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Estimation of Shielding Thickness for a Prototype Department of Energy National Spent Nuclear Fuel Program Transport Cask

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Prepared by

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**Estimation of Shielding Thickness for a Prototype
Department of Energy
National Spent Nuclear Fuel Program Transport Cask**

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Abstract

Preliminary shielding calculations were performed for a prototype National Spent Nuclear Fuel Program (NSNFP) transport cask. This analysis is intended for use in the selection of cask shield material type and preliminary estimate of shielding thickness. The radiation source term was modeled as cobalt-60 with radiation exposure strength of 100,000 R/hr. Cobalt-60 was chosen as a surrogate source because it simultaneously emits two high-energy gammas, 1.17 MeV and 1.33 MeV. This gamma spectrum is considered to be large enough that it will upper bound the spectra of all the various spent nuclear fuels types currently expected to be shipped within the prototype cask. Point-kernel shielding calculations were performed for a wide range of shielding thickness of lead and depleted uranium material. The computational results were compared to three shielding limits: 200 mrem/hr dose rate limit at the cask surface, 50 mR/hr exposure rate limit at one meter from the cask surface, and 10 mrem/hr limit dose rate at two meters from the cask surface.

The results obtained in this study indicated that a shielding thickness of 13 cm is required for depleted uranium and 21 cm for lead in order to satisfy all three shielding requirements without taking credit for stainless steel liners. The system analysis also indicated that required shielding thicknesses are strongly dependent upon the gamma energy spectrum from the radiation source term. This later finding means that shielding material thickness, and hence cask weight, can be significantly reduced if the radiation source term can be shown to have a softer, lower energy, gamma energy spectrum than that due to cobalt-60.

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ES. EXECUTIVE SUMMARY

ES.1 Purpose

The United States Department of Energy Office of Environment Management's (DOE/EM's) National Spent Nuclear Fuel Program (NSNFP), through a collaboration between Sandia National Laboratories (SNL) and Idaho National Engineering and Environmental Laboratory (INEEL), is conducting a preliminary systematic shielding analysis for a prototype transport cask. This cask is intended for use in shipping spent nuclear fuels (SNFs) and high-level wastes (HLWs) with a contact exposure rate of up to 100,000 R/hr. The analysis results from this study identify the shielding requirements necessary to meet the governing regulatory limits for various radiation source term spectra. These results are intended to provide DOE/EM with a technical basis for determining an optimal design for the prototype cask design.

ES.2 Introduction

This report discusses point-kernel shielding calculations for a prototype transportation cask for use with DOE-owned SNF and HLW, which are planned to be disposed of in the potential repository at the Yucca Mountain Site (YMS). The shielding calculations were performed with use of a small computational code, supplied in Appendix C, which was automated so that sensitivity results were obtained for several shielding materials with a wide variation of radiation source gamma energies. The code was also designed to

generate results for inclusion of stainless steel liners for the cask shielding material (see Figure ES-1). Also incorporated into the computer code design was the robustness for easy modifications for possible future use in estimating the transport cask weight.

The radiation source term was conservatively bounded with a gamma energy spectrum from cobalt-60, a high-energy gamma emitter, with a radiation exposure rate of 100,000 R/hr.

Figure ES-1. Schematic of National Spent Fuel Program (NSNFP) transport cask. (Inner basket is one of several preliminary designs.)

ES.3 Results

The general findings from this study are as follows:

- Depleted uranium provides superior shielding characteristics versus lead shielding material.
- The most stringent shielding requirement was the regulatory limit requiring that the radiation dose rate be less than 10 mrem/hr at a distance of two meters from the cask surface. The thickness of depleted uranium required to meet this regulatory limit was approximately 13 cm (without shielding credit for the stainless steel liners, see Figure ES-2) and 10 cm (with shielding credit for the stainless liners, see Figure ES-3).
- Sensitivity analysis results indicated that there is a strong correlation between the required shielding thickness and the gamma-ray energy. If it can be demonstrated

that this expected source term gamma-ray spectrum is significantly less than the spectrum from cobalt-60, then shielding thickness and mass can be reduced.

DU Shield Thickness Required Without Shielding Credit for SS Liners

Figure ES-2. Depleted uranium shielding thickness, without shielding credit for stainless steel liners, for various regulatory limits as a function of gamma-ray energy. (Vertical line corresponds to maximum cobalt-60 gamma-ray energy.)

DU Shield Thickness Required With Shielding Credit for SS Liners

Figure ES-3. Depleted uranium shielding thickness, with shielding credit for stainless steel liners, for various regulatory limits as a function of gamma-ray energy. (Vertical line corresponds to maximum cobalt-60 gamma-ray energy.)

1. INTRODUCTION

A request was made by the Idaho National Engineering and Environmental Laboratory (INEEL) Transportation Group for an estimate of the shielding thickness required for a prototype National Spent Nuclear Fuel Program (NSNFP) transport cask under current study. The cask is required for the transportation of United States Department of Energy (DOE) spent nuclear fuel (SNF) and/or waste components. The cask must meet the following shielding limits: dose rate at the surface of the cask less than 200 mrem/hr, radiation exposure less than 50 mR/hr at one meter from the cask surface, and dose rate less than 10 mrem/hr at two meters from the cask surface. All calculations presented in this study were estimated at the cask mid-height, since this location yields the maximum dose rates.

1.1 Cask Geometry

The design for the prototype cask is constructed from two layers of stainless steel, with a layer of either lead or depleted uranium between the stainless steel to provide gamma shielding. The inner layer of stainless steel is 2.54 cm (1.00 in) thick and the outer is 3.81 cm (1.50 in). A schematic of the transport cask is provided in Figure 1.1-1.

Figure 1.1-1. Schematic of National Spent Fuel Program (NSNFP) transport cask. (Inner basket is one of several preliminary designs.)

The shielding of the prototype cask is comprised of three zones. The shield consists of a right-hand cylinder of inner diameter of 182. cm (71.7 in) with the inner most zone corresponding to the 2.54 cm (1.00 in) thick stainless steel liner. The lead or depleted uranium shielding zone surrounds the inner liner. The two inner zones are then encased within a 3.81 cm (1.50 in) stainless steel liner. The overall dimensions of the prototype cask are 2.28 m (89.9 in) diameter by 5.54 m (218. in) in length.

1.2 Radiation Source Term and Shielding Requirements

The radioactive source term may be comprised of several different types of high-level wastes, spent nuclear fuels and/or reactor components. Current design criteria require the radiation source to be bound by an exposure rate of 100,000 R/hr with a gamma spectrum corresponding to Co-60. This spectrum is used since it is expected that some of the reactor components to be transported will contain significant quantities of Co-60 due to neutron activation of stellite materials [Lengyel 1999]. The major significance of the source term is the gamma-ray energy of Co-60. This radionuclide emits two high-energy gamma-rays per each disintegration, one at 1.17 MeV and the other at 1.33 MeV.

There are three shielding limits that were considered as part of this study:

1. In accordance with 10 CFR 71.43, the dose rate at the surface of the cask must be less than 200 mrem/hr.
2. A design criterion for cask handling, used for illustrative purposes, was that the radiation exposure rate be less than 50 mR/hr at one meter from the external surface of the cask. (Although not a radiation standard, per se, this corresponds to the determination of a Transport Index [TI] of 50 given in 10 CFR 71.4.)
3. In accordance with 10 CFR 71.43, the dose rate at two meters from the cask surface must be less than 10 mrem/hr.

