MAR 06 1998

ENGINEERING DATA TRANSMITTAL

Page 1 of 1
1. EDT 623802

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) DA Burbank/TM Hohl/MJ Klem	4. Related EDT No.: NA
5. Proj./Prog./Dept./Div.: W-465, W-520	6. Design Authority/ Design Agent/Cog. Engr.: CA Petersen/DA Burbank	7. Purchase Order No.: NA
8. Originator Remarks: For approval and release		9. Equip./Component No.: NA
		10. System/Bldg./Facility: NA
11. Receiver Remarks: 11A. Design Baseline Document? ☐ Yes ☒ No		12. Major Assm. Dwg. No.: NA
		13. Permit/Permit Application No.: NA
		14. Required Response Date: --

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Trans- mittal	Originator Dispo- sition	Receiver Dispo- sition
1	HNF-2110	--	0	Phase 1 Immobilized Low-Activity Waste Operational Source Term	N/A	1,2	1	1

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

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)											
(G) Reason	(H) Disp.	(I) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(I) Name	(K) Signature	(L) Date	(M) MSIN
1	/	Design Authority CA Petersen	<i>CA Petersen</i>	3/6/98	H6-37						
		Design Agent									
1	1	Cog. Eng. DA Burbank	<i>DA Burbank</i>	3/5/98	H6-37						
1	1	Cog. Mgr. RP Marshall	<i>RP Marshall</i>	3/6/98	H5-61						
		QA									
		Safety									
		Env.									

18. TM Hohl Signature of EDT Originator <i>TM Hohl</i> Date 3/5/98	19. EC Petersen Authorized Representative Date for Receiving Organization <i>EC Petersen</i> Date 3/6/98	20. CA Petersen Design Authority/Cognizant Manager <i>CA Petersen</i> Date 3/6/98	21. DOE APPROVAL (if required) Ctrl. No. N/A ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments
---	---	--	---

Phase 1 Immobilized Low-Activity Waste Operational Source Term

D. A. Burbank, T. M. Hohl, M. J. Klem

SGN Eurisys Services Corporation, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 623802

UC: 721

Org Code: S1400

Charge Code: D4DKM

B&R Code: EW3130010

Total Pages: 107

Key Words: Low-activity waste, ILAW, Source term, TWRS, Contact-handled, Remote-handled, Phase 1, Privatization

Abstract: This report presents an engineering analysis of the Phase 1 privatization feeds to establish an operational source term for storage and disposal of immobilized low-activity waste packages at the Hanford Site. The source term information is needed to establish a preliminary estimate of the numbers of remote-handled and contact-handled waste packages. A discussion of the uncertainties and their impact on the source term and waste package distribution is also presented. It should be noted that this study is concerned with operational impacts only. Source terms used for accident scenarios would differ due to alpha and beta radiation which were not significant in this study.

TRADEMARK DISCLAIMER. 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.

Printed in the United States of America. To obtain copies of this document, contact: Document Control Services, P.O. Box 950, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2426, Fax (509) 376-4989.

A. Wickstrand
Release Approval

3.6.98
Date

Release Stamp

Approved for Public Release

HNF-2110 Rev 0

PHASE 1 IMMOBILIZED LOW-ACTIVITY WASTE OPERATIONAL SOURCE TERM

March 1998

D. A. Burbank
T. M. Hohl
M. J. Klem

SGN Eurisys Services Corporation
Richland, Washington

Prepared for:

Lockheed Martin Hanford Corporation
Richland, Washington

HNF-2110 Rev 0

This page intentionally left blank.

EXECUTIVE SUMMARY

This report presents an engineering analysis of the Tank Waste Remediation System Phase 1 privatization feeds to establish an operational source term for storage and disposal of immobilized low-activity waste packages at the Hanford Site. The source term information is needed to establish a preliminary estimate of the number of remote-handled and contact-handled waste packages. The report also presents the uncertainties and their impact on the source term and waste package distribution. It should be noted that this study covers operational impacts only. Source terms used for accident scenarios would differ because of alpha and beta radiation, which were not significant in this study.

The key conclusions of this study are that the radiation dose rate is a strong function of package wall thickness and cesium removal efficiency, that cesium removal alone will not make all the immobilized low-activity waste packages contact handled, and the waste packages from Envelope B will have a significantly higher dose rate than those from Envelopes A and C.

This study uncovered a high probability that a significant quantity of both remote-handled and contact-handled waste will be produced. A cost savings should be realized as less expensive disposal and transportation systems could be used for handling the contact-handled immobilized low-activity waste. A follow-up study should be performed when additional information from the two vendors and the revised Tank Waste Remediation System Operation and Utilization Plan are available.

HNF-2110 Rev 0

This page intentionally left blank.

CONTENTS

1.0 INTRODUCTION	1
1.1 BACKGROUND	1
1.2 OVERVIEW	1
1.3 CONCLUSIONS	2
1.4 RECOMMENDATIONS	2
2.0 PROBLEM STATEMENT	3
2.1 OBJECTIVES	3
2.2 KEY ISSUES	3
2.2.1 Solubility of Key Radionuclides	3
2.2.2 Waste Package Type	4
2.3 SCOPE AND BASIS	4
2.3.1 Phase 1 Waste Retrieval Sequence and Feed Composition	4
2.3.2 Phase 1 Waste Significant Radionuclides	5
2.3.3 Phase 1 Decay Date for Source Term	5
3.0 CONSTRAINTS AND ASSUMPTIONS	7
3.1 CONSTRAINTS	7
3.1.1 Privatization Specification Number 2	7
3.1.2 Interface Control Document	7
3.2 ASSUMPTIONS	7
3.2.1 TWRS Operation and Utilization Plan	7
3.2.2 Solubility of Waste Feed Constituents	7
3.2.3 Radionuclide Source Term	10
3.2.4 Waste Form Geometry	10
3.2.5 Waste Package Size	11
3.2.6 Waste Container Wall Thickness	11
3.2.7 Contribution to Dose Rate from Neutron Emission	12
3.3 UNCERTAINTIES	12
3.3.1 Cesium Separations Efficiency	12
3.3.2 Waste Form Geometry	12
3.3.3 Waste Package Size	12
3.3.4 Waste Container Wall Thickness	13
3.3.5 Waste Package Dose Rate Distribution	13
4.0 SOURCE TERM AND DOSE RATE ANALYSIS	14
4.1 BASE CASE	14
4.1.1 Base-Case Radionuclide Source Term	14
4.1.2 Base-Case Dose Rate Distribution	14
4.1.3 Base-Case Remote-Handled and Contact-Handled Package Counts	14
4.2 EFFECT OF WASTE CONTAINER WALL THICKNESS	14

4.2.1 Dose Rate Distribution	16
4.2.2 Remote-Handled and Contact-Handled Package Counts	16
4.3 EFFECT OF CESIUM SEPARATION EFFICIENCY	16
4.3.1 Radionuclide Source Term	16
4.3.2 Dose Rate Distribution	16
4.3.3 Remote-Handled and Contact-Handled Package Counts	16
4.4 EFFECT OF DECAYING WASTE TO FEED DELIVERY DATE BY BATCH ..	18
4.4.1 Radionuclide Source Term	18
4.4.2 Dose Rate Distribution	19
4.4.3 Remote-Handled and Contact-Handled Package Counts	19
4.5 EFFECT OF CHANGES IN WASTE LOADING	19
4.5.1 Radionuclide Source Term	19
4.5.2 Dose Rate Distribution	20
4.5.3 Remote-Handled and Contact-Handled Package Counts	20
4.6 EFFECT OF WASTE FORM GEOMETRY	22
4.6.1 Radionuclide Source Term	22
4.6.2 Dose Rate Distribution	22
4.6.3 Remote-Handled and Contact-Handled Package Counts	22
4.7 EFFECT OF WASTE PACKAGE SIZE	23
4.7.1 Dose Rate Distribution	23
4.7.2 Remote-Handled and Contact-Handled Package Counts	24
5.0 SUMMARY AND CONCLUSIONS	25
6.0 REFERENCES	26
APPENDIX A	
Radionuclide Source Terms for Base and Sensitivity Cases	A-1
APPENDIX B	
ILAW Shielding Evaluation	B-1

LIST OF FIGURES

4-1.	Contact-Handled ILAW Packages vs. Package Wall Thickness for the Base Case.	17
4-2.	Contact-Handled ILAW Packages Relative to Cesium Removal Efficiency.	17
4-3.	Effect of Decaying ILAW Source Term to Feed Delivery Date on CH Packages.	21
4-4.	Effect of Waste Loadings on Contact-Handled Package Count.	21

LIST OF TABLES

2-1.	Significant Isotopes for ILAW Operational Source Term.	6
3-1.	Specific Product Requirements of Concern for ILAW Operational Source Term.	8
3-2.	Assumptions Made for Base Case Scenario.	9
4-1.	Summary of Results for all Cases.	15
4-2.	Remote- and Contact-Handled Package Counts for Cesium Separation Efficiency Sensitivity Cases.	18
4-3.	Remote- and Contact-Handled Package Counts for Waste Loading Sensitivity Cases.	22

ACRONYMS AND ABBREVIATIONS

BBI	Best-Basis Inventory
CH	Contact-Handled
DF	Decontamination Factor
DOE	Department of Energy
DST	Double-Shell Tank
ILAW	Immobilized Low-Activity Waste
RH	Remote-Handled
TWRS	Tank Waste Remediation System
TWRSO&UP	Tank Waste Remediation System Operation and Utilization Plan

PHASE 1 IMMOBILIZED LOW ACTIVITY WASTE OPERATIONAL SOURCE TERM

1.0 INTRODUCTION

This report presents an engineering analysis of the Tank Waste Remediation System (TWRS) Phase 1 privatization feeds to establish an operational source term for storage and disposal of immobilized low-activity waste (ILAW) packages at the Hanford Site. The source term information is needed to establish a preliminary estimate of the numbers of remote-handled and contact-handled waste packages. The report also presents the uncertainties and their impact on the source term and waste package distribution. It should be noted that this study covers operational impacts only. Source terms used for accident scenarios would differ because of alpha and beta radiation, which were not significant in this study.

1.1 BACKGROUND

The interface control document for the ILAW waste product (ICD-15) (Berry 1997) and the alternatives generation analysis report for ILAW disposal (Burbank and Klem 1997) identifies the technical issues and impacts on ILAW package dose rates and establishing the preliminary estimate on quantity of remote- and contact-handled waste packages. The alternative concepts for the ILAW disposal system layouts assume that waste packages will be stacked six high, and contain a single waste type with one of four possible combinations of waste characteristics. The characteristic combinations are remote- or contact-handled mixed waste and remote- or contact-handled non-mixed waste. The different waste characteristics have different shielding and disposal system design requirements. The likelihood that remote handling equipment and shielded facilities may not be required for a significant fraction of the ILAW packages provides an opportunity for substantial cost savings over the life of the disposal program.

1.2 OVERVIEW

The mission of the TWRS ILAW disposal project is to receive, transport, store, and dispose of treated low-activity tank waste in a safe and environmentally sound manner. The ILAW disposal program schedule shows disposal capacity to be required beginning in 2005 when the ILAW storage vaults are filled to capacity. The most recent estimate of ILAW production for the maximum order quantity in Phase 1 (ending in 2011) is 11,370 packages based on retrieval and treatment of waste from 11 double-shell tanks (DST) as specified in the *Tank Waste Remediation System Operation and Utilization Plan* (Kirkbride et al. 1997). The previous estimate was 13,200 based the *TWRS Process Technical Baseline* (Orme 1996).

The Phase 2 ILAW source term and projected mixture of the estimated 85,000 packages as remote-handled and contact-handled waste will be evaluated at a future date.

1.3 CONCLUSIONS

- The radiation dose rate is a strong function of package wall thickness and cesium removal efficiency.
- Cesium removal alone will not make all the ILAW packages contact handled.
- ILAW waste packages from Envelope B have a significantly higher dose rate than those from Envelopes A and C.
- Glass marbles provide less self-shielding than monoliths and therefore produce a higher dose rate.
- Waste package size has a negligible effect on the dose rate.
- At least 50 percent of the ILAW packages will be contact handled.
- At least 25 percent of the ILAW packages will be remote handled unless additional removal of radionuclides is undertaken.

1.4 RECOMMENDATIONS

- A follow-up study should be performed when additional information from the two vendors and the revised Tank Waste Remediation System Operation and Utilization Plan (TWRSO&UP) are available.
- The key radionuclides identified in this study should be included in the process modeling portions of the revised TWRSO&UP.
- Because shielded vaults are the only type available at the beginning of Phase 1B processing, it is recommended that the higher dose rate packages, i.e., Envelope B, be processed first.

2.0 PROBLEM STATEMENT

This section describes the problem statement, the objectives, the scope and basis, and key issues identified during the analysis.

2.1 OBJECTIVES

The problem statement for this analysis is: What is the projected number of contact-handled and remote-handled ILAW packages for Phase 1 storage and disposal?

The objectives of this evaluation are as follows:

- Evaluate the inventory of radionuclides in the 11 DSTs for Phase 1 privatization based on information in the *Tank Waste Remediation System Operation and Utilization Plan* (Kirkbride et al. 1997) and the best-basis inventory (BBI) (Jones et al. 1997a, 1997b, 1997c, 1997d, and 1997e, Place 1997a, and 1997b, Shelton 1997, Shelton et al. 1997a, 1997b and 1997c). The BBI values used are the values published in August 1997, reflecting the Revision F version of the best-basis values, which are based on data published in tank characterization reports.
- Determine an operational source term for the Phase 1 ILAW feed.
- Determine the distribution of remote-handled and contact-handled ILAW for the 11,370 waste packages.

2.2 KEY ISSUES

This section describes the key issues that have been identified during the course of this analysis.

2.2.1 Solubility of Key Radionuclides

The feed staging and radionuclide solubility data from the TWRSO&UP and total inventory of other radionuclides from the BBI are used to establish source terms for the ILAW packages. The data from the TWRSO&UP is reported as solid and liquid fractions while the data from the BBI is reported as a complete tank inventory. Solubilities of the radionuclides from the BBI data are not available at this time. These radionuclides are assumed to be completely soluble and follow the sodium into the ILAW for this study. The few exceptions to this assumption which explained in Section 3.2.2.

The assumption that the BBI radionuclides are completely soluble is conservative and has an impact on the source terms generated in this study. The fiscal year (FY) 1998 revision of the TWRSO&UP is expected to contain more extensive information on radionuclide inventory and

solubility. After the revised TWRSO&UP document is available, this study should be revisited to determine the effect of any new feed staging and radionuclide solubility data.

2.2.2 Waste Package Type

The TWRS Privatization Specification 2 (DOE-RL 1996) requires that the ILAW products be in a sealed metal container that encloses the waste form and is leak tight. The closure system must remain intact for a storage period of 50 years in an ambient-temperature, ventilated enclosure. The container material must be resistant to degradation by microbial action, moisture, radiation effects, or chemical reactions with the container contents under the expected storage, handling, and disposal operations. The integrity of the container must not be jeopardized by wind, blowing sand, precipitation, sunlight, or extreme temperatures.

The above package criteria do not limit the waste container to a single metal barrier or single wall thickness. The containment could consist of multiple small packages placed inside the designated size of waste package. Detailed information on the type of waste package and containment is not available at this time.

2.3 SCOPE AND BASIS

The technical basis of this analysis is derived from the *Tank Waste Remediation System Operation and Utilization Plan* (Kirkbride et al. 1997) and best-basis inventory (Jones et al. 1997a, 1997b, 1997c, 1997d, and 1997e, Place 1997a, and 1997b, Shelton 1997, Shelton et al. 1997a, 1997b and 1997c). These source documents are described in more detail in the following subsections.

2.3.1 Phase 1 Waste Retrieval Sequence and Feed Composition

The *Tank Waste Remediation System Operation and Utilization Plan* (Kirkbride et al. 1997) establishes the operating scenario and plans for delivering the waste feed to two private contractors and overall process flowsheets for Phase 1 and Phase 2 of privatization effort. The document is to be updated regularly with the most recent inventory and sludge washing data.

Waste from 11 DSTs will be retrieved and transferred to feed staging tanks 241-AP-102 and 241-AP-104 and quantified before transfer to the private contractors' feed tanks (241-AP-106 and 241-AP-108). A total of 22 feed batches will be prepared and transferred to the private contractors.

Three feed envelopes (Envelope A, B and C) are established by the Privatization Specification 7 (DOE-RL 1996). Each envelope provides a different technical challenge for the private contractors.

2.3.2 Phase 1 Waste Significant Radionuclides

The BBI provides the inventory and estimates of chemical and radionuclide constituents for the 11 Phase 1 DSTs. From the BBI data, a selection of radionuclides that contributed a significant portion of the dose was selected. To be selected, a radionuclide must be a gamma emitter (or have a daughter that is) and contribute greater than 0.1 percent of the total dose. This selection was deemed as conservative for estimating the Phase 1 dose rate.

Table 2-1 lists the isotopes that were found to contribute greater than 0.1 percent of the dose rate for Phase 1 privatization. In addition to the following radionuclides, ^{134}Cs was identified by Savino (1998). It was not included because it will decay to a dose contribution level of less than 0.1 percent before the waste is delivered to the private contractors. See Appendix A for total dose rates. The details of the selection of the significant “key” radionuclides are presented in Appendix B.

2.3.3 Phase 1 Decay Date for Source Term

The radionuclides contained in the BBI are decayed to a uniform date of January 1, 1994. The radionuclide data in the TWRSO&UP also were decayed to a uniform date of January 1, 1994, to match the decay date of the BBI. For the base case in this study, the radionuclide data from the TWRSO&UP and BBI were decayed to July 1, 2002, for Envelopes A, B, and C. This date was chosen because it represents the approximate date that the private contractors will begin to process feed.

The decay dates and, therefore, the inventories of the radionuclides could have been adjusted to accommodate for the specific delivery date for each batch. However, a change in the schedule or processing order could limit the usability of this source term. By using the fixed date of July 1, 2002, this source term will retain its utility if schedule or processing changes occur, and offer a minor degree of conservatism as well. Section 4.4 presents a sensitivity case that studied the effects of decaying the radionuclides to the feed delivery date for each batch.

Table 2-1. Significant Isotopes for ILAW Operational Source Term.

Isotope	Half Life ¹ (yr)	Specific Activity ² (Ci/g)	Unit Dose Rate ³ $\left(\frac{mRem \cdot m^3}{hr \cdot Ci} \right)$
⁶⁰ Co	5.271	1.13E+03	6.70E+02
⁹⁰ Sr	28.78	1.38E+02	7.53E-01
¹⁰⁶ Ru	1.020	3.31E+03	4.12E+01
¹²⁵ Sb	2.758	1.04E+03	6.82E+01
¹²⁶ Sn	2.5E+5	1.14E-02	3.03E+02
¹³⁷ Cs	30.07	8.68E+01	1.10E+02
¹⁵² Eu	13.54	1.74E+02	2.54E+02
¹⁵⁴ Eu	8.593	2.70E+02	2.89E+02

Note: ¹ Source of information is Parrington (1996).

² Does not include activity of daughter products.

³ Source of information is Savino (1998), based on 1.27 cm (0.5 in.) steel shielding (package/box), marble waste form, standard waste package size and includes doses from daughter decay products.

3.0 CONSTRAINTS AND ASSUMPTIONS

This section describes the constraints and assumptions that define the framework of this analysis.

3.1 CONSTRAINTS

Constraints are requirements imposed on the system by outside agencies and are beyond control of design, construction and operating organizations.

3.1.1 Privatization Specification Number 2

The Product Requirements Section of the Privatization Specification 2 (DOE-RL 1996) controls the physical and radiological characteristics of the ILAW packages. The specific product requirements of concern to this study are listed in Table 3-1 with a description of the constraints the requirement imposes.

3.1.2 Interface Control Document

This engineering study is driven by Issue 15T, "Package Dose Rate Issue," in the interface control document (Berry 1997). This issue questions the rationale for establishing the current design basis of 100 percent remote-handled packages. The issue also directs that if the current design basis cannot be justified, a source term must be developed to determine the expected dose rates of the Phase 1 ILAW packages and from this the amount of contact- and remote-handled waste. This engineering study will provide some resolution of this issue.

3.2 ASSUMPTIONS

Assumptions are made for areas where limited information is available and the required analysis has not been completed. The main assumptions used in this analysis and the rational behind them are described in Table 3-2.

3.2.1 TWRs Operation and Utilization Plan

The source of the Phase 1 ILAW source term data is *Tank Waste Remediation System Operation and Utilization Plan* (Kirkbride et al. 1997). Therefore, all assumptions in Kirkbride et al. (1997) are implied here as well.

3.2.2 Solubility of Waste Feed Constituents

The key isotopes are ^{60}Co , ^{90}Sr , ^{106}Ru , ^{125}Sb , ^{126}Sn , ^{137}Cs , ^{152}Eu , and ^{154}Eu . The inventories of soluble ^{90}Sr and ^{137}Cs will be obtained from the TWRsO&UP. The inventories of the other six key isotopes will be obtained from the BBI. The solubilities of ^{90}Sr and ^{137}Cs are based on

Table 3-1. Specific Product Requirements of Concern for ILAW Operational Source Term.

Product Requirement	Description of Requirement
Package Description	The immobilized low-activity waste (ILAW) products shall be in the form of a package. The constituent parts of each package are: a sealed metal container enclosing a waste form, in which the ILAW product is emplaced; and optional matrix material, which may be used to encapsulate the waste form; and an optional filler material, which may be used to fill void spaces in the container before it is closed.
Waste Loading	For every gram-mole of sodium provided to the Contractor in Waste Envelopes A and C, the Contractor may produce up to 100 cm ³ of ILAW product (based on the external dimensions of the package). For every gram-mole of sodium in Waste Envelope B, the Contractor may produce up to 250 cm ³ of ILAW product (based on the external dimensions of the package).
Size and Configuration	The package shall be a rectangular metal container and shall have an external dimension, including all appurtenances, of 1.8m (length) x 1.2m (width) x 1.2m (Height), ± 0.2 m. Once a package size is selected, the dimension of all packages shall be constant and have a dimensional tolerance of ± 0.01 m.
Mass	The mass of each package shall not exceed 10,000 kg.
Void Space	The head space in the fully loaded package shall not exceed 1 percent of the total internal volume of the container. A non-compactable filler material (screened to 4 mesh size or smaller) may be used to meet this requirement. If the waste form and matrix materials are loaded into the container in a manner that results in void spaces between the emplaced pieces, the filler material shall be used to fill the void spaces. If a filler material is used, it shall be compatible with the other materials in the package.
Radionuclide Concentration Limitations	The average concentrations of ¹³⁷ Cs, ⁹⁰ Sr and ⁹⁹ Tc shall be limited as follows: ¹³⁷ Cs < 3 Ci/m ³ , ⁹⁰ Sr < 20 Ci/m ³ and ⁹⁹ Tc < 0.3 Ci/m ³ . The average concentrations shall be calculated by adding the inventories of each of the above radionuclides in the packages that have been presented to date for acceptance and dividing by the total volume of waste in these packages.
Surface Dose Rate Limitations	The dose rate at any point on the external surface of the package shall not exceed 1,000 mrem/hr.

the assumptions in the TWRSO&UP (Kirkbride et al., 1997). Unlike the isotopes tracked in the TWRSO&UP, the isotopes from the BBI are not separated into solid and liquid fractions. For this study, the BBI-based isotopes are assumed to be completely soluble in the supernatant and sludge wash liquids and follow the sodium into the ILAW package. This assumption provides a conservatively high estimate for the concentration and level of activity of radionuclides in the ILAW package.

Table 3-2. Assumptions Made for Base Case Scenario.

Area of limited information	Assumptions
Tank Waste Remediation System Operation and Utilization Plan	<ul style="list-style-type: none"> • The TWRSO&UP is one of our data sources; therefore its assumptions also are assumed for this study.
Solubility of waste feed constituents	<ul style="list-style-type: none"> • The solubility of the key isotopes ^{137}Cs and ^{90}Sr are based on the assumptions in the TWRSO&UP. • The key isotopes ^{60}Co, ^{106}Ru, ^{125}Sb, ^{126}Sn, ^{152}Eu, and ^{154}Eu are completely soluble and follow the sodium into the ILAW package for Envelopes A and C. • Ten percent of the ^{60}Co, 20 percent of the ^{125}Sb and five percent of the ^{152}Eu and ^{154}Eu in tanks AZ-101 and AZ-102 (Envelope B) are in solution. The ^{106}Ru and ^{126}Sn isotopes in AZ-101 and AZ-102 are completely soluble.
Radionuclide source term	<ul style="list-style-type: none"> • Batches are discrete with no commingling between batches. • Concentrations of ^{137}Cs, ^{90}Sr, and ^{99}Tc are held to their average concentration limit (3.0, 20.0 and 0.3 Ci/m³, respectively) in accordance with Privatization Specification 2, Section 2.2.2.8 (DOE-RL 1996).
Waste form geometry	<ul style="list-style-type: none"> • Waste form is glass (composition is LD6-5510), formed as marbles. • Waste form is 20 wt.% Na₂O for Envelopes A and C, 8 wt.% Na₂O for Envelope B. • Waste volume is 80 vol% of the external package volume. • Waste form has a specific gravity of 2.65. • No filler material or optional matrix materials in the ILAW package.
Waste package size	<ul style="list-style-type: none"> • External dimensions of 1.8 m (l) x 1.2 m (w) x 1.2 m (h), (2.6 m³).
Waste container wall thickness	<ul style="list-style-type: none"> • 1.27 cm (0.5 in.). Graphically presented over a range from 1.0 to 8.9 cm (0.4 to 3.5 in.).
Contribution to dose rate from neutron emission	<ul style="list-style-type: none"> • The contribution to the dose rate caused by neutrons is negligible.

Notes: TWRSO&UP = Tank Waste Remediation System Operation and Utilization Plan

ILAW = immobilized low-activity waste

Exceptions to this overly conservative assumption apply to the ^{60}Co , ^{125}Sb , ^{152}Eu , and ^{154}Eu solubilities in tanks 241-AZ-101 and 241-AZ-102 (Envelope B). If these isotopes are assumed to be completely soluble for these tanks, their dose contribution would comprise more than 95 percent of the dose from the ILAW waste packages in Envelope B. The high dose rate of the Envelope B waste made it prudent to more accurately represent its true radionuclide inventory.

Unpublished concentration data (Esch 1998) from supernate samples taken in 1995 from these tanks reveal that most of the cobalt, antimony, and europium are in the solids. These solids will be removed from the ILAW feed and will be handled as high-level waste. The data show that less than 8 percent of ^{60}Co , less than 17 percent of ^{125}Sb , and less than 3 percent of ^{154}Eu will

be present in the supernate when it is transferred and separated from the solids. Therefore, this study will assume that for Envelope B (Tanks 241-AZ-101 and 241-AZ-102) the inventory in solution of the cobalt isotopes will be 10 percent, antimony isotopes will be 20 percent, and europium isotopes will be 5 percent of the BBI's inventory for those isotopes. Additional work is currently under way that will update the TWRSO&UP and model the solubility of all the radionuclides in the BBI.

3.2.3 Radionuclide Source Term

The base-case radionuclide concentration of the ILAW package is 3 Ci/m³ for ¹³⁷Cs, which is the average concentration limit listed in Specification 2, Section 2.2.2.8. The other two average radionuclide concentration limits of Specification 2 are ⁹⁰Sr = 20 Ci/m³ and ⁹⁹Tc = 0.3 Ci/m³. The specific concentration for all three radionuclides will be reached in some of the waste packages. For these cases, the radionuclide concentrations will be assumed to be their average concentration limits.

The feed staging batches delivered to the private contractors are assumed to be discrete, with no commingling between batches. The scheduled batch transfers are significantly large and minimize downstream impacts or are scheduled to take advantage of low heels in the vendors' feed tanks at the beginning of a feed envelope. The large batch transfers will reduce the potential variability of significant contributors to the ILAW dose rate.

3.2.4 Waste Form Geometry

The base-case assumption of the encapsulated waste form is glass. The assumed composition of the glass is formulation LD6-5510 (20.00 wt% Na₂O, 1.52 wt% K₂O, 10.00 wt% Al₂O₃, 5.00 wt% B₂O₃, 5.00 wt% CaO, 56.78 wt% SiO₂ and 1.70 wt% "Other"). Differences in the composition of the glass are not anticipated to have an appreciable effect on the self-shielding characteristics of the glass or the dose rate.

The base-case assumption for waste form geometry is marbles. This waste form geometry is currently being used at Savannah River's M Area Remediation Site and will give a conservatively higher dose rate than the monolith and cullet waste forms.

The base-case assumption for waste loading is 73.1 cm³ of waste form per gram mole of sodium for Envelopes A and C, and 182.75 cm³ of waste form per gram mole of sodium for Envelope B. These assumptions are based on U.S. Department of Energy (DOE) guidance provided in written communication from Brown (1996). Brown (1996), from which these values were derived, provides the following guidance:

- The waste form is 20 wt% Na₂O for Envelopes A and C and 8 wt% Na₂O for Envelope B
- The waste volume is 80 vol.% of the external package volume
- The waste form has a specific gravity of 2.65.

The base-case assumption will also comply with the waste loading guidance in Specification 2, Section 2.2.2.2 (DOE-RL 1996). This specification defines the lower limit of sodium loading for the waste form based on the external package dimensions. This specification does not preclude the private contractors from using higher sodium loadings. By being based on the external package dimensions, this specification is written such that the sodium loading within the waste form itself (marbles, monoliths) is vague.

For this study, the total sodium loading of the waste form will be based on the external dimensions of the package despite which waste form geometry is used. This gives waste packages with a constant sodium inventory per package, but actual sodium loading within the glass itself would vary with the waste form studied. This basis explains why the total package count is unaffected by the change from the base case waste form (marbles) to the sensitivity case waste form (monoliths) presented in Section 4.6.

