E+13	1.0000	1.645E+01	3.175E-05
17	4.157E+14	2.155E+13	1.2250	6.457E+01	1.188E-04
18	1.600E+13	7.059E+12	1.4750	2.054E+01	3.614E-05
19	2.581E+13	1.611E+12	1.7000	2.759E+01	4.718E-05
20	3.373E+11	3.373E+11	1.9000	6.590E-01	1.094E-06
21	1.978E+10	1.963E+10	2.1000	6.090E-02	9.744E-08
22	3.478E+07	8.348E+06	2.3000	1.591E-04	2.450E-10
23	5.704E+07	4.177E+06	2.5000	3.795E-04	5.768E-10
24	2.828E+07	1.852E+06	2.7000	2.601E-04	3.850E-10
25	7.802E+05	7.802E+05	3.0000	1.090E-05	1.558E-11
0 TOTAL	1.898E+17	1.933E+16		9.898E+02	2.023E-03

1	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 5 FEET				
0	SOURCE SHIELDS DIST TO DETECTOR 3.724E+02 CM.				
+	SLAB	SLAB			VOL.=1.991E+08 CC
0	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH = 1.600E+03 CM		
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.813E+01 YRS AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00 1.524E+02
0	GROUP	TOTAL GROUP	GROUP	GROUP	DOSE RATE
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT
		PHOTONS	PHOTONS	MEV	ROENTGENS/HOUR
1	4.817E+15	4.795E+15	0.0150	0.000E+00	0.000E+00
2	2.750E+15	2.704E+15	0.0250	0.000E+00	0.000E+00
3	8.003E+15	1.614E+15	0.0350	0.000E+00	0.000E+00
4	1.095E+15	1.094E+15	0.0450	0.000E+00	0.000E+00
5	7.883E+14	7.883E+14	0.0550	5.485E-21	1.256E-26
6	6.639E+14	6.625E+14	0.0650	7.442E-16	1.407E-21
7	5.932E+14	5.932E+14	0.0750	6.929E-13	1.188E-18
8	5.288E+14	5.288E+14	0.0850	1.024E-10	1.656E-16

9	4.716E+14	4.709E+14	0.0950	5.192E-10	8.322E-16
10	2.433E+15	2.123E+15	0.1500	2.088E-05	3.609E-11
11	7.505E+14	6.935E+14	0.2500	7.436E-04	1.457E-09
12	3.376E+14	3.371E+14	0.3500	7.536E-03	1.552E-08
13	2.895E+14	2.516E+14	0.4750	7.969E-02	1.626E-07
14	1.425E+17	1.492E+14	0.6500	7.534E+02	1.567E-03
15	1.939E+14	5.512E+13	0.8250	3.044E+00	6.088E-06
16	2.866E+14	3.712E+13	1.0000	1.313E+01	2.534E-05
17	3.292E+14	1.889E+13	1.2250	5.113E+01	9.407E-05
18	1.232E+13	6.186E+12	1.4750	1.582E+01	2.784E-05
19	2.105E+13	1.412E+12	1.7000	2.250E+01	3.847E-05
20	2.955E+11	2.955E+11	1.9000	5.774E-01	9.584E-07
21	1.719E+10	1.719E+10	2.1000	5.293E-02	8.469E-08
22	7.754E+05	1.851E+05	2.3000	3.546E-06	5.461E-12
23	1.274E+06	9.288E+04	2.5000	8.472E-06	1.288E-11
24	6.316E+05	4.130E+04	2.7000	5.809E-06	8.598E-12
25	1.743E+04	1.743E+04	3.0000	2.434E-07	3.480E-13
0 TOTAL	1.668E+17	1.692E+16		8.597E+02	1.760E-03

GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 6 FEET					
SOURCE SHIELDS DIST TO DETECTOR 4.029E+02 CM.					
+ SLAB SLAB THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM VOL.=1.991E+08 CC					
0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05					
0 1800 CANISTER IRRADIATION					
REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 0.000E+00 SEC AFTER SHUTDOWN					
0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED					
0 SHIELD THICKNESS, CM. 6.533E+01 4.826E-01 5.588E-01 1.270E+00 1.829E+02					
0 GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX	DOSE RATE
	PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT	AT DOSE POINT
	PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR
1	4.033E+19	2.818E+19	0.0150	0.000E+00	0.000E+00
2	3.155E+19	1.602E+19	0.0250	0.000E+00	0.000E+00
3	3.786E+19	1.050E+19	0.0350	0.000E+00	0.000E+00
4	1.175E+19	7.652E+18	0.0450	0.000E+00	0.000E+00
5	9.453E+18	5.915E+18	0.0550	1.194E-19	2.733E-25
6	6.010E+18	4.773E+18	0.0650	1.787E-14	3.380E-20
7	9.239E+18	3.999E+18	0.0750	3.630E-11	6.222E-17
8	1.374E+19	3.446E+18	0.0850	1.221E-08	1.975E-14
9	5.119E+18	3.044E+18	0.0950	2.770E-08	4.441E-14
10	8.803E+19	1.794E+19	0.1500	1.281E-02	2.214E-08
11	8.427E+19	7.496E+18	0.2500	2.565E+00	5.027E-06
12	7.169E+19	3.811E+18	0.3500	7.239E+01	1.491E-04
13	1.288E+20	3.048E+18	0.4750	2.183E+03	4.454E-03
14	1.656E+20	2.050E+18	0.6500	8.486E+04	1.765E-01
15	1.150E+20	8.891E+17	0.8250	2.014E+05	4.028E-01
16	5.567E+19	7.269E+17	1.0000	3.350E+05	6.466E-01
17	6.084E+19	5.269E+17	1.2250	1.473E+06	2.710E+00
18	6.151E+19	2.972E+17	1.4750	1.745E+07	3.072E+01
19	1.270E+19	1.469E+17	1.7000	2.730E+06	4.668E+00
20	1.104E+19	9.763E+16	1.9000	4.729E+06	7.851E+00
21	1.319E+19	6.607E+16	2.1000	9.510E+06	1.522E+01
22	6.050E+18	4.491E+16	2.3000	6.894E+06	1.062E+01
23	1.249E+19	3.097E+16	2.5000	2.195E+07	3.336E+01
24	4.405E+18	2.154E+16	2.7000	1.124E+07	1.664E+01
25	1.527E+19	2.527E+16	3.0000	6.310E+07	9.023E+01
0 TOTAL	1.072E+21	1.208E+20		1.397E+08	2.132E+02

GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 6 FEET					
SOURCE SHIELDS DIST TO DETECTOR 4.029E+02 CM.					
+ SLAB SLAB THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM VOL.=1.991E+08 CC					
0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05					
0 1800 CANISTER IRRADIATION					
REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.443E+01 YRS AFTER SHUTDOWN					

0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED

0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	1.829E+02	
0	GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX	DOSE RATE	
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT	AT DOSE POINT	
		PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR	
1		6.754E+15	6.725E+15	0.0150	0.000E+00	0.000E+00	
2		3.923E+15	3.786E+15	0.0250	0.000E+00	0.000E+00	
3		1.104E+16	2.262E+15	0.0350	0.000E+00	0.000E+00	
4		1.539E+15	1.532E+15	0.0450	0.000E+00	0.000E+00	
5		1.102E+15	1.102E+15	0.0550	1.392E-23	3.187E-29	
6		9.277E+14	9.258E+14	0.0650	2.759E-18	5.217E-24	
7		8.281E+14	8.281E+14	0.0750	3.254E-15	5.577E-21	
8		7.484E+14	7.377E+14	0.0850	6.651E-13	1.076E-18	
9		6.575E+14	6.568E+14	0.0950	3.559E-12	5.704E-18	
10		3.557E+15	2.960E+15	0.1500	5.178E-07	8.947E-13	
11		1.072E+15	9.663E+14	0.2500	3.263E-05	6.396E-11	
12		4.774E+14	4.695E+14	0.3500	4.820E-04	9.930E-10	
13		6.270E+14	3.502E+14	0.4750	1.063E-02	2.168E-08	
14		1.965E+17	2.077E+14	0.6500	1.007E+02	2.095E-04	
15		8.996E+14	7.676E+13	0.8250	1.576E+00	3.151E-06	
16		5.102E+14	5.171E+13	1.0000	3.070E+00	5.925E-06	
17		6.003E+14	2.633E+13	1.2250	1.453E+01	2.674E-05	
18		4.102E+13	8.635E+12	1.4750	1.164E+01	2.049E-05	
19		3.522E+13	1.978E+12	1.7000	7.572E+00	1.295E-05	
20		4.352E+11	4.195E+11	1.9000	1.864E-01	3.094E-07	
21		1.865E+11	2.875E+10	2.1000	1.345E-01	2.151E-07	
22		1.041E+10	2.580E+09	2.3000	1.187E-02	1.827E-08	
23		1.693E+10	1.269E+09	2.5000	2.975E-02	4.522E-08	
24		8.387E+09	5.548E+08	2.7000	2.140E-02	3.168E-08	
25		2.312E+08	2.312E+08	3.0000	9.552E-04	1.366E-09	
0	TOTAL	2.318E+17	2.367E+16		1.395E+02	2.794E-04	