The maximum radiation dose rates and exposures will occur at the cask mid-height, because cask ends have additional shielding due to cask end effects. Thus, only one-dimensional shielding calculations are necessary to investigate the maximum radiation field outside of the transport cask at this location.

1.3 Computational Code

The shielding calculations can be performed by several methods, the two most notable are the Boltzmann transport equation [Schaeffer 1973] and the much simpler, point-kernel method [Jaeger 1968]. In general, solutions to the transport equation are more accurate but require more time to setup and execute. The point-kernel method was chosen as the computational method since the analysis for this study was for a prototype design, not requiring extreme accuracy. A computer program called SHIELD was developed to calculate the dose rates. It is a small code and is listed in Appendix C. SHIELD was developed since a large number of calculations were to be performed and known commercial codes (i.e., MICROSHIELD) were not available that met these

requirements due to the large number of calculations needed. (The equations used in SHIELD are identified in Appendix A.) SHIELD is completely self contained and at present is programmed to perform on the order of one thousand calculations for each of the three shielding limits. This large of a set of calculations would not be practical with transport codes, nor with MICROSHIELD.

The computational results presented in this study (see Section 4) indicate that the shielding thickness is strongly dependent upon the gamma-ray energy of the source term. To emphasize this finding, the results presented in this report are shown for a wide variation of gamma-ray energies.

The shielding calculations were performed only for gamma radiation because betas and alphas would not penetrate the stainless steel liners that surround the radiation shielding material. Neutrons are not included because they typically have a dose equivalent rate that is about two or three orders of magnitude less than that from gammas.

2. MODELING TECHNIQUES

The calculations in this study estimate the surface dose rate on the outer surface of a SNF cask, the exposure rate at one meter from the cask, and the dose rate at two meters from cask surface. The computational steps used for the gamma shielding are shown in Table 2-1 (followed by limited discussion on the appropriate units used for presenting shielding results).

Table 2-1. Calculation Steps For Cask Shielding Calculations	
Step	Calculation
1	Determine the corresponding gamma-ray flux for the identified exposure rate of the radionuclide source term. Thus, the total internal source strength is estimated as generating a uniform normal surface flux. Since the gamma spectrum of the expected source term is unknown, its spectrum is assumed to be that of Co-60, which gives off two simultaneous gamma-rays, one at 1.17 MeV and the other at 1.33 MeV. A wide range of gamma-ray energies will be investigated to determine shielding requirements as a function of energy.
2	Use the point kernel shielding method to generate the code SHIELD for gamma-ray flux attenuation within the shielding material region. This method is modeled in a small computational code to allow a sensitivity analysis to be performed on: 1) shield material type, 2) shielding region thickness, and 3) gamma-ray energy. The shielding model includes: 1) proper integration of point sources over the extended source term (right-hand cylindrical geometry), and 2) use of associated isotropic exposure buildup factor for shield materials being investigated.
3	Determine the gamma-ray flux on the outside of the cask as a function of shield material, thickness and gamma-ray energy. Results will be generated for several levels of conservatism: 1) no credit for the actual gamma-ray spectrum, 2) no credit for the outer stainless steel (SS) liner around the shielding material, and 3) no credit for the inner SS liner. Computational results for the study will be at the cask mid-height where maximum gamma-ray flux density and corresponding cask surface dose rates will occur.
4	Using the gamma-ray flux results from step #3, identify the dose equivalent rate. This requires several steps: 1) convert gamma-ray flux values into exposure rate values, 2) convert exposure rate values into absorbed dose rate values, and 3) convert the absorbed dose rate values into the requested dose equivalent rate values.
5	From the above sensitivity analysis results, identify the shielding thickness required to meet a surface contact limit (200 mrem/hr limit, see Section 1.2) for scenarios of: 1) lead shielding region/with credit for SS liners, 2) lead shielding region/without credit for SS liners, 3) depleted uranium (DU) shielding region/with credit for SS liners, and 4) DU shielding region/without credit for SS liners.
6	For selected combinations of shielding thickness and gamma-ray energy, identify the dose equivalent rates and exposure rates external to the cask. This analysis will address the dose rate limit at 2 meters from the accessible cask surface and the exposure rate limit at 1 meter from the cask surface.
7	For comparative purposes, identify a typical light water reactor (LWR) SNF gamma-ray spectrum. This information will be used to determine the gamma-ray spectra that may be expected from SNFs that would be shipped within the transport cask. The presented LWR gamma-ray spectra will be flux density weighted to determine a flux averaged gamma-ray energy, which could be compared to mono-energetic gamma-ray shielding calculations from Step #5.

Steps 1 through 4 of Table 2-1 incorporate gamma properties in various units related to biological effects. These properties (such as radiation exposure) are identified in the following few equations:

Equation 2-1 calculates the dose equivalent rate (abbreviated as dose rate for this report). The dose rate incorporates the quality factor, which takes into account that different types of radiation have different biological effects.

$$\dot{H} = Q \dot{D}, \text{ rewritten as: } \dot{D} = \dot{H} / Q \quad [2-1]$$

Equation 2-2 relates the absorbed dose rate to the exposure rate through the parameter f . Equation 2-3 relates the exposure rate to gamma-ray flux density.

$$\dot{D} = f \dot{X}, \text{ rewritten as: } \dot{X} = \dot{D} / f \quad [2-2]$$

$$\dot{X} = C_d \phi, \text{ rewritten as: } \phi = \dot{X} / C_d \quad [2-3]$$

where:

$\dot{H}$ = dose equivalent rate [rem/hr]

$\dot{D}$ = absorbed dose rate [rad/hr]

Q = quality factor [rem/rad]

$\dot{X}$ = exposure rate [R/hr]

f = exposure to absorbed dose conversion ratio [rad/R]

$$= 0.874 \frac{(\mu_a / \rho)^{tissue}}{(\mu_a / \rho)^{air}} \quad [2-4]$$

ϕ = gamma-ray flux density [$\gamma / cm^2 - s$]

C_d = flux-to-dose conversion factor [$(cm^2 - sec/\gamma)x(R/hr)$]

$$= 0.0659 E_\gamma (\mu_a / \rho)^{air}$$

E_γ = gamma-ray energy [MeV]

$(\mu_a / \rho)^i$ = mass energy-absorption coefficient for i [cm^2 / gm]

where i = air or tissue

The above equations are a synopsis of the dose rate and exposure rate equations identified in Appendix A.

2.1 Capabilities

The code SHIELD used in this study (see Appendix C for code listing) can easily be adapted for changes in shielding materials and/or geometry. Also, it performs ancillary calculations for linear cask weight (expressed as metric tons per linear meter of length, not including end caps). This feature is not extensively used in this study. However, it is expected that any future optimization studies and decision analysis may advantageously benefit from this feature. The standard output of SHIELD generated for this study is listed in Appendix D.