The base-case assumption for filler material is no filler material in the ILAW package. The use of a small marble waste form geometry would not require the use of filler material to fill void spaces of the package per Specification 2, Section 2.2.2.5 (DOE-RL 1996).

The base-case assumption on head space above the waste form is maximum 1 percent of the total internal volume of the container. This precludes the need for a filler material per Specification 2, Section 2.2.2.5 (DOE-RL 1996). The addition of filler materials would decrease the dose rate.

The base-case assumption is no use of optional matrix materials as allowed per Specification 2, Section 2.2.2.1 (DOE-RL 1996).

3.2.5 Waste Package Size

The base-case assumption is a package with external dimensions of 1.8 m (l) x 1.2 m (w) x 1.2 m (h) (2.6 m³) based on Specification 2, Section 2.2.2.3 (DOE-RL 1996), the median case. The base-case assumption is the mass of the package will not exceed 10,000 kg based on Specification 2, Section 2.2.2.4 (DOE-RL 1996).

3.2.6 Waste Container Wall Thickness

The base-case assumption for the wall thickness of the waste container is 1.27 cm (0.5 in.). This wall thickness is reasonably conservative and is the same thickness used in a related study of ILAW produced from Tank AN-107 waste (Holton 1997). The fixed wall thickness will be used to compare the results of the various sensitivity cases to the base case. However, unit dose rate information is available over a range of wall thicknesses, from 1.0 to 8.9 cm (0.4 to 3.5 in.) (Savino 1998). Graphical data for the different cases will be presented over this range.

3.2.7 Contribution to Dose Rate from Neutron Emission

The contribution to the dose rate caused by neutrons is assumed to be negligible. This assumption is based on a study performed by Savino (1998) of the neutron dose rate from the ILAW packages. In this study, the neutron dose rate was less than 0.01 percent of the gamma dose rate and, therefore, does not need to be accounted for separately in the evaluation of the dose rates outside the package.

3.3 UNCERTAINTIES

Uncertainties are identified where insufficient information exists to perform a required analysis. The main uncertainties identified in this analysis are described in the following sections.

3.3.1 Cesium Separations Efficiency

Cesium removal will be required to meet the ILAW specification of 3.0 Ci/m^3 ^{137}Cs . The decontamination factor (DF) required to meet the concentration limit range from 75 to 207 for Envelopes A and C, and is around 827 for Envelope B. The private contractors' might exceed the required DFs for some of these batches. The actual DFs may reduce the dose rates of some batches to reclassify the ILAW packages as contact handled. Section 4.3 presents the sensitivity of dose rate to cesium separation efficiency.

3.3.2 Waste Form Geometry

The base-case waste form geometry for this study is marbles. The other waste form geometries considered were monoliths and cullet. The marble geometry provides less self-shielding and thus a higher dose rate than the other geometries. The monolith and cullet would have a lower dose rate provided by greater self-shielding. The monolithic waste form will be studied as a sensitivity case in this study. Section 4.6 presents the results of this sensitivity case.

3.3.3 Waste Package Size

The base-case waste package size is $1.8 \text{ m} \times 1.2 \text{ m} \times 1.2 \text{ m}$ based on the nominal dimensions of the privatization specification. The privatization specification allows a contractor to deviate from these dimensions $\pm 0.2 \text{ m}$ for each side. It also requires the dimensions of all the packages to be constant and have a dimensional tolerance of $\pm 0.01 \text{ m}$ once a package size is selected. The dimensions of a package are anticipated to have a minimal effect on the surface dose rate of the package as long as the container wall thickness remains constant. However, the size of the package is indirectly proportional to the maximum allowable shielding thickness of the container because of the 10,000 kg mass limitation of the package. Section 4.7 analyzes the sensitivity of dose rate to package size.

3.3.4 Waste Container Wall Thickness

The base-case wall thickness is 1.27 cm (0.5 in.) and is based on a reasonably conservative assumption (Section 3.2.6). The wall thickness of the container has a significant effect on the dose rate. Section 4.2 analyzes the sensitivity of dose rate to wall thickness.

3.3.5 Waste Package Dose Rate Distribution

The base-case assumes the radionuclides in the waste form are homogenous for each batch. It is unlikely that the waste within an entire batch would be homogenous, but the variability is unknown. As the waste within a batch becomes less homogenous, there is a greater potential that some of the waste packages assumed to be contact handled (surface dose rate < 200 mrem/h) could have a higher dose rate and be reclassified as remote-handled waste. However, this reasoning also holds true for the opposite case; some of the remote-handled batch may qualify to become contact handled. Therefore, the effect of this uncertainty depends on the relative amounts of remote- and contact-handled wastes and how close the waste packages in a batch are to the 200 mrem/h surface dose rate.

4.0 SOURCE TERM AND DOSE RATE ANALYSIS

This section presents the results of this study. The base-case results are presented first followed by results of analyses on sensitivity cases. The sensitivity cases studied are waste container wall thickness, cesium separation efficiency, lower and higher waste loadings, waste form geometry and waste package size. Table 4-1 summarizes the results.

Dose rate contributions for unit concentrations of each key radionuclide were determined by Savino (1998). The unit dose rates were presented as a function of package wall thickness ranging from 1.0 to 8.9 cm (0.4 to 3.5 in.) and based on a steel-walled container.

4.1 BASE CASE

4.1.1 Base-Case Radionuclide Source Term

The radionuclide source term for the base case is based on the assumptions listed in Section 3.2. The source term lists the concentrations of the radionuclides of concern for each batch. The unit used for reporting the source term is curies per cubic meter of ILAW volume in the waste packages. The source term data are presented in Appendix A on page A-5.

4.1.2 Base-Case Dose Rate Distribution

The dose rate calculations were performed for uniformly distributed radionuclides in a 1.2 m x 1.2 m x 1.8 m container with steel walls measuring 1.27 cm (0.5 in.) thick. For Envelope A, the dose rates from the ILAW packages ranged from 374 to 538 mrem/hr. For Envelope C, the range of dose rates was broader, ranging from 352 to 599 mrem/hr. The dose rate from Envelope B was by far the highest at 999 mrem/hr, which by the slimmest margin, met the criteria (dose rate $\leq$ 1,000 mrem/hr.) to be acceptable as ILAW.

4.1.3 Base-Case Remote-Handled and Contact-Handled Package Counts

The Phase 1 package count for the base case is 11,370 packages. The base-case evaluation results in all the Phase 1 ILAW packages having surface dose rates of greater than or equal to 200 mrem per hour (100 percent remote-handled waste) and will require shielded transport and disposal in shielded underground vaults. The results support early studies by Eiholzer (1995), Mitchell (1995), and Mann et al. (1997).

4.2 EFFECT OF WASTE CONTAINER WALL THICKNESS

The waste container wall thickness is an important factor in this study. A thicker wall provides better radiation shielding at the expense of a reduced internal volume to waste container size (increased package count) and increased package weight. A sensitivity case is presented

Table 4-1. Summary of Results for all Cases.

Case	CH packages, count (%)	RH packages, count (%)	Total package count	Cesium DF	Waste loading	Decay date	Waste form geometry	Package size, LxWxH, m	Max wall thickness, cm (in.)
Base case	0 (0)	11,370 (100)	11,370	base case	base case	7/1/2002	marbles	1.8x1.2x1.2	8.9 (3.5)
Cs DF=210	0 (0)	11,370 (100)	11,370	210 (Env. A&C)	base case	7/1/2002	marbles	1.8x1.2x1.2	8.9 (3.5)
Cs DF=300	2,264 (19.9)	9,106 (80.1)	11,370	300 (Env. A&C)	base case	7/1/2002	marbles	1.8x1.2x1.2	8.9 (3.5)
Cs DF=1,000	7,163 (62.8)	4,227 (37.2)	11,370	1,000	base case	7/1/2002	marbles	1.8x1.2x1.2	8.9 (3.5)
Realistic decay dates	0 (0)	11,370 (100)	11,370	base case	base case	batch feed delivery date	marbles	1.8x1.2x1.2	8.9 (3.5)
Realistic decay dates and Cs DF=1,000	8,649 (76.1)	2,721 (23.9)	11,370	1,000	base case	batch feed delivery date	marbles	1.8x1.2x1.2	8.9 (3.5)
Low waste loading	0 (0)	15,550 (100)	15,550	base case	minimum	7/1/2002	marbles	1.8x1.2x1.2	8.9 (3.5)
High waste loading	0 (0)	9,101 (100)	9,101	base case	maximum	7/1/2002	marbles	1.8x1.2x1.2	8.9 (3.5)
Monolithic waste geometry	0 (0)	11,370 (100)	11,370	base case	base case	7/1/2002	monoliths	1.8x1.2x1.2	5.7 (2.2)
Large package size	0 (0)	7,542 (100)	7,542	base case	base case	7/1/2002	marbles	2.0x1.4x1.4	3.5 (1.4)

Notes:

CH = contact-handled

RH = remote-handled

Contact- and remote-handled package counts are based on a 1.27 cm (0.5 in.) package wall thickness.

that shows the effect of changing the wall thickness on the resulting contact- and remote-handled package counts.

4.2.1 Dose Rate Distribution

This sensitivity case is essentially the base-case scenario analyzed for package wall thicknesses ranging from 1.0 to 8.9 cm (0.4 to 3.5 in.). Figure 4-1 shows the percent of ILAW packages that are contact-handled over a range of wall thickness. This sensitivity case will be used to represent the base case in comparisons with the rest of the sensitivity cases.

4.2.2 Remote-Handled and Contact-Handled Package Counts

The Phase 1 ILAW package count is 100 percent remote-handled at wall thicknesses up to 2.2 cm (0.9 in.). As the wall thickness is increased from 2.2 to 3.4 cm (1.3 in.), the contact-handled package count shoots up from 0 percent to 93.7 percent. This demonstrates how sensitive the dose rate (and package classification as contact-handleable) is to the package wall thickness. The remaining 6.3 percent of the packages (all from Envelope B) also become contact handled when the wall thickness is finally increased to 4.3 cm (1.7 in.).

4.3 EFFECT OF CESIUM SEPARATION EFFICIENCY

4.3.1 Radionuclide Source Term

The base case cesium separation efficiency was increased to evaluate the impact of lower ^{137}Cs concentrations on dose rate distribution and the number of remote-handled and contact-handled waste packages. The base-case cesium separation efficiencies (DF) to meet the concentration limit of 3 Ci/m^3 of ^{137}Cs range from 75 to 207 for Envelopes A and C, and is about 827 for Envelope B. Three sensitivity cases were analyzed based on cesium DFs of 210, 300, and 1,000. The source term data for these sensitivity cases are presented in Appendix A on pages A-6 through A-8.

4.3.2 Dose Rate Distribution

The dose rate calculations were performed in the same manner as those for the base case. The only changes in the calculations were the cesium DFs. The details for the three sensitivity cases at the base-case wall thickness of 1.27 cm are listed in Table 4-2. Figure 4-2 shows the percent of ILAW packages that are contact handled for these sensitivity cases.

4.3.3 Remote-Handled and Contact-Handled Package Counts

Table 4-2 summarizes the cesium DF results for sensitivity cases 1, 2, and 3. All the 11,370 waste packages are remote handled based on a cesium DF of 210 for Envelopes A and C and a cesium DF of about 827 for Envelope B. About 20 percent (2,264) of the waste packages

Figure 4-1. Contact Handled ILAW Packages vs. Package Wall Thickness for the Base Case.

Figure 4-2. Contact Handled ILAW Packages Relative to Cesium Removal Efficiency.

become contact handled by increasing the cesium DF to 300 for Envelopes A and C and maintaining the cesium DF at about 827 for Envelope B. About 63 percent (7,143) of the waste packages are contact handled based on a cesium DF of 1,000 for Envelopes A, B, and C. As more cesium is removed at the lower DFs, more of the Phase 1 ILAW packages become contact handled. However, some of the batches within Phase 1 cannot have their dose rate lowered enough to become contact handled with higher cesium DFs alone. Increasing the cesium DF beyond 1,000 will not reclassify these batches as contact handled. These batches (primarily in Envelope B) contain appreciable amounts of ^{154}Eu , ^{60}Co , and in some cases ^{125}Sb that contribute a significant amount of the dose rate. Significant reduction in the dose rate for these batches will require other means teamed with increased cesium removal.

Table 4-2. Remote- and Contact-Handled Package Counts for Cesium Separation Efficiency Sensitivity Cases.

Sensitivity case	Decontamination factor		Contact-handled packages, count (%)	Remote-handled packages, count (%)
	Envelopes A and C	Envelope B		
Base case	Base case (~75-207)	Base case (~827)	0 (0)	11,370 (100)
1	210	Base case (~827)	0 (0)	11,370 (100)
2	300	Base case (~827)	2,264 (19.9)	9,106 (80.1)
3	1,000	1,000	7,143 (62.8)	4,227 (37.2)

4.4 EFFECT OF DECAYING WASTE TO FEED DELIVERY DATE BY BATCH

4.4.1 Radionuclide Source Term

This sensitivity case decays the radionuclides for a batch to the feed delivery date for that batch. This case was evaluated as the alternative to the single decay date for the base case (July 1, 2002). This section discusses the effect of changing the decay dates on dose rate distribution and the number of remote-handle and contact-handled packages. Another sensitivity case that combines the effects of decaying the waste to the feed delivery date by batch and enhanced cesium separation also is studied. The source terms for these sensitivity cases are presented in Appendix A on pages A-9 and A-10.

4.4.2 Dose Rate Distribution

The dose rate calculations were performed for uniformly distributed radionuclides in a 1.2 m x 1.2 m x 1.8 m container with steel walls measuring 1.27 cm (0.5 in.) thick. For Envelope A, the dose rates from the ILAW packages ranged from 367 to 516 mrem/hr. For Envelope C, the range of dose rates was broader, ranging from 350 to 541 mrem/hr. The dose rate from Envelope B was the highest at 795 mrem/hr.

It should be noted that the dose rate contributions from ^{137}Cs and, for some batches (to a much lesser degree), ^{90}Sr are not affected by the different decay dates in this sensitivity case. However, using the batch-specific decay dates reduces the DFs required to remove ^{137}Cs and ^{90}Sr to meet the ILAW specifications. An interesting case is shown by combining the effect of this sensitivity case with that of the cesium removal sensitivity case (Section 4.3, cesium DF=1,000). Figure 4-3 shows the percent of ILAW packages that are contact handled over a range of wall thicknesses for this sensitivity case.

4.4.3 Remote-Handled and Contact-Handled Package Counts

The total package count for this sensitivity case is 11,370 packages, the same as the base case. Even with the lower dose rate from the decay dates being adjusted for each individual batch, all the Phase 1 ILAW packages still have surface dose rates of greater than or equal to 200 mrem per hour (100 percent remote-handled waste) and therefore will require shielded transport and disposal in shielded underground vaults.

Results from the combined sensitivity case (cesium DF = 1,000 and radionuclides decayed by individual batch) show how well the two factors compliment each other. With just a cesium DF of 1,000 (wall thickness of 1.27 cm), the percent of ILAW packages that are contact handleable is 62.8 percent (note: higher DFs alone will not yield more CH packages). When the radionuclides also are decayed to each batch's feed delivery date, the percent of ILAW packages that are contact handleable increases to 76.1 percent, an increase of 13.3 percent (1,506 packages).

4.5 EFFECT OF CHANGES IN WASTE LOADING

This sensitivity case studies the effect of varying the waste loading on the number of remote- and contact-handled packages. The two sensitivity cases evaluated are when the sodium loading is both minimized to the limits specified in the privatization specification and maximized to the practical upper limit that retains good glass performance.

4.5.1 Radionuclide Source Term

The base case assumes a sodium loading of 73.1 cm^3 of waste package per gram mole of sodium (20 wt.% Na_2O) for Envelopes A and C, and a sodium loading of 182.75 cm^3 of waste

package per gram mole of sodium (8 wt.% Na_2O) for Envelope B. Privatization Specification 2 (DOE-RL 1996) allows a contractor to lower the sodium loading to 100 cm^3 of waste package per gram mole of sodium for Envelopes A and C, and a sodium loading of 250 cm^3 of waste package per gram mole of sodium for Envelope B. This corresponds to 14.6 wt.% Na_2O in the waste form for Envelopes A and C, and 5.8 wt.% Na_2O in the waste form for Envelope B. This will serve as the lower waste loading sensitivity case. The higher waste loading sensitivity case to be analyzed has the sodium loading increased to 58.5 cm^3 of waste package per gram mole of sodium for Envelopes A and C, and a sodium loading of 146.25 cm^3 of waste package per gram mole of sodium for Envelope B. This corresponds to 25 wt.% Na_2O in the waste form for Envelopes A and C, and 10 wt.% Na_2O in the waste form for Envelope B. These two sensitivity cases will show the relative effect of reducing or increasing the waste loading on the dose rate of the Phase 1 ILAW. The source terms for these sensitivity cases are presented in Appendix A on pages A-11 and A-12.

4.5.2 Dose Rate Distribution

The dose rate calculations were performed in the same manner as those for the base case. The only changes in the calculations were the sodium loadings. Table 4-3 lists the details for the two sensitivity cases at the base case wall thickness of 1.27 cm. Figure 4-4 shows the percent of ILAW packages that are contact-handled for these sensitivity cases.

4.5.3 Remote-Handled and Contact-Handled Package Counts

Table 4-3 presents the results of the calculations performed on the two sodium loading sensitivity cases. For both extremes of waste loading, the package counts remain at 100 percent remote handled. The most notable effect of varying the waste loading shown in the table is the change in the total number of ILAW packages. When the waste loading is lowered to the level allowed by the privatization specification, the total package count increases to 15,550 packages, a 36.8 percent increase from the 11,370 packages of the base case. Likewise, when the waste loading is increased to its practical upper limit, the total package count decreases to 9,101 packages, a 20.0 percent decrease from the base case.

Another observation that can only be gleaned from the graph in Figure 4-4 is the change in the sensitivity of the contact-handled package count (and dose rate) to varying wall thicknesses for various waste loadings. The graph shows that the ILAW packages remain remote handled up to a wall thickness of 2.2 cm (0.9 in.) regardless of the waste loading. However, an increase in the wall thickness to 3.9 cm (1.5 in.) will reclassify all the low waste loading ILAW as contact handled. For the high waste loading ILAW, a wall thickness of 4.6 cm (1.8 in.) is required to achieve the same result.

Figure 4-3. Effect of Decaying ILAW Source Term to Feed Delivery Date on CH Packages.

Figure 4-4. Effect of Waste Loadings on Contact Handled Package Count.

Table 4-3. Remote- and Contact-Handled Package Counts for Waste Loading Sensitivity Cases.

Sensitivity case	cm ³ waste/gmol Na (percent Na ₂ O)		Contact handled packages, count (%)	Remote handled packages, count (%)	Total packages, count
	Envelopes A & C (%)	Envelope B (%)			
Low waste load	100 (14.6)	250 (5.8)	0 (0)	15,550 (100)	15,550
Base case	73.1 (20.0)	182.75 (8.0)	0 (0)	11,370 (100)	11,370
High waste load	58.5 (25.0)	146.25 (10.0)	0 (0)	9,101 (100)	9,101

4.6 EFFECT OF WASTE FORM GEOMETRY

The monolithic waste form was evaluated as the alternative to marbles. This section discusses the effect of the monolithic waste form on dose rate distribution and the number of remote-handle and contact-handled packages.

4.6.1 Radionuclide Source Term

This sensitivity case required recalculation of the unit dose rate values for the monolithic waste form. The results of this recalculation, performed in Savino (1998), found that the dose rates are essentially reduced by one-third when changing from a composition of 67 percent glass/33 percent air (marbles) to 100 percent glass (monoliths) by volume. Other than this, the dose rate calculations were performed in the same manner as those for base case. The source term for this sensitivity case is presented in Appendix A on page A-13.

4.6.2 Dose Rate Distribution

For Envelope A, the dose rates from the ILAW packages ranged from 249 to 358 mrem/hr. For Envelope C, the range of dose rates was broader, ranging from 235 to 399 mrem/hr. The dose rate from Envelope B was still the highest at 666 mrem/hr, but was much lower than the base case scenario where it barely met the specifications for ILAW.

4.6.3 Remote-Handled and Contact-Handled Package Counts

The total package count for this sensitivity case is 11,370 packages, the same as the base case. Even with the lower dose rate from the monolithic waste form, all the Phase 1 ILAW

packages have surface dose rates of greater than or equal to 200 mrem per hour (100 percent remote-handled waste) and will require shielded transport and disposal in shielded underground vaults. However, the outcome of this scenario has 6,176 packages (54 percent) having a dose rate of between 200 and 300 mrem/hr compared to zero packages (0 percent) for the base case. This shows that a large number of the packages will be closer to being classified as contact handled under this scenario.

As stated in Section 3.2.4, the total sodium loadings of the waste forms in this study are based on the external dimensions of the packages. For this sensitivity case, the sodium loading within the waste form (monoliths) is 67 percent of the loading of the base case waste form (marbles). The total sodium within a package remains the same however. This basis explains why the total package count is unaffected by the change from the waste form for this sensitivity case.

4.7 EFFECT OF WASTE PACKAGE SIZE

The base-case waste package size (1.8m x 1.2m x 1.2m) was increased to the limit allowed in the privatization specification (2.0m x 1.4m x 1.4m). This size package was studied to determine the impact on the dose rate distribution and the resulting remote-handled and contact-handled package counts. The larger waste package size corresponds to the waste package size used in the Preliminary Safety Evaluation of the handling of the ILAW packages (FDNW 1997).

As stated in Section 3.3.3, the maximum waste container wall thickness depends on the waste package size and weight limit (10,000 kg). The thickest wall that could be used for a maximum size (2.0 m x 1.4 m x 1.4 m) waste container is 3.5 cm. This value is based on a steel wall container with a steel density of 7.8 g/cm³, waste in the form of marbles with a density of 2.65 g/cm³, a void space of 33.3 percent, and the 10,000 kg maximum weight limit. If similar assumptions are used for a monolithic waste form (void space of 0 percent) in the same size container, the mass of the waste form (waste and package) is greater than 10,000 kg for any container wall thickness.

4.7.1 Dose Rate Distribution

This sensitivity case required recalculation of the unit dose rate values for the larger package size. The results of this recalculation, performed in Savino (1998), found that the change in dose rate versus package wall thickness was found to be negligible when increasing the package size from the base-case size to the size in this sensitivity case. The unit dose rates for the base case also are valid for this sensitivity case. Therefore, the dose rate calculations for this sensitivity case are the same as for the base case (Section 4.1.2).

4.7.2 Remote-Handled and Contact-Handled Package Counts

The effect of the larger package size does not affect the percent breakdown of the ratio of contact- to remote-handled waste. It remains the same as the base case (Section 4.1.3) at 100 percent remote handled. It does, however, reduce the total number of packages because more waste is placed in each individual package. The total package count for this scenario is 7,542, which is 33 percent less than the total package count for the base case (11,370).

5.0 SUMMARY AND CONCLUSIONS

Results from this engineering study are based on the assumptions listed in Section 3.2. One of these assumptions was that the wall thickness of the ILAW packages would be 1.27 cm (0.5 in.) although wall thicknesses ranging from 1.0 to 8.9 cm are encompassed in this study. One of our findings was how sensitive the dose rate of the entire group of Phase 1 ILAW packages was to the package wall thickness. This sensitivity is quite evident by the steepness of the curves shown in the figures in Section 4. Because of this sensitivity, it should be noted that the remaining conclusions from this study are based on our assumed wall thickness of 1.27 cm.

This engineering study revealed that at least 50 percent of the waste most likely will be contact handled. This conclusion is based on the sensitivity case in which the cesium DF=1,000 and the radionuclides in each batch were decayed to their feed delivery date to the private contractors. This sensitivity case is considered representative of the actual conditions that the ILAW will be processed under based on our current knowledge. The cesium DF of 1,000 is only 20% greater than the DF of ~827 required to meet the privatization specification for Envelope B. It would be reasonable to assume that the privatization contractors would build at least this much excess capacity into their design for cesium removal and would use this capacity for all the ILAW feed. The validity of using actual dates for decay purposes is obvious.

This sensitivity case also revealed that not less than 25 percent of the ILAW packages will be remote handled unless additional removal of radionuclides is undertaken. The ILAW feeds contain other gamma-emitting radionuclides that contribute significantly to the dose from the waste packages. Besides ^{137}Cs , the main gamma contributors are ^{154}Eu , ^{60}Co , and ^{125}Sb . These three radionuclides all have half-lives of less than 10 years and are most evident in the waste feed for Envelope B.

We found that increasing the cesium DF beyond 1,000 has no appreciable effect on the dose rate from packages from Envelopes A and C. Even for Envelope B, the effect of additional cesium removal becomes less evident because of the dose contributions from ^{154}Eu , ^{60}Co , and ^{125}Sb . These findings strongly support our conclusion that cesium removal alone will not make all the ILAW packages contact-handled.

Two other conclusions that can be made were based on findings by Savino (1998), (Appendix B). One conclusion is that the glass marble waste form provides less self-shielding than a monolithic waste form and therefore produces a higher dose rate for a fixed package waste loading. The other conclusion is that the waste package size has a negligible effect on the dose rate for the package sizes allowed by the privatization specification.

6.0 REFERENCES

- Berry, J. B., 1997, *Interface Control Document Between DOE and the PHMC - Phase 1 Privatization - Immobilized Low-Activity Waste Product*, HNF-SP-1219 (ICD-15) Draft, Lockheed Martin Hanford Corporation, Richland, Washington.
- Burbank, D. A, M. J. Klem, 1997, *Analysis of Alternatives for Immobilized Low-Activity Waste Disposal*, HNF-SD-TWR-AGA-004, Rev 1, SGN Eurisys Services Corporation, Richland, Washington.
- Brown, N. R., 1996, DSI to R. M. Orme, Westinghouse Hanford Company, *LLW Product Waste Loading Assumptions for the TWRS Process Flowsheet*, dated April, 23.
- DOE-RL 1996, *TWRS Privatization Contract Awards*, Contracts DE-RP06-96RL13308 and DE-RP06-96RL13309, dated September 25, 1996, U.S. Department of Energy-Richland Operations Office, Richland, Washington.
- Eiholzer, C. R. 1995, *Disposal Facility Data for the Interim Performance Assessment*, WHC-SD-WM-RPT-159, Rev 0, Westinghouse Hanford Company, Richland, Washington.
- Esch, R. A., 1998, Electronic Mail to T. M. Hohl, *AZ-101 and AZ-102 Results*, February 13, 1998, Waste Management Federal Services of Hanford, Inc., Richland, Washington.
- FDNW, 1997, *Preliminary Safety Evaluation for Project W-465 Immobilized Low-Activity Waste Interim Storage Facility*, HNF-SD-W465-PSE-001 Rev 0, Fluor Daniel Northwest Incorporated, Richland, Washington.
- Holton, L. , 1997, DSI to N. R. Brown, U.S. Department of Energy-Richland Operations Office, *AN-107 Activity and Dose Rate Distribution*, dated October 15, 1997.
- Jones, T. E., R. T. Winward, M. J. Kupfer, 1997a, *Tank Characterization Report for Double Shell Tank 241-AN-106*, WHC-SD-WM-ER-569, Rev 0A, Lockheed Martin Hanford Corporation, Richland, Washington.
- Jones, T. E., R. T. Winward, M. J. Kupfer, 1997b, *Tank Characterization Report for Double Shell Tank 241-AN-107*, WHC-SD-WM-ER-600, Rev 0A, Lockheed Martin Hanford Corporation, Richland, Washington.
- Jones, T. E., R. T. Winward, M. J. Kupfer, 1997c, *Tank Characterization Report for Double Shell Tank 241-AW-101*, WHC-SD-WM-ER-470, Rev 0A, Lockheed Martin Hanford Corporation, Richland, Washington.

- Jones, T. E., R. T. Winward, M. J. Kupfer, 1997d, *Tank Characterization Report for Double Shell Tank 241-SY-101*, WHC-SD-WM-ER-409, Rev 0A, Lockheed Martin Hanford Corporation, Richland, Washington.
- Jones, T. E., R. T. Winward, M. J. Kupfer, 1997e, *Tank Characterization Report for Double Shell Tank 241-SY-103*, WHC-SD-WM-ER-471, Rev 1A, Lockheed Martin Hanford Corporation, Richland, Washington.
- Kirkbride, R. A., G. K. Allen, P. J. Certa, A. F. Manuel, R. M. Orme, L. W. Shelton, E. J. Slaathaug and R. S. Whitman (NHC), G. T. MacLean and D. L. Penwell (SESC), 1997, *Tank Waste Remediation System Operation and Utilization Plan*, HNF-SD-WM-SP-012, Rev 0A, Numatec Hanford Corporation, Richland, Washington.
- Mann, F. M. and P. D. Rittman (FDNW), J. A. Voogd (LMHC), N. K. Kline (LMSI), Y. Chen, C. R. Eiholzer and B. P. McGrail (PNNL), A. H. Lu, and G. F. Williamson (rtd.), N. R. Brown and P. E. LaMont (U.S. DOE-RL), 1997, *Hanford Low-Level Tank Waste Interim Performance Assessment*, HNF-EP-0884, Rev 1, Lockheed Martin Hanford Company, Richland, Washington.
- Mitchell, D. E., 1995, *Immobilized Low-Level Waste Disposal Options Configuration Study*, WHC-SD-WM-TI-686, Rev 0, Westinghouse Hanford Company, Richland, Washington.
- Orme, R. M. 1996, *TWRS Privatization Process Technical Baseline*, WHC-SD-WM-TI-174, Rev 0, Westinghouse Hanford Company, Richland, Washington..
- Parrington, J. R., H. D. Knox, S. L. Breneman, E. M. Baum and F. Feiner, 1996, *Nuclides and Isotopes*, Fifteenth Edition, General Electric Company and KAPL, Inc.
- Place, D. E., 1997a, *Tank Characterization Report for Double Shell Tank 241-AZ-101*, WHC-SD-WM-ER-410, Rev 0A, SGN Eurisys Services Corporation, Richland, Washington.
- Place, D. E., 1997b, *Tank Characterization Report for Double Shell Tank 241-AZ-102*, WHC-SD-WM-ER-411, Rev 0B, SGN Eurisys Services Corporation, Richland, Washington.
- Savino, A. V, 1998, *ILAW Shielding Evaluation*, EBU-RCAL-001, Rev 0, Waste Management Federal Services, Inc., Northwest Operations, Richland, Washington.
- Shelton, L. W., 1997, *Tank Characterization Report for Double Shell Tank 241-AN-102*, WHC-SD-WM-ER-545, Rev 1A, Lockheed Martin Hanford Corporation, Richland, Washington.