0 GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 6 FEET
 0 SOURCE SHIELDS DIST TO DETECTOR 4.029E+02 CM.

+ SLAB SLAB THICKNESS = 6.533E+01 CM HEIGHT = 1.905E+03 CM WIDTH = 1.600E+03 CM VOL. = 1.991E+08 CC
 0 INTEGRATION SPECS NTHETA = 45 NPSI = 23 DELR = 4.0000E-01 NTHETA X NPSI X T(1) / DELR = 1.6904E+05
 0 1800 CANISTER IRRADIATION

0 REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 1.715E+01 YRS AFTER SHUTDOWN

0 TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED

0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00	1.829E+02	
0	GROUP	TOTAL GROUP	GROUP	GROUP	ENERGY FLUX	DOSE RATE	
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT	AT DOSE POINT	
		PHOTONS	PHOTONS	MEV	MEV/CMS/SEC	ROENTGENS/HOUR	
1		6.301E+15	6.274E+15	0.0150	0.000E+00	0.000E+00	
2		3.630E+15	3.535E+15	0.0250	0.000E+00	0.000E+00	
3		1.035E+16	2.111E+15	0.0350	0.000E+00	0.000E+00	
4		1.433E+15	1.431E+15	0.0450	0.000E+00	0.000E+00	
5		1.030E+15	1.030E+15	0.0550	1.300E-23	2.977E-29	
6		8.668E+14	8.652E+14	0.0650	2.578E-18	4.874E-24	
7		7.742E+14	7.742E+14	0.0750	3.042E-15	5.214E-21	
8		6.935E+14	6.898E+14	0.0850	6.164E-13	9.967E-19	
9		6.150E+14	6.143E+14	0.0950	3.328E-12	5.335E-18	
10		3.282E+15	2.769E+15	0.1500	4.778E-07	8.256E-13	
11		9.968E+14	9.039E+14	0.2500	3.034E-05	5.947E-11	
12		4.433E+14	4.392E+14	0.3500	4.476E-04	9.222E-10	
13		4.870E+14	3.277E+14	0.4750	8.254E-03	1.684E-08	
14		1.840E+17	1.943E+14	0.6500	9.431E+01	1.962E-04	
15		5.219E+14	7.180E+13	0.8250	9.141E-01	1.828E-06	
16		4.522E+14	4.835E+13	1.0000	2.721E+00	5.252E-06	
17		5.285E+14	2.460E+13	1.2250	1.279E+01	2.354E-05	
18		2.637E+13	8.060E+12	1.4750	7.482E+00	1.317E-05	
19		3.174E+13	1.841E+12	1.7000	6.823E+00	1.167E-05	
20		3.884E+11	3.861E+11	1.9000	1.664E-01	2.762E-07	