2.2 Scoping Analysis

As can be seen from the standard output from the code SHIELD in Appendix D, the output is presented in a sensitivity analysis form. The results are generated for a range of different key input parameters, namely:

- Gamma-Ray Energy -- The gamma energy range from 0.25 MeV to a maximum of 1.5 MeV. This range exceeds the energy from cobalt-60 gammas, which are 1.17 MeV and 1.33 MeV. The average of the cobalt-60 gamma energies is 1.25 MeV, which is also a standard output value.
- SS Liner Thickness -- The calculations are performed for cases where shielding credit is given and not given for the stainless steel liners. (See flux results for shielding Regions 1 and 3 in standard output from SHIELD.)
- Shielding Thickness -- The calculations are performed for a wide range of shielding thickness (i.e., 2 cm up to 20 cm of shielding) for both lead and depleted uranium shielding material. (See flux results for shielding Region 2 in standard output from SHIELD.)

2.3 Limitations

There are accuracy limitations with any type of shielding calculations. As a general rule, the accuracy of gamma radiation shielding calculations is not extremely accurate. The results from state-of-the-art deterministic finite codes for deep shielding (decreasing the gamma flux by several orders of magnitude) as required for this study are within a factor of two or three (roughly a third of an order of magnitude). Monte Carlo transport codes may fair slightly better, but they require significant efforts to optimize the computational results and would require significant computational time. The point-kernel method used in this study, requires an insignificant amount of computational time, but has an accuracy of plus or minus an order of magnitude for the gamma-ray flux (including uncertainties from the flux-to-dose conversion factors). For the results presented in Appendix D, this is reflected in an uncertainty of about one and a half to two centimeters of shielding thickness. Since this study is preliminary and the final dimensions will be fine-tuned during the cask design phase, these uncertainties are acceptable at present.

3. RESULTS

This section presents selected results obtained from SHIELD (see Appendix C for code listing and Appendix D for standard output). A significant finding from this study was that the shielding results (both dose rate and exposure rate) are extremely sensitive to the assumed average gamma-ray energy of the radionuclide source term. This sensitivity is so large that if it is determined that the averaged gamma-ray energy should be less than 0.6 MeV, then the cask mass could be reduced by a factor of two or more. Three dimensional shielding results are presented in Appendices E and F for lead and depleted uranium shielding materials, respectfully. Sections 3.1 and 3.2 contain select results from the appendices for depleted uranium and lead shielding material, respectfully. Limited discussion on these figures can be found in Table 3-1, which is presented to serve as a key to the figures and as a summary of the results of the shielding calculations. Synopsis results are presented in Figures 3-1, 3-2, and 3-3 (note these figures are constructed from the shielding limit intercepts from the figures in Sections 3.1 and 3.2).

Table 3-1. Discussion of Shielding Results

Figure	Discussion
3-1	This figure identifies the minimum shielding thickness required to meet the 200 mrem/hr dose rate on the cask surface. This is investigated for the four cases: 1) lead shield with no credit for the stainless (SS) liners, 2) lead shield with SS liners, 3) depleted uranium (DU) without credit for the SS liners, and 4) DU with SS liners. Results indicate the superiority of DU versus lead for shielding material. Also apparent from this overall systems analysis figure is the significance of the shielding due to the SS liners. Thus, if credit for the SS liners can be obtained then significant reduction in the shielding region thickness and mass could be made.
3-2	This figure resembles Figure 3-1, but presents results for the exposure limit of 50 mR/hr at 1 meter from the cask surface.
3-3	This figure resembles Figure 3-1, but presents results for the dose rate limit of 10 mrem/hr at 2 meters from the cask surface.
3.1-1	This figure identifies the dose rate at cask surface as a function of lead shielding thickness for selected gamma-ray energies. This figure also takes shielding credit for the SS liners.
3.1-2	This figure resembles Figure 3.1-1, but does not take credit for the SS liners.
3.1-3	This figure identifies the exposure rate at 1 meter from the cask surface as a function of lead shielding thickness for selected gamma-ray energies. This figure also takes shielding credit for the SS liners.
3.1-4	This figure resembles Figure 3.1-3, but does not take credit for the SS liners.
3.1-5	This figure identifies the dose rate at 2 meter from the cask surface as a function of lead shielding thickness for selected gamma-ray energies. This figure also takes shielding credit for the SS liners.
3.1-6	This figure resembles Figure 3.1-5, but does not take credit for the SS liners.
3.2-1	This figure identifies the dose rate at cask surface as a function of depleted uranium shielding thickness for selected gamma-ray energies. This figure also takes shielding credit for the SS liners.
3.2-2	This figure resembles Figure 3.2-1, but does not take credit for the SS liners.
3.2-3	This figure identifies the exposure rate at 1 meter from the cask surface as a function of depleted uranium shielding thickness for selected gamma-ray energies. This figure also takes shielding credit for the SS liners.
3.2-4	This figure resembles Figure 3.2-3, but does not take credit for the SS liners
3.2-5	This figure identifies the dose rate at 2 meter from the cask surface as a function of depleted uranium shielding thickness for selected gamma-ray energies. This figure also takes shielding credit for the SS liners.
3.2-6	This figure resembles Figure 3.2-5, but does not take credit for the SS liners.

Shielding Thickness Required for Cask Surface Dose Rate of 200 mrem/hr

Figure 3-1. Shielding thickness, as a function of gamma-ray energy, required to meet regulatory limit of 200 mrem/hr at cask surface. (Shielding thickness at gamma-ray energy of 1.33 MeV corresponds to cobalt-60 source term.)

Shielding Thickness Required for Exposure Rate of 50 mR/hr at 1 meter from Cask Surface

Figure 3-2. Shielding thickness, as a function of gamma-ray energy, required to meet shielding limit of 50 mR/hr at one meter from cask surface. (Shielding thickness at gamma-ray energy of 1.33 MeV corresponds to cobalt-60 source term.)

Shielding Thickness Required for Dose Rate of 10 mrem/hr at 2 meters from Cask Surface

Figure 3-3. Shielding thickness, as a function of gamma-ray energy, required to meet regulatory limit of 10 mrem/hr at two meters from cask surface. (Shielding thickness at gamma-ray energy of 1.33 MeV corresponds to cobalt-60 source term.)

3.1 Lead Shielding Material

The following figures identify the dose rates and exposure rates (at desired distances from the cask surface) as a function of lead shield material thickness.

Cask Surface Dose Rate for Lead Shielding
(dose rate @ surface, 2.54 & 3.81 cm SS liners)

Figure 3.1-1. Dose rate at cask surface as a function of lead shielding thickness for selected gamma-ray energies with shielding credit for SS liners. Data compared to dose rate limit of 200 mrem/hr at cask surface.

Cask Surface Dose Rate for Lead Shielding
(dose rate @ surface, 0.00 & 0.00 cm SS liners)

Figure 3.1-2. Dose rate at cask surface as a function of lead shielding thickness for selected gamma-ray energies without shielding credit for SS liners. Data compared to dose rate limit of 200 mrem/hr at cask surface.

Exposure Rate 1m from Cask Surface for Lead Shielding
(2.54 & 3.81 cm SS liners)

Figure 3.1-3. Exposure rate at one meter from cask surface as a function of lead shielding thickness for selected gamma-ray energies with shielding credit for SS liners. Data compared to exposure rate limit of 50 mR/hr at one meter from cask surface.

Exposure Rate 1m from Cask Surface for Lead Shielding
(0.00 & 0.00 cm SS liners)

Figure 3.1-4. Exposure rate at one meter from cask surface as a function of lead shielding thickness for selected gamma-ray energies without shielding credit for SS liners. Data compared to exposure rate limit of 50 mR/hr at one meter from cask surface.