HNF-2110 Rev 0

Shelton, L. W., B. C. Simpson, 1997a, *Tank Characterization Report for Double Shell Tank 241-AN-103*, WHC-SD-WM-ER-702, Rev 0, Lockheed Martin Hanford Corporation, Richland, Washington.

Shelton, L. W., B. C. Simpson, 1997b, *Tank Characterization Report for Double Shell Tank 241-AN-104*, WHC-SD-WM-ER-690, Rev 0, Lockheed Martin Hanford Corporation, Richland, Washington.

Shelton, L. W., B. C. Simpson, 1997c, *Tank Characterization Report for Double Shell Tank 241-AN-105*, WHC-SD-WM-ER-678, Rev 0B, Lockheed Martin Hanford Corporation, Richland, Washington.

APPENDIX A

Radionuclide Source Terms for Base and Sensitivity Cases

HNF-2110 Rev 0

This page intentionally left blank.

CONTENTS

Source Term for the Base Case	A-5
Source Term for Cesium Separation Efficiency, DF=210 (Envelopes A and C)	A-6
Source Term for Cesium Separation Efficiency, DF=300 (Envelopes A and C)	A-7
Source Term for Cesium Separation Efficiency, DF=1,000 (Envelopes A, B and C)	A-8
Source Term for Waste Decayed to Feed Delivery Date by Batch	A-9
Source Term for Cesium DF=1,000 and Waste Decayed to Feed Delivery Date by Batch ..	A-10
Source Term for Low Waste Loading	A-11
Source Term for High Waste Loading	A-12
Source Term for Monolithic Waste Form Geometry	A-13

HNF-2110 Rev 0

This page intentionally left blank.

This sheet converts total radionuclide inventory (feed) to radionuclide concentration in glass (Ci/m³) It also displays ILAW volumes Cs, Sr and Tc loading limits and their DF's All radionuclides decayed to 7-1-2002

Data Source	half-life (y)	lambda (y ⁻¹)	Batch 1		Batch 2		Batch 3		Batch 4		Batch 5		Batch 6		Batch 7		Batch 8		Batch 9		Batch 10		Batch 11	
			A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
			C1-B1	C2-B1	C1-B2	C2-B2	C1-B3	C2-B3	C1-B4	C2-B4	C1-B5	C2-B5	C1-B6	C2-B6	C1-B7	C2-B7	C1-B8	C2-B8	C1-B9	C2-B9	C1-B10	C2-B10	C1-B11	C2-B11
Envelope																								
Stream																								
Contractor-Batch																								
Component																								
670E+02	5.271	0.1315	1.55E-02	1.55E-02	1.79E-02	1.79E-02	2.60E-02	2.60E-02	1.23E-02	1.23E-02	1.41E-01	1.41E-01	3.29E-02	3.29E-02	3.29E-02	3.29E-02	1.02E-01	1.02E-01	7.63E-04	7.63E-04	2.38E-02	2.38E-02	2.26E-02	2.26E-02
60Co			1.55E-02	1.55E-02	1.79E-02	1.79E-02	2.60E-02	2.60E-02	1.23E-02	1.23E-02	1.41E-01	1.41E-01	3.29E-02	3.29E-02	3.29E-02	3.29E-02	1.02E-01	1.02E-01	7.63E-04	7.63E-04	2.38E-02	2.38E-02	2.26E-02	2.26E-02
90Sr	28.78	0.0241	1.23E-01	1.23E-01	4.77E-01	4.77E-01	9.73E-01	9.73E-01	1.30E-01	1.30E-01	5.70E+00	5.69E+00	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	1.76E+01	2.00E+01
137Cs	2.11E+05	3.29E-06	3.00E-01	3.00E-01	1.62E-02	1.62E-02	2.50E-01	2.50E-01	2.85E-02	2.85E-02	8.86E-04	8.86E-04	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	2.80E-01	2.79E-01
125Sb	1.020	0.6796	6.68E-08	6.67E-08	3.69E-08	3.69E-08	8.67E-08	8.67E-08	5.57E-08	5.57E-08	3.06E-01	3.06E-01	5.56E-08	5.56E-08	5.56E-08	5.56E-08	6.21E-08	6.21E-08	2.65E-09	2.65E-09	4.13E-08	4.13E-08	3.93E-08	3.92E-08
126Sb	2.758	0.2513	6.01E-02	6.02E-02	3.24E-02	3.24E-02	6.40E-02	6.40E-02	3.44E-02	3.44E-02	2.86E-02	2.86E-02	5.65E-02	5.65E-02	5.65E-02	5.65E-02	7.74E-03	7.74E-03	1.77E-03	1.77E-03	3.73E-02	3.73E-02	3.55E-02	3.61E-02
137Cs	2.5E+05	2.77E-06	1.27E-02	1.27E-02	6.32E-03	6.32E-03	1.04E-02	1.04E-02	6.32E-03	6.32E-03	5.68E-02	5.68E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.30E-02	1.30E-02	3.35E-04	3.35E-04	9.77E-03	9.78E-03	7.55E-03	9.22E-03
137Cs	30.07	0.0231	1.85E+00	1.85E+00	2.19E+00	2.19E+00	2.95E+00	2.95E+00	2.32E+00	2.32E+00	3.00E+00	3.00E+00	2.76E+00	2.76E+00	2.76E+00	2.76E+00	1.61E+00	1.61E+00	1.78E+00	1.78E+00	1.07E+00	1.07E+00	1.13E+00	1.14E+00
137Cs	13.54	0.0512	6.68E-03	6.67E-03	3.45E-03	3.45E-03	5.32E-03	5.32E-03	3.44E-03	3.44E-03	7.58E-03	7.58E-03	6.51E-03	6.51E-03	6.51E-03	6.51E-03	1.08E-02	1.08E-02	1.66E-04	1.66E-04	5.08E-03	5.08E-03	4.83E-03	4.80E-03
154Eu	8.593	0.0807	1.09E-01	1.09E-01	1.25E-01	1.25E-01	6.22E-01	6.22E-01	1.02E-01	1.02E-01	1.18E+00	1.18E+00	7.67E-01	7.67E-01	7.67E-01	7.67E-01	7.78E-02	7.78E-02	1.90E-02	1.90E-02	6.00E-01	6.00E-01	5.70E-01	4.76E-01

	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³
TWRSO&UP	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	5.47E+00	5.47E+00	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01

	vol/Na (cm ³ /gmol Na)	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	182.75	182.75	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1
Total ext. package vol. (based on Na loading)		1635.0	1631.9	1700.6	1700.4	1361.5	1361.5	1858.6	1858.6	935.6	932.1	378.9	378.9	864.6	864.7	1517.8	1517.8	1305.2	1305.2	1858.6	1858.6	1437.5	1437.5	1071.1
Total waste volume (80% of package volume)		1308.0	1305.5	1360.4	1360.3	1089.2	1089.2	1486.9	1486.9	748.5	737.6	303.1	303.1	691.7	691.8	1214.2	1214.2	1044.2	1044.2	1505.4	1505.4	1150.0	1150.0	858.8
Number of packages:		830	628	655	655	524	524	716	716	360	355	146	146	333	333	585	585	503	503	753	753	554	554	413

Volume of package (m³): 2.6

DF's used for calculation	¹³⁷ Cs DF	210,000	210,000	210,000	210,000	210,000	210,000	210,000	210,000	210,000	827,179	826,087	210,000	210,000	210,000	210,000	210,000	210,000	210,000	210,000	210,000	210,000	210,000	210,000
⁹⁰ Sr DF	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
¹³⁷ Cs DF	1,442	1,449	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,305	1,305	1,307	1,306	1,503	1,503	7,184	7,184	1,129	1,115	1,000	1,000

¹³⁷ Cs in batch at limit of	3.0	Ci/m ³	3924.1	3916.5	4081.3	4081.0	3267.6	3267.5	4460.7	4460.7	2245.5	2212.9	909.3	909.3	2075.1	2075.4	3642.6	3642.6	3132.6	3132.6	4696.3	4694.0	3450.1	2570.5
⁹⁰ Sr in batch at limit of	20.0	Ci/m ³	26180.5	26109.8	27208.9	27207.0	21783.7	21783.7	29737.7	29737.7	14969.7	14752.8	6061.7	6061.7	13834.2	13835.9	24284.2	24284.2	20883.8	20883.8	31293.1	31293.1	23004.4	17136.8
¹³⁷ Cs in batch at limit of	0.3	Ci/m ³	392.4	391.6	408.1	408.1	326.8	326.8	446.1	446.1	224.5	221.3	90.9	90.9	207.5	207.5	364.3	364.3	313.3	313.3	469.4	469.4	345.0	257.1

minimum ¹³⁷ Cs DF to achieve 3.0 Ci ¹³⁷ Cs/m ³	129.544	129.795	153.295	153.306	206.432	206.432	162.175	162.175	827.179	826.087	193.525	193.524	193.147	193.123	112.716	112.716	124.828	124.828	74.938	74.938	79.338	79.864
minimum ⁹⁰ Sr DF to achieve 20.0 Ci ⁹⁰ Sr/m ³	0.006	0.006	0.024	0.024	0.049	0.049	0.007	0.007	0.285	0.284	6.681	6.681	6.587	6.586	5.003	5.003	1.454	1.454	1.294	1.294	0.880	1.183
minimum ¹³⁷ Cs DF to achieve 0.3 Ci ¹³⁷ Cs/m ³	1.442	1.449	0.054	0.054	0.835	0.835	0.095	0.095	0.003	0.003	1.305	1.305	1.307	1.306	1.503	1.503	7.184	7.184	1.129	1.115	0.933	0.929

Decay date	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02
------------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

Wall Thickness (cm): 1.27

Dose from box per 1 Ci/m ³ (mrem/h)	Batch 1		Batch 2		Batch 3		Batch 4		Batch 5		Batch 6		Batch 7		Batch 8		Batch 9		Batch 10		Batch 11	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	C1-B1	C2-B1	C1-B2	C2-B2	C1-B3	C2-B3	C1-B4	C2-B4	C1-B5	C2-B5	C1-B6	C2-B6	C1-B7	C2-B7	C1-B8	C2-B8	C1-B9	C2-B9	C1-B10	C2-B10	C1-B11	C2-B11
6.70E+02 60Co	10.38	10.41	12.00	12.00	17.40	17.40	8.25	8.25	94.67	94.67	22.02	22.02	22.02	22.02	22.02	22.02	22.02	22.02	22.02	22.02	22.02	22.02
7.53E-01 90Sr (& 90Y)	0.09	0.09	0.35	0.35	0.73	0.73	0.10	0.10	4.29	4.29	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06
4.12E+01 106Ru (& 106Rh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.82E+01 125Sb	4.10	4.11	2.21	2.21	4.37	4.37	2.35	2.35	195.36	195.31	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86
3.03E+02 126Sb (126mSb, 126Sb)	3.84	3.85	1.91	1.91	3.14	3.14	1.91	1.91	17.19	17.19	3.31	3.32	3.32	3.31	3.32	3.32	3.31	3.32	3.32	3.31	3.32	3.31
1.10E+02 137Cs (& 137mBa)	204.03	204.43	241.44	241.45	325.13	325.13	255.42	255.42	330.75	330.75	304.80	304.80	304.20	304.17	177.53	177.53	196.60	196.60	118.03	118.03	124.96	124.96
2.54E+02 152Eu	1.69	1.70	0.88	0.88	1.35	1.35	0.88	0.88	1.93	1.93	1.66	1.66	1.66	1.66	2.76	2.76	0.04	0.04	1.29	1.29	1.00	1.00
2.69E+02 154Eu	31.48	31.54	36.21	36.21	179.96	179.96	29.60	29.60	342.19	342.44	221.90	221.95	221.96	221.91	22.50	22.50	5.51	5.51	173.55	173.55	114.69	114.69
TOTAL	255.62	256.11	295.00	295.02	532.09	532.09	298.51	298.51	999.91	999.40	572.60	572.68	572.08	571.98	290.79	290.79	217.94	217.94	329.38	329.38	269.30	269.30

isotope (w/daughters)	4.06%	4.06%	4.07%	4.0
-----------------------	-------	-------	-------	-----

This sheet converts total radionuclide inventory (feed) to radionuclide concentration in glass (Ci/m³) It also displays ILAW volumes Cs, Sr and Tc loading limits and their DF's All radionuclides decayed to 7-1-2002

Data Source	half-life (y)	lambda (y ⁻¹)	Envelope Stream	Contractor-Batch	Component	Batch 1		Batch 2		Batch 3		Batch 4		Batch 5		Batch 6		Batch 7		Batch 8		Batch 9		Batch 10		Batch 11	
						A	A	A	A	A	A	A	A	B	B	C	C	C	C	C	C	C	C	C-west	C-west	C-west	C-west
						C1-B1	C2-B1	C1-B2	C2-B2	C1-B3	C2-B3	C1-B4	C2-B4	C1-B5	C2-B5	C1-B6	C2-B6	C1-B7	C2-B7	C1-B8	C2-B8	C1-B9	C2-B9	C1-B10	C2-B10	C1-B11	C2-B11
BB1	5.271	0.1315			⁶⁰ Co	1.55E-02	1.55E-02	1.79E-02	1.79E-02	2.80E-02	2.80E-02	1.23E-02	1.23E-02	1.41E-01	1.41E-01	3.29E-02	3.29E-02	3.29E-02	3.29E-02	1.02E-01	1.02E-01	7.63E-04	7.63E-04	2.38E-02	2.38E-02	1.68E-02	2.00E-02
TWRSO&UP	28.78	0.0241			⁹⁰ Sr	1.23E-01	1.20E-01	4.77E-01	4.77E-01	9.73E-01	9.73E-01	1.30E-01	1.30E-01	5.70E+00	5.69E+00	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	1.76E+01	2.00E+01
TWRSO&UP	2.11E+05	3.29E-06			⁹⁹ Tc	3.00E-01	3.00E-01	1.62E-02	1.62E-02	2.50E-01	2.50E-01	2.85E-02	2.85E-02	8.88E-04	8.98E-04	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	2.80E-01	2.79E-01
BB1	1.020	0.6796			¹³⁷ Cs	6.66E-08	6.67E-08	3.69E-08	3.69E-08	8.67E-08	8.67E-08	5.57E-08	5.57E-08	3.06E-01	3.06E-01	5.56E-08	5.56E-08	5.56E-08	5.56E-08	5.56E-08	5.56E-08	6.21E-08	6.21E-08	2.65E-09	2.65E-09	4.13E-08	3.93E-08
BB1	2.758	0.2513			¹³⁴ Sr	6.01E-02	6.02E-02	3.24E-02	3.24E-02	6.40E-02	6.40E-02	3.44E-02	3.44E-02	2.86E+00	2.87E+00	5.65E-02	5.65E-02	5.65E-02	5.65E-02	7.74E-03	7.74E-03	1.77E-03	1.77E-03	3.73E-02	3.55E-02	2.95E-02	3.61E-02
BB1	2.5E+05	2.77E-06			¹³⁵ Sr	1.27E-02	1.27E-02	6.32E-03	6.32E-03	1.04E-02	1.04E-02	6.32E-03	6.32E-03	5.68E-02	5.68E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.30E-02	1.30E-02	3.35E-04	3.35E-04	9.77E-03	9.28E-03	7.55E-03	9.22E-03
TWRSO&UP	30.07	0.0231			¹³⁷ Cs	1.30E+00	1.30E+00	1.53E+00	1.53E+00	2.06E+00	2.06E+00	1.62E+00	1.62E+00	3.00E+00	3.00E+00	1.94E+00	1.94E+00	1.93E+00	1.93E+00	1.13E+00	1.13E+00	1.25E+00	1.25E+00	7.49E-01	7.50E-01	7.93E-01	7.99E-01
BB1	13.54	0.0512			¹³⁴ Sr	6.68E-03	6.67E-03	3.45E-03	3.45E-03	5.32E-03	5.32E-03	3.44E-03	3.44E-03	7.59E-03	7.59E-03	6.51E-03	6.51E-03	6.51E-03	6.51E-03	1.08E-02	1.08E-02	1.66E-04	1.66E-04	5.08E-03	4.83E-03	3.93E-03	4.80E-03
BB1	8.593	0.0807			¹³⁵ Sr	1.09E-01	1.09E-01	1.25E-01	1.25E-01	1.62E-01	1.62E-01	1.02E-01	1.02E-01	1.18E+00	1.18E+00	7.67E-01	7.67E-01	7.67E-01	7.67E-01	7.78E-01	7.78E-01	1.90E-02	1.90E-02	6.00E-01	5.70E-01	3.97E-01	4.76E-01

	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³
TWRSO&UP	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	5.47E+00	5.47E+00	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01

	volNa (cm ³ /mol Na)	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1
Total ext. package vol. (based on Na loading):		1635.0	1631.9	1700.6	1700.4	1361.5	1361.5	1858.6	1858.6	935.6	922.1	378.9	378.9	664.6	654.7	1517.8	1517.8	1305.2	1305.2	1956.8	1955.8	1437.5	1071.1				
Total waste volume (80% of package volume):		1308.0	1305.5	1360.4	1360.3	1089.2	1089.2	1486.9	1486.9	748.5	737.6	303.1	303.1	691.7	691.8	1214.2	1214.2	1044.2	1044.2	1565.4	1564.7	1150.0	858.8				
Number of packages:		630	628	655	655	524	524	716	716	360	355	146	146	333	333	585	585	503	503	753	753	554	413				

Volume of package (m ³):	2.6
--------------------------------------	-----

DF's used for calculation	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000
¹³⁷ Cs DF	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
⁹⁰ Sr DF	1.442	1.449	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
⁹⁹ Tc DF	1.442	1.449	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

¹³⁷ Cs in batch at limit of	3.0	Ci/m ³	3924.1	3916.5	4081.3	4081.0	3287.6	3287.5	4480.7	4480.7	2245.5	2212.9	909.3	909.3	2075.1	2075.1	3642.6	3642.6	3132.6	3132.6	4696.3	4696.4	3450.1	2570.5			
⁹⁰ Sr in batch at limit of	20.0	Ci/m ³	26160.5	26109.8	27208.9	27207.0	21783.7	21783.7	29737.7	29737.7	14969.7	14752.6	6061.7	6061.7	13834.2	13835.9	24284.2	24284.2	20683.8	20683.8	31308.4	31293.1	23000.4	17136.8			
⁹⁹ Tc in batch at limit of	0.3	Ci/m ³	392.4	391.6	408.1	408.1	328.6	328.6	446.1	446.1	224.5	221.3	90.9	90.9	207.5	207.5	364.3	364.3	313.3	313.3	469.6	469.6	345.0	257.1			
minimum ¹³⁷ Cs DF to achieve 3.0 Ci ¹³⁷ Cs/m ³			129.544	129.795	153.295	153.306	206.432	206.432	162.175	162.175	827.179	826.087	193.525	193.524	193.147	193.123	112.716	112.716	124.828	124.828	74.938	74.975	79.338	79.864			
minimum ⁹⁰ Sr DF to achieve 20.0 Ci ⁹⁰ Sr/m ³			0.006	0.006	0.024	0.024	0.049	0.049	0.007	0.007	0.285	0.284	6.681	6.681	6.587	6.586	5.003	5.003	1.454	1.454	1.294	1.294	0.880	1.182			
minimum ⁹⁹ Tc DF to achieve 0.3 Ci ⁹⁹ Tc/m ³			1.442	1.449	0.054	0.054	0.835	0.835	0.095	0.095	0.003	0.003	1.305	1.305	1.307	1.306	1.503	1.503	7.184	7.184	1.129	1.129	0.933	0.929			

Decay date	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02
------------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

Wall Thickness (cm): 1.27

Dose from box per 1 Ci/m ³ (mrem/h)	Isotope (w/daughters)	C1-B1		C2-B1		C1-B2		C2-B2		C1-B3		C2-B3		C1-B4		C2-B4		C1-B5		C2-B5		C1-B6		C2-B6		C1-B7		C2-B7		C1-B8		C2-B8		C1-B9		C2-B9		C1-B10		C2-B10		C1-B11		C2-B11		C1-B12		C2-B12																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
		mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h

This sheet converts total radionuclide inventory (feed) to radionuclide concentration in glass (Ci/m³) It also displays ILAW volumes Cs, Sr and Tc loading limits and their DF's All radionuclides decayed to 7-1-2002

Data Source	half-life (y)	lambda (y ⁻¹)	Component	Batch 1		Batch 2		Batch 3		Batch 4		Batch 5		Batch 6		Batch 7		Batch 8		Batch 9		Batch 10		Batch 11	
				A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
				C1-B1	C2-B1	C1-B2	C2-B2	C1-B3	C2-B3	C1-B4	C2-B4	C1-B5	C2-B5	C1-B6	C2-B6	C1-B7	C2-B7	C1-B8	C2-B8	C1-B9	C2-B9	C1-B10	C2-B10	C1-B11	C2-B11
BB1	5.271	0.1315	⁶⁰ Co	1.65E-02	1.55E-02	1.79E-02	1.79E-02	2.60E-02	2.60E-02	1.23E-02	1.23E-02	1.41E-01	1.41E-01	3.29E-02	3.29E-02	3.29E-02	3.29E-02	1.02E-01	1.02E-01	7.63E-04	7.63E-04	2.38E-02	2.38E-02	1.66E-02	2.00E-02
TWRSO&UP	28.78	0.0241	⁹⁰ Sr	1.23E-01	1.20E-01	4.77E-01	4.77E-01	9.73E-01	9.73E-01	1.30E-01	1.30E-01	5.70E+00	5.89E+00	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	1.76E+01	2.00E+01
BB1	1.020	0.6796	¹³⁷ Cs	3.00E-01	3.00E-01	1.62E-02	1.62E-02	2.50E-01	2.50E-01	2.85E-02	2.85E-02	8.86E-04	8.86E-04	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	2.80E-01	2.79E-01
BB1	2.758	0.2513	¹³⁵ Sr	6.66E-08	6.67E-08	3.69E-08	3.69E-08	6.87E-08	6.87E-08	5.57E-08	5.57E-08	3.06E-01	3.06E-01	5.56E-08	5.56E-08	5.56E-08	5.56E-08	6.21E-08	6.21E-08	2.65E-09	2.65E-09	4.13E-08	3.93E-08	3.21E-08	3.92E-08
BB1	2.5E+05	2.77E-06	¹³⁵ Sr	6.01E-02	6.02E-02	3.24E-02	3.24E-02	6.40E-02	6.40E-02	3.44E-02	3.44E-02	2.86E+00	2.86E+00	5.65E-02	5.65E-02	5.65E-02	5.65E-02	7.74E-03	7.74E-03	1.77E-03	1.77E-03	3.73E-02	3.55E-02	2.95E-02	3.61E-02
TWRSO&UP	30.07	0.0231	¹³⁷ Cs	1.27E-02	1.27E-02	6.32E-03	6.32E-03	1.04E-02	1.04E-02	6.32E-03	6.32E-03	5.68E-02	5.68E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.30E-02	1.30E-02	3.35E-04	3.35E-04	9.77E-03	9.28E-03	7.55E-03	9.22E-03
BB1	13.54	0.0512	¹³⁷ Cs	3.89E-01	3.89E-01	4.60E-01	4.60E-01	6.19E-01	6.19E-01	6.19E-01	6.19E-01	4.87E-01	4.87E-01	5.81E-01	5.81E-01	5.79E-01	5.79E-01	3.38E-01	3.38E-01	3.74E-01	3.74E-01	2.25E-01	2.25E-01	2.38E-01	2.40E-01
BB1	8.593	0.0807	¹⁵² Eu	6.66E-03	6.67E-03	3.45E-03	3.45E-03	5.32E-03	5.32E-03	3.44E-03	3.44E-03	7.58E-03	7.58E-03	5.51E-03	5.51E-03	5.51E-03	5.51E-03	1.08E-02	1.08E-02	1.66E-04	1.66E-04	5.08E-03	4.83E-03	3.93E-03	4.80E-03
BB1			¹⁵² Eu	1.09E-01	1.09E-01	1.25E-01	1.25E-01	6.22E-01	6.22E-01	1.02E-01	1.02E-01	1.18E+00	1.18E+00	1.67E-01	1.67E-01	1.67E-01	1.67E-01	7.78E-02	7.78E-02	1.90E-02	1.90E-02	6.00E-01	5.70E-01	3.97E-01	4.76E-01
				kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³
TWRSO&UP	--	--	Na+	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	5.47E+00	5.47E+00	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
				volNa (cm ³ /gmol Na)	73.1	73.1	73.1	73.1	73.1	73.1	73.1	182.75	182.75	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1
				Total ext. package vol. (based on Na loading)	1635.0	1631.9	1700.6	1700.4	1361.5	1361.5	1858.6	936.6	922.1	378.9	378.9	864.6	864.7	1517.8	1517.8	1305.2	1305.2	1956.8	1955.8	1437.5	1071.1
				Total waste volume (80% of package volume)	1308.0	1306.5	1360.4	1360.3	1089.2	1089.2	1466.9	746.5	737.6	303.1	303.1	691.7	691.8	1214.2	1214.2	1044.2	1044.2	1565.4	1564.7	1150.0	856.8
				Number of packages:	630	628	655	655	524	524	716	360	355	146	146	333	333	585	585	503	503	753	753	554	413
Volume of package (m ³):				2.6																					

This data is the calculation of external volume, waste volume and package counts based on the sodium loading. This value also determines the DF's for Cs, Sr and Tc

This section lists the DF's used to arrive at the Cs, Sr and Tc concentrations. If a value of 1.000 is listed, no removal of the radionuclide will be done.

This section lists the amounts of Cs, Sr and Tc in a batch based on their "maximum average concentration" The concentration limits are entered in cells C34 to C36.

This section lists the minimum DF's to achieve the "maximum average concentration." Values > 1 will require decon to take place, values < 1 are assumed to be 1 for calculation in the DF list two above this one.

These are the decay dates used for each batch

Here is the individual dose contribution for each radionuclide for each batch.