21	3.809E+10	2.310E+10	2.1000	2.747E-02	4.395E-08
22	1.565E+09	3.816E+08	2.3000	1.783E-03	2.746E-09
23	2.556E+09	1.893E+08	2.5000	4.491E-03	6.827E-09
24	1.267E+09	8.337E+07	2.7000	3.233E-03	4.785E-09
25	3.493E+07	3.493E+07	3.0000	1.443E-04	2.064E-10
0 TOTAL	2.164E+17	2.211E+16		1.253E+02	2.520E-04
1					
0					
0	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 6 FEET				
0	SOURCE SHIELDS DIST TO DETECTOR 4.029E+02 CM.				
0	SLAB	SLAB	VOL.=1.991E+08 CC		
0	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH = 1.600E+03 CM		
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.264E+01 YRS AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00 1.829E+02
0	GROUP	TOTAL GROUP	GROUP	GROUP	DOSE RATE
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT
		PHOTONS	PHOTONS	MEV	ROENTGENS/HOUR
1	5.504E+15	5.479E+15	0.0150	0.000E+00	0.000E+00
2	3.149E+15	3.089E+15	0.0250	0.000E+00	0.000E+00
3	9.097E+15	1.845E+15	0.0350	0.000E+00	0.000E+00
4	1.251E+15	1.251E+15	0.0450	0.000E+00	0.000E+00
5	9.005E+14	9.005E+14	0.0550	1.137E-23	2.604E-29
6	7.582E+14	7.568E+14	0.0650	2.255E-18	4.264E-24
7	6.774E+14	6.774E+14	0.0750	2.662E-15	4.563E-21
8	6.043E+14	6.038E+14	0.0850	5.370E-13	8.683E-19
9	5.384E+14	5.377E+14	0.0950	2.914E-12	4.671E-18
10	2.820E+15	2.424E+15	0.1500	4.104E-07	7.092E-13
11	8.641E+14	7.916E+14	0.2500	2.630E-05	5.155E-11
12	3.860E+14	3.847E+14	0.3500	3.897E-04	8.029E-10
13	3.548E+14	2.871E+14	0.4750	6.013E-03	1.227E-08
14	1.618E+17	1.702E+14	0.6500	8.293E+01	1.725E-04
15	2.697E+14	6.290E+13	0.8250	4.723E-01	9.446E-07
16	3.591E+14	4.236E+13	1.0000	2.161E+00	4.170E-06
17	4.157E+14	2.155E+13	1.2250	1.006E+01	1.852E-05
18	1.600E+13	7.059E+12	1.4750	4.540E+00	7.990E-06
19	2.581E+13	1.611E+12	1.7000	5.550E+00	9.490E-06
20	3.373E+11	3.373E+11	1.9000	1.445E-01	2.398E-07
21	1.978E+10	1.963E+10	2.1000	1.427E-02	2.283E-08
22	3.478E+07	8.348E+06	2.3000	3.963E-05	6.103E-11
23	5.704E+07	4.177E+06	2.5000	1.002E-04	1.523E-10
24	2.828E+07	1.852E+06	2.7000	7.218E-05	1.068E-10
25	7.802E+05	7.802E+05	3.0000	3.223E-06	4.609E-12
0 TOTAL	1.898E+17	1.933E+16		1.059E+02	2.139E-04
1					
0					
0	GAMMA ATTENUATION CALCULATION 1800 CANISTER LOCATIONS, TOP - MODEL B1800 - 6 FEET				
0	SOURCE SHIELDS DIST TO DETECTOR 4.029E+02 CM.				
0	SLAB	SLAB	VOL.=1.991E+08 CC		
0	THICKNESS = 6.533E+01 CM	HEIGHT = 1.905E+03 CM	WIDTH = 1.600E+03 CM		
0	INTEGRATION SPECS NTHETA = 45	NPSI = 23	DELR = 4.0000E-01	NTHETA X NPSI X T(1) / DELR = 1.6904E+05	
0	1800 CANISTER IRRADIATION				
0	REACTOR DATA 2.698E+06 MWD IN 406.00 DAYS 2.264E+01 YRS AFTER SHUTDOWN				
0	TAYLOR BUILDUP DATA FOR SHIELD 5 WITH EFFECTIVE ATOMIC NUMBER OF 4.0 USED				
0	SHIELD THICKNESS, CM.	6.533E+01	4.826E-01	5.588E-01	1.270E+00 1.829E+02
0	GROUP	TOTAL GROUP	GROUP	GROUP	DOSE RATE
		PRODUCTION RATE	BREMSSTRAHLUNG	AVERAGE ENERGY	AT DOSE POINT
		PHOTONS	PHOTONS	MEV	ROENTGENS/HOUR
1	5.504E+15	5.479E+15	0.0150	0.000E+00	0.000E+00
2	3.149E+15	3.089E+15	0.0250	0.000E+00	0.000E+00
3	9.097E+15	1.845E+15	0.0350	0.000E+00	0.000E+00
4	1.251E+15	1.251E+15	0.0450	0.000E+00	0.000E+00
5	9.005E+14	9.005E+14	0.0550	1.137E-23	2.604E-29
6	7.582E+14	7.568E+14	0.0650	2.255E-18	4.264E-24
7	6.774E+14	6.774E+14	0.0750	2.662E-15	4.563E-21
8	6.043E+14	6.038E+14	0.0850	5.370E-13	8.683E-19
9	5.384E+14	5.377E+14	0.0950	2.914E-12	4.671E-18
10	2.820E+15	2.424E+15	0.1500	4.104E-07	7.092E-13
11	8.641E+14	7.916E+14	0.2500	2.630E-05	5.155E-11
12	3.860E+14	3.847E+14	0.3500	3.897E-04	8.029E-10
13	3.548E+14	2.871E+14	0.4750	6.013E-03	1.227E-08
14	1.618E+17	1.702E+14	0.6500	8.293E+01	1.725E-04
15	2.697E+14	6.290E+13	0.8250	4.723E-01	9.446E-07
16	3.591E+14	4.236E+13	1.0000	2.161E+00	4.170E-06
17	4.157E+14	2.155E+13	1.2250	1.006E+01	1.852E-05
18	1.600E+13	7.059E+12	1.4750	4.540E+00	7.990E-06
19	2.581E+13	1.611E+12	1.7000	5.550E+00	9.490E-06
20	3.373E+11	3.373E+11	1.9000	1.445E-01	2.398E-07
21	1.978E+10	1.963E+10	2.1000	1.427E-02	2.283E-08
22	3.478E+07	8.348E+06	2.3000	3.963E-05	6.103E-11
23	5.704E+07	4.177E+06	2.5000	1.002E-04	1.523E-10
24	2.828E+07	1.852E+06	2.7000	7.218E-05	1.068E-10
25	7.802E+05	7.802E+05	3.0000	3.223E-06	4.609E-12
0 TOTAL	1.898E+17	1.933E+16		1.059E+02	2.139E-04