Dose Rate at 2m from Cask Surface for Lead Shielding
(2.54 & 3.81 cm SS liners)

Figure 3.1-5. Dose rate at two meters from cask surface as a function of lead shielding thickness for selected gamma-ray energies with shielding credit for SS liners. Data compared to dose rate limit of 10 mrem/hr at two meters from cask surface.

Dose Rate at 2m from Cask Surface for Lead Shielding
(0.00 & 0.00 cm SS liners)

Figure 3.1-6. Dose rate at two meters from cask surface as a function of lead shielding thickness for selected gamma-ray energies without shielding credit for SS liners. Data compared to dose rate limit of 10 mrem/hr at two meters from cask surface.

3.2 Depleted Uranium Shield Material

The following figures identify the dose rates and exposure rates (at desired distances from the cask surface) as a function of depleted uranium shield material thickness.

Figure 3.2-1. Dose rate at cask surface as a function of depleted uranium shielding thickness for selected gamma-ray energies with shielding credit for SS liners. Data compared to dose rate limit of 200 mrem/hr at cask surface.

Cask Surface Dose Rate for DU Shielding
(dose rate @ surface, 0.00 & 0.00 cm SS liners)

Figure 3.2-2. Dose rate at cask surface as a function of depleted uranium shielding thickness for selected gamma-ray energies without shielding credit for SS liners. Data compared to dose rate limit of 200 mrem/hr at cask surface.

Exposure Rate 1m from Cask Surface for DU Shielding
(2.54 & 3.81 cm SS liners)

Figure 3.2-3. Exposure rate at one meter from cask surface as a function of depleted uranium shielding thickness for selected gamma-ray energies with shielding credit for SS liners. Data compared to exposure rate limit of 50 mR/hr at one meter from cask surface.

Exposure Rate 1m from Cask Surface for DU Shielding (0.00 & 0.00 cm SS liners)

Figure 3.2-4. Exposure rate at one meter from cask surface as a function of depleted uranium shielding thickness for selected gamma-ray energies without shielding credit for SS liners. Data compared to exposure rate limit of 50 mR/hr at one meter from cask surface.

Dose Rate at 2m from Cask Surface for DU Shielding
(2.54 & 3.81 cm SS liners)

Figure 3.2-5. Dose rate at two meters from cask surface as a function of depleted uranium shielding thickness for selected gamma-ray energies with shielding credit for SS liners. Data compared to dose rate limit of 10 mrem/hr at two meters from cask surface.

Dose Rate at 2m from Cask Surface for DU Shielding
(surface, 0.00 & 0.00 cm SS liners)

Figure 3.2-6. Dose rate at two meters from cask surface as a function of depleted uranium shielding thickness for selected gamma-ray energies without shielding credit for SS liners. Data compared to dose rate limit of 10 mrem/hr at two meters from cask surface.

4. CONCLUSIONS

The results obtained from the shielding calculations in this study indicate the following major findings:

1. Depleted uranium is a superior shielding material in comparison to lead shielding material.
2. It is desirable to receive shielding credit for the stainless steel liners. By obtaining credit for the stainless steel liners it is possible to reduce the shielding material thickness by over 2 centimeters. This is a significant saving in total cask weights.
3. The required shielding thickness is strongly dependent upon the gamma-ray energy. Calculations indicate that large shielding thicknesses are required for gamma-ray energies greater than 1.0 MeV.

The results presented in Figures 3-1, 3-2, and 3-3 indicate that shielding thickness on the order of 10 to 13 centimeters of depleted uranium are required for cobalt-60 type gamma spectra (maximum gamma-ray energy = 1.33 MeV). The actual thickness will be determined by whether credit can be taken for the liners.

5. RECOMMENDATION FOR FUTURE WORK

- **Updating Gamma-Ray Spectrum for Source Term**

The shielding thickness is strongly dependent upon the gamma-ray energy spectrum of the radiation source. This finding is significant and indicates that future work may be desirable to determine if spectra softer than that from cobalt-60 can be used. Figure 5-1 illustrates this point. This figure presents "energy averaged" gamma-ray spectra after various times of decay for pressurized water reactor (PWR) spent nuclear fuel. This data was analyzed in Table 5-1, which also generated "flux averaged" gamma-ray energies at various post-reactor times. The flux average data are plotted in Figure 5-2, which indicates that very low average gamma-ray energies (less than 0.3 MeV) may occur after five years. Unfortunately, this spectrum may not be typical of DOE SNFs and even more importantly, the appropriate average gamma-ray energy should be "dose equivalent rate averaged" based on shielding calculations for each gamma line. This work would require detailed analysis and could be advantageous only if the proposed radiation source forms (SNF and HLW) can be identified as not being bounded by cobalt-60.

- **Cask Mass Optimization (Minimization) Study**

Further engineering and system analysis could be performed using the SHIELD code (Appendix B) to minimize the cask mass. At its present level, this code estimates cask mass per unit length. Selected results are presented in Figures 5-3, 5-4 and 5-5. These figures indicate that required cask mass (SS liners and shielding mass) is smallest when depleted uranium is used for the shielding material. These mass values are only for the cask main body and do not include masses due to auxiliary components such as: cask impact limiters (end caps), hold-down equipment, personnel protection barrier, etc. Since SHIELD is a small code that is easy to modify, it can be used directly in a mass optimization/cost analysis study.

- **Radiation Transport Code Analysis**

Final cask dimensions should be obtained/fine-tuned with use of calculations from a radiation transport code (i.e., a code that obtains a numerical solution to the collisional Boltzmann transport equation). By using SHIELD to obtain an optimal solution, only a small number of calculations would be needed for this process. Only these calculations would require quality assurance associations.

Gamma Spectra for Typical PWR SNF

Figure 5-1. Typical gamma-ray spectra at selected post reactor times for typical pressurized water reactor (PWR) spent nuclear fuel (SNF). (After Ref. Croff 1980, construction of spectra performed in Table 5-1. Histograms from top to bottom correspond to 5 yr, 10 yr, 50 yr, and 100yr.)

Flux Averaged Gamma Energy for Typical PWR SNF

Figure 5-2. Flux-averaged gamma-ray energy from typical PWR SNF as a function of time. (Data generate using Figure 5-1, data analysis performed in Table 5-1.)

Table 5-1. Calculations for Flux Averaged Gamma-Ray Energies for Pressurized Water Reactor (PWR) Spent Nuclear Fuel (SNF) at Various Times After Burn-up. (Select Results From This Table Are Presented in Figures 5-1 and 5-2.)