Percent dose contribution per radionuclide per batch.

contact handled (CH) packages:		630	628	655	655	0	0	716	716	0	0	0	0	0	0	0	585	585	503	503	0	0	554	413	7143	62.8%
remote handled (RH) packages:		0	0	0	0	524	524	0	0	360	355	146	146	333	333	0	0	0	0	753	753	0	0	4227	37.2%	
TOTAL																									11370	
1000 nrem/hr or less (within Spec.):		630	628	655	655	524	524	716	716	360	355	146	146	333	333	585	585	503	503	753	753	554	413	11370	100.0%	

Source Term for Waste Decayed to Feed Delivery Date by Batch

HNF-2110 Rev. 0

This sheet converts total radionuclide inventory (feed) to radionuclide concentration in glass (C/m³)
It also displays ILAW volumes Cs, Sr and Tc loading limits and their DF's
All radionuclides decayed to Feed Delivery Date by Batch

Data Source			half-life (y ⁻¹)			lambda (y ⁻¹)			Envelope Stream			Contractor-Batch Component			Batch 1		Batch 2		Batch 3		Batch 4		Batch 5		Batch 6		Batch 7		Batch 8		Batch 9		Batch 10		Batch 11											
															A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
															C1-B1	C2-B1	C1-B2	C2-B2	C1-B3	C2-B3	C1-B4	C2-B4	C1-B5	C2-B5	C1-B6	C2-B6	C1-B7	C2-B7	C1-B8	C2-B8	C1-B9	C2-B9	C1-B10	C2-B10	C1-B11	C2-B11										
															C1-B1	C2-B1	C1-B2	C2-B2	C1-B3	C2-B3	C1-B4	C2-B4	C1-B5	C2-B5	C1-B6	C2-B6	C1-B7	C2-B7	C1-B8	C2-B8	C1-B9	C2-B9	C1-B10	C2-B10	C1-B11	C2-B11										
BEI	5.271	0.1315	¹³⁷ Cs	1.55E-02	1.55E-02	1.67E-02	1.67E-02	2.20E-02	2.20E-02	9.66E-03	9.66E-03	9.88E-02	9.88E-02	2.21E-02	2.20E-02	2.18E-02	2.18E-02	6.46E-02	6.45E-02	4.42E-04	4.42E-04	1.28E-02	1.22E-02	7.99E-03	9.65E-03																					
TWRSO&UP	28.78	0.0241	⁹⁰ Sr	1.23E-01	1.20E-01	4.71E-01	4.71E-01	9.44E-01	9.44E-01	1.25E-01	1.25E-01	5.34E+00	5.33E+00	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	1.54E+01	2.00E+01																					
BB1	1.020	0.6798	¹³⁷ Cs	3.00E-01	3.00E-01	1.62E-02	1.62E-02	2.50E-01	2.50E-01	2.85E-02	2.85E-02	8.86E-04	8.86E-04	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	1.54E+01	2.00E+01																					
BB1	2.758	0.2513	⁹⁰ Sr	6.66E-08	6.67E-08	2.58E-08	2.57E-08	3.70E-08	3.67E-08	1.59E-08	1.58E-08	4.82E-02	4.82E-02	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.80E+01	2.79E+01																					
BB1	2.56E+05	0.0039	¹²⁹ Xe	6.01E-02	6.02E-02	2.84E-02	2.83E-02	4.67E-02	4.66E-02	2.16E-02	2.16E-02	1.45E+00	1.45E+00	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	1.54E+01	2.00E+01																					
TWRSO&UP	30.07	0.0231	¹³⁷ Cs	1.27E-02	1.27E-02	6.32E-03	6.32E-03	1.04E-02	1.04E-02	6.32E-03	6.32E-03	5.68E-02	5.68E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.30E-02	1.30E-02	3.35E-04	3.35E-04	9.77E-03	9.28E-03	7.55E-03	9.22E-03																					
BB1	13.54	0.0512	¹³⁷ Cs	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00																					
BB1	8.593	0.0807	¹⁵⁴ Eu	6.66E-03	6.67E-03	3.36E-03	3.36E-03	4.99E-03	4.99E-03	3.13E-03	3.13E-03	6.59E-03	6.59E-03	5.57E-03	5.57E-03	5.55E-03	5.54E-03	9.07E-03	9.07E-03	1.34E-04	1.34E-04	3.99E-03	3.79E-03	2.96E-03	3.61E-03																					
				kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³																					
				1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	5.47E+00	5.47E+00	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01																					
				vol/Na (cm ³ /gmol Na)	73.1	73.1	73.1	73.1	73.1	73.1	73.1	182.75	182.75	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1	73.1																					
				Total ext. package vol. (based on Na loading)	1635.0	1631.9	1700.6	1700.4	1361.5	1361.5	1858.6	1858.6	935.6	922.1	378.9	378.9	864.6	864.7	1517.8	1517.8	1308.2	1305.2	1956.8	1955.8	1071.1																					
				Total waste volume (80% of package volume)	1308.0	1305.5	1360.4	1360.3	1089.2	1089.2	1485.9	1486.9	748.5	737.6	303.1	303.1	691.7	691.8	1214.2	1214.2	1044.2	1044.2	1565.4	1564.7	1150.0																					
				Number of packages:	630	628	655	655	524	524	716	716	360	355	146	146	333	333	585	585	503	503	753	753	554																					
				Volume of package (m ³):	2.6																																									

This data is the calculation of external volume, waste volume and package counts based on the sodium loading. This value also determines the DF's for Cs, Sr and Tc

DF's used for calculation	¹³⁷ Cs DF																													
	129.544 129.795 151.449 151.431 200.550 200.500 155.402 155.372 776.932 775.857 180.444 180.408 179.762 179.706 104.001 103.975 113.445 113.424 67.221 67.237 69.807 70.256																													
	⁹⁰ Sr DF 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 6.210 6.209 6.111 6.109 4.600 4.598 1.316 1.316 1.155 1.155 1.000 1.000																													
¹³⁷ Cs DF 1.442 1.449 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.305 1.304 1.306 1.306 1.503 1.503 7.183 7.183 1.129 1.115 1.000 1.000																														
¹³⁷ Cs in batch at limit of	3.0	Ci/m ³	3924.1 3916.5 4081.3 4081.0 3267.6 3267.5 4460.7 4460.7 2245.5 2212.9 909.3 909.3 2075.1 2075.4 3642.6 3642.6 3132.6 3132.6 4696.3 4694.0 3450.1 2570.5																											
			26160.5 26109.8 27208.9 27207.0 21783.7 21783.7 29737.7 29737.7 14969.7 14752.8 6061.7 6061.7 13834.2 13835.9 24284.2 24284.2 20883.8 20883.8 31293.1 31293.1 23000.4 17136.8																											
			392.4 391.6 408.1 408.1 326.8 326.8 446.1 446.1 224.5 221.3 90.9 90.9 207.5 207.5 364.3 364.3 313.3 313.3 469.6 469.4 345.0 257.1																											
⁹⁰ Sr in batch at limit of	20.0	Ci/m ³	26160.5 26109.8 27208.9 27207.0 21783.7 21783.7 29737.7 29737.7 14969.7 14752.8 6061.7 6061.7 13834.2 13835.9 24284.2 24284.2 20883.8 20883.8 31293.1 31293.1 23000.4 17136.8																											
¹³⁷ Cs in batch at limit of	0.3	Ci/m ³	392.4 391.6 408.1 408.1 326.8 326.8 446.1 446.1 224.5 221.3 90.9 90.9 207.5 207.5 364.3 364.3 313.3 313.3 469.6 469.4 345.0 257.1																											
minimum ¹³⁷ Cs DF to achieve 3.0 Ci ¹³⁷ Cs/m ³	3.0	Ci/m ³	129.544 129.795 151.449 151.431 200.550 200.500 155.402 155.372 776.932 775.857 180.444 180.408 179.762 179.706 104.001 103.975 113.445 113.424 67.221 67.237 69.807 70.256																											
			0.006 0.006 0.024 0.024 0.047 0.047 0.006 0.006 0.267 0.266 6.210 6.209 6.111 6.109 4.600 4.598 1.316 1.316 1.155 1.155 1.000 1.000																											
			1.442 1.449 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.305 1.304 1.306 1.306 1.503 1.503 7.183 7.183 1.129 1.115 0.933 0.933																											
minimum ⁹⁰ Sr DF to achieve 20.0 Ci ⁹⁰ Sr/m ³	20.0	Ci/m ³	26160.5 26109.8 27208.9 27207.0 21783.7 21783.7 29737.7 29737.7 14969.7 14752.8 6061.7 6061.7 13834.2 13835.9 24284.2 24284.2 20883.8 20883.8 31293.1 31293.1 23000.4 17136.8																											
minimum ¹³⁷ Cs DF to achieve 0.3 Ci ¹³⁷ Cs/m ³	0.3	Ci/m ³	392.4 391.6 408.1 408.1 326.8 326.8 446.1 446.1 224.5 221.3 90.9 90.9 207.5 207.5 364.3 364.3 313.3 313.3 469.6 469.4 345.0 257.1																											

This section lists the DF's used to arrive at the Cs, Sr and Tc concentrations. If a value of 1.000 is listed, no removal of the radionuclide will be done.

This section lists the amounts of Cs, Sr and Tc in a batch based on their "maximum average concentration". The concentration limits are entered in cells C34 to C36.

This section lists the minimum DF's to achieve the "maximum average concentration." Values > 1 will require decon to take place, values < 1 are assumed to be 1 for calculation in the DF list two above this one.

These are the decay dates used for each batch

Decay date		7/1/02	7/1/02	1/9/03	1/12/03	10/2/03	10/6/03	5/7/04	5/10/04	3/20/05	3/21/05	7/14/05	7/17/05	8/12/05	8/15/05	12/27/05	12/31/05	8/24/06	8/27/06	3/19/07	3/23/07	1/19/08	1/22/08
Wall Thickness (cm):	1.27																						
Dose from box per 1Ci/m ³ (mrem/h)	Isotopes (w/daughters)																						
	A 7 C1-B1 mrem/h	A 8 C2-B1 mrem/h	A 15 C1-B2 mrem/h	A 16 C2-B2 mrem/h	A 23 C1-B3 mrem/h	A 24 C2-B3 mrem/h	A 31 C1-B4 mrem/h	A 32 C2-B4 mrem/h	B 6 C1-B5 mrem/h	B 7 C2-B5 mrem/h	B 8 C1-B6 mrem/h	B 9 C2-B6 mrem/h	C 9 C1-B7 mrem/h	C 10 C2-B7 mrem/h	C 17 C1-B8 mrem/h	C 17 C2-B8 mrem/h	C 25 C1-B9 mrem/h	C 26 C2-B9 mrem/h	C-west 22 C1-B10 mrem/h	C-west 24 C2-B10 mrem/h	C-west 24 C1-B11 mrem/h	C-west 24 C2-B11 mrem/h	
6.70E+02 60Co	10.39	10.41	11.20	11.19	14.76	14.74	6.47	6.46	66.16	66.19	14.77	14.76	14.62	14.60	43.27	43.21	0.30	0.30	8.58	8.14	5.35	6.46	
7.53E+01 90Sr (& 90Y)	0.09	0.09	0.35	0.35	0.71	0.71	0.09	0.09	4.02	4.01	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	
4.12E+01 106Ru (& 106Rh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.99	1.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
6.82E+01 125Sb	4.10	4.11	1.94	1.93	3.19	3.18	1.47	1.47	98.65	98.66	1.80	1.79	1.76	1.76	1.76	1.76	0.22	0.22	0.04	0.04	0.78	0.74	
3.03E+02 126Sr (126mSb, 126Sb)	3.84	3.85	1.91	1.91	3.14	3.14	1.91	1.91	17.18	17.19	3.31	3.32	3.32	3.31	3.32	3.32	0.10	0.10	2.96	2.91	2.28	2.78	
1.10E+02 137Cs (& 137mBa)	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	
2.54E+02 152Eu	1.69	1.70	0.85	0.85	1.27	1.27	0.80	0.80	1.68	1.68	1.42	1.42	1.41	1.41	2.31	2.31	0.03	0.03	1.02	0.97	0.75	0.92	
2.89E+02 154Eu	31.48	31.54	34.70	34.68	162.65	162.51	25.50	25.48	274.80	274.95	173.70	173.62	172.64	172.48	16.98	16.97	3.94	3.94	118.65	112.66	73.28	87.97	
TOTAL	382.33	382.43	381.71	381.67	516.46	516.29	366.99	366.96	795.23	795.41	540.80	540.71	539.55	539.37	412.51	412.43	390.22	390.22	477.78	471.12	424.51	444.56	

Here is the individual dose contribution for each radionuclide for each batch.

Isotope (w/daughters)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
-----------------------	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

This sheet converts total radionuclide inventory (feed) to radionuclide concentration in glass (C/m³). It also displays LLAW values, Cs, Sr and Tc loading limits and their DF's. All radionuclides decayed to Feed Delivery Date by Batch

			Batch 1		Batch 2		Batch 3		Batch 4		Batch 5		Batch 6		Batch 7		Batch 8		Batch 9		Batch 10		Batch 11				
			A	A	A	A	A	A	A	B	B	C	C	C	C	C	C	C	C	C	C-west	C-west	C-west	C-west			
			7	8	15	16	23	24	31	32	6	7	7	8	9	10	17	18	25	26	22	24	26	27			
			Envelope		C1-B1		C1-B2		C1-B3		C1-B4		C1-B5		C1-B6		C1-B7		C1-B8		C1-B9		C1-B10		C1-B11		
			Stream		C1m ³		C2m ³		C1m ³		C2m ³		C1m ³		C2m ³		C1m ³		C2m ³		C1m ³		C2m ³				
			Contractor-Batch		C1m ³		C2m ³		C1m ³		C2m ³		C1m ³		C2m ³		C1m ³		C2m ³		C1m ³		C2m ³				
Data Source	half-life (y)	lambda (y ⁻¹)	Component		60Co		1.55E-02	1.55E-02	1.67E-02	1.67E-02	2.20E-02	2.20E-02	9.88E-03	9.88E-02	9.88E-02	2.21E-02	2.20E-02	2.18E-02	2.18E-02	6.45E-02	6.45E-02	4.42E-04	4.42E-04	1.28E-02	1.22E-02	7.99E-03	9.65E-03
BBI	5.271	0.1315	60Co		90Sr		1.23E-01	1.20E-01	4.71E-01	4.71E-01	9.44E-01	9.44E-01	1.25E-01	1.25E-01	5.34E+00	5.33E+00	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	1.54E+01	2.00E+01	
TWRSO&UP	28.78	0.0241	90Sr		137Cs		3.00E-01	3.00E-01	1.62E-02	1.62E-02	2.50E-01	2.50E-01	2.85E-02	2.85E-02	8.86E-04	8.86E-04	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	2.80E-01	2.79E-01	
TWRSO&UP	2.11E+05	3.29E-06	137Cs		106Ru		6.66E-08	6.67E-08	2.58E-08	2.57E-08	3.70E-08	3.67E-08	1.58E-08	1.58E-08	4.82E-02	4.82E-02	7.07E-09	7.03E-09	6.70E-09	6.66E-09	5.79E-09	5.75E-09	1.58E-10	1.57E-10	1.68E-09	1.58E-09	
BBI	1.020	0.6796	106Ru		125Sb		6.01E-02	6.02E-02	2.84E-02	2.83E-02	4.67E-02	4.66E-02	2.16E-02	2.16E-02	1.45E+00	1.45E+00	2.63E-02	2.63E-02	2.58E-02	2.58E-02	3.22E-03	3.21E-03	6.23E-04	6.22E-04	1.14E-02	1.08E-02	
BBI	2.758	0.2513	125Sb		129Sn		1.27E-02	1.27E-02	6.32E-03	6.32E-03	1.04E-02	1.04E-02	6.32E-03	6.32E-03	5.68E-02	5.68E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.30E-02	1.30E-02	3.35E-04	3.35E-04	9.77E-03	9.28E-03	
TWRSO&UP	2.5E+05	2.77E-06	129Sn		137Cs		3.89E-01	3.89E-01	4.54E-01	4.54E-01	6.02E-01	6.02E-01	4.66E-01	4.66E-01	2.33E+00	2.33E+00	5.41E-01	5.41E-01	5.39E-01	5.39E-01	3.12E-01	3.12E-01	3.40E-01	3.40E-01	2.02E-01	2.02E-01	
BBI	30.07	0.0231	137Cs		134Eu		6.66E-03	6.67E-03	3.36E-03	3.36E-03	4.99E-03	4.99E-03	3.13E-03	3.13E-03	6.59E-03	6.60E-03	5.57E-03	5.57E-03	5.55E-03	5.54E-03	9.07E-03	9.07E-03	1.34E-04	1.34E-04	3.99E-03	3.79E-03	
TWRSO&UP	13.54	0.0512	134Eu		154Eu		1.09E-01	1.09E-01	1.20E-01	1.20E-01	5.62E-01	5.62E-01	8.82E-02	8.82E-02	9.51E-01	9.51E-01	6.01E-01	6.00E-01	5.97E-01	5.96E-01	5.87E-02	5.87E-02	1.36E-02	1.36E-02	4.10E-01	3.90E-01	
BBI	8.593	0.0807	154Eu																								

				kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³
--	--	--	--	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------

Volume of package (m³): 2.6

DF's used for calculation	¹³⁷ Cs DF	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000	1000.000</
---------------------------------	----------------------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	------------

137Cs in batch at limit of				3.0	C1m ³	3924.1	3916.5	4081.3	4081.0	3267.6	3267.5	4460.7	4460.7	2245.5	2212.9	909.3	909.3	2075.1	2075.4	3642.6	3642.6	3132.6	3132.6	4696.3	4694.0	3460.1	2570.5															
----------------------------	--	--	--	-----	------------------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	-------	-------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

This sheet converts total radionuclide inventory (feed) to radionuclide concentration in glass (Ci/m³)
It also displays LAW volumes Cs, Sr and Tc loading limits and their DFs
All radionuclides decayed to 7-1-2002

Data Source	half-life (y)	lambda (y ⁻¹)	Component	Batch 1		Batch 2		Batch 3		Batch 4		Batch 5		Batch 6		Batch 7		Batch 8		Batch 9		Batch 10		Batch 11	
				A	A	A	A	A	A	A	A	B	B	C	C	C	C	C	C	C	C	C-west	C-west	C-west	C-west
				7	8	15	18	23	24	31	32	6	7	7	8	9	10	17	18	25	26	22	24	26	27
Envelope Stream				C1-B1	C2-B1	C1-B2	C2-B2	C1-B3	C2-B3	C1-B4	C2-B4	C1-B5	C2-B5	C1-B6	C2-B6	C1-B7	C2-B7	C1-B8	C2-B8	C1-B9	C2-B9	C1-B10	C2-B10	C1-B11	C2-B11
Contractor-Batch				Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³
BB1	5.271	0.1315	⁶⁰ Co	1.13E-02	1.14E-02	1.31E-02	1.31E-02	1.90E-02	1.90E-02	9.01E-03	9.01E-03	1.03E-01	1.03E-01	2.40E-02	2.40E-02	2.40E-02	2.40E-02	7.48E-02	7.48E-02	5.58E-04	5.58E-04	1.74E-02	1.65E-02	1.21E-02	1.47E-02
TWRSO&UP	28.78	0.0241	⁹⁰ Sr	8.96E-02	8.79E-02	3.49E-01	3.49E-01	7.11E-01	7.11E-01	9.53E-02	9.53E-02	4.16E+00	4.16E+00	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	1.89E+01	1.89E+01	1.29E+01	1.73E+01
BB1	2.11E+05	3.29E-06	⁹⁹ Tc	3.00E-01	3.00E-01	1.18E-02	1.18E-02	1.83E-01	1.83E-01	2.08E-02	2.08E-02	6.48E-04	6.48E-04	2.86E-01	2.86E-01	2.87E-01	2.86E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	2.45E-01	2.04E-01
TWRSO&UP	1.020	0.6796	¹⁰⁶ Ru	4.87E-08	4.88E-08	2.70E-08	2.70E-08	6.33E-08	6.33E-08	4.07E-08	4.07E-08	2.24E-01	2.24E-01	4.07E-08	4.07E-08	4.07E-08	4.07E-08	4.54E-08	4.54E-08	1.94E-09	1.94E-09	2.45E-01	2.45E-01	2.05E-01	2.04E-01
BB1	2.758	0.2513	¹²⁵ Sb	4.39E-02	4.40E-02	2.37E-02	2.37E-02	4.68E-02	4.68E-02	2.51E-02	2.51E-02	2.09E+00	2.09E+00	4.13E-02	4.13E-02	4.13E-02	4.13E-02	5.66E-03	5.66E-03	1.29E-03	1.29E-03	2.73E-02	2.59E-02	2.15E-02	2.64E-02
BB1	2.5E+05	2.77E-06	¹²⁵ Sb	9.28E-03	9.29E-03	4.62E-03	4.62E-03	7.58E-03	7.58E-03	4.62E-03	4.62E-03	4.15E-02	4.15E-02	8.01E-03	8.01E-03	8.01E-03	8.01E-03	9.48E-03	9.48E-03	2.45E-04	2.45E-04	7.14E-03	6.79E-03	5.52E-03	6.74E-03
TWRSO&UP	30.07	0.0231	¹³⁷ Cs	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00
BB1	13.54	0.0512	¹⁵² Eu	4.67E-03	4.88E-03	2.52E-03	2.52E-03	3.89E-03	3.89E-03	2.51E-03	2.51E-03	5.54E-03	5.54E-03	4.76E-03	4.76E-03	4.76E-03	4.76E-03	7.93E-03	7.93E-03	1.21E-04	1.21E-04	3.72E-03	3.53E-03	2.87E-03	3.51E-03
BB1	8.593	0.0807	¹⁵⁴ Eu	7.96E-02	7.97E-02	9.15E-02	9.15E-02	4.55E-01	4.55E-01	7.48E-02	7.48E-02	8.85E-01	8.86E-01	5.61E-01	5.61E-01	5.61E-01	5.61E-01	5.69E-02	5.69E-02	1.39E-02	1.39E-02	4.39E-01	4.17E-01	2.90E-01	3.48E-01

	vol/Na (cm ³ /gmol Na)	100	100	100	100	100	100	100	100	250	250	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Total ext. package vol. (based on Na loading):	2236.7	2232.4	2326.3	2326.2	1862.5	1862.5	2542.6	2542.6	1279.9	1261.4	518.3	518.3	1182.8	1183.0	2076.3	2076.3	1785.5	1785.5	2676.8	2675.5	1966.5	1465.2	1465.2	1465.2	1465.2	1465.2
Total waste volume (80% of package volume):	1789.4	1785.9	1861.1	1860.9	1490.0	1490.0	2034.0	2034.0	1023.9	1009.1	414.6	414.6	946.3	946.4	1661.0	1661.0	1428.4	1428.4	2141.5	2140.4	1573.2	1172.1	1172.1	1172.1	1172.1	1172.1
Number of packages:	861	859	896	896	717	717	979	979	493	486	200	200	456	456	799	799	688	688	1030	1030	757	564	564	564	564	564

Volume of package (m³): 2.6

DFs used for calculation	¹³⁷ Cs DF	⁹⁰ Sr DF	⁹⁹ Tc DF	94.697	94.880	112.059	112.067	150.901	150.902	118.550	118.550	604.668	603.870	141.467	141.466	141.191	141.173	82.395	82.395	91.249	91.249	54.779	54.806	57.996	58.380
	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	1.054	1.060	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

¹³⁷ Cs in batch at limit of	3.0	Ci/m ³	5368.1	5357.7	5582.2	5582.8	4470.0	4470.0	6102.1	6102.1	3071.8	3027.3	1243.9	1243.9	2838.6	2839.1	4983.1	4983.1	4285.3	4285.3	6424.4	6421.3	4719.6	3516.4
⁹⁰ Sr in batch at limit of	20.0	Ci/m ³	35787.3	35718.0	37221.5	37218.9	29799.9	29799.8	40680.8	40680.8	20478.4	20161.7	8292.3	8292.4	18925.0	18927.4	33220.6	33220.6	28568.7	28568.7	42829.6	42808.6	31464.3	23443.0
⁹⁹ Tc in batch at limit of	0.3	Ci/m ³	536.8	535.8	558.3	558.3	447.0	447.0	610.2	610.2	307.2	302.7	124.4	124.4	283.9	283.9	498.3	498.3	428.5	428.5	642.4	642.1	472.0	351.6

minimum ¹³⁷ Cs DF to achieve 3.0 Ci ¹³⁷ Cs/m ³	94.697	94.880	112.059	112.067	150.901	150.902	118.550	118.550	604.668	603.870	141.467	141.466	141.191	141.173	82.395	82.395	91.249	91.249	54.779	54.806	57.996	58.380
minimum ⁹⁰ Sr DF to achieve 20.0 Ci ⁹⁰ Sr/m ³	0.004	0.004	0.017	0.017	0.036	0.036	0.005	0.005	0.208	0.208	4.884	4.884	4.815	4.814	3.657	3.657	1.063	1.063	0.946	0.946	0.644	0.664
minimum ⁹⁹ Tc DF to achieve 0.3 Ci ⁹⁹ Tc/m ³	1.054	1.060	0.039	0.039	0.610	0.610	0.069	0.069	0.002	0.002	0.954	0.954	0.955	0.955	1.098	1.098	5.251	5.251	0.826	0.815	0.682	0.679

Decay date	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02
------------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

Wall Thickness (cm): 1.27

Dose from box per 1Ci/m ³	A		A		A		A		B		B		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C		C	
---	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--	---	--

This sheet converts total radionuclide inventory (feed) to radionuclide concentration in glass (Ci/m³) It also displays ILAW volumes Cs, Sr and Tc loading limits and their DF's All radionuclides decayed to 7-1-2002

			Batch 1		Batch 2		Batch 3		Batch 4		Batch 5		Batch 6		Batch 7		Batch 8		Batch 9		Batch 10		Batch 11					
			A	A	A	A	A	A	A	A	B	B	C	C	C	C	C	C	C	C	C-west	C-west	C-west	C-west				
			7	8	15	16	23	24	31	32	6	7	7	7	8	9	10	17	18	25	26	22	24	27				
			Envelope	Stream	Contractor-Batch	Component	C1-B1	C2-B1	C1-B2	C2-B2	C1-B3	C2-B3	C1-B4	C2-B4	C1-B5	C2-B5	C1-B6	C2-B6	C1-B7	C2-B7	C1-B8	C2-B8	C1-B9	C2-B9	C1-B10	C2-B10	C1-B11	C2-B11
Data Source	half-life (y)	lambda (y ⁻¹)	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³	
			⁶⁰ Co	1.94E-02	1.94E-02	2.24E-02	2.24E-02	3.25E-02	3.25E-02	1.54E-02	1.54E-02	1.77E-01	1.77E-01	4.11E-02	4.11E-02	4.11E-02	4.11E-02	1.28E-01	1.28E-01	9.53E-04	9.53E-04	2.98E-02	2.98E-02	2.07E-02	2.07E-02	2.51E-02		
			⁹⁰ Sr	1.53E-01	1.50E-01	5.96E-01	5.96E-01	1.22E+00	1.22E+00	1.63E-01	1.63E-01	7.12E+00	7.11E+00	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	
			¹³⁷ Cs	3.00E-01	3.00E-01	2.02E-02	2.02E-02	3.00E-01	3.00E-01	3.56E-02	3.56E-02	1.11E-03	1.12E-03	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	
			¹³⁸ La	8.32E-08	8.33E-08	4.61E-08	4.61E-08	1.08E-07	1.08E-07	6.96E-08	6.96E-08	8.82E-01	8.83E-01	6.95E-08	6.95E-08	6.95E-08	6.95E-08	6.95E-08	6.95E-08	7.78E-08	7.78E-08	3.31E-09	3.31E-09	5.16E-08	4.91E-08	4.01E-08	4.90E-08	
			¹²⁵ Sb	7.51E-02	7.53E-02	4.05E-02	4.05E-02	8.00E-02	8.00E-02	4.30E-02	4.30E-02	3.58E+00	3.58E+00	7.06E-02	7.06E-02	7.06E-02	7.06E-02	9.67E-03	9.67E-03	2.21E-03	2.21E-03	4.66E-02	4.43E-02	3.68E-02	4.51E-02			
			¹³² Sn	1.59E-02	1.59E-02	7.90E-03	7.90E-03	1.30E-02	1.30E-02	7.90E-03	7.90E-03	7.10E-02	7.10E-02	1.37E-02	1.37E-02	1.37E-02	1.37E-02	1.62E-02	1.62E-02	4.18E-04	4.18E-04	1.22E-02	1.16E-02	9.43E-03	1.15E-02			
			¹³⁷ Cs	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	
			¹⁵² Eu	8.32E-03	8.33E-03	4.31E-03	4.31E-03	6.65E-03	6.65E-03	4.30E-03	4.30E-03	9.47E-03	9.48E-03	8.13E-03	8.13E-03	8.13E-03	8.13E-03	1.36E-02	1.36E-02	2.08E-04	2.08E-04	6.35E-03	6.04E-03	4.91E-03	5.99E-03			
			¹⁵⁴ Eu	1.36E-01	1.36E-01	1.56E-01	1.56E-01	1.78E-01	1.78E-01	1.28E-01	1.28E-01	1.48E+00	1.48E+00	9.59E-01	9.59E-01	9.59E-01	9.59E-01	9.72E-02	9.72E-02	2.38E-02	2.38E-02	7.50E-01	7.13E-01	4.96E-01	5.95E-01			
				kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	
				1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01	1.71E+01
				volNa (cm ³ /gmol Na)	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5
			Total ext. package vol (based on Na loading)	1308.5	1305.9	1360.9	1360.8	1089.6	1089.6	1487.4	1487.4	747.7	737.9	303.2	303.2	691.9	692.0	1214.6	1214.6	1044.5	1044.5	1566.0	1565.2	1150.4	857.1	595.5		
			Total waste volume (90% of package volume)	1046.8	1044.8	1088.7	1088.7	871.6	871.6	1189.9	1189.9	599.0	599.0	242.6	242.6	553.6	553.6	971.7	971.7	835.6	835.6	1252.8	1252.2	920.3	685.7			
			Number of packages:	504	503	524	524	420	420	573	573	289	284	117	117	267	267	468	468	402	402	603	603	443	330	330		

Volume of package (m³): 2.6

DF's used for calculation	¹³⁷ Cs DF	161.874	162.188	191.553	191.567	257.951	257.952	202.649	202.649	1033.621	1032.256	241.824	241.822	241.352	241.322	140.848	140.847	155.981	155.981	93.640	93.686	99.139	99.795
	⁹⁰ Sr DF	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	⁹⁹ Tc DF	1.802	1.811	1.000	1.000	1.043	1.043	1.000	1.000	1.000	1.000	1.630	1.630	1.633	1.632	1.878	1.878	8.976	8.976	1.411	1.394	1.166	1.161

¹³⁷ Cs in batch at limit of	3.0	Ci/m ³	3140.3	3134.3	3266.2	3266.0	2614.9	2614.9	3599.7	3599.7	1797.0	1770.9	727.7	727.7	1660.7	1660.9	2915.1	2915.1	2506.9	2506.9	3758.3	3756.5	2761.0	2057.1
⁹⁰ Sr in batch at limit of	20.0	Ci/m ³	20935.5	20895.0	21774.6	21773.0	17432.9	17432.9	23798.3	23798.3	11979.9	11806.3	4851.0	4851.1	11071.2	11072.5	19434.0	19434.0	16712.7	16712.7	25053.3	25043.0	18406.6	13714.1
⁹⁹ Tc in batch at limit of	0.3	Ci/m ³	314.0	313.4	326.6	326.6	261.5	261.5	357.0	357.0	179.7	177.1	72.8	72.8	166.1	166.1	291.5	291.5	250.7	250.7	375.8	375.6	276.1	205.7

minimum ¹³⁷ Cs DF to achieve 3.0 Ci ¹³⁷ Cs/m ³	161.874	162.188	191.553	191.567	257.951	257.952	202.649	202.649	1033.621	1032.256	241.824	241.822	241.352	241.322	140.848	140.847	155.981	155.981	93.640	93.686	99.139	99.795
minimum ⁹⁰ Sr DF to achieve 20.0 Ci ⁹⁰ Sr/m ³	0.008	0.008	0.030	0.030	0.061	0.061	0.008	0.008	0.356	0.356	8.348	8.348	8.231	8.230	6.252	6.252	1.817	1.817	1.616	1.617	1.100	1.477
minimum ⁹⁹ Tc DF to achieve 0.3 Ci ⁹⁹ Tc/m ³	1.802	1.811	1.067	1.067	1.043	1.043	1.019	1.019	0.004	0.004	1.630	1.630	1.633	1.632	1.878	1.878	8.976	8.976	1.411	1.394	1.166	1.161

Decay date	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02
------------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