WHC-SD-NR-ER-105 Rev. 0

9	4.716E+14	4.709E+14	0.0950	2.552E-12	4.091E-18
10	2.433E+15	2.123E+15	0.1500	3.542E-07	6.120E-13
11	7.505E+14	6.935E+14	0.2500	2.284E-05	4.477E-11
12	3.376E+14	3.371E+14	0.3500	3.409E-04	7.022E-10
13	2.895E+14	2.516E+14	0.4750	4.907E-03	1.001E-08
14	1.425E+17	1.492E+14	0.6500	7.302E+01	1.519E-04
15	1.939E+14	5.512E+13	0.8250	3.396E-01	6.793E-07
16	2.866E+14	3.712E+13	1.0000	1.724E+00	3.328E-06
17	3.292E+14	1.889E+13	1.2250	7.969E+00	1.466E-05
18	1.232E+13	6.186E+12	1.4750	3.497E+00	6.155E-06
19	2.105E+13	1.412E+12	1.7000	4.525E+00	7.738E-06
20	2.955E+11	2.955E+11	1.9000	1.266E-01	2.101E-07
21	1.719E+10	1.719E+10	2.1000	1.240E-02	1.984E-08
22	7.754E+05	1.851E+05	2.3000	8.836E-07	1.361E-12
23	1.274E+06	9.288E+04	2.5000	2.237E-06	3.401E-12
24	6.316E+05	4.130E+04	2.7000	1.612E-06	2.386E-12
25	1.743E+04	1.743E+04	3.0000	7.199E-08	1.029E-13
0. TOTAL	1.668E+17	1.692E+16		9.122E+01	1.847E-04

APPENDIX E

INDEPENDENT REVIEWER'S COMMENT

This page intentionally left blank.

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED

NUMBER: WHC-SD-NR-ER-105 Rev. 0TITLE: CONSOLIDATED FUEL SHIELDING CALCULATIONAUTHOR(s): W. D. WITTEKIND

I. Method(s) of Review

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

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

- ☒ (X) Task completely defined
- ☒ (X) Activity consistent with task specification
- ☒ (X) Necessary assumptions explicitly stated and supported
- ☒ (X) Resources properly identified and referenced
- ☒ (X) Resource documentation appropriate for this application
- ☒ (X) Input data explicitly stated
- ☒ (X) Input data verified to be consistent with original source
- ☒ (X) Geometric model adequate representation of actual geometry
- ☒ (X) Material properties appropriate and reasonable
- ☒ (X) Mathematical derivations checked including dimensional consistency
- ☒ (X) Hand calculations checked for errors
- ☒ (X) Assumptions explicitly stated and justified
- ☒ (X) Computer software appropriate for task and used within range of validity
- ☐ (NA) Use of resource outside range of established validity is justified
- ☒ (X) Software runstreams correct and consistent with results
- ☒ (X) Software output consistent with input
- ☒ (X) Results consistent with applicable previous experimental or analytical findings
- ☒ (X) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
- ☒ (X) Conclusions consistent with analytical results and established limits
- ☐ (NA) Uncertainty assesment appropriate and reasonable
- ☒ (X) Other (define) Uncertainties, although not specifically
addressed, are covered by using upper bounds.

III. Comments: The results of this study adequately address the water
shielding requirements for consolidated storage of fuel
canisters.

IV. REVIEWER: Robert L. Simons DATE: July 26, 1994

This page intentionally left blank.