Photons from Activation+Actinides+Fission Products in PWR Spent Fuel
As a Function of Decay Time (Basis = 1.0 MTHM) Time= 5yr [Ref. ORG1]

Photon Range [MeV]	Energy <AVE> [MeV]	Activation Products [photon/s]	Actinides [photon/s]	Fission Products [photon/s]	Total [photon/s]	Photon * Energy [MeV-p/s]	Fraction of Flux []
.000 -> .020	.015	9.586E+12	3.642E+13	4.869E+15	4.915E+15	7.373E+13	2.905E-01
.020 -> .031	.025	1.358E+13	9.461E+11	1.114E+15	1.129E+15	2.821E+13	6.671E-02
.031 -> .048	.038	3.784E+12	1.798E+11	1.045E+15	1.049E+15	3.934E+13	6.200E-02
.048 -> .071	.058	9.889E+11	1.374E+13	9.664E+14	9.811E+14	5.641E+13	5.799E-02
.071 -> .105	.085	3.946E+11	5.853E+11	6.218E+14	6.228E+14	5.294E+13	3.681E-02
.105 -> .175	.125	2.280E+11	4.712E+11	5.601E+14	5.608E+14	7.010E+13	3.315E-02
.175 -> .300	.225	1.088E+12	3.682E+11	5.336E+14	5.351E+14	1.204E+14	3.163E-02
.300 -> .475	.375	6.206E+12	2.683E+10	2.887E+14	2.949E+14	1.106E+14	1.743E-02
.475 -> .712	.575	7.964E+12	7.629E+08	5.157E+15	5.165E+15	2.970E+15	3.053E-01
0.71 -> 1.05	0.85	1.664E+11	7.904E+08	1.120E+15	1.120E+15	9.521E+14	6.621E-02
1.05 -> 1.50	1.25	3.016E+14	3.564E+08	2.299E+14	5.315E+14	6.644E+14	3.142E-02
1.50 -> 2.00	1.75	1.500E+08	7.844E+07	8.687E+12	8.687E+12	1.520E+13	5.135E-04
2.00 -> 2.50	2.25	1.599E+09	3.510E+07	5.146E+12	5.148E+12	1.158E+13	3.043E-04
2.50 -> 3.13	2.75	4.947E+06	7.687E+07	1.524E+11	1.525E+11	4.193E+11	9.013E-06
3.13 -> 4.25	3.50	3.252E-05	1.830E+07	1.943E+10	1.945E+10	6.807E+10	1.150E-06
4.25 -> 6.00	5.00	9.672E-06	7.828E+06	5.957E-05	7.828E+06	3.914E+07	4.627E-10
6.00 -> 9.00	7.00	6.276E-07	9.024E+05	3.865E-06	9.024E+05	6.317E+06	5.334E-11
9.0 -> 20.0	11.0	3.969E-08	1.037E+05	2.444E-07	1.037E+05	1.141E+06	6.130E-12
Total =		3.456E+14	5.274E+13	1.652E+16	1.692E+16	5.165E+15	1.000E+00

$$\text{Average Energy} = 5.165\text{E}+15 / 1.692\text{E}+16 = 0.3053 \text{ MeV}$$

Photons from Activation+Actinides+Fission Products in PWR Spent Fuel
As a Function of Decay Time (Basis = 1.0 MTHM) Time= 10yr [Ref. ORG1]

Photon Range [MeV]	Energy <AVE> [MeV]	Activation Products [photon/s]	Actinides [photon/s]	Fission Products [photon/s]	Total [photon/s]	Photon * Energy [MeV-p/s]	Fraction of Flux []
.000 -> .020	.015	4.670E+12	3.962E+13	3.335E+15	3.379E+15	5.069E+13	3.230E-01
.020 -> .031	.025	4.039E+12	1.597E+12	7.180E+14	7.236E+14	1.809E+13	6.916E-02
.031 -> .048	.038	1.268E+12	2.288E+11	6.970E+14	6.985E+14	2.619E+13	6.676E-02
.048 -> .071	.058	4.897E+11	2.331E+13	6.484E+14	6.722E+14	3.865E+13	6.425E-02
.071 -> .105	.085	1.943E+11	5.817E+11	4.016E+14	4.024E+14	3.420E+13	3.846E-02
.105 -> .175	.125	9.590E+10	4.605E+11	3.271E+14	3.277E+14	4.096E+13	3.132E-02
.175 -> .300	.225	3.218E+11	3.505E+11	3.419E+14	3.426E+14	7.708E+13	3.274E-02
.300 -> .475	.375	1.779E+12	2.715E+10	1.594E+14	1.612E+14	6.045E+13	1.541E-02
.475 -> .712	.575	2.279E+12	9.553E+08	3.357E+15	3.359E+15	1.932E+15	3.211E-01
0.71 -> 1.05	0.85	9.679E+10	7.981E+08	2.820E+14	2.821E+14	2.398E+14	2.696E-02
1.05 -> 1.50	1.25	1.563E+04	3.326E+08	1.107E+14	1.107E+14	1.384E+14	1.058E-02
1.50 -> 2.00	1.75	5.863E+07	6.960E+07	3.417E+12	3.417E+12	5.980E+12	3.266E-04
2.00 -> 2.50	2.25	8.282E+08	2.915E+07	8.080E+10	8.166E+10	1.837E+11	7.804E-06
2.50 -> 3.13	2.75	2.563E+06	8.764E+07	4.820E+09	4.910E+09	1.350E+10	4.693E-07

3.13 -> 4.25	3.50	1.328E-07	1.520E+07	6.243E+08	6.395E+08	2.238E+09	6.112E-08
4.25 -> 6.00	5.00	3.449E-08	6.500E+06	6.085E-05	6.500E+06	3.250E+07	6.212E-10
6.00 -> 9.00	7.00	2.233E-09	7.492E+05	3.949E-06	7.492E+05	5.244E+06	7.160E-11
9.0 -> 20.0	11.0	1.414E-10	8.605E+04	2.497E-07	8.605E+04	9.466E+05	8.224E-12

Total =	1.523E+13	6.618E+13	1.038E+16	1.046E+16	2.662E+15	1.000E+00
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Average Energy = 2.662E+15 / 1.046E+16 = 0.2544 MeV

Photons from Activation+Actinides+Fission Products in PWR Spent Fuel
As a Function of Decay Time (Basis = 1.0 MTHM) Time= 30yr [Ref. ORG1]

Photon Range [MeV]	Photon Energy <AVE> [MeV]	Activation Products [photon/s]	Actinides [photon/s]	Fission Products [photon/s]	Total [photon/s]	Photon * Energy [MeV-p/s]	Fraction of Flux []
.000 -> .020	.015	4.169E+11	4.557E+13	2.014E+15	2.060E+15	3.090E+13	3.436E-01
.020 -> .031	.025	8.153E+10	3.020E+12	4.173E+14	4.204E+14	1.051E+13	7.012E-02
.031 -> .048	.038	3.725E+10	3.333E+11	3.986E+14	3.990E+14	1.496E+13	6.655E-02
.048 -> .071	.058	3.420E+10	4.424E+13	3.891E+14	4.334E+14	2.492E+13	7.228E-02
.071 -> .105	.085	1.347E+10	5.655E+11	2.343E+14	2.349E+14	1.996E+13	3.918E-02
.105 -> .175	.125	5.618E+09	4.234E+11	1.650E+14	1.654E+14	2.068E+13	2.759E-02
.175 -> .300	.225	3.794E+09	2.974E+11	2.017E+14	2.020E+14	4.545E+13	3.369E-02
.300 -> .475	.375	1.278E+10	2.796E+10	8.678E+13	8.682E+13	3.256E+13	1.448E-02
.475 -> .712	.575	1.577E+10	1.337E+09	1.928E+15	1.928E+15	1.109E+15	3.216E-01
0.71 -> 1.05	0.85	8.876E+10	7.701E+08	3.054E+13	3.063E+13	2.604E+13	5.109E-03
1.05 -> 1.50	1.25	1.126E+13	2.671E+08	2.277E+13	3.403E+13	4.254E+13	5.676E-03
1.50 -> 2.00	1.75	1.162E+07	4.315E+07	9.030E+11	9.031E+11	1.580E+12	1.506E-04
2.00 -> 2.50	2.25	5.965E+07	1.414E+07	3.952E+07	1.133E+08	2.549E+08	1.890E-08
2.50 -> 3.13	2.75	1.846E+05	7.343E+07	5.086E+03	7.362E+07	2.025E+08	1.228E-08
3.13 -> 4.25	3.50	1.231E-07	7.357E+06	6.646E+02	7.358E+06	2.575E+07	1.227E-09
4.25 -> 6.00	5.00	3.346E-08	3.143E+06	6.132E-05	3.143E+06	1.572E+07	5.242E-10
6.00 -> 9.00	7.00	2.167E-09	3.619E+05	3.979E-06	3.619E+05	2.533E+06	6.036E-11
9.0 -> 20.0	11.0	1.372E-10	4.154E+04	2.516E-07	4.154E+04	4.569E+05	6.929E-12