Wall Thickness (cm): 1.27

Dose from box per 1Ci/m ³ (mrem/h)	Batch 1		Batch 2		Batch 3		Batch 4		Batch 5		Batch 6		Batch 7		Batch 8		Batch 9		Batch 10		Batch 11	
	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	7	8	15	16	23	24	31	32	6	7	7	7	8	9	10	17	18	25	26	22	24	27
	C1-B1	C2-B1	C1-B2	C2-B2	C1-B3	C2-B3	C1-B4	C2-B4	C1-B5	C2-B5	C1-B6	C2-B6	C1-B7	C2-B7	C1-B8	C2-B8	C1-B9	C2-B9	C1-B10	C2-B10	C1-B11	C2-B11
6.70E+02 60Co	12.98	13.00	14.99	14.99	21.74	21.74	10.31	10.31	118.21	118.30	27.52	27.52	27.53	27.52	85.58	85.58	6.64	6.64	19.33	18.94	13.88	16.78
7.53E+01 90Sr (< 90Y)	0.12	0.11	0.45	0.45	0.82	0.82	0.12	0.12	5.36	5.35	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06
4.12E+01 106Ru (< 106Rh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.76	15.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.82E+01 125Sb	5.12	5.13	2.76	2.76	5.46	5.46	2.93	2.93	244.12	244.30	4.82	4.82	4.82	4.82	0.66	0.66	0.15	0.15	3.18	3.03	2.51	3.08
3.03E+02 126Sn (126mSb, 126Sb)	4.80	4.81	2.39	2.39	3.92	3.92	2.39	2.39	21.47	21.48	4.14	4.14	4.14	4.14	4.90	4.90	0.13	0.13	3.69	3.51	2.85	3.49
1.10E+02 137Cs (< 137mBa)	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75	330.75
2.54E+02 152Eu	2.12	2.12	1.10	1.10	1.69	1.69	1.09	1.09	2.41	2.41	2.07	2.07	2.07	2.07	3.45	3.45	0.06	0.06	1.62	1.54	1.29	1.53
2.89E+02 154Eu	36.33	36.41	45.24	45.25	224.88	224.88	36.99	36.99	427.59	427.51	277.28	277.34	277.36	277.30	28.12	28.12	6.88	6.88	216.88	206.11	143.31	172.15
TOTAL	395.21	395.33	397.68	397.68	589.36	589.36	384.58	384.58	1165.66	1166.27	661.63	661.70	661.72	661.65	468.52	468.52	353.65	353.65	591.09	578.92	509.61	542.82

Isotope (w/daughters)																						
60Co	3.28%	3.29%	3.77%	3.77%	3.69%	3.69%	2.68%	2.68%	10.14%	10.14%	4.16%	4.16%	4.16%	4.16%	18.27%	18.27%	0.18%	0.18%	3.37%	3.27%	2.72%	3.09%
90Sr (& 90Y)	0.03%	0.03%	0.11%	0.11%	0.16%	0.16%	0.03%	0.03%	0.48%	0.46%	2.28%	2.28%	2.28%	2.28%	3.21%	3.21%	4.26%	4.26%	2.55%	2.60%	2.95%	2.77%
136Eu (& 160Er)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.35%	1.35%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
137Cs	1.30%	1.30%	0.65%	0.65%	0.93%	0.93%	0.20%	0.20%	0.73%	0.73%	0.00%	0.00%	0.00%	0.00%	0.73%	0.73%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
126Sn (126mSn, 126Sb)	1.21%	1.22%	0.60%	0.60%	0.67%	0.67%	0.62%	0.62%	1.84%	1.84%	0.63%	0.63%	0.63%	0.63%	1.05%	1.05%	0.04%	0.04%	0.62%	0.61%	0.56%	0.64%
137Ba (& 137mBa)	83.69%	83.69%	83.17%	83.17%	56.12%	56.12%	86.00%	86.00%	28.37%	28.36%	49.99%	49.99%	49.99%	49.99%	70.50%	70.50%	93.52%	93.52%	55.96%	57.13%	84.90%	69.93%
152Eu	0.54%	0.54%	0.28%	0.28%	0.29%	0.29%	0.28%	0.28%	0.21%	0.21%	0.31%	0.31%	0.31%	0.31%	0.74%	0.74%	0.01%	0.01%	0.27%	0.27%	0.24%	0.28%
154Eu	9.95%	9.97%	11.38%	11.38%	38.16%	38.16%	9.62%	9.62%	38.69%	38.69%	41.91%	41.91%	41.91%	41.91%	6.00%	6.00%	1.95%	1.95%	35.60%	35.60%	38.12%	37.1%
TOTAL	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Source Term for Monolithic Waste Form Geometry

HNF-2110 Rev. 0

This sheet converts total radionuclide inventory (feed) to radionuclide concentration in glass (Ci/m³) It also displays LAW volumes, Cs, Sr and Tc loading limits and their DF's All radionuclides decayed to 7-1-2002

Data Source	half-life (y)	lambda (y ⁻¹)	Batch 1		Batch 2		Batch 3		Batch 4		Batch 5		Batch 6		Batch 7		Batch 8		Batch 9		Batch 10		Batch 11	
			A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
			C1-B1	C2-B1	C1-B2	C2-B2	C1-B3	C2-B3	C1-B4	C2-B4	C1-B5	C2-B5	C1-B6	C2-B6	C1-B7	C2-B7	C1-B8	C2-B8	C1-B9	C2-B9	C1-B10	C2-B10	C1-B11	C2-B11
Envelope	Stream	Contractor-Batch	Component																					
BB1	5.271	0.1315	1.55E-02	1.55E-02	1.79E-02	1.79E-02	2.60E-02	2.60E-02	1.23E-02	1.23E-02	1.41E-01	1.41E-01	3.29E-02	3.29E-02	1.02E-01	1.02E-01	7.63E-04	7.63E-04	2.38E-02	2.38E-02	2.26E-02	2.26E-02	1.69E-02	2.00E-02
TWRSO&UP	28.78	0.0241	1.23E-01	1.20E-01	4.77E-01	4.77E-01	9.73E-01	9.73E-01	1.30E-01	1.30E-01	5.70E+00	5.69E+00	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	1.76E+01	2.00E+01
BB1	2.11E+05	3.29E-06	3.00E-01	3.00E-01	1.62E-02	1.62E-02	2.50E-01	2.50E-01	2.85E-02	2.85E-02	8.86E-04	8.86E-04	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	2.80E-01	2.79E-01
BB1	1.020	0.6796	6.66E-08	6.67E-08	3.69E-08	3.69E-08	8.67E-08	8.67E-08	5.57E-08	5.57E-08	3.06E-01	3.06E-01	5.56E-08	5.56E-08	5.56E-08	5.56E-08	6.21E-08	6.21E-08	2.65E-09	2.65E-09	4.13E-08	3.93E-08	3.21E-08	3.92E-08
BB1	2.758	0.2513	6.01E-02	6.02E-02	3.24E-02	3.24E-02	6.40E-02	6.40E-02	3.44E-02	3.44E-02	2.87E+00	2.87E+00	5.65E-02	5.65E-02	5.65E-02	5.65E-02	7.74E-03	7.74E-03	1.77E-03	1.77E-03	3.73E-02	3.55E-02	2.95E-02	3.61E-02
BB1	2.5E+05	2.77E-06	1.27E-02	1.27E-02	6.32E-03	6.32E-03	1.04E-02	1.04E-02	6.32E-03	6.32E-03	5.68E-02	5.68E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.30E-02	1.30E-02	3.35E-04	3.35E-04	9.77E-03	9.28E-03	7.55E-03	9.22E-03
TWRSO&UP	30.07	0.0231	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00
BB1	13.54	0.0512	6.66E-03	6.67E-03	3.45E-03	3.45E-03	5.32E-03	5.32E-03	3.44E-03	3.44E-03	7.58E-03	7.58E-03	6.51E-03	6.51E-03	6.51E-03	6.51E-03	1.08E-02	1.08E-02	1.66E-04	1.66E-04	5.08E-03	4.83E-03	3.93E-03	4.70E-03
BB1	8.593	0.0807	1.09E-01	1.09E-01	1.25E-01	1.25E-01	6.22E-01	6.22E-01	1.02E-01	1.02E-01	1.18E+00	1.18E+00	7.67E-01	7.67E-01	7.67E-01	7.67E-01	7.78E-02	7.78E-02	1.90E-02	1.90E-02	6.00E-01	5.70E-01	3.97E-01	4.86E-01
			kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³	kg-mol/m ³
TWRSO&UP	--	--	Na+	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	5.47E+00	5.47E+00	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01

This data is the calculation of external volume, waste volume and package counts based on the sodium loading. This value also determines the DF's for Cs, Sr and Tc

This section lists the DF's used to arrive at the Cs, Sr and Tc concentrations. If a value of 1.000 is listed, no removal of the radionuclide will be done.

This section lists the amounts of Cs, Sr and Tc in a batch based on their "maximum average concentration". The concentration limits are entered in cells C34 to C36.

This section lists the minimum DF's to achieve the "maximum average concentration." Values > 1 will require decon to take place, values < 1 are assumed to be 1 for calculation in the DF list two above this one.

These are the decay dates used for each batch

Here is the individual dose contribution for each radionuclide for each batch.

Percent dose contribution per radionuclide per batch.

Volume of package (m³): 2.6

DF's used for calculation	¹³⁷ Cs DF	129.544	129.795	153.295	153.306	206.432	206.432	162.175	162.175	827.179	826.087	193.525	193.524	193.147	193.123	112.716	112.716	124.828	124.828	74.938	74.975	79.338	79.664
	⁹⁰ Sr DF	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	6.681	6.681	6.587	6.586	5.003	5.003	1.454	1.454	1.294	1.294	1.000	1.182
	⁹⁹ Tc DF	1.442	1.449	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.305	1.305	1.307	1.306	1.503	1.503	7.184	7.184	1.129	1.115	1.000	1.000

¹³⁷ Cs in batch at limit of	3.0	Ci/m ³																						
			3924.1	3916.5	4081.3	4081.0	3287.6	3267.5	4460.7	4460.7	2245.5	2212.9	909.3	909.3	2075.1	2075.4	3542.6	3542.6	3132.6	3132.6	4696.3	4694.0	3450.1	2570.5
			26160.5	26109.8	27208.9	27207.0	21783.7	21783.7	29737.7	29737.7	14959.7	14752.8	6061.7	6061.7	13934.2	13935.9	24284.2	24284.2	20883.8	20883.8	31308.4	31293.1	23000.4	17136.8
⁹⁰ Sr in batch at limit of	20.0	Ci/m ³	392.4	391.6	408.1	408.1	328.8	326.8	446.1	446.1	224.5	221.3	90.9	90.9	207.5	207.5	354.3	354.3	313.3	313.3	469.6	469.4	345.0	257.1
⁹⁹ Tc in batch at limit of	0.3	Ci/m ³	392.4	391.6	408.1	408.1	328.8	326.8	446.1	446.1	224.5	221.3	90.9	90.9	207.5	207.5	354.3	354.3	313.3	313.3	469.6	469.4	345.0	257.1

minimum ¹³⁷ Cs DF to achieve 3.0 Ci ¹³⁷ Cs/m ³	129.544	129.795	153.295	153.306	206.432	206.432	162.175	162.175	827.179	826.087	193.525	193.524	193.147	193.123	112.716	112.716	124.828	124.828	74.938	74.975	79.338	79.664	1.000	1.000
minimum ⁹⁰ Sr DF to achieve 20.0 Ci ⁹⁰ Sr/m ³	0.006	0.006	0.024	0.024	0.049	0.049	0.007	0.007	0.285	0.284	6.681	6.681	6.587	6.586	5.003	5.003	1.454	1.454	1.294	1.294	0.880	0.880	1.000	1.000
minimum ⁹⁹ Tc DF to achieve 0.3 Ci ⁹⁹ Tc/m ³	1.442	1.449	0.054	0.054	0.835	0.835	0.095	0.095	0.003	0.003	1.305	1.305	1.307	1.306	1.503	1.503	7.184	7.184	1.129	1.115	0.933	0.929	1.000	1.000

Decay date	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02	7/1/02
------------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

Wall Thickness (cm): 1.27

Dose from box per 10cm ² (mrem/h)	Isotope (w/daughters)	A		A		A		A		B		C		C		C		C		C		C-west		C-west		C-west		C-west	
		7	8	15	16	23	24	31	32	6	7	7	7	8	9	10	17	18	25	26	C-west	C-west	C-west	C-west	C-west	C-west	C-west	C-west	
		C1-B1	C2-B1	C1-B2	C2-B2	C1-B3	C2-B3	C1-B4	C2-B4	C1-B5	C2-B5	C1-B6	C2-B6	C1-B7	C2-B7	C1-B8	C2-B8	C1-B9	C2-B9	C1-B10	C2-B10	C1-B11	C2-B11	C1-B12	C2-B12	C1-B13	C2-B13		
		mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h	mrem/h
4.46E+02	60Co	6.92	6.94	8.00	8.00	11.60	11.60	5.50	5.50	63.07	63.11	14.68	14.68	14.68	14.68	45.66	45.66	0.34	0.34	10.63	10.11	7.41	8.95						
5.02E-01	90Sr (& 90Y)	0.06	0.06	0.24	0.24	0.49	0.49	0.07	0.07	2.88	2.88	10.04	10.04	10.04	10.04	10.04	10.04	10.04	10.04	10.04	10.04	10.04	8.84	10.04					
2.75E+01	106Ru (& 106Rh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.41	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
4.55E+01	125Sb	2.73	2.74	1.47	1.47	2.91	2.91	1.56	1.56	130.24	130.34	2.57	2.57	2.57	2.57	0.36	0.35	0.08	0.08	1.70	1.61	1.34	1.64						
2.02E+02	126Sn (126mSb, 126Sb)	2.56	2.56	1.28	1.28	2.09	2.09	1.28	1.28	11.45	11.46	2.21	2.21	2.21	2.21	2.62	2.62	0.07	0.07	1.97	1.87	1.52	1.86						
7.35E+01	137Cs (& 137mBa)	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	220.50	
1.70E+02	152Eu	1.13	1.13	0.59	0.59	0.90	0.90	0.58	0.58	1.29	1.29	1.10	1.10	1.10	1.10	1.84	1.84	0.03	0.03	0.86	0.82	0.67	0.81						
1.93E+02	154Eu	20.98	21.02	24.14	24.14	119.98	119.98	19.73	19.73	228.12	228.30	147.93	147.97	147.97	147.94	15.00	15.00	3.67	3.67	115.70	109.96	76.46	91.65						
TOTAL		254.89	254.96	256.21	256.21	358.47	358.47	249.22	249.22	665.94	666.27	399.03	399.07	399.08	399.04	296.00	296.00	234.72	234.72	361.40	354.91	316.73	316.85						

HNF-2110 Rev 0

APPENDIX B

ILAW Shielding Evaluation

HNF-2110 Rev 0

This page intentionally left blank.

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 1 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

1.0 INTRODUCTION AND SUMMARY

Immobilized Low-Activity Waste (ILAW) produced from tank wastes by privatized treatment vendors will be stored and disposed in near surface facilities on the Hanford site. Product specifications for the ILAW allow radiation dose rates to be up to 1000 mR/hr on the surface of the package, which would require the waste packages to be handled remotely. Packages with dose rates below 200 mR/hr can be contact handled. In order to determine the number of contact-handled and remote-handled ILAW packages that would be expected, an operational source term is being developed by SESC. This source term will be used to calculate the expected radiation dose rates from the ILAW packages produced in Phase 1B of the privatization contract period.

Twenty-two discrete feed batches will be delivered to the private vendors. The feed batches will result in product batches with varying source terms. In order to determine the radiation exposures from the various product batches, an analysis of shielding and dose rates is required. Sensitivity cases will also be developed to determine the effect of changes in key parameters (i.e., waste density, geometry) on the dose rates. A general analysis of dose rates as a function of package wall thickness and radionuclide concentration will allow the calculation of package dose rates for all of the cases.

SESC provided radioactive inventory data for the tanks involved in Phase 1 of the privatization program. Section 2 of this report documents the evaluation performed on the tank radioactive inventory data to determine which isotopes are key contributors to the direct dose outside the package. A criteria of 0.1% of the total dose was used to screen out unimportant isotopes, i.e., isotopes contributing greater than 0.1% to the total direct dose were considered key contributors, and were analyzed in Section 3.

Section 3 contains the results of the evaluation of dose rates as a function of package wall thickness for the isotopes considered key contributors. A second order polynomial fit of the $\log_{10}$ of the dose rate versus package wall thickness was performed for each of the key contributors. These equations provide a simple method to estimate the surface dose rate for each isotope for a given wall thickness, and can be used to estimate the number of CH and RH packages for that wall thickness. The dose rate versus wall thickness was found to be insensitive to the package size for the range of package sizes prescribed by the privatization contract. The dose rate versus wall thickness was found to be inversely proportional to the waste density. That is, the dose rates for a monolith (100% glass density) was 2/3 of the dose rate for glass marbles (67% glass density).

Section 4 includes an evaluation of the neutron dose contribution to the total dose rate outside the package. The neutron dose rate was found to be less than 0.01% of the gamma dose rate, and therefore, does not need to be accounted for separately in the evaluation of the dose rates outside the package.

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 2 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

2.0 SELECTION OF KEY RADIONUCLIDES

A spreadsheet containing tank waste radioactive inventory data for Phase 1 tanks was provided to WMNW by SESC. This spreadsheet is listed in Appendix A. This data was used to estimate the dose contribution from each isotope to determine which isotopes contributed greater than 0.1% to the total direct dose.

It was assumed that the relative amount of each isotope's activity in the ILAW was the same as that which exists in the tanks based on the tank inventory data from the spreadsheet. The only exception was for cesium where ion exchange columns will be used to reduce the cesium activity concentration by a factor of approximately 200 to meet the cesium activity concentration limit set forth in the privatization contract. For this analysis, a cesium reduction factor of 200 was selected and was agreed upon by SESC. Note that the final results, in terms of which radionuclides are important contributors to the direct dose, are not very sensitive to the assumed cesium reduction factor for a reasonable range of values.

The ORIGEN2 (Schmittroth 1995) computer code was used to calculate the time-dependent concentration of the isotopes present in the tank waste for a 50 year decay time. Table 1 lists the total initial radioactive inventory of each isotope for all of the Phase 1 tanks, as well as the inventory at decay times of 10 years and 50 years. Note that the inventory at 0 years is actually for a 1 day decay time to build in equilibrium daughter products. These activity values were used as input to the ILAW waste package shielding model after application of a reduction factor of 200 for the cesium isotopes (Cs134, Cs137).

The ISO-PC Version 2.1 computer program (Rittmann 1995) was used for all of the gamma-ray dose rate calculations in this report. ISO-PC uses the point-kernel integration method to compute the dose rate at a detector location. Bremsstrahlung photons are accounted for in the dose rate calculations. Fluence-to-dose conversion factors were based on anterior-to-posterior irradiation pattern (ANSI/ANS 1991). The shielding attenuation properties for the bulk materials used in the analysis were obtained from the ISO-PC data library. Note that ISO-PC Version 2.1 has not gone through the verification and validation (V&V) process required by the WMNW Quality Assurance Program at this time. Appendix F contains a justification for use of ISO-PC Version 2.1 for the applications in this report.

A nominal configuration of the ILAW waste package was modeled using the ISO-PC computer code. The nominal configuration consisted of a waste package in the form of a rectangular steel box 1.2 m tall x 1.2 m wide x 1.8 m long, with a total wall thickness of 8 cm of steel for the waste package and shipping container. The ILAW waste form was assumed to be glass marbles consisting of 67% glass and 33% air by volume. The ILAW waste composition was based on LD6-5510 waste glass previously analyzed by WMNW (Savino, 1997). Table 2 lists the glass composition from Savino (1997). A wall thickness of 8 cm was considered a reasonable estimate for the total wall thickness for the evaluation of key contributors to the dose.

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 3 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

The relative contribution of each isotope to the total dose was evaluated at these three time periods (0, 10, and 50 years) to identify which isotopes contributed greater than 0.1% to the total dose. The relative contributions were obtained by manipulating the ISO-PC output data. The aging waste tanks (AZ-101, AZ-102) were also evaluated separately as a special case due to the unique nature of the waste in these tanks. The same process described above was followed for Tank AZ-101 waste using the tank-specific radioactive inventory in Appendix A. The radioactive waste composition of Tanks AZ-101 and AZ-102 are similar enough that only one of the two tanks needs to be evaluated to determine which radionuclides are important from a direct-dose standpoint. Table 1 lists the Tank AZ-101 inventory at decay times of 0, 10, and 50 years. The ORIGEN2 input files for both cases are included in Appendix B. The ISO-PC input files for the initial inventory for the all Phase 1 tanks case and the AZ-101 case are included in Appendix C. Note that some isotopes present in the waste are not included in the ISO-PC data library, however, these isotopes are unimportant from a direct-dose standpoint.

Table 3 lists the approximate dose contributions for each isotope as calculated by the ISO-PC computer code. From this table it is found that the following 10 isotopes contributed greater than 0.1% to the total direct dose:

Co60, Y90, Rh106, Sb125, Sb126m, Sb126, Cs134, Ba137m, Eu152, Eu154

Note that several of these isotopes are daughter products, as shown below, along with the parent-to-daughter branching ratio:

Parent	Daughter (Branching Ratio)
Sr90 →	Y90 (1.0)
Ru106 →	Rh106 (1.0)
Sn126 →	Sb126m (1.0) → Sb126 (0.14)
Cs137 →	Ba137m (0.946)

In summary, the following isotopes are selected for further evaluation in this report: Co60, Sr90/Y90, Ru106/Rh106, Sb125, Sn126/Sb126m/Sb126, Cs134, Cs137/Ba137m, Eu152, and Eu154. Section 3.0 contains the calculations to determine the dose rate for each of these isotopes for an activity loading of 1 Ci/m³, and for steel wall thickness up to 20 cm. Note that the results will be reported in terms of total dose rate in rem/h per Ci/m³ activity concentration of the parent isotope. For example, Y90 is in transient equilibrium with its parent isotope Sr90; i.e., the activity of Y90 is equal to the activity of Sr90. Therefore, the results will be reported in terms of rem/h per Ci/m³ of Sr90; however, the dose rate will include the contributions from 1 Ci/m³ of both Sr90 and Y90. Similarly, the results for Ru106 will include 1 Ci/m³ of both Ru106 and Rh106, and Cs137 will include 1 Ci/m³ of Cs137 and 0.946 Ci/m³ Ba137m. Finally, the results for Sn126 will include 1 Ci/m³ of Sn126 and Sb126m, and 0.14 Ci/m³ of Sb126.

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 4 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Saving Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

3.0 DOSE RATE CALCULATIONS VERSUS WALL THICKNESS.

The base ISO-PC model discussed in Section 2.0 was used for all of the calculations in this section. The model consisted of a waste package in the form of a rectangular steel box 1.2 m tall x 1.2 m wide x 1.8 m long, with waste in the form of glass marbles consisting of 67% glass and 33% air by volume. Dose rates were calculated at the package surface, which is typically taken to be 1 cm from the outside of the package. The first wall thickness analyzed was 1 cm, with the remaining thicknesses increasing from 2 cm to 20 cm in 2 cm increments. The package wall was modeled as iron with a density of 7.86 g/cc.

Table 4 contains the dose rate results for each isotope. Figures 1 and 2 display the results on a semi-log plot of dose rate versus wall thickness. These plots indicate that the $\log_{10}$ of the dose rate varies nearly linearly as a function of wall thickness. A linear regression was performed on the $\log_{10}$ of the dose rate versus the wall thickness for each isotope and it was found that for all but a few isotopes the fit resulted in errors less than 10%. However, since some errors were as large as 30%, a polynomial regression fit was performed for all isotopes. A second order polynomial fit markedly improved the results for those isotopes with larger fitting errors; therefore, a second order polynomial fit will be used for all isotopes for the final results reported herein.

The basic formula for calculating the dose rate using the polynomial fit is:

$$(\text{at}^2 + \text{bt} + \text{c})$$

$$\text{Dose Rate (rem/h)} = 10$$

where, a, b, and c are the fitting coefficients and t is the steel wall thickness in cm. The polynomial fits resulted in fitting errors of less than 5% for all isotopes except Sr90 which had errors of 12% and 10.3% for 1 cm and 4 cm thicknesses, respectively. Table 5 lists the fitting coefficients for each isotope. Appendix D contains example ISO-PC input files for Sr90/Y90 and Sn126/Sb126m/Sb126. Appendix E contains the output from a spreadsheet showing the percent differences between the calculated dose rates and the fitted values using the polynomial regression.

3.1 SENSITIVITY CASES

Two sensitivity cases were performed for Cs137/Ba137m. The first case is on package size, with the goal of examining the effect of increasing the package to 1.4 m x 1.4 m x 2.0 m. The second case examines the effect of using a monolithic waste form consisting of 100% glass by volume.

The ISO-PC cases for Cs137/Ba137m were rerun with the larger package size. The change in dose rate versus package wall thickness was found to be negligible when increasing the package size from 1.2 m x 1.2 m x 1.8 m to 1.4 m x 1.4 m x 2.0 m for

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 5 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Cs137/Ba137m. Similar results are obtained for the other isotopes of interest in this report. Therefore, the polynomial fits developed in Section 3.0 for a package size of 1.2 m x 1.2 m x 1.8 m are valid for a package size of 1.4 m x 1.4 m x 2.0 m.

The dose rates are essentially reduced by a factor of 2/3 when changing from a composition of 67% glass/33% air to 100% glass by volume. This is a result of the use of a glass density of 1.66 g/cc for the glass marble case versus a glass density of 2.5 g/cc for the glass monolith case. The dose rates outside the package are nearly proportional to the glass waste density for a fixed average activity loading (Ci/m³) inside the package. Note that the activity loading (Ci/m³) being discussed here is based on the total volume of the package, not the volume of the waste. That is, an activity loading of 1 Ci/m³ in the package is equal to an activity loading of 1.5 Ci/m³ in the glass waste matrix for the glass marbles case where the waste composition is 67% glass and 33% air by volume.

In summary, the dose rate as a function of wall thickness is *relatively insensitive to the* package size for the range of package sizes of interest in this report. The dose rates for a monolithic package are simply 2/3 of the dose rates for waste in the form of glass marbles. Appendix D contains the ISO-PC files for the 2 sensitivity cases.

4.0 EVALUATION OF THE NEUTRON DOSE CONTRIBUTION

The neutron source term was calculated using the ORIGEN2 computer code. The neutron source rate [S(T)] for the total Phase 1 tank radioactive inventory is 9.6 E+07 neutrons/s which includes contributions from spontaneous fission as well as (alpha,n) reactions. The (alpha,n) contribution was calculated assuming an oxide fuel. The concentration of fissile material is low, so neutron multiplication will also be low. The neutron dose rate was estimated using the methods described in *Estimation of Neutron Dose Rates from Nuclides Waste Packages* (Nelson 1996) and was found to be insignificant (<0.01%) compared to the gamma dose rate, as shown below. Note that the output data from the ORIGEN2 run documented in Section 2 was used to obtain the total neutron source reported in this section.

$$\text{Estimated Neutron Dose Rate (rem/h)} = \frac{0.01 \times S(T) \cdot 0.01 \times 9.67}{r^2} = \frac{\quad}{60^2} = 270 \text{ rem/h}$$

where, S(T) is the total neutron source rate (neutrons/s), and r is the distance (cm) from the center of the source to the detector. For the ILAW, which is in the shape of a rectangular box, r was taken to be 60 cm, which is the smallest distance from the center of the source to the edge of the box. The gamma dose rate for the total Phase 1 tank radioactive inventory is approximately 3.8 E+06 rem/h from the ISO-PC case discussed in Section 2. The neutron dose contribution is approximately 0.007% of the gamma dose rate, which is

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 6 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

insignificant, and therefore, does not need to be accounted for in the evaluation of the dose rates outside the package.

5.0 CONCLUSIONS

The ORIGEN2 computer code was used to determine the amount of each isotope present (including daughter products) in the Phase 1 tanks for decay times of 0 years, 10 years, and 50 years using the initial radioactive inventory data provided by SESC for Phase 1 tanks. Note that the inventory at 0 years is actually for a 1 day decay time to build in equilibrium daughter products. Table 1 summarizes the radioactive inventory for these three time periods.

The ISO-PC computer code was used to determine which isotopes present in the tank waste were considered key contributors to the dose, i.e., which isotopes contributed greater than 0.1% to the total direct dose outside the package for the three time periods (see Table 3). The following isotopes were found to be key contributors: Co60, Sr90/Y90, Ru106/Rh106, Sb125, Sn126/Sb126m/Sb126, Cs134, Cs137/Ba137m, Eu152, and Eu154.

The dose rate versus wall thickness for an activity loading of 1 Ci/m³ was calculated for each of the key contributors using the ISO-PC computer code. Table 4 and Figures 1 and 2 present these results. A second order polynomial fit of the log₁₀ of the dose rate versus package wall thickness was found to provide a reasonably accurate fit of the data, with fitting errors of less than 5% for all isotopes except Sr90 which had errors of 12% and 10.3% for 1 cm and 4 cm thicknesses (see Appendix E). Table 5 contains the polynomial regression fitting coefficients for the key contributors.

The dose rate versus wall thickness was found to be insensitive to the package size for the range of package sizes prescribed by the privatization contract. The dose rate versus wall thickness was found to be inversely proportional to the waste density. That is, the dose rates for a monolith (100% glass density) was 2/3 of the dose rate for glass marbles (67% glass density).

The neutron dose rate was found to be less than 0.01% of the gamma dose rate, and therefore, does not need to be accounted for separately in the evaluation of the dose rates outside the package.