Total =		1.197E+13	9.448E+13	5.889E+15	5.995E+15	1.379E+15	1.000E+00

Average Energy = 1.379E+15 / 5.995E+15 = 0.2300 MeV

Photons from Activation+Actinides+Fission Products in PWR Spent Fuel
As a Function of Decay Time (Basis = 1.0 MTHM) Time= 100yr [Ref. ORG1]

Photon Range [MeV]	Photon Energy <AVE> [MeV]	Activation Products [photon/s]	Actinides [photon/s]	Fission Products [photon/s]	Total [photon/s]	Photon * Energy [MeV-p/s]	Fraction of Flux []
.000 -> .020	.015	7.104E+10	4.175E+13	3.801E+14	4.219E+14	6.329E+12	3.467E-01
.020 -> .031	.025	4.979E+09	3.525E+12	7.874E+13	8.227E+13	2.057E+12	6.761E-02
.031 -> .048	.038	1.327E+09	3.552E+11	7.475E+13	7.511E+13	2.816E+12	6.172E-02
.048 -> .071	.058	7.048E+08	5.167E+13	7.311E+13	1.248E+14	7.175E+12	1.025E-01
.071 -> .105	.085	2.905E+08	5.285E+11	4.401E+13	4.454E+13	3.786E+12	3.660E-02
.105 -> .175	.125	1.295E+08	3.603E+11	2.846E+13	2.882E+13	3.603E+12	2.368E-02
.175 -> .300	.225	8.069E+07	2.266E+11	3.757E+13	3.780E+13	8.504E+12	3.106E-02
.300 -> .475	.375	2.885E+08	2.918E+10	1.631E+13	1.634E+13	6.127E+12	1.343E-02
.475 -> .712	.575	2.659E+08	1.437E+09	3.815E+14	3.815E+14	2.194E+14	3.135E-01
0.71 -> 1.05	0.85	8.769E+10	6.314E+08	2.693E+12	2.781E+12	2.364E+12	2.286E-03
1.05 -> 1.50	1.25	1.130E+09	1.881E+08	9.345E+11	9.358E+11	1.170E+12	7.690E-04

1.50	->	2.00	1.75	4.126E+04	1.914E+07	6.978E+10	6.980E+10	1.221E+11	5.736E-05
2.00	->	2.50	2.25	5.983E+03	1.998E+06	7.462E+06	9.466E+06	2.130E+07	7.779E-09
2.50	->	3.13	2.75	1.851E+01	3.438E+07	2.797E-04	3.438E+07	9.455E+07	2.825E-08
3.13	->	4.25	3.50	1.147E-07	9.832E+05	2.060E-04	9.832E+05	3.441E+06	8.080E-10
4.25	->	6.00	5.00	3.346E-08	4.163E+05	6.132E-05	4.163E+05	2.082E+06	3.421E-10
6.00	->	9.00	7.00	2.167E-09	4.743E+04	3.979E-06	4.743E+04	3.320E+05	3.898E-11
9.0	->	20.0	11.0	1.372E-10	5.417E+03	2.516E-07	5.417E+03	5.959E+04	4.452E-12

Total = 1.679E+11 9.845E+13 1.118E+15 1.217E+15 2.634E+14 1.000E+00

Average Energy = 2.634E+14 / 1.217E+15 = 0.2165 MeV

Shielding Mass Required for Cask Surface Dose Rate of 200 mrem/hr

Figure 5-3. Shielding mass, as a function of gamma-ray energy, required to meet regulatory limit of 200 mrem/hr at cask surface. (Vertical line corresponds to maximum cobalt-60 gamma-ray energy.)

Shielding Mass Required for Exposure Rate of 50 mR/hr at 1 meter from Cask Surface

Figure 5-4. Shielding mass, as a function of gamma-ray energy, required to meet shielding limit of 50 mR/hr at one meter from cask surface. (Vertical line corresponds to maximum cobalt-60 gamma-ray energy.)

Shielding Mass Required for Dose Rate
of 10 mrem/hr at 2 meters from Cask Surface

Figure 5-5. Shielding mass, as a function of gamma-ray energy, required to meet regulatory limit of 10 mrem/hr at two meters from cask surface. (Vertical line corresponds to maximum cobalt-60 gamma-ray energy.)

6. REFERENCES

[ASM 1990]

ASM International Handbook Committee; **Metals Handbook, Volume 2, Properties and Selection: Nonferrous Alloys and Special-Purpose Materials**, ASM International, Materials Park OH, 1990. (Density of "chemical" lead = 11.35 g/cc from page 545 and density of depleted "shielding alloy" uranium = 18.5 g/cc from page 673.)

[Croff 1980]

Croff, A.G. and Alexander, C.W.; "Decay Characteristics of Once-Through LWR and LMFBR Spent Fuels, High-Level Wastes, and Fuel-Assembly Structural Material Wastes", ORNL/TM-7431, Oak Ridge National Laboratory, November 1980.

[Davis 1994]

Davis, J.R. (Editor); **Stainless Steel**, ASM International, Materials Park OH, 1994. (Density of 304L stainless steel = 8.0 g/cc from page 22.)

[Jaeger 1968]

Jaeger, R.G. (Editor), et al.; **Engineering Compendium on Radiation Shielding, Volume I – Shielding Fundamentals and Methods**; Springer-Verlag; Berlin; 1968; pg. 383.

[Lengyel 1999]

Personal communications with Lengyel L. Arpad (INEEL Consultant); 1999.

[Schaeffer 1973]

Schaeffer, N.M. (Editor); **Reactor Shielding for Nuclear Engineers**; U.S. Atomic Energy Commission (UC-80), 1973, TID-25951, ISBN 0-87079-004-8, LCCCN 73-600001.

[USCFR 1994]

United States Code of Federal Regulations, Title 10, Part 71.43, U.S. Government Printing Office, Washington, 1994.

7. APPENDICES

7.1 Appendix A – Details of Point Kernel Shielding Calculations

This appendix contains an abbreviated description of the point-kernel method for gamma-ray shielding calculations. The shielding calculations were performed only for gamma radiation because betas and alphas would not penetrate the inner stainless steel liner. Neutrons are not included because the dose equivalent rate from neutrons is expected to be several orders of magnitude less than that for gammas. The computational steps used for gamma shielding are shown in Table A-1.

Table A-1. Calculation Steps For Gamma Shielding Calculations *	
Step	Calculation
1	Use the flux exposure rate relationship for shielding to determine the gamma-ray flux density corresponding to the source term exposure rate.
2	Use the proper shielding equation with the point source isotropic exposure buildup factor for a self-shielding distributed source to identify the gamma flux density at the material interfaces within the cask and at locations exterior to the cask.
3	Determine the corresponding dose and exposure rates from the computed gamma flux values.
4	Repeat steps 2 and 3 for various gamma-ray energies.

Step 1 requires use of Equation A-1 [La-1], which incorporates the "quality factor" (see Table A-2) which is a factor that takes into account the fact that equal absorbed doses of radiation of different types (qualities) have, in general, different biological effects.

$$\dot{H} = Q\dot{D}, \text{ rewritten as: } \dot{D} = \dot{H} / Q \quad [A-1]$$

Likewise, Equation A-2 [La-1b] relates the absorbed dose rate to the exposure rate through the parameter f (see Figure A-1) and Equation A-3 [La-1c], which describes the biological shielding (shielding to reduce radiation exposure to persons in the vicinity of radiation sources), relates the exposure rate to the gamma-ray flux density.

$$\dot{D} = f \dot{X}, \text{ rewritten as: } \dot{X} = \dot{D} / f \quad [\text{A-2}]$$

$$\dot{X} = C_d \phi, \text{ rewritten as: } \phi = \dot{X} / C_d \quad [\text{A-3}]$$

where:

$\dot{H}$ = dose equivalent rate [rem/hr]

$\dot{D}$ = absorbed dose rate [rad/hr]

Q = quality factor [rem/rad]

$\dot{X}$ = exposure rate [R/hr]

f = exposure to absorbed dose conversion ratio [rad/R]

$$= 0.874 \frac{(\mu_a / p)^{tissue}}{(\mu_a / p)^{air}} \quad [\text{La-1b}] \quad [\text{A-3b}]$$

ϕ = gamma-ray flux density [$\gamma / \text{cm}^2 - \text{s}$]

C_d = flux-to-dose conversion factor [$(\text{cm}^2 - \text{sec} / \gamma) \times (\text{R} / \text{hr})$]

$$= (0.0659E-03) E_\gamma (\mu_a / p)^{air} \quad [\text{La-1c}] \quad [\text{A-3c}]$$

E_γ = gamma-ray energy [MeV]

$(\mu_a / p)^{air}$ = mass energy-absorption coefficient for air [cm^2 / g]

Table A-2. Quality Factors for Various Types of Radiation *

Type of Radiation	Q
x-rays and γ -rays	1
β -rays, $E_{\max} > 0.03 \text{ MeV}$	1†
β -rays, $E_{\max} < 0.03 \text{ MeV}$	1.7†
Naturally occurring α -particles	10
Heavy recoil nuclei	20
Neutrons;	
Thermal to 1 keV	2
10 keV	2.5
100 keV	7.5
500 keV	11
1 MeV	11
2.5 MeV	9
5 MeV	8
7 MeV	7
10 MeV	6.5
14 MeV	7.5
20 MeV	8
Energy not specified	10

* Taken from Lamarsh [La-1d], based on NCRP Report 39 [Nc-1].
† Recommended in ICRP publication 9 [Ic-1].

Figure A-1. Parameter f as function of gamma-ray energy. (Taken from Ref. La-1b, originally from Mo-1.)

The mass energy-absorption coefficients (μ_a/ρ) for air and tissue for various gamma-ray energies are shown in Table A-3. Performing Step 1 of Table A-1 with the use of Equation A-3 yields Equation A-4, which identifies the maximum allowable canister (cask) surface gamma flux density for a given maximum allowable surface dose (equivalent) rate.

$$\phi_s(\text{max}) = \frac{\dot{X}_s(\text{max})}{C_d} = \frac{\dot{D}_s(\text{max})}{C_d f} = \frac{\dot{H}_s(\text{max})}{C_d f Q} \quad [\text{A-4a}]$$

$$= \frac{\dot{H}_s(\text{max})}{(0.0659E-03)E_\gamma(\mu_a/\rho)^{\text{air}} f Q} = \frac{\dot{H}_s(\text{max})}{(5.7966E-05)E_\gamma(\mu_a/\rho)^{\text{tissue}} Q} \quad [\text{A-4b}]$$

Table A-3. Mass Energy-Absorption Coefficients for Air*		
Gamma-ray Energy [MeV]	Mass Energy-Absorption Coefficient (μ_a / ρ) ^x [cm ² / g]	
	Air	Tissue
0.1	0.0233	0.0271
0.15	0.0251	0.0282
0.2	0.0268	0.0293
0.3	0.0288	0.0312
0.4	0.0296	0.0317
0.5	0.0297	0.0320
0.6	0.0296	0.0319
0.8	0.0289	0.0311
1.0	0.0280	0.0300
1.25	0.0268	0.0288
1.50	0.0256	0.0276
2.0	0.0238	0.0256
3.0	0.0211	0.0220
4.0	0.0194	0.0206
5.0	0.0181	0.0192
6.0	0.0172	0.0182
8.0	0.0160	0.0168
10.0	0.0153	0.0160
* Data from Ref La-1f. NOTE: these are energy-absorption coefficients, which are to be used for dose calculations. They are not attenuation coefficients, which are used for shielding calculations.		

If there is more than one radionuclide emitting gammas to be included in the gamma source term, then the total dose (equivalent) rate is composed of several components (see Equation A-5). Likewise, the gamma flux density will be composed of several components (not necessarily of the same gamma energy distribution).

$$\dot{H}_{total} = \sum_i \dot{H}_i \quad [A-5]$$

Now the gamma flux density due to gamma-ray attenuation is needed. The equations for a point source are given by Equations A-6 and A-7.

$$\phi_o = \frac{S}{4\pi R^2} \quad [\gamma / \text{cm}^2 - \text{sec}] \quad [\text{A-6}]$$

$$\phi_u = \phi_o e^{-\mu t} = \frac{S e^{-\mu t}}{4\pi R^2} \quad [\text{A-7}]$$

where:

ϕ_o = gamma-ray flux of an unshielded uncollided isotropic point source

ϕ_u = gamma-ray flux of a shielded uncollided isotropic point source

S = source strength $[\gamma / \text{sec}]$

R = distance from the point source $[\text{cm}]$

t = shielding thickness $[\text{cm}]$

μ = linear attenuation coefficient for shield $[1/\text{cm}]$

$$= \text{mass attenuation coefficient} \times \text{mass density} = (\mu_s/\rho) \times \rho \quad [\text{A-7b}]$$

Equation A-6 corresponds to a bare isotropic point (gamma emitting) source and describes the direct-beam (uncollided) component of the unshielded source. Equation A-7 includes the attenuation (the $e^{-\mu t}$ term) of an intervening absorbing material (ϕ_u corresponds only to the uncollided component of the gamma flux). ϕ_u does not include, however, important effects due to: 1) the Compton effect (scattering with loss of energy: this is very important since non-direct beams can be scattered to detector locations), 2) the photoelectric effect (producing x-rays), and 3) pair production (the incident photon in the vicinity of a nucleus produces a electron-positron pair and the annihilation of the positron with an electron generates gamma-ray radiation). The importance of these effects can be identified from Figures A-2 and A-3, which show qualitative effects on gamma energy spectra due to shielding material.