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 7 of 55
Subject: ILAW Shielding Evaluation
Preparer: Anthony Savino AVS Date 2/5/98
Checker: John McCov Date 2/5/98
Section Chief: Janet McFadden Date 2/6/98

6.0 REFERENCES

- ANSI/ANS, 1991, *Neutron and Gamma-ray Fluence-to-dose Factors*, ANSI/ANS-6.1.1-1991, American National Standards Institute/American Nuclear Society, New York, New York.
- Nelson, J. V., 1996, *Estimation of Neutron Dose Rates from Nuclear Waste Packages*, (internal memo 8M730-JVN-96-007 to J. R. Green, March 8), Westinghouse Hanford Company, Richland, Washington.
- Rittmann, P. D., 1995, *ISO-PC Version 1.98 - User's Guide*, WHC-SD-WM-UM-030, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Savino, A. V., 1997, *Transmittal of Packaging Reports for Immobilized Low-Activity Waste Transport*, WMNW-9756121, July 21, 1997, Waste Management Federal Services, Inc., Northwest Operations, Richland, Washington.
- Schmittroth, F. A., 1994, *Conversion of ORIGEN2 to Sun Workstations*, WHC-SD-NR-SWD-006 Rev. 1, Westinghouse Hanford Company, Richland, Washington.

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 8 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Table 1 Phase 1 Tanks Radioactive Inventory, Ci

Isotope	Total for All Phase 1 Tanks			Tank AZ-101		
	Initial	10 yrs	50 yrs	Initial	10 yrs	50 yrs
H 3	1.95E+04	1.11E+04	1.18E+03	4.00E+00	2.28E+00	2.42E-01
C 14	3.10E+04	3.10E+04	3.08E+04	4.30E-01	4.30E-01	4.28E-01
NI59	1.00E+02	1.00E+02	1.00E+02	1.99E+01	1.99E+01	1.99E+01
CO60	9.63E+03	2.58E+03	1.34E+01	4.61E+03	1.24E+03	6.42E+00
NI63	1.04E+04	9.63E+03	7.12E+03	2.30E+03	2.14E+03	1.58E+03
SE79	1.71E+02	1.71E+02	1.71E+02	4.13E+01	4.13E+01	4.13E+01
SR90	5.12E+08	4.03E+08	1.56E+08	6.36E+06	5.02E+06	1.94E+06
Y 90	5.12E+08	4.03E+08	1.56E+08	6.36E+06	5.02E+06	1.94E+06
ZR93	9.30E+02	9.30E+02	9.30E+02	1.99E+02	1.99E+02	1.99E+02
NB93M	5.80E+02	7.01E+02	8.60E+02	8.75E+01	1.28E+02	1.81E+02
TC99	2.12E+04	2.12E+04	2.12E+04	1.10E+03	1.10E+03	1.10E+03
RU106	1.82E+05	1.88E+02	2.15E-10	1.06E+05	1.09E+02	1.24E-10
RH106	1.82E+05	1.88E+02	2.15E-10	1.06E+05	1.09E+02	1.25E-10
CD113M	6.62E+03	4.12E+03	6.16E+02	2.12E+03	1.32E+03	1.97E+02
SB125	2.30E+05	1.89E+04	8.49E-01	1.31E+05	1.07E+04	4.83E-01
TE125M	6.30E+02	4.61E+03	2.07E-01	3.58E+02	2.62E+03	1.18E-01
SN126	2.94E+02	2.94E+02	2.93E+02	6.57E+01	6.57E+01	6.57E+01
SB126	2.23E+00	4.11E+01	4.11E+01	5.01E-01	9.20E+00	9.20E+00
SB126M	2.94E+02	2.94E+02	2.93E+02	6.57E+01	6.57E+01	6.57E+01
I 129	3.83E+01	3.83E+01	3.83E+01	7.10E+00	7.10E+00	7.10E+00
CS134	8.55E+04	2.97E+03	4.29E-03	4.34E+04	1.51E+03	2.18E-03
CS137	2.54E+07	2.02E+07	8.00E+06	7.43E+06	5.90E+06	2.34E+06
BA137M	2.40E+07	1.91E+07	7.57E+06	7.03E+06	5.58E+06	2.22E+06

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 9 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Isotope	Total for All Phase 1 Tanks			Tank AZ-101		
	Initial	10 yrs	50 yrs	Initial	10 yrs	50 yrs
SM151	6.70E+05	6.20E+05	4.56E+05	1.42E+05	1.32E+05	9.67E+04
EU152	5.48E+02	3.29E+02	4.29E+01	2.73E+02	1.64E+02	2.14E+01
EU154	9.23E+04	4.12E+04	1.64E+03	5.76E+04	2.57E+04	1.02E+03
EU155	1.44E+05	3.56E+04	1.33E+02	7.15E+04	1.77E+04	6.60E+01
TL207	6.33E-05	6.61E-02	1.29E-01	1.86E-06	1.57E-03	2.69E-03
TL208	4.74E-04	1.35E+01	8.48E+00	5.43E-09	1.50E-04	1.05E-04
TL209	8.33E-06	8.09E-03	1.91E-02			
PB209	2.51E-04	3.75E-01	8.84E-01	1.22E-09	1.86E-06	1.27E-05
PB210	3.81E-08	1.46E-03	4.35E-03	1.25E-09	4.79E-05	1.42E-04
PB211	6.35E-05	6.63E-02	1.29E-01	1.87E-06	1.58E-03	2.70E-03
PB212	1.32E-03	3.75E+01	2.36E+01	1.51E-08	4.17E-04	2.92E-04
PB214	9.11E-04	5.48E-03	5.58E-03	2.99E-05	1.80E-04	1.82E-04
BI210	1.72E-09	1.46E-03	4.35E-03	5.64E-11	4.80E-05	1.42E-04
BI211	6.35E-05	6.63E-02	1.29E-01	1.87E-06	1.58E-03	2.70E-03
BI212	1.32E-03	3.75E+01	2.36E+01	1.51E-08	4.17E-04	2.92E-04
BI213	3.86E-04	3.75E-01	8.84E-01	1.88E-09	1.86E-06	1.27E-05
BI214	9.11E-04	5.48E-03	5.58E-03	2.99E-05	1.80E-04	1.82E-04
PO210	2.19E-12	1.46E-03	4.35E-03	7.17E-14	4.80E-05	1.42E-04
PO211	1.78E-07	1.86E-04	3.61E-04	5.23E-09	4.42E-06	7.56E-06
PO212	8.45E-04	2.40E+01	1.51E+01	9.68E-09	2.67E-04	1.87E-04
PO213	3.77E-04	3.67E-01	8.65E-01	1.83E-09	1.82E-06	1.24E-05
PO214	9.11E-04	5.48E-03	5.58E-03	2.99E-05	1.80E-04	1.82E-04
PO215	6.35E-05	6.63E-02	1.29E-01	1.87E-06	1.58E-03	2.70E-03
PO216	3.61E-03	3.75E+01	2.36E+01	4.06E-08	4.17E-04	2.92E-04

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 10 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Isotope	Total for All Phase 1 Tanks			Tank AZ-101		
	Initial	10 yrs	50 yrs	Initial	10 yrs	50 yrs
PO218	9.12E-04	5.48E-03	5.58E-03	2.99E-05	1.80E-04	1.82E-04
AT217	3.86E-04	3.75E-01	8.84E-01	1.88E-09	1.86E-06	1.27E-05
RN219	6.35E-05	6.63E-02	1.29E-01	1.87E-06	1.58E-03	2.70E-03
RN220	3.61E-03	3.75E+01	2.36E+01	4.06E-08	4.17E-04	2.92E-04
RN222	9.12E-04	5.48E-03	5.58E-03	2.99E-05	1.80E-04	1.82E-04
FR221	3.86E-04	3.75E-01	8.84E-01	1.88E-09	1.86E-06	1.27E-05
FR223	4.70E-04	9.14E-04	1.78E-03	1.38E-05	2.17E-05	3.72E-05
RA223	6.35E-05	6.63E-02	1.29E-01	1.87E-06	1.58E-03	2.70E-03
RA224	3.61E-03	3.75E+01	2.36E+01	4.06E-08	4.17E-04	2.92E-04
RA225	1.13E-02	3.75E-01	8.84E-01	5.49E-08	1.86E-06	1.27E-05
RA226	5.50E-03	5.48E-03	5.58E-03	1.80E-04	1.80E-04	1.82E-04
RA228	1.06E+01	4.48E+00	1.13E+00			
AC225	3.86E-04	3.75E-01	8.84E-01	1.88E-09	1.86E-06	1.27E-05
AC227	3.40E-02	6.62E-02	1.29E-01	1.00E-03	1.58E-03	2.70E-03
AC228	9.94E+00	4.48E+00	1.13E+00			
TH227	1.22E-03	6.54E-02	1.27E-01	3.59E-05	1.56E-03	2.66E-03
TH228	4.20E-02	3.75E+01	2.36E+01	4.57E-07	4.17E-04	2.92E-04
TH229	2.47E-01	3.75E-01	8.84E-01	1.20E-06	1.86E-06	1.27E-05
TH230	1.03E-06	3.76E-03	1.88E-02	2.96E-08	1.08E-04	5.45E-04
TH231	7.84E-01	1.64E+00	1.64E+00	2.11E-02	4.40E-02	4.41E-02
TH232	1.07E+00	1.07E+00	1.07E+00			
TH234	1.26E+00	4.45E+01	4.45E+01	2.33E-02	8.20E-01	8.20E-01
PA231	1.52E-01	1.52E-01	1.54E-01	3.10E-03	3.11E-03	3.15E-03
PA233	1.84E+00	7.27E+01	7.36E+01	4.97E-01	1.97E+01	2.00E+01

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 11 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Isotope	Total for All Phase 1 Tanks			Tank AZ-101		
	Initial	10 yrs	50 yrs	Initial	10 yrs	50 yrs
PA234M	1.26E+00	4.45E+01	4.45E+01	2.33E-02	8.20E-01	8.20E-01
PA234	1.04E-03	5.78E-02	5.78E-02	1.91E-05	1.07E-03	1.07E-03
U 232	3.54E+01	3.21E+01	2.18E+01	4.60E-04	4.18E-04	2.85E-04
U 233	1.36E+02	1.36E+02	1.36E+02	2.70E-04	1.13E-03	4.60E-03
U 234	4.18E+01	4.18E+01	4.19E+01	1.20E+00	1.21E+00	1.22E+00
U 235	1.64E+00	1.64E+00	1.64E+00	4.40E-02	4.40E-02	4.41E-02
U 236	2.20E+00	2.20E+00	2.20E+00	9.90E-02	9.91E-02	9.94E-02
U 237	9.59E-02	6.08E-01	8.87E-02	2.39E-02	1.52E-01	2.21E-02
U 238	4.45E+01	4.45E+01	4.45E+01	8.20E-01	8.20E-01	8.20E-01
NP237	7.25E+01	7.27E+01	7.36E+01	1.96E+01	1.97E+01	2.00E+01
NP239	3.70E+00	1.45E+01	1.44E+01	2.55E+00	9.98E+00	9.94E+00
PU238	5.24E+02	4.85E+02	3.53E+02	1.65E+02	1.53E+02	1.11E+02
PU239	3.04E+03	3.04E+03	3.03E+03	9.58E+02	9.58E+02	9.57E+02
PU240	8.71E+02	8.71E+02	8.67E+02	2.72E+02	2.72E+02	2.71E+02
PU241	4.01E+04	2.48E+04	3.61E+03	1.00E+04	6.18E+03	9.01E+02
PU242	1.64E-01	1.64E-01	1.64E-01	7.40E-02	7.40E-02	7.40E-02
AM241	6.73E+04	6.67E+04	6.33E+04	2.26E+04	2.24E+04	2.12E+04
AM243	1.45E+01	1.45E+01	1.44E+01	9.99E+00	9.98E+00	9.94E+00
CM242	4.13E+01	7.60E-06	0.00	2.53E+01	4.65E-06	0.00
CM243	6.91E+00	5.42E+00	2.05E+00	4.36E+00	3.42E+00	1.29E+00
CM244	1.60E+02	1.09E+02	2.35E+01	1.02E+02	6.96E+01	1.51E+01

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 12 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Table 2: Elemental Composition of Glass Waste Material*			
Element	Weight Fraction	Elemental Density in Glass Marbles g/cc	Elemental Density inside Waste Package ^b g/cc
Na	0.141	0.371	0.247
Al	0.082	0.132	0.088
Si	0.251	0.683	0.456
K	0.018	0.032	0.021
B	0.017	0.039	0.026
Ca	0.031	0.089	0.060
O	0.461	1.154	0.769
Total	1.000	2.500	1.667

* From Savino 1997.

^b Density in waste package = 2/3 density in glass marbles

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 13 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Table 3 Approximate % Dose Contribution for Each Isotope

Isotope	Total for All Phase 1 Tanks			Tank AZ-101		
	Initial	10 yrs	50 yrs	Initial	10 yrs	50 yrs
C 14	0.00	0.00	0.00	0.00	0.00	0.00
CO 60*	3.25	0.95	0.02	12.64	8.47	0.32
SE 79	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.04	0.03	0.05	0.00	0.01	0.02
Y 90*	79.11	69.25	95.71	7.87	15.55	44.04
ZR 93	0.00	0.00	0.00	0.00	0.00	0.00
NB 93m	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	0.00	0.00	0.00	0.00	0.00
RH106*	1.66	0.00	0.00	7.68	0.02	0.00
CD113m	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	0.00	0.00	0.00	0.00	0.00
SB125*	2.51	0.24	0.00	11.18	2.37	0.00
SB126*	0.00	0.01	0.02	0.00	0.02	0.15
SB126m*	0.03	0.03	0.11	0.05	0.12	0.88
TE125m	0.00	0.00	0.00	0.00	0.00	0.00
I 129	0.00	0.00	0.00	0.00	0.00	0.00
CS134*	0.04	0.00	0.00	0.16	0.01	0.00
CS137	0.00	0.00	0.00	0.00	0.00	0.00
BA137m*	2.60	24.17	3.30	6.01	12.73	36.86
SM151	0.00	0.00	0.00	0.00	0.00	0.00
EU152*	0.06	0.04	0.02	0.26	0.39	0.36
EU154*	10.70	5.26	0.75	54.16	60.32	17.36

HNF-2110 Rev 0

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 14 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Isotope	Total for All Phase 1 Tanks			Tank AZ-101		
	Initial	10 yrs	50 yrs	Initial	10 yrs	50 yrs
EU155	0.00	0.00	0.00	0.00	0.00	0.00
TL207	0.00	0.00	0.00	0.00	0.00	0.00
TL208	0.00	0.01	0.03	0.00	0.00	0.00
TL209	0.00	0.00	0.00	0.00	0.00	0.00
PB209	0.00	0.00	0.00	0.00	0.00	0.00
PB210	0.00	0.00	0.00	0.00	0.00	0.00
PB211	0.00	0.00	0.00	0.00	0.00	0.00
PB212	0.00	0.00	0.00	0.00	0.00	0.00
PB214	0.00	0.00	0.00	0.00	0.00	0.00
BI210	0.00	0.00	0.00	0.00	0.00	0.00
BI211	0.00	0.00	0.00	0.00	0.00	0.00
BI212	0.00	0.00	0.00	0.00	0.00	0.00
BI213	0.00	0.00	0.00	0.00	0.00	0.00
BI214	0.00	0.00	0.00	0.00	0.00	0.00
PO214	0.00	0.00	0.00	0.00	0.00	0.00
RN219	0.00	0.00	0.00	0.00	0.00	0.00
RN220	0.00	0.00	0.00	0.00	0.00	0.00
RN222	0.00	0.00	0.00	0.00	0.00	0.00
FR221	0.00	0.00	0.00	0.00	0.00	0.00
RA223	0.00	0.00	0.00	0.00	0.00	0.00
RA224	0.00	0.00	0.00	0.00	0.00	0.00
RA225	0.00	0.00	0.00	0.00	0.00	0.00
RA226	0.00	0.00	0.00	0.00	0.00	0.00
RA228	0.00	0.00	0.00	0.00	0.00	0.00
AC225	0.00	0.00	0.00	0.00	0.00	0.00

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-PCAL-001 Rev. 0 Project No. 772028 Page 15 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Isotope	Total for All Phase 1 Tanks			Tank AZ-101		
	Initial	10 yrs	50 yrs	Initial	10 yrs	50 yrs
AC227	0.00	0.00	0.00	0.00	0.00	0.00
AC228	0.00	0.00	0.00	0.00	0.00	0.00
TH227	0.00	0.00	0.00	0.00	0.00	0.00
TH228	0.00	0.00	0.00	0.00	0.00	0.00
TH229	0.00	0.00	0.00	0.00	0.00	0.00
TH230	0.00	0.00	0.00	0.00	0.00	0.00
TH231	0.00	0.00	0.00	0.00	0.00	0.00
TH232	0.00	0.00	0.00	0.00	0.00	0.00
TH234	0.00	0.00	0.00	0.00	0.00	0.00
PA231	0.00	0.00	0.00	0.00	0.00	0.00
PA233	0.00	0.00	0.00	0.00	0.00	0.00
PA234m	0.00	0.00	0.00	0.00	0.00	0.00
PA234	0.00	0.00	0.00	0.00	0.00	0.00
U 232	0.00	0.00	0.00	0.00	0.00	0.00
U 233	0.00	0.00	0.00	0.00	0.00	0.00
U 234	0.00	0.00	0.00	0.00	0.00	0.00
U 235	0.00	0.00	0.00	0.00	0.00	0.00
U 236	0.00	0.00	0.00	0.00	0.00	0.00
U 237	0.00	0.00	0.00	0.00	0.00	0.00
U 238	0.00	0.00	0.00	0.00	0.00	0.00
NP237	0.00	0.00	0.00	0.00	0.00	0.00
NP239	0.00	0.00	0.00	0.00	0.00	0.00
PU238	0.00	0.00	0.00	0.00	0.00	0.00
PU239	0.00	0.00	0.00	0.00	0.00	0.00
PU240	0.00	0.00	0.00	0.00	0.00	0.00

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 16 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Isotope	Total for All Phase 1 Tanks			Tank AZ-101		
	Initial	10 yrs	50 yrs	Initial	10 yrs	50 yrs
PU241	0.00	0.00	0.00	0.00	0.00	0.00
PU242	0.00	0.00	0.00	0.00	0.00	0.00
AM241	0.00	0.00	0.00	0.00	0.00	0.00
AM243	0.00	0.00	0.00	0.00	0.00	0.00
CM242	0.00	0.00	0.00	0.00	0.00	0.00
CM243	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	0.00	0.00	0.00	0.00	0.00

* Isotope contributing >0.1% to the total direct dose.

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 17 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Table 4 Dose Rate per Unit Activity Loading, rem/h/Ci/m3									
cm	Co60	Sr90*	Ru106*	Sb125	Sn126 ^c	Cs134	Cs137 ^d	Eu152	Eu154
1	7.88E-01	1.01E-03	5.10E-02	8.56E-02	3.64E-01	3.86E-01	1.35E-01	3.06E-01	3.46E-01
2	4.78E-01	4.70E-04	2.66E-02	4.22E-02	2.05E-01	2.07E-01	7.10E-02	1.77E-01	2.02E-01
4	1.92E-01	1.31E-04	8.14E-03	1.14E-02	7.15E-02	6.59E-02	2.15E-02	6.65E-02	7.57E-02
6	8.04E-02	4.26E-05	2.69E-03	3.27E-03	2.64E-02	2.21E-02	6.80E-03	2.66E-02	3.00E-02
8	3.44E-02	1.51E-05	9.37E-04	9.63E-04	1.00E-02	7.64E-03	2.19E-03	1.10E-02	1.23E-02
10	1.49E-02	5.67E-06	3.41E-04	2.89E-04	3.90E-03	2.70E-03	7.15E-04	4.61E-03	5.11E-03
12	6.48E-03	2.24E-06	1.30E-04	8.79E-05	1.54E-03	9.72E-04	2.35E-04	1.97E-03	2.16E-03
14	2.84E-03	9.14E-07	5.09E-05	2.70E-05	6.17E-04	3.56E-04	7.75E-05	8.51E-04	9.22E-04
16	1.25E-03	3.85E-07	2.07E-05	8.39E-06	2.51E-04	1.33E-04	2.56E-05	3.71E-04	3.98E-04
18	5.51E-04	1.66E-07	8.61E-06	2.63E-06	1.03E-04	5.04E-05	8.52E-06	1.63E-04	1.73E-04
20	2.44E-04	7.34E-08	3.67E-06	8.26E-07	4.30E-05	1.94E-05	2.84E-06	7.21E-05	7.59E-05

- * Includes Sr90 and Y90
- ^b Includes Ru106 and Rh106
- ^c Includes Sn126, Sb126m, and Sb126
- ^d Includes Cs137 and Ba137m

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 18 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Table 5 Polynomial Regression Fitting Coefficients			
Isotope	a	b	c
Co60	0.000654	-0.197	0.075
Sr90	0.00313	-0.279	-2.774
Ru106	0.002311	-0.265	-1.052
Sb125	0.001031	-0.284	-0.807
Sn126	0.001191	-0.23	-0.229
Cs134	0.001292	-0.252	-0.18
Cs137	0.000641	-0.258	-0.631
Eu152	0.001104	-0.212	-0.327
Eu154	0.001048	-0.213	-0.27

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 19 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino
 Checker: John McCov *AM*
 Section Chief: Janet McFadden *JO*
 Date 2/5/98
 Date 2/5/98
 Date 2/6/98

Figure 1

Dose Rate vs Package Wall Thickness for 1 Ci/m³ Activity Concentration

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 20 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Figure 2

Dose Rate vs Package Wall Thickness for 1 Ci/m³ Activity Concentration

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 21 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino
 Checker: John McCov
 Section Chief: Janet McFadden

Date 2/5/98
 Date 2/5/98
 Date 2/6/98

APPENDIX A

Spreadsheet of Radioactive Inventory for Phase 1 Tanks

Isotope	Units	Sample Based	AN-102	AN-103	AN-104	AN-105	AN-106	AN-107
3H	C1	0.371	1.27 S	9.31 S	43.3 S	1410 HDW	27.5 E/H	329 HDW
14C	C1	3.631	0.648 S	112 S	104 HDW	198 HDW	3.57 E/H	148 HDW
59Ni	C1	1.104	11.5 HDW	7.58 HDW	5.61 HDW	11.1 HDW	0.257 E/H	6.49 HDW
60Co	C1	37.394	759 S	<112 S	<149 S	124 S	4.87 E/H	200 HDW
63Ni	C1	1.111	1140 HDW	747 HDW	552 HDW	1090 HDW	22.1 E/H	442 HDW
79Se	C1	0.511	1.01 S	12.3 HDW	11.3 HDW	21.9 HDW	0.458 E/H	14.5 HDW
90Sr	C1	56.571	368000 S	8030 S	93800 S	33600 S	137 E	554000 S
90Y	C1	53.111	368000 S	8030 S	93800 S	33600 S	137 E	554000 S
93Nb	C1	0.001	13.8 HDW	43.2 HDW	40.2 HDW	77.6 HDW	1.62 E/H	51 HDW
93Zr	C1	0.001	101 HDW	59.6 HDW	55.3 HDW	106 HDW	2.2 E/H	71.3 HDW
99Tc	C1	51.644	49.7 S	456 S	345 S	1170 S	26.3 E/H	1160 HDW
106Ru	C1	0.001	0.0495 HDW	0.0533 HDW	0.0323 HDW	0.056 HDW	0.0018 E/H	0.0356 HDW
113mCd	C1	0.001	565 HDW	302 HDW	290 HDW	552 HDW	10.9 E/H	389 HDW
125Sb	C1	2.211	159 S	865 HDW	745 HDW	1330 HDW	31.2 E/H	951 HDW
126Sn	C1	0.001	31.5 HDW	18.8 HDW	17.2 HDW	33.2 HDW	0.699 E/H	21.8 HDW
129I	C1	40.561	3.17 HDW	8.32 S	<7.53 S	11 S	0.0507 E/H	2.25 HDW
134Cs	C1	0.041	19.7 S	189 HDW	123 HDW	208 HDW	5.28 E/H	57.1 HDW
137mBa	C1	43.201	1.4E+06S	2.2E+06S	2.2E+06S	794000 S	19400 E	1.4E+06S
137Cs	C1	43.281	1.5E+06S	2.3E+06S	2.3E+06S	836000 S	20500 E	1.5E+06S
151Sm	C1	0.001	73400 HDW	43600 HDW	40000 HDW	77200 HDW	1620 E/H	50800 HDW
152Eu	C1	0.001	<40.7 S	15.8 HDW	14.5 HDW	26.9 HDW	0.536 E/H	20 HDW
154Eu	C1	19.791	375 S	<604 S	<676 S	<565 S	78.9 E/H	3030 HDW
155Eu	C1	8.394	322 S	<3300 S	<4730 S	<2260 S	33.2 E/H	1220 HDW
226Ra	C1	0.001	0.0008 HDW	0.0006 HDW	0.0005 HDW	0.0009 HDW	2E-05 E/H	0.0005 HDW
227Ac	C1	0.001	0.0049 HDW	0.0036 HDW	0.0039 HDW	0.0057 HDW	0.0001 E/H	0.0033 HDW
228Ra	C1	0.001	1.72 HDW	1.05 HDW	1.03 HDW	2.03 HDW	0.0281 E/H	2.05 HDW
229Th	C1	0.001	0.0399 HDW	0.0243 HDW	0.0239 HDW	0.0471 HDW	0.0007 E/H	0.0474 HDW
231Pa	C1	0.001	0.0235 HDW	0.0143 HDW	0.0128 HDW	0.0249 HDW	0.0005 E/H	0.016 HDW
232Th	C1	0.001	0.183 HDW	0.103 HDW	0.109 HDW	0.212 HDW	0.0027 E/H	0.232 HDW
232U	C1	0.001	5.33 HDW	3.59 HDW	3.17 HDW	6.32 HDW	0.0952 E/H	5.48 HDW
233U	C1	0.001	20.4 HDW	13.8 HDW	12.1 HDW	24.2 HDW	0.38 E/H	21 HDW
234U	C1	0.111	4.22 HDW	4.87 HDW	3.59 HDW	5.5 HDW	0.227 E/H	2.69 HDW
235U	C1	0.371	0.168 HDW	0.189 HDW	0.14 HDW	0.216 HDW	0.0088 E/H	0.104 HDW
236U	C1	1.904	0.15 HDW	0.285 HDW	0.193 HDW	0.249 HDW	0.015 E/H	0.0951 HDW
237Np	C1	44.881	<0.477 S	<31 S	<30.7 S	25.8 S	0.094 E/H	3.98 HDW
238Pu	C1	21.781	11.7 S	12.6 HDW	7.97 HDW	11.9 HDW	0.528 E/H	5.98 HDW
238U	C1	0.491	5.36 HDW	4.84 HDW	3.86 HDW	6.53 HDW	0.201 E/H	4.07 HDW
239/240Pu	C1	79.481	57.5 S	12.3 S	9.7 S	6.43 S	NR	261 S
239Pu	C1	23.501	NR	NR	NR	NR	9.11 E/H	NR
240Pu	C1	14.441	NR	NR	NR	NR	1.85 E/H	NR
241Am	C1	66.151	812 S	21.7 S	<50 S	10.1 S	11.4 E/H	3650 S
241Pu	C1	15.781	672 HDW	1060 HDW	654 HDW	920 HDW	47.8 E/H	429 HDW
242Cm	C1	0.144	0.0014 S	0.623 HDW	0.524 HDW	0.987 HDW	0.0216 E/H	0.633 HDW
242Pu	C1	0.001	0.0036 HDW	0.005 HDW	0.0031 HDW	0.0046 HDW	0.0002 E/H	0.0023 HDW
243Am	C1	0.001	0.0138 HDW	0.0021 HDW	0.0012 HDW	0.0188 HDW	0.0009 E/H	0.0099 HDW
243Cm	C1	95.241	0.513 S	<4.85 S	<0.48 S	<0.17 S	0.0022 E/H	0.0633 HDW
244Cm	C1	54.011	15.4 S	<13 S	<12 S	<4.1 S	0.0309 E/H	0.463 HDW

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 22 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino
 Checker: John McCoy
 Section Chief: Janet McFadden

Date 2/5/98Date 2/5/98Date 2/6/98

Isotope	Units	Sample Based	A9-101	A2-101	A2-102	SY-101	SY-103	TOTAL
3H	CI	0.371	958 HDW	4.3 S	14700 HDW	1360 HDW	3.16 S	19465.5
14C	CI	3.834	124 HDW	0.43 S	0.63 S	204 HDW	105 HDW	1000.48
59Ni	CI	1.101	7.18 HDW	19.9 E	10.8 E	13 HDW	6.51 HDW	99.927
60Co	CI	37.351	173 HDW	4610 E	3420 E	228 HDW	105 S	9623.87
63Ni	CI	1.111	707 HDW	2300 E	1250 E	1280 HDW	639 HDW	10369.1
79Se	CI	0.511	14.8 HDW	41.3 E	22.8 E	20.3 HDW	10.5 HDW	171.168
90Sr	CI	56.571	31300 E	6.4E+06E	3.7E+06E	125000 S	79000 S	1.1E+07
90Y	CI	53.111	31300 E	6.4E+06E	3.7E+06E	125000 S	79000 S	1.1E+07
93mNb	CI	0.001	52.4 HDW	87.4 E	43.3 E	72.1 HDW	37.3 HDW	579.92
93Zr	CI	0.001	71.5 HDW	199 E	111 E	99.5 HDW	51.5 HDW	929.9
99Tc	CI	51.641	922 HDW	1100 E	559 S	14600 S	759 S	21187
106Ru	CI	0.001	0.0607 HDW	106000 E	76200 E	0.0416 HDW	0.0216 HDW	182200
113mCd	CI	0.001	362 HDW	2120 E	1220 E	526 HDW	273 HDW	6615.9
125Sb	CI	2.211	1180 HDW	131000 E	92700 E	989 HDW	523 HDW	230473
126Sn	CI	0.001	22.6 HDW	65.7 E	35.4 E	30.6 HDW	15.8 HDW	293.299
129I	CI	40.564	1.78 HDW	7.1 S	1.52 E	2.79 HDW	0.258 S	38.2387
134Cs	CI	0.041	265 HDW	43400 E	41200 E	16.8 HDW	9 HDW	85492.9
137mBa	CI	43.204	1.7E+06E	6.9E+06E	4E+06 E	2.1E+06S	1.1E+06S	2.4E+07
137Cs	CI	43.281	1.8E+06E	7.4E+06E	4.3E+06E	2.2E+06S	1.1E+06S	2.5E+07
151Sm	CI	0.001	52400 HDW	142000 E	80200 E	71400 HDW	36900 HDW	469520
152Eu	CI	0.001	17.9 HDW	273 E	142 E	24.6 HDW	12.7 HDW	567.936
154Eu	CI	19.791	2690 HDW	57600 E	23100 E	3730 HDW	1620 S	92223.9
155Eu	CI	8.391	1140 HDW	71500 E	66900 E	1460 HDW	1410 S	143985
226Ra	CI	0.001	0.0006 HDW	0.0002 E	8.5E-05E	0.0009 HDW	0.0004 HDW	0.0055
227Ac	CI	0.001	0.004 HDW	0.001 E	0.0005 E	0.0054 HDW	0.0028 HDW	0.03401
228Ra	CI	0.001	1.31 HDW	1.3E-08E	72-69 E	0.865 HDW	0.556 HDW	10.6391
229Th	CI	0.001	0.0304 HDW	1.2E-06E	6.8E-07E	0.0203 HDW	0.013 HDW	0.24695
231Pa	CI	0.001	0.0171 HDW	0.0031 E	0.0018 E	0.025 HDW	0.0128 HDW	0.15181
232Th	CI	0.001	0.127 HDW	1.6E-08E	9.4E-09E	0.0584 HDW	0.0458 HDW	1.07291
232U	CI	0.001	4.53 HDW	0.0005 S/E	0.0007 S/E	4.4 HDW	0.218 HDW	35.3304
233U	CI	0.001	17.4 HDW	0.0003 S/E	0.0004 S/E	16.9 HDW	9.22 HDW	135.401
234U	CI	0.411	10.1 HDW	1.2 S/E	2.24 S/E	4.75 HDW	2.39 HDW	41.777
235U	CI	0.374	0.39 HDW	0.044 S/E	0.0813 S/E	0.192 HDW	0.0965 HDW	1.63656
236U	CI	1.901	0.7 HDW	0.099 S/E	0.164 S/E	0.149 HDW	0.0752 HDW	2.1943
237Np	CI	44.881	3.31 HDW	19.6 E	11.7 E	5.24 HDW	2.74 HDW	72.464
238Pu	CI	21.761	83.4 HDW	165 S	161 S	8.6 HDW	35.4 S	523.978
238U	CI	0.451	8.79 HDW	0.82 S/E	1.53 S/E	5.56 HDW	2.86 HDW	44.421
239/240Pu	CI	79.481	NR	NR	NR	46.6 S	134 S	527.53
239Pu	CI	23.501	817 HDW	958 S	1250 S/E	NR	NR	3034.11
240Pu	CI	14.441	225 HDW	272 S	372 S/E	NR	NR	870.85
241Am	CI	66.151	388 HDW	22600 E	37700 S	633 S	1440 S	87267.2
241Pu	CI	16.781	8330 HDW	9990 S	17100 S	584 HDW	295 HDW	40091.8
242Cm	CI	0.141	0.698 HDW	25.4 E	11.2 E	0.938 HDW	0.47 HDW	41.496
242Pu	CI	0.001	0.0319 HDW	0.074 E	0.034 E	0.0032 HDW	0.0016 HDW	0.16342
243Am	CI	0.001	0.0311 HDW	9.98 S	4.42 E	0.0123 HDW	0.0063 HDW	14.4964
243Cm	CI	95.241	0.0712 HDW	4.36 E	1.77 E	0.087 HDW	0.0436 HDW	6.91027
244Cm	CI	54.011	1 HDW	102 E	39.3 E	0.841 HDW	0.421 HDW	159.456

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 23 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino
 Checker: John McCoy
 Section Chief: Janet McFadden

Date 2/5/98
 Date 2/5/98
 Date 2/6/98

APPENDIX B

ORIGEN2 Input File for All Phase 1 Tanks

```

-1
-1
-1
TIT      Phase 1 Tanks - Total Inventory
BAS      DECAY
LIP      0 0 0
LIB      0 1 2 3 381 382 383 9 0 0 1 1
PHO      101 102 103 10
RDA      Shield Source Term
INP      -1 1 -1 -1 1 1
RDA      SHORT DECAY
MOV      -1 1 0 1.00
RDA
DEC      1.00      1 2 4 1      DECAY FOR 1 DAY
DEC      10.0     2 3 4 0      DECAY FOR 10 DAYS
DEC      1.00     3 4 5 0      DECAY FOR 1 YEAR
DEC      10.0     4 5 5 0      DECAY FOR 10 YEARS
DEC      20.0     5 6 5 0      DECAY FOR 20 YEARS
DEC      30.0     6 7 5 0      DECAY FOR 30 YEARS
DEC      40.0     7 8 5 0      DECAY FOR 40 YEARS
DEC      50.0     8 9 5 0      DECAY FOR 50 YEARS
RDA
CUT      5 1.E-10 7 1.E-10 9 1.E-10 -1
OPTL     4*8 8 8 7 8 7 15*8
OPTF     4*8 8 8 7 8 7 15*8
OPTA     4*8 8 8 7 8 7 15*8
OUT      9 1 -1 0
STP      4
3 10030 2.017E+00 60140 6.956E+03 340790 2.458E+03 380900 3.749E+06
3 390900 9.400E+02 410931 2.052E+00 400930 3.701E+05 430990 1.250E+06
3 441060 5.446E+01 481131 3.053E+01 511250 2.232E+02 501260 1.034E+04
3 531290 2.166E+05 551340 6.609E+01 561371 4.430E+02 551370 2.920E+05
3 621510 2.545E+04 631520 3.169E+00 631540 3.417E+02 631550 3.096E+02
1 280590 1.320E+03 270600 8.513E+00 280630 1.682E+02 0 0.000E+00
2 882260 5.559E-03 892270 4.703E-04 882280 4.547E-02 902290 1.161E+00
2 912310 3.215E+00 902320 9.784E+06 922320 1.651E+00 922330 1.399E+04
2 922340 6.687E+03 922350 7.572E+05 922360 3.392E+04 922370 1.028E+05
2 942380 3.061E+01 922380 1.322E+08 942390 4.882E+04 942400 3.822E+03
2 952410 1.960E+04 942410 3.892E+02 962420 1.255E-02 942420 4.281E+01
2 952430 7.273E+01 962430 1.339E-01 962440 1.971E+00 0 0.000E+00
U
END

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 24 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino
 Checker: John McCoy
 Section Chief: Janet McFadden

Date 2/5/98
 Date 2/5/98
 Date 2/6/98

ORIGEN2 Input File for Tank A2-101

```

-1
-1
-1
TIT      AZ-101 - Total Inventory
BAS      DECAF
LIP      0 0 0
LIB      0 1 2 3 381 382 383 9 0 0 1 1
PHO      101 102 103 10
RDA      Shield Source Term
IMP      -1 1 -1 -1 1 1
RDA      SHORT DECAF
MOV      -1 1 0 1.00
RDA
DEC      1.00      1 2 4 1      DECAF FOR 1 DAY
DEC      10.0     2 3 4 0      DECAF FOR 10 DAYS
DEC      1.00     3 4 5 0      DECAF FOR 1 YEAR
DEC      10.0     4 5 5 0      DECAF FOR 10 YEARS
DEC      20.0     5 6 5 0      DECAF FOR 20 YEARS
DEC      30.0     6 7 5 0      DECAF FOR 30 YEARS
DEC      40.0     7 8 5 0      DECAF FOR 40 YEARS
DEC      50.0     8 9 5 0      DECAF FOR 50 YEARS
RDA
CUT      5 1.E-10 7 1.E-10 9 1.E-10 -1
OPTL     4*8 8 8 7 8 7 15*8
OPTF     4*8 8 8 7 8 7 15*8
OPTA     4*8 8 8 7 8 7 15*8
OUT      9 1 -1 0.
STP      4
3 10030 4.146E-04 60140 9.649E-02 340790 5.930E+02 380900 4.663E+04
3 390900 1.169E+01 410931 3.093E-01 400930 7.921E+04 430990 6.490E+04
3 441060 3.169E+01 481131 9.778E+00 511250 1.269E+02 501260 2.316E+03
3 531290 4.022E+04 551340 3.355E+01 561371 1.289E-02 551370 8.543E+04
3 621510 5.399E+03 631520 1.579E+00 631540 2.134E+02 631550 1.538E+02
1 280590 2.628E+02 270600 4.078E+00 280630 3.730E+01 0 0.000E+00
2 882260 1.821E-04 892270 1.383E-05 882280 5.556E-11 902290 5.642E-06
3 912310 6.564E-02 902320 1.459E-01 922320 2.150E-05 922330 2.790E-02
2 922340 1.921E+02 922350 2.036E+04 922360 1.530E+03 932370 2.781E+04
2 942380 9.640E+00 922380 2.439E+06 942390 1.541E+04 942400 1.194E+03
2 952410 6.586E+03 942410 9.699E+01 952420 7.683E-03 942420 1.938E+01
2 952430 5.007E+01 952430 8.448E-02 962440 1.261E+00 0 0.000E+00
END

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 25 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

APPENDIX C

ISO-PC Input File at Time 0 for All Phase 1 Tanks

```

0      2      ILAW - All Phase 1 Tanks - Initial
Rectangular Source Geom - Dose Rate at Surface
Input Next= 1, ISpec= 3, IGeom= 10, ICONC=0, SFACT=1, DUNIT=7,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=1,
SLTH= 180.,
Y= 120.,
T(1)= 120.,
T(2)= 8.,
X= 129.,
WEIGHT(451) = 3.10E+04,
WEIGHT(472) = 9.63E+03,
WEIGHT( 27) = 1.71E+02,
WEIGHT( 82) = 5.12E+08,
WEIGHT( 84) = 5.12E+08,
WEIGHT(102) = 9.30E+02,
WEIGHT(103) = 5.80E+02,
WEIGHT(141) = 2.12E+04,
WEIGHT(170) = 1.82E+05,
WEIGHT(172) = 1.82E+05,
WEIGHT(206) = 6.62E+03,
WEIGHT(269) = 2.30E+05,
WEIGHT(270) = 6.30E+02,
WEIGHT(272) = 2.94E+02,
WEIGHT(274) = 2.23E+00,
WEIGHT(273) = 2.94E+02,
WEIGHT(290) = 3.83E+01,
WEIGHT(319) = 8.55E+04,
WEIGHT(335) = 2.54E+07,
WEIGHT(336) = 2.40E+07,
WEIGHT(403) = 6.70E+05,
WEIGHT(408) = 5.48E+02,
WEIGHT(415) = 9.22E+04,
WEIGHT(418) = 1.44E+05,
WEIGHT(332) = 6.33E-05,
WEIGHT(414) = 4.74E-04,
WEIGHT(392) = 8.33E-06,
WEIGHT(482) = 2.51E-04,
WEIGHT(508) = 3.81E-08,
WEIGHT(341) = 6.35E-05,
WEIGHT(524) = 1.32E-03,
WEIGHT(510) = 9.11E-04,
WEIGHT(483) = 1.72E-09,
WEIGHT(537) = 6.35E-05,
WEIGHT(525) = 1.32E-03,
WEIGHT(509) = 3.86E-04,
WEIGHT(511) = 9.11E-04,
WEIGHT(512) = 9.11E-04,
WEIGHT(351) = 6.35E-05,
WEIGHT(523) = 3.61E-03,
WEIGHT(514) = 9.12E-04,
WEIGHT(513) = 3.86E-04,
WEIGHT(362) = 6.35E-05,
WEIGHT(522) = 3.61E-03,
WEIGHT(515) = 1.13E-02,
WEIGHT(485) = 5.50E-03,
WEIGHT(488) = 1.06E+01,

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 26 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

WEIGHT(516) = 3.86E-04 ,
 WEIGHT(487) = 3.40E-02 ,
 WEIGHT(436) = 9.94E+00 ,
 WEIGHT(364) = 1.22E-03 ,
 WEIGHT(442) = 4.20E-02 ,
 WEIGHT(517) = 2.47E-01 ,
 WEIGHT(518) = 1.03E-06 ,
 WEIGHT(450) = 7.84E-01 ,
 WEIGHT(431) = 1.07E+00 ,
 WEIGHT(530) = 1.26E+00 ,
 WEIGHT(371) = 1.52E-01 ,
 WEIGHT(490) = 1.84E+00 ,
 WEIGHT(533) = 1.26E+00 ,
 WEIGHT(441) = 1.04E-03 ,
 WEIGHT(429) = 3.53E+01 ,
 WEIGHT(519) = 1.36E+02 ,
 WEIGHT(520) = 4.18E+01 ,
 WEIGHT(476) = 1.64E+00 ,
 WEIGHT(398) = 2.19E+00 ,
 WEIGHT(491) = 9.59E-02 ,
 WEIGHT(526) = 4.45E+01 ,
 WEIGHT(502) = 7.25E+01 ,
 WEIGHT(503) = 3.70E+00 ,
 WEIGHT(492) = 5.24E+02 ,
 WEIGHT(493) = 3.04E+03 ,
 WEIGHT(494) = 8.71E+02 ,
 WEIGHT(495) = 4.01E+04 ,
 WEIGHT(497) = 1.63E-01 ,
 WEIGHT(496) = 5.73E+04 ,
 WEIGHT(505) = 1.45E+01 ,
 WEIGHT(504) = 4.13E+01 ,
 WEIGHT(506) = 3.91E+00 ,
 WEIGHT(500) = 1.63E+02 , &
 Na 5 0.247
 Al 7 0.088
 Si 27 0.456
 K 32 0.021
 B 6 0.026
 Ca 33 0.060
 O 23 0.769
 Air 3 4.06E-4
 1Fe 9 7.86
 End of Input
 \$Input Hex= 6 4

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 27 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

ISO-PC Input File at Time 0 for Tank AZ-101

```

0      2      ILAW - AZ-101 Tank - Initial - Cs Reduction Factor=200
Rectangular Source Geom - Dose Rate at Surface
Input Next= 1 , ISpec= 3 , IGeom= 10 , ICON=0, SPACT=1, DUNIT=7,
NThota= 30, NPsi= 30, NShld= 2 , JBuf= 2, OPTION=1,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)= 8.,
X= 129.
WEIGHT(451) = 4.30E-01 ,
WEIGHT(472) = 4.61E+03 ,
WEIGHT( 27) = 4.13E+01 ,
WEIGHT( 82) = 6.36E+06 ,
WEIGHT( 84) = 6.36E+06 ,
WEIGHT(102) = 1.99E+02 ,
WEIGHT(103) = 8.75E+01 ,
WEIGHT(141) = 1.10E+03 ,
WEIGHT(170) = 1.06E+05 ,
WEIGHT(172) = 1.06E+05 ,
WEIGHT(206) = 2.12E+03 ,
WEIGHT(269) = 1.31E+05 ,
WEIGHT(270) = 3.58E+02 ,
WEIGHT(272) = 6.57E+01 ,
WEIGHT(274) = 5.01E-01 ,
WEIGHT(273) = 6.57E+01 ,
WEIGHT(290) = 7.10E+00 ,
WEIGHT(319) = 2.20E+02 ,
WEIGHT(335) = 3.70E+04 ,
WEIGHT(336) = 3.50E+04 ,
WEIGHT(403) = 1.42E+05 ,
WEIGHT(408) = 2.73E+02 ,
WEIGHT(415) = 5.76E+04 ,
WEIGHT(418) = 7.15E+04 ,
WEIGHT(332) = 1.86E-06 ,
WEIGHT(414) = 5.43E-09 ,
WEIGHT(482) = 1.22E-09 ,
WEIGHT(508) = 1.25E-09 ,
WEIGHT(341) = 1.87E-06 ,
WEIGHT(524) = 1.51E-08 ,
WEIGHT(510) = 2.98E-05 ,
WEIGHT(483) = 5.64E-11 ,
WEIGHT(337) = 1.87E-06 ,
WEIGHT(525) = 1.51E-08 ,
WEIGHT(509) = 1.87E-09 ,
WEIGHT(511) = 2.98E-05 ,
WEIGHT(512) = 2.98E-05 ,
WEIGHT(351) = 1.87E-06 ,
WEIGHT(523) = 4.06E-08 ,
WEIGHT(514) = 2.99E-05 ,
WEIGHT(513) = 1.87E-09 ,
WEIGHT(362) = 1.87E-06 ,
WEIGHT(522) = 4.06E-08 ,
WEIGHT(515) = 5.49E-08 ,
WEIGHT(485) = 1.80E-04 ,
WEIGHT(516) = 1.87E-09 ,
WEIGHT(487) = 1.00E-03 ,
WEIGHT(364) = 3.59E-05 ,
WEIGHT(442) = 4.57E-07 ,
WEIGHT(517) = 1.20E-06 ,

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 28 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

WEIGHT(518) = 2.96E-08 ,
 WEIGHT(450) = 2.11E-02 ,
 WEIGHT(530) = 2.33E-02 ,
 WEIGHT(371) = 3.10E-03 ,
 WEIGHT(490) = 4.97E-01 ,
 WEIGHT(533) = 2.33E-02 ,
 WEIGHT(441) = 1.91E-05 ,
 WEIGHT(429) = 4.60E-04 ,
 WEIGHT(519) = 2.70E-04 ,
 WEIGHT(520) = 1.20E+00 ,
 WEIGHT(476) = 4.40E-02 ,
 WEIGHT(398) = 9.90E-02 ,
 WEIGHT(491) = 2.39E-02 ,
 WEIGHT(526) = 8.20E-01 ,
 WEIGHT(502) = 1.96E+01 ,
 WEIGHT(503) = 2.55E+00 ,
 WEIGHT(492) = 1.65E+02 ,
 WEIGHT(493) = 9.58E+02 ,
 WEIGHT(494) = 2.72E+02 ,
 WEIGHT(495) = 9.99E+03 ,
 WEIGHT(497) = 7.40E-02 ,
 WEIGHT(496) = 2.26E+04 ,
 WEIGHT(505) = 9.98E+00 ,
 WEIGHT(504) = 2.53E+01 ,
 WEIGHT(506) = 4.36E+00 ,
 WEIGHT(500) = 1.02E+02 , &
 Na 25 0.247
 Al 7 0.088
 Si 27 0.456
 K 32 0.021
 S 6 0.026
 Ca 33 0.060
 O 23 0.769
 Air 3 4.06E-4
 lFe 9 7.86
 End of Input
 \$Input Next= 6 &

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 29 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

APPENDIX D

Example ISO-PC Input File to Determine the Dose Rate vs Wall Thickness - Sr90/Y90

```

0      2  ILAW - 1 Ci/m3 of Sr-90/Y-90 in Waste Package
Dose Rate at Surface - 1 cm Steel
Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)= 1.00 ,
X= 122. ,
WEIGHT(82) = 1.0,
WEIGHT(84) = 1.0, &
Na 25 0.247
Al 7 0.088
Si 27 0.456
K 32 0.021
B 6 0.026
Ca 33 0.060
O 23 0.769
Air 3 4.06E-4
lFe 9 7.86
Dose Rate at Surface - 2 cm Steel
Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)= 2.00 ,
X= 123. ,
WEIGHT(82) = 1.0,
WEIGHT(84) = 1.0, &
Na 25 0.247
Al 7 0.088
Si 27 0.456
K 32 0.021
B 6 0.026
Ca 33 0.060
O 23 0.769
Air 3 4.06E-4
lFe 9 7.86
Dose Rate at Surface - 4 cm Steel
Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)= 4.00 ,
X= 125. ,
WEIGHT(82) = 1.0,
WEIGHT(84) = 1.0, &
Na 25 0.247
Al 7 0.088
Si 27 0.456
K 32 0.021
B 6 0.026
Ca 33 0.060
O 23 0.769

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 30 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

```

Air      3  4.06E-4
lFe      9      7.86
Dose Rate at Surface - 6 cm Steel
$Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTW= 180.,
Y = 120.,
T(1)= 120.,
T(2)= 6.00,
X= 127.,
WEIGHT(82) = 1.0,
WEIGHT(84) = 1.0, &
Na      25  0.247
Al      7  0.088
Si      27  0.456
K       32  0.021
B       6  0.026
Ca      33  0.060
O       23  0.769
Air      3  4.06E-4
lFe      9      7.86
Dose Rate at Surface - 8 cm Steel
$Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTW= 180.,
Y = 120.,
T(1)= 120.,
T(2)= 8.00,
X= 129.,
WEIGHT(82) = 1.0,
WEIGHT(84) = 1.0, &
Na      25  0.247
Al      7  0.088
Si      27  0.456
K       32  0.021
B       6  0.026
Ca      33  0.060
O       23  0.769
Air      3  4.06E-4
lFe      9      7.86
Dose Rate at Surface -10 cm Steel
$Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTW= 180.,
Y = 120.,
T(1)= 120.,
T(2)=10.00,
X= 131.,
WEIGHT(82) = 1.0,
WEIGHT(84) = 1.0, &
Na      25  0.247
Al      7  0.088
Si      27  0.456
K       32  0.021
B       6  0.026
Ca      33  0.060
O       23  0.769
Air      3  4.06E-4
lFe      9      7.86
Dose Rate at Surface -12 cm Steel
$Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
  
```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 31 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

```

SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)=12.00 ,
X= 133. ,
WEIGHT(82) = 1.0,
WEIGHT(84) = 1.0, &
Na 25 0.247
Al 7 0.088
Si 27 0.456
K 32 0.021
B 6 0.026
Ca 33 0.060
O 23 0.769
Air 3 4.06E-4
lFe 9 7.86
Dose Rate at Surface -14 cm Steel
iInput Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)=14.00 ,
X= 135. ,
WEIGHT(82) = 1.0,
WEIGHT(84) = 1.0, &
Na 25 0.247
Al 7 0.088
Si 27 0.456
K 32 0.021
B 6 0.026
Ca 33 0.060
O 23 0.769
Air 3 4.06E-4
lFe 9 7.86
Dose Rate at Surface -16 cm Steel
iInput Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)=16.00 ,
X= 137. ,
WEIGHT(82) = 1.0,
WEIGHT(84) = 1.0, &
Na 25 0.247
Al 7 0.088
Si 27 0.456
K 32 0.021
B 6 0.026
Ca 33 0.060
O 23 0.769
Air 3 4.06E-4
lFe 9 7.86
Dose Rate at Surface -18 cm Steel
iInput Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)=18.00 ,
X= 139. ,

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 32 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

WEIGHT(82) = 1.0,
 WEIGHT(84) = 1.0, 6
 Na 25 0.247
 Al 7 0.088
 Si 27 0.456
 K 32 0.021
 B 6 0.026
 Ca 33 0.060
 O 23 0.769
 Air 3 4.06E-4
 lFe 9 7.86

Dose Rate at Surface -20 cm Steel

Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
 NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
 SLTH= 180.,
 Y = 120.,
 T(1)= 120.,
 T(2)=20.00',
 X= 141.,
 WEIGHT(82) = 1.0,
 WEIGHT(84) = 1.0, 6
 Na 25 0.247
 Al 7 0.088
 Si 27 0.456
 K 32 0.021
 B 6 0.026
 Ca 33 0.060
 O 23 0.769
 Air 3 4.06E-4
 lFe 9 7.86
 End of Input
 Input Next= 6 6

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 33 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Example ISO-PC Input File to Determine the Dose Rate vs Wall Thickness - Sn126/Sb126m/Sb126

0 2 ILAW - 1 Ci/m3 of Sn-126/Sb-126m/Sb-126 in Waste Package

Dose Rate at Surface - 1 cm Steel

&Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,

NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,

SLTH= 180.,

y = 120.,

T(1)= 120.,

T(2)= 1.00 ,

X= 122. ,

WEIGHT(272) = 1.0,

WEIGHT(273) = 1.0,

WEIGHT(274) = 0.14, &

Na 25 0.247

Al 7 0.088

Si 27 0.456

K 32 0.021

B 6 0.026

Ca 33 0.060

O 23 0.769

Air 3 4.06E-4

Ife 9 7.86

Dose Rate at Surface - 2 cm Steel

&Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,

NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,

SLTH= 180.,

y = 120.,

T(1)= 120.,

T(2)= 2.00 ,

X= 123. ,

WEIGHT(272) = 1.0,

WEIGHT(273) = 1.0,

WEIGHT(274) = 0.14, &

Na 25 0.247

Al 7 0.088

Si 27 0.456

K 32 0.021

B 6 0.026

Ca 33 0.060

O 23 0.769

Air 3 4.06E-4

Ife 9 7.86

Dose Rate at Surface - 4 cm Steel

&Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,

NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,

SLTH= 180.,

y = 120.,

T(1)= 120.,

T(2)= 4.00 ,

X= 125. ,

WEIGHT(272) = 1.0,

WEIGHT(273) = 1.0,

WEIGHT(274) = 0.14, &

Na 25 0.247

Al 7 0.088

Si 27 0.456

K 32 0.021

B 6 0.026

Ca 33 0.060

O 23 0.769

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 34 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

```

Air      3  4.06E-4
Ife      9      7.86
Dose Rate at Surface - 6 cm Steel
Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)= 6.00,
X= 127.,
WEIGHT(272) = 1.0,
WEIGHT(273) = 1.0,
WEIGHT(274) = 0.14, &
Na      25  0.247
Al      7  0.088
Si      27  0.456
K       32  0.021
B       6  0.026
Ca      33  0.060
O       23  0.769
Air      3  4.06E-4
Ife      9      7.86
Dose Rate at Surface - 8 cm Steel
Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)= 8.00,
X= 129.,
WEIGHT(272) = 1.0,
WEIGHT(273) = 1.0,
WEIGHT(274) = 0.14, &
Na      25  0.247
Al      7  0.088
Si      27  0.456
K       32  0.021
B       6  0.026
Ca      33  0.060
O       23  0.769
Air      3  4.06E-4
Ife      9      7.86
Dose Rate at Surface -10 cm Steel
Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)=10.00,
X= 131.,
WEIGHT(272) = 1.0,
WEIGHT(273) = 1.0,
WEIGHT(274) = 0.14, &
Na      25  0.247
Al      7  0.088
Si      27  0.456
K       32  0.021
B       6  0.026
Ca      33  0.060
O       23  0.769
Air      3  4.06E-4
Ife      9      7.86
  
```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 35 of 55
 Subject: ILAW Shielding Evaluation
 Prepare: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

Dose Rate at Surface -12 cm Steel

*Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
 NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,

SLTH= 180.,

y = 120.,

T(1)= 120.,

T(2)=12.00,

X= 133.,

WEIGHT(272) = 1.0,

WEIGHT(273) = 1.0,

WEIGHT(274) = 0.14, &

Na 25 0.247

Al 7 0.088

Si 27 0.456

K 32 0.021

B 6 0.026

Ca 33 0.060

O 23 0.769

Air 3 4.06E-4

lFe 9 7.86

Dose Rate at Surface -14 cm Steel

*Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
 NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,

SLTH= 180.,

y = 120.,

T(1)= 120.,

T(2)=14.00,

X= 135.,

WEIGHT(272) = 1.0,

WEIGHT(273) = 1.0,

WEIGHT(274) = 0.14, &

Na 25 0.247

Al 7 0.088

Si 27 0.456

K 32 0.021

B 6 0.026

Ca 33 0.060

O 23 0.769

Air 3 4.06E-4

lFe 9 7.86

Dose Rate at Surface -16 cm Steel

*Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
 NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,

SLTH= 180.,

y = 120.,

T(1)= 120.,

T(2)=16.00,

X= 137.,

WEIGHT(272) = 1.0,

WEIGHT(273) = 1.0,

WEIGHT(274) = 0.14, &

Na 25 0.247

Al 7 0.088

Si 27 0.456

K 32 0.021

B 6 0.026

Ca 33 0.060

O 23 0.769

Air 3 4.06E-4

lFe 9 7.86

Dose Rate at Surface -18 cm Steel

*Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 36 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

```

NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)=18.00,
X= 139.,
WEIGHT(272) = 1.0,
WEIGHT(273) = 1.0,
WEIGHT(274) = 0.14, &
Na 25 0.247
Al 7 0.088
Si 27 0.456
K 32 0.021
B 6 0.026
Ca 33 0.060
O 23 0.769
Air 3 4.06E-4
lFe 9 7.86
Dose Rate at Surface -20 cm Steel
<Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 180.,
y = 120.,
T(1)= 120.,
T(2)=20.00,
X= 141.,
WEIGHT(272) = 1.0,
WEIGHT(273) = 1.0,
WEIGHT(274) = 0.14, &
Na 25 0.247
Al 7 0.088
Si 27 0.456
K 32 0.021
B 6 0.026
Ca 33 0.060
O 23 0.769
Air 3 4.06E-4
lFe 9 7.86
End of Input
<Input Next= 6 &

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 37 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

ISO-PC Input File to Determine the Dose Rate vs Wall Thickness -
Csl37/Bal37m for a 1.4 m x 1.4 m x 2.0 m Package Size

0 2 ILAW - 1 Ci/m3 of Cs-137/Ba-137m in Larger Waste Package
 Dose Rate at Surface - 1 cm Steel
 4Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
 NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
 SLTH= 200.,
 y = 140.,
 T(1)= 140.,
 T(2)= 1.00,
 X= 142.,
 WEIGHT(335) = 1.0,
 WEIGHT(336) = 0.946, 6
 Na 25 0.247
 Al 7 0.098
 Si 27 0.456
 K 32 0.021
 B 6 0.026
 Ca 33 0.060
 O 23 0.769
 Air 3 4.06E-4
 lfe 9 7.86
 Dose Rate at Surface - 2 cm Steel
 4Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
 NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
 SLTH= 200.,
 y = 140.,
 T(1)= 140.,
 T(2)= 2.00,
 X= 143.,
 WEIGHT(335) = 1.0,
 WEIGHT(336) = 0.946, 6
 Na 25 0.247
 Al 7 0.098
 Si 27 0.456
 K 32 0.021
 B 6 0.026
 Ca 33 0.060
 O 23 0.769
 Air 3 4.06E-4
 lfe 9 7.86
 Dose Rate at Surface - 4 cm Steel
 4Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
 NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
 SLTH= 200.,
 y = 140.,
 T(1)= 140.,
 T(2)= 4.00,
 X= 145.,
 WEIGHT(335) = 1.0,
 WEIGHT(336) = 0.946, 6
 Na 25 0.247
 Al 7 0.098
 Si 27 0.456
 K 32 0.021
 B 6 0.026
 Ca 33 0.060
 O 23 0.769
 Air 3 4.06E-4

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 38 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

lfe 9 7.86
 Dose Rate at Surface - 6 cm Steel
 Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
 NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
 SLTH= 200.,
 y = 140.,
 T(1)= 140.,
 T(2)= 6.00 ,
 X= 147. ,
 WEIGHT(335) = 1.0,
 WEIGHT(336) = 0.946, &
 Na 25 0.247
 Al 7 0.088
 Si 27 0.456
 K 32 0.021
 B 6 0.026
 Ca 33 0.060
 O 23 0.769
 Air 3 4.06E-4

lfe 9 7.86
 Dose Rate at Surface - 8 cm Steel
 Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
 NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
 SLTH= 200.,
 y = 140.,
 T(1)= 140.,
 T(2)= 8.00 ,
 X= 149. ,
 WEIGHT(335) = 1.0,
 WEIGHT(336) = 0.946, &
 Na 25 0.247
 Al 7 0.088
 Si 27 0.456
 K 32 0.021
 B 6 0.026
 Ca 33 0.060
 O 23 0.769
 Air 3 4.06E-4

lfe 9 7.86
 Dose Rate at Surface -10 cm Steel
 Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
 NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
 SLTH= 200.,
 y = 140.,
 T(1)= 140.,
 T(2)=10.00 ,
 X= 151. ,
 WEIGHT(335) = 1.0,
 WEIGHT(336) = 0.946, &
 Na 25 0.247
 Al 7 0.088
 Si 27 0.456
 K 32 0.021
 B 6 0.026
 Ca 33 0.060
 O 23 0.769
 Air 3 4.06E-4

lfe 9 7.86
 Dose Rate at Surface -12 cm Steel
 Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
 NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
 SLTH= 200.,

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 39 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

```

y = 140.,
T(1)= 140.,
T(2)=12.00,
X= 153.,
WEIGHT(335) = 1.0,
WEIGHT(336) = 0.946, &
Na 25 0.247
Al 7 0.088
Si 27 0.456
K 32 0.021
B 6 0.026
Ca 33 0.060
O 23 0.769
Air 3 4.06E-4
lFe 9 7.86
Dose Rate at Surface -14 cm Steel
&Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
Ntheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 200.,
y = 140.,
T(1)= 140.,
T(2)=14.00,
X= 155.,
WEIGHT(335) = 1.0,
WEIGHT(336) = 0.946, &
Na 25 0.247
Al 7 0.088
Si 27 0.456
K 32 0.021
B 6 0.026
Ca 33 0.060
O 23 0.769
Air 3 4.06E-4
lFe 9 7.86
Dose Rate at Surface -16 cm Steel
&Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
Ntheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 200.,
y = 140.,
T(1)= 140.,
T(2)=16.00,
X= 157.,
WEIGHT(335) = 1.0,
WEIGHT(336) = 0.946, &
Na 25 0.247
Al 7 0.088
Si 27 0.456
K 32 0.021
B 6 0.026
Ca 33 0.060
O 23 0.769
Air 3 4.06E-4
lFe 9 7.86
Dose Rate at Surface -18 cm Steel
&Input Next= 1, ISpec= 3, IGeom= 10, ICONC=1, SFACT=1, DUNIT=1,
Ntheta= 30, NPsi= 30, NShld= 2, JBuf= 2, OPTION=0,
SLTH= 200.,
y = 140.,
T(1)= 140.,
T(2)=18.00,
X= 159.,
WEIGHT(335) = 1.0,

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 40 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

```

WEIGHT(336) = 0.946, g
Na  25  0.247
Al  7   0.088
Si  27  0.456
K   32  0.021
S   6   0.026
Ca  33  0.060
O   23  0.769
Alr  3  4.06E-4
lFe  9   7.86
Dose Rate at Surface -20 cm Steel
Input Next= 1, lSpec= 3, lGeom= 10, lCONC=1, lFACT=1, lUNIT=1,
NTheta= 30, NPsi= 30, NShld= 2, JBuf= 2, lOPTION=0,
SLTH= 200.,
y = 140.,
T(1)= 140.,
T(2)=20.00,
X= 161.,
WEIGHT(335) = 1.0,
WEIGHT(336) = 0.946, g
Na  25  0.247
Al  7   0.088
Si  27  0.456
K   32  0.021
S   6   0.026
Ca  33  0.060
O   23  0.769
Alr  3  4.06E-4
lFe  9   7.86
End of Input
Input Next= 6 g
  
```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 41 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Saving Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

APPENDIX E

Spreadsheet Showing Percent Differences Between Calculated and Fitted Dose Rates

1 Ci/m3 of Co-60 in Waste Package

Poly Regression: $\begin{matrix} a \\ 0.075 \end{matrix}$ $\begin{matrix} b \\ -0.197 \end{matrix}$ $\begin{matrix} c \\ 0.000654 \end{matrix}$

cm	Calc'd rem/h	Poly-Fit rem/h	Poly-Fit tdiff
1	0.7883	0.75623	4.07
2	0.4779	0.482632	-0.99
4	0.1916	0.198365	-3.53
6	0.08035	0.082517	-2.70
8	0.03437	0.034742	-1.08
10	0.01487	0.014805	0.44
12	0.006483	0.006385	1.51
14	0.002841	0.002787	1.89
16	0.001249	0.001231	1.40
18	0.000551	0.000551	0.10
20	0.000244	0.000249	-2.27

1 Ci/m3 of Sr-90/Y-90

Poly Regression: $\begin{matrix} a \\ -2.774 \end{matrix}$ $\begin{matrix} b \\ -0.279 \end{matrix}$ $\begin{matrix} c \\ 0.00313 \end{matrix}$

cm	Calc'd rem/h	Poly-Fit rem/h	Poly-Fit tdiff
1	0.001014	0.000892	12.08
2	0.00047	0.000479	-1.89
4	0.000131	0.000145	-10.28
6	4.26E-05	4.62E-05	-8.49
8	1.51E-05	1.56E-05	-3.73
10	5.67E-06	5.61E-06	1.10
12	2.24E-06	2.13E-06	4.67
14	9.14E-07	8.58E-07	6.16
16	3.85E-07	3.66E-07	5.05
18	1.66E-07	1.65E-07	0.70
20	7.34E-08	7.91E-08	-7.71

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 42 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

1 Ci/m3 of Ru-106/Rh-106

Poly Regression: $\begin{matrix} a & b & c \\ -1.052 & -0.265 & 0.002311 \end{matrix}$

cm	Calc'd rem/h	Poly-Fit rem/h	Poly-Fit %diff
1	0.05098	0.048452	4.96
2	0.0266	0.026745	-0.55
4	0.008138	0.008413	-3.39
6	0.002689	0.002762	-2.71
8	0.000937	0.000946	-1.02
10	0.000341	0.000338	0.93
12	0.00013	0.000126	2.61
14	5.09E-05	4.91E-05	3.58
16	2.07E-05	1.99E-05	3.51
18	8.61E-06	8.45E-06	1.92
20	3.67E-06	3.74E-06	-1.69

1 Ci/m3 of Sb-125

Poly Regression: $\begin{matrix} a & b & c \\ -0.807 & -0.284 & 0.001031 \end{matrix}$

cm	Calc'd rem/h	Poly-Fit rem/h	Poly-Fit %diff
1	0.08555	0.081289	4.98
2	0.0422	0.042572	-0.88
4	0.01142	0.011844	-3.71
6	0.003271	0.003358	-2.67
8	0.000953	0.00097	-0.73
10	0.000289	0.000286	1.13
12	8.79E-05	8.58E-05	2.43
14	2.7E-05	2.62E-05	2.93
16	8.39E-06	8.18E-06	2.50
18	2.63E-06	2.6E-06	0.94
20	8.26E-07	8.42E-07	-1.95

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 43 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

1 Ci/m3 of Sn-126/Sb-126m/Sb-126

Poly Regression: $\begin{matrix} a & b & c \\ -0.229 & -0.23 & 0.001191 \end{matrix}$

cm	Calc'd rem/h	Poly-Fit rem/h	Poly-Fit %diff
1	0.3637	0.348491	4.18
2	0.2046	0.206902	-1.12
4	0.07148	0.074141	-3.72
6	0.02638	0.027137	-2.94
8	0.01003	0.010168	-1.37
10	0.003895	0.003891	0.09
12	0.001538	0.001522	1.02
14	0.000617	0.000609	1.27
16	0.000251	0.000249	0.71
18	0.000103	0.000104	-0.74
20	4.3E-05	4.44E-05	-3.19

1 Ci/m3 of Cs-134

Poly Regression: $\begin{matrix} a & b & c \\ -0.18 & -0.252 & 0.001292 \end{matrix}$

cm	Calc'd rem/h	Poly-Fit rem/h	Poly-Fit %diff
1	0.3857	0.37093	3.83
2	0.2072	0.209492	-1.11
4	0.0659	0.068026	-3.23
6	0.02211	0.022621	-2.31
8	0.007643	0.007703	-0.79
10	0.0027	0.002687	0.50
12	0.000972	0.00096	1.31
14	0.000356	0.000351	1.50
16	0.000133	0.000131	1.09
18	5.04E-05	5.04E-05	-0.06
20	1.94E-05	1.98E-05	-1.88

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 44 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

1 Ci/m3 of Cs-137/Ba-137m

Poly Regression: $\begin{matrix} a \\ -0.631 \end{matrix}$ $\begin{matrix} b \\ -0.258 \end{matrix}$ $\begin{matrix} c \\ 0.000641 \end{matrix}$

cm	Calc'd rem/h	Poly-Fit rem/h	Poly-Fit %diff
1	0.1349	0.129313	4.14
2	0.07095	0.071708	-1.07
4	0.02149	0.022247	-3.52
6	0.006802	0.006984	-2.67
8	0.002194	0.002218	-1.11
10	0.000715	0.000713	0.31
12	0.000235	0.000232	1.22
14	7.75E-05	7.63E-05	1.44
16	2.56E-05	2.54E-05	0.85
18	8.52E-06	8.57E-06	-0.60
20	2.84E-06	2.92E-06	-3.04

1 Ci/m3 of Eu-152

Poly Regression: $\begin{matrix} a \\ -0.327 \end{matrix}$ $\begin{matrix} b \\ -0.212 \end{matrix}$ $\begin{matrix} c \\ 0.001104 \end{matrix}$

cm	Calc'd rem/h	Poly-Fit rem/h	Poly-Fit %diff
1	0.306	0.289804	5.29
2	0.1772	0.179232	-1.15
4	0.06647	0.069609	-4.72
6	0.02655	0.02759	-3.92
8	0.01095	0.01116	-1.92
10	0.004612	0.004607	0.11
12	0.001971	0.001941	1.53
14	0.000851	0.000834	1.99
16	0.000371	0.000366	1.37
18	0.000163	0.000164	-0.52
20	7.21E-05	7.49E-05	-3.87

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 45 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

1 Ci/m3 of Eu-154

Poly Regression: a b c
 -0.27 -0.213 0.001048

cm	Calc'd rem/h	Poly-Fit rem/h	Poly-Fit diff
1	0.3464	0.329646	4.84
2	0.2016	0.203326	-0.86
4	0.07567	0.078482	-3.72
6	0.03002	0.030884	-2.88
8	0.01226	0.01239	-1.06
10	0.005105	0.005068	0.73
12	0.002157	0.002113	2.04
14	0.000922	0.000898	2.54
16	0.000398	0.000389	2.11
18	0.000173	0.000172	0.63
20	7.59E-05	7.75E-05	-2.15

□

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 46 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

APPENDIX F

Justification for Use of ISO-PC Version 2.1 for this Application

As mentioned in Section 2.0, ISO-PC Version 2.1 has not gone through the verification and validation (V&V) process required by the WMNW Quality Assurance Program at this time. This appendix provides justification for use of ISO-PC Version 2.1 for the applications in this report.

The ISO-PC computer code was used for this application due to its speed, ease of use, and the simplicity of the geometry of the ILAW package. Because of the number of separate cases that had to be run for this analysis, the ISO-PC computer code was preferred over the slower and more cumbersome monte carlo computer programs. The ISO-PC Version 2.1 computer code is a derivative of the ISOSHLDP-PC computer code which has had extensive use at the Hanford Site over the years, and has gone through a V&V process similar to that required by the WMNW QA program (Lourant 1989). In order to validate its use for this application, a series of benchmark cases were run using the MCNP Version 4A (Breisemeister, J. F., 1993, and Carter, L. L., 1995) monte carlo computer code. MCNP Version 4A has gone through the WMNW V&V process.

Three cases were run in MCNP to assess the adequacy of the ISO-PC results for the current application. The first case was for the nominal configuration of the ILAW waste package, which consists of a rectangular steel box 1.2 m tall x 1.2 m wide x 1.8 m long with a total wall thickness of 8 cm of steel, was modeled in MCNP. The geometry and material composition used in both MCNP and ISO-PC were the same. The source term (photon emission rate) used in MCNP was taken from the ORIGIN outputs discussed in Section 2.0 for the Phase 1 tank inventory. Cases 2 and 3 were for a 1 Ci/m³ activity loading of Cs137 with total wall thicknesses of 2 cm and 18 cm, respectively. The MCNP input files are included at the end of this appendix.

The results obtained from ISO-PC and MCNP for these three cases are shown below. The ISO-PC results for Cases 2 and 3 were taken from Table 4 on page 17 of this report. The ISO-PC dose rate for Case 1 was obtained from the output of the ISO-PC model described in Section 2 and listed in Appendix C.

	Surface Dose Rate, mrem/h		Description
	ISO-PC	MCNP	
Case 1	3.80e6	3.96E6	Phase 1 Tank Inventory (Cs reduced by factor of 200), 8 cm steel
Case 2	71	72	1 Ci/m ³ of Cs137, 2 cm steel
Case 3	0.00852	0.010	1 Ci/m ³ of Cs137, 18 cm steel

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 47 of 55
Subject: ILAW Shielding Evaluation
Preparer: Anthony Savino Date 2/5/98
Checker: John McCoy Date 2/5/98
Section Chief: Janet McFadden Date 2/6/98

These three cases adequately demonstrate that ISO-PC provides results that are consistent with the more rigorous and computationally accurate MCNP code. The two computer codes use completely different computational methods, with ISO-PC using the point kernel method, and MCNP using the more sophisticated monte carlo method. Both codes produced consistent results for a wide range of wall thicknesses (2, 8, 18 cm of steel), and for a single isotope (Cs137) as well as a large group of isotopes (Phase 1 tank inventory from Table 1).

It is concluded that ISO-PC yields acceptably accurate results for the shielding configurations and source terms addressed in this report.

References

Breismeister, J. F., Editor, 1993, *MCNP—A General Monte Carlo Code N-Particle Transport Code, Version 4a*, LA-12625, Los Alamos National Laboratory, Los Alamos, New Mexico.

Carter, L. L., 1995, *Certification of MCNP Version 4A for WHC Computer Platforms*, WHC-SD-MP-SWD-30001, Rev. 7, ECN 605701, Westinghouse Hanford Company, Richland, Washington.

Lourant, I, 1989, *Validation of ISOSHLD-PC on the IBM-PC*, WHC-SD-SQA-CSWD-303, Rev 0, Westinghouse Hanford Company, Richland, Washington.

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 48 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

MCNP Input File for Case 1 - Phase 1 Tank Inventory with 8 cm steel

```

ILAW - Phase 1 Inventory (Cs reduced by 200) - 8 cm Fe
c    cell cards
1    2 -1.667 2 -3 6 -7 10 -11          $ Source
2    3 -7.86 (1 -4 5 -6 10 -11):(1 -2 6 -7 10 -11)
c
      Back      Left
      :(-4 6 -7 10 -11):(1 -4 5 -7 11 -12):(1 -4 5 -7 9 -10)
c      Right      Top      Bottom
21   3 -7.86 (1 -4 7 -71 9 -12)          $ Front - cell for importance
22   3 -7.86 (1 -4 71 -72 9 -12)         $ Front - cell for importance
23   3 -7.86 (1 -4 72 -73 9 -12)         $ Front - cell for importance
24   3 -7.86 (1 -4 73 -74 9 -12)         $ Front - cell for importance
3    1 -0.00122 -20 7 #2 #21 #22 #23 #24 #5
31   1 -0.00122 -20 -7 #1 #2
4    0 20
5    1 -0.00122 (74 -75 21 -22 101 -111)  $ Air tally cell - surface

c    surface cards
1    px -92
2    px -90
21   px -15
22   px 15
3    px 90
4    px 92
5    py -62
6    py -60
7    py 60
71   py 62
72   py 64
73   py 66
74   py 68
75   py 70
9    pz -62
10   pz -60
101  pz -15
111  pz 15
11   pz 60
12   pz 62
20   so 300

mode p          $ photon
c *****
c    SOURCE - Phase 1 Inventory with Cs Reduced by 200
c *****
sdef    cel=1 pos=0 0 0 wgt=2.316e18 erg=d4
        x=d1 y=d2 z=d3
scl     x extent
sil     -90 90

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 49 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

```

spl      0 1
sc2      y extent
si2      -60 60
sp2      0 1
sc3      z extent
si3      -60 60
sp3      0 1
sc4      Source distribution from ORIGEN for 5 Canisters
#         si4      sp4      sb4
          l         d         d
          1.500E-02  1.135E+18  .001
          2.500E-02  2.464E+17  .001
          3.750E-02  1.647E+17  .001
          5.750E-02  2.377E+17  .001
          8.500E-02  1.490E+17  .01
          1.250E-01  1.010E+17  .1
          2.250E-01  1.402E+17  1.
          3.750E-01  6.945E+16  1.
          5.750E-01  4.916E+16  1.
          8.500E-01  1.533E+16  1.
          1.250E+00  8.173E+15  1.
          1.750E+00  6.977E+14  1.
          2.250E+00  8.028E+12  1.
          2.750E+00  1.077E+12  1.
          3.500E+00  1.595E+11  1.
          5.000E+00  1.421E+06  1.
          7.000E+00  1.568E+05  0.1
          1.100E+01  1.755E+04  0.1
          "Total"    2.316E+18
c
c      ansi/ans-6.1.1-1991 fluence-to-dose, photons (mrem/hr/ (p/cm**2/s)
c
de0    log   .01 .015 .02 .03 .04 .05
          .06 .08 .10 .15 .20 .30
          .40 .50 .60 .80 1.0 1.5
          2.0 3.0 4.0 5.0 6.0 8.0
          10. 12.
df0    log   2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
          1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
          7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
          2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
          8.892e-3 1.040e-2
e0     1.500e-02 2.500e-02 3.750e-02 5.750e-02 8.500e-02 1.250e-01
          2.250e-01 3.750e-01 6.620e-01 8.500e-01 1.250e+00 1.750e+00
          2.250e+00 2.750e+00 3.500e+00 5.000e+00 7.000e+00 1.100e+01
c
c      Material Definitions
c
ml     7000.01p -0.765    $ air - Nitrogen
          8000.01p -0.235    $ air - Oxygen

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 50 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

```

c      Model source as glass
m2      8000.01p -1.152 11000.01p -0.351 13000.01p -0.206
      14000.01p -0.627 19000.01p -0.045 5000.01p -0.041
      20000.01p -0.077
m3      26000.01p -67.97      $ SS-304
      24000.01p -20.0
      28000.01p -10.0
      25000.01p -2.00
      6000.01p -0.03

print
c
phys:p j 1 1      $ Brems on & Coherent Scattering Off
fc04 Surface cell
f04:p 5
imp:p
c
c      Cell Importances
c
c      Cell 1 2 21 22 23 24 25 26 27 28 29
c      1 1 3 8.5 20 60
c      Cell 3 31 4 5
c      1 1 0 60
nps      1000000 $history

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 51 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

MCNP Input File for Case 2 - 1 Ci/m3 of Cs137 with 2 cm steel

ILAW with Shipping Container - Cs-137 1 Ci/m3 (2.592 Ci total) - 2 cm Fe

```

c    cell cards
1    2 -1.667 2 -3 6 -7 10 -11          $ Source
2    3 -7.86 (1 -4 5 -6 10 -11):(1 -2 6 -7 10 -11)
c
      Back      Left
      : (3 -4 6 -7 10 -11):(1 -4 5 -7 11 -12):(1 -4 5 -7 9 -10)
c
      Right     Top      Bottom
21   3 -7.86 (1 -4 7 -71 9 -12)          $ Front - cell for importance
22   3 -7.86 (1 -4 71 -72 9 -12)         $ Front - cell for importance
3    1 -0.00122 -20 7 #2 #21 #22 #5
31   1 -0.00122 -20 -7 #1 #2
4    0 20
5    1 -0.00122 (72 -73 21 -22 101 -111) $ Air tally cell - surface

```

c surface cards

```

1    px -92
2    px -90
21   px -15
22   px 15
3    px 90
4    px 92
5    py -62
6    py -60
7    py 60
71   py 61
72   py 62
73   py 64
9    pz -62
10   pz -60
101  pz -15
111  pz 15
11   pz 60
12   pz 62
20   so 300

```

```

mode p                               $ photon
c *****
c SOURCE = 2.592 Ci Cs = 8.165e10 photons/s - 0.6616 Mev
c *****
sdef cel=1 pos=0 0 0 wgt=8.165e10 erg=0.6616
    x=d1 y=d2 z=d3
sc1  x extent
s11  -90 90
sp1  0 1
sc2  y extent
s12  -60 60
sp2  0 1

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 52 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

```

sc3      z extent
si3      -60 60
sp3      0 1
c         ansi/ans-6.1.1-1991 fluence-to-dose,photons (mrem/hr/ (p/cm**2/s)
c
de0      log .01 .015 .02 .03 .04 .05
           .06 .08 .10 .15 .20 .30
           .40 .50 .60 .80 1.0 1.5
           2.0 3.0 4.0 5.0 6.0 8.0
           10. 12.
df0      log 2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
           1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
           7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
           2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
           8.892e-3 1.040e-2
e0        1.500e-02 2.500e-02 3.750e-02 5.750e-02 8.500e-02 1.250e-01
           2.250e-01 3.750e-01 6.620e-01 8.500e-01 1.250e+00 1.750e+00
           2.250e+00
c
c         Material Definitions
c
m1        7000.01p -0.765      $ air - Nitrogen
           8000.01p -0.235      $ air - Oxygen
c         Model source as glass
m2        8000.01p -1.152      11000.01p -0.351      13000.01p -0.206
           14000.01p -0.627      19000.01p -0.045      5000.01p -0.041
           20000.01p -0.077
m3        26000.01p -67.97      $ SS-304
           24000.01p -20.0
           28000.01p -10.0
           25000.01p -2.00
           6000.01p -0.03
print
c
phys:p j 1 1      $ Brems on & Coherent Scattering Off
fc04      Surface cell
f04:p 5
imp:p
c
c         Cell Importances
c
c         Cell 1      2 21      22      23      24      25      26      27      28      29
c         1      1      3.85      8.9
c         1      1      3.85      8.9      12.6      21      38      69      128      240      480
c         Cell 3      31      4      5      6      7
c         8.9      1      0      8.9
nps       200000 $history

```

□

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 53 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino
 Checker: John McCoy
 Section Chief: Janet McFadden

Date 2/5/98
 Date 2/5/98
 Date 2/6/98

MCNP Input File for Case 2 - 1 Ci/m3 Cs137 with 18 cm steel

ILAW with Shipping Container - Cs-137 1 Ci/m3 (2.592 Ci total) - 18 cm Fe

```

c    cell cards
1    2 -1.667 2 -3 6 -7 10 -11          $ Source
2    3 -7.86 (1 -4 5 -6 10 -11):(1 -2 6 -7 10 -11)
c
      Back      Left
      : (3 -4 6 -7 10 -11):(1 -4 5 -7 11 -12):(1 -4 5 -7 9 -10)
c
      Right     Top      Bottom
21   3 -7.86 (1 -4 7 -71 9 -12)          $ Front - cell for importance
22   3 -7.86 (1 -4 71 -72 9 -12)         $ Front - cell for importance
23   3 -7.86 (1 -4 72 -73 9 -12)         $ Front - cell for importance
24   3 -7.86 (1 -4 73 -74 9 -12)         $ Front - cell for importance
25   3 -7.86 (1 -4 74 -75 9 -12)         $ Front - cell for importance
26   3 -7.86 (1 -4 75 -76 9 -12)         $ Front - cell for importance
27   3 -7.86 (1 -4 76 -77 9 -12)         $ Front - cell for importance
28   3 -7.86 (1 -4 77 -78 9 -12)         $ Front - cell for importance
29   3 -7.86 (1 -4 78 -79 9 -12)         $ Front - cell for importance
3    1 -0.00122 -20 7 #2 #21 #22 #23 #24 #25 #26 #27 #28 #29 #5
31   1 -0.00122 -20 -7 #1 #2
4    0 20
5    1 -0.00122 (79 -8 21 -22 101 -111)  $ Air tally cell - surface

```

```

c    surface cards
1    px -92
2    px -90
21   px -15
22   px 15
3    px 90
4    px 92
5    py -62
6    py -60
7    py 60
71   py 62
72   py 64
73   py 66
74   py 68
75   py 70
76   py 72
77   py 74
78   py 76
79   py 78
8    py 80
9    pz -62
10   pz -60
101  pz -15
111  pz 15
11   pz 60
12   pz 62

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 54 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCoy Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

20 so 300

```

mode p                      $ photon
c *****
c SOURCE = 2.592 Ci Cs = 8.165e10 photons/s - 0.6616 Mev
c *****
sdef cel=1 pos=0 0 0 wgt=8.165e10 erg=0.6616
    x=d1 y=d2 z=d3
sc1 x extent
si1 -90 90
sp1 0 1
sc2 y extent
si2 -60 60
sp2 0 1
sc3 z extent
si3 -60 60
sp3 0 1
c ansi/ans-6.1.1-1991 fluence-to-dose,photons(mrem/hr/(p/cm**2/s)
c
de0 log .01 .015 .02 .03 .04 .05
    .06 .08 .10 .15 .20 .30
    .40 .50 .60 .80 1.0 1.5
    2.0 3.0 4.0 5.0 6.0 8.0
    10. 12.
df0 log 2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
    1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
    7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
    2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
    8.892e-3 1.040e-2
e0 1.500e-02 2.500e-02 3.750e-02 5.750e-02 8.500e-02 1.250e-01
    2.250e-01 3.750e-01 6.620e-01 8.500e-01 1.250e+00 1.750e+00
    2.250e+00
c
c Material Definitions
c
m1 7000.01p -0.765 $ air - Nitrogen
    8000.01p -0.235 $ air - Oxygen
c Model source as glass
m2 8000.01p -1.152 11000.01p -0.351 13000.01p -0.206
    14000.01p -0.627 19000.01p -0.045 5000.01p -0.041
    20000.01p -0.077
m3 26000.01p -67.97 $ SS-304
    24000.01p -20.0
    28000.01p -10.0
    25000.01p -2.00
    6000.01p -0.03
print
c
phys:p j 1 1 $ Brems on & Coherent Scattering Off

```

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. EBU-RCAL-001 Rev. 0 Project No. 772028 Page 55 of 55
 Subject: ILAW Shielding Evaluation
 Preparer: Anthony Savino Date 2/5/98
 Checker: John McCov Date 2/5/98
 Section Chief: Janet McFadden Date 2/6/98

fc04 Surface cell
 f04:p 5
 imp:p
 c
 c Cell Importances
 c
 c Cell 1 2 21 22 23 24 25 26 27 28 29
 1 1 3 9 27 81 243 730 2200 6600 1.5E4
 c Cell 3 31 4 5
 1 1 0 1.5e4
 nps 1000000 \$history

□

HNF-2110 Rev 0

This page intentionally left blank.

DISTRIBUTION SHEET

To Distribution	From DA Burbank/TM Hohl/MJ Klem	Page 1 of 1
		Date 03/05/98
Project Title/Work Order		EDT No. 623802
HNF-2110, Rev. 0, "Phase 1 Immobilized Low-Activity Waste Operational Source Term"		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
Central Files	B1-07	X			
Project Files - 2	H6-08	X			
<u>Fluor Daniel Northwest Services</u>					
T. A. Carlson	H6-37	X			
F. M. Mann	B4-43	X			
W. W. Pickett	H6-37	X			
<u>Lockheed Martin Hanford Corporation</u>					
K. C. Burgard	H6-37	X			
R. J. Murkowski	H6-37	X			
S. M. O'Toole	G3-21	X			
W. T. Thompson	G3-21	X			
J. A. Voogd	H6-37	X			
<u>Numatec Hanford Corporation</u>					
G. K. Allen	H5-49	X			
P. J. Certa	H5-61	X			
J. S. Garfield	H5-49	X			
P. Mouette	R1-49	X			
C. A. Petersen	H6-37	X			
J. W. Shade	H5-27	X			
<u>SGN Eurisys Services Corporation</u>					
D. A. Burbank	H6-37	X			
G. R. Chiramonte	B4-51	X			
L. A. Fort	H5-61	X			
T. M. Hohl	B4-51	X			
M. J. Klem	R3-86	X			
D. L. Penwell	H5-27	X			
D. E. Place	H5-27	X			
J. J. Zimmer	B4-51	X			
<u>Waste Management Federal Services, Inc., Northwest Operations</u>					
A. V. Savino	H1-15	X			