Figure A-2. Energy spectrum of incident gamma-ray beam. (Taken from Ref. La-1g.)

Figure A-3. Energy spectrum of gamma-rays emerging from shield. (Taken from Ref. La-1g.)

The necessary correction factor for these effects is the gamma buildup factor ($B_p(\mu t)$ tabulated in many references and for many cases yielding acceptable estimates for calculated gamma fluxes) for the gamma-ray transport. The addition of this term yields Equation A-8.

$$\phi_b = B_p(\mu t)\phi_u = B_p(\mu t)\phi_o e^{-\mu t} = SB_p(\mu t) \frac{e^{-\mu t}}{4\pi R^2} \quad [A-8]$$

If more accurate gamma-ray transport calculations are needed, they should be performed with the Boltzmann transport equation which incorporates the complete treatment of the scattering component (this was not deemed necessary for this scoping study). The time-independent transport theory (Boltzmann Equation) for photons is given by [Sc-1b]:

$$\nabla \cdot \phi(r, \Omega, E) + \Sigma_t(r, E)\phi(r, \Omega, E) = \int \int_{E' \Omega'} \Sigma_s(r, E') p(E' \rightarrow E, \Omega' \rightarrow \Omega) \phi(r, \Omega', E') d\Omega' dE' + S(r, \Omega, E) \quad [A-9]$$

where:

r = gamma-ray position vector

E = gamma-ray energy

Ω = solid angle

ϕ = gamma-ray flux

p = probability that a particle of energy E' and direction Ω' scatters into

dE about E and $d\Omega$ about Ω

S = source term

Σ_i = macroscopic cross section ($i=t \rightarrow$ total, $i=s \rightarrow$ scattering)

=atom density x microscopic cross-section

Equation A-9 is a complex integral differential equation which has the extra dimensions of particle energy (E) and angular distribution (Ω), thus a one dimensional steady-state problem is actually a three dimensional problem. There are a significant number of available discrete ordinates and Monte Carlo codes for solving the Boltzmann equation, but this extra level of effort is not necessary for the problem at hand.

Proceeding with the simple shielding expressions, Equation A-8 represents the total (direct and scattered) component with an intervening absorbing and scattering shield for a point source. The buildup factor is a function of the shielding thickness and the gamma-ray linear attenuation coefficient, which is dependent on gamma energy. Note; the buildup factors are problem specific; there is separate buildup factor for each source type – mono-directional beam, isotropic, etc. There are various buildup factors for different specific geometries, such as a point source, line source, etc., see Refs. Sc-1 & Ja-1. Since real geometries correspond to distributed sources, it is necessary to integrate the collective fluxes from multi-point sources that are used to represent a distributed gamma

source. Thus Equation A-8 (which is for a point source) is integrated over all point source strengths convoluted with the attenuation kernel to yield Equation A-10:

$$\phi(r) = \int_{\text{all space}} S_v(r') K(|r' - r|) dr' \quad [\text{A-10}]$$

r = vector to the measuring point

r' = vector to any source-bearing point in space

$S_v(r')$ = source strength per unit volume at r'

This equation for the "extended source term" (integrated volumetric source term) has the exponential point attenuation kernel given by:

$$K(R) = B(\mu t) \frac{e^{-\mu R}}{4\pi R^2} \quad [\text{A-11}]$$

The solution to Equation A-10, for simple cases of uniformly distributed source geometries, is an exponential integral function [Gl-1], whose general form is given by Equation A-12.

$$E_n(x) = x^{n-1} \int_x^\infty \frac{e^{-p}}{p^n} dp \quad [\text{A-12}]$$

Further description of the exponential point attenuation kernel can be found in Ref. Gl-1b.

For the problem at hand, the uncollided gamma flux at the interface of the stainless-steel liners with the shielding material and at the canister outer diameter is given by Equation A-13 [Ja-1].

$$\phi_{u1} = \phi_{uo} E_2(\mu_{ss} t_1) \quad [\text{A-13a}]$$

$$\phi_{u2} = \phi_{u1} E_2(\mu_{\text{material}} t_2) \quad [\text{A-13b}]$$

$$\phi_{u3} = \phi_{u2} E_2(\mu_{ss} t_3) \quad [\text{A-13c}]$$

where: ϕ_{ui} = uncollided gamma flux density at outer diameter of region i [$\gamma/\text{cm}^2\text{-s}$]

μ_i = linear attenuation coefficient of region i [$1/\text{cm}$]

t_i = thickness of region i [cm]

The above uncollided fluxes are evaluated at the canister center plane (mid-height) and have a gamma mean free path (mfp) lengths (also called the relaxation length) in the radial direction given by (μt). The shield material thicknesses are obtained from the canister design and typical mass attenuation coefficients can be seen in Table A-4.

Table A-4. Mass Attenuation Coefficients*							
Gamma Energy [MeV]	Mass Attenuation Coefficients, (μ_s/p) ^x [cm ² /g]						
	<i>Air</i>	<i>Concrete</i>	<i>Iron</i>	<i>Calcium</i>	<i>Silicon</i>	<i>Aluminum</i>	<i>Oxygen</i>
0.1	0.151	0.169	0.344	0.238	0.172	0.161	0.151
0.3	0.106	0.107	0.106	0.109	0.107	0.103	0.107
0.5	0.0868	0.0870	0.0828	0.0876	0.0869	0.0840	0.0870
0.6	0.0804	0.0804	0.0762	0.0809	0.0802	0.0777	0.0806
0.8	0.0706	0.0706	0.0664	0.0708	0.0706	0.0683	0.0708
1.0	0.0635	0.0635	0.0595	0.0634	0.0635	0.0614	0.0636
1.5	0.0517	0.0517	0.0485	0.0518	0.0517	0.0500	0.0518
2.0	0.0445	0.0445	0.0424	0.0451	0.0447	0.0423	0.0445
* Data from Ref. Ra-1 (see Equation A-7b for usage).							

Modifying Equation A-13 to include the gamma flux buildup results in:

$$\phi_{b1} = B(\mu_{ss}t_1)\phi_{uo}E_2(\mu_{ss}t_1) \quad [A-14a]$$

$$\phi_{b2} = B(\mu_{material}t_2)\phi_{b1}E_2(\mu_{material}t_2) \quad [A-14b]$$

$$\phi_{b3} = B(\mu_{ss}t_3)\phi_{b2}E_2(\mu_{ss}t_3) \quad [A-14c]$$

where:

B = buildup factor for the shield material

Buildup factors can be seen in Table A-5 and the solution for E_2 is shown in Figure A-4.

Table A-5. Dose Buildup Factors for a Point Isotropic Source (a)

Material	Gamma Energy [MeV]	Relaxation Lengths, μx (b)				
		1	2	4	7	10
Water	0.5	2.52	5.14	14.3	38.8	77.6
	1.0	2.13	3.71	7.68	16.2	27.1
	2.0	1.83	2.77	4.88	8.46	12.4
Aluminum	0.5	2.37	4.24	9.47	21.5	38.9
	1.0	2.02	3.31	6.57	13.1	21.2
	2.0	1.75	2.61	4.62	8.05	11.9
Iron	0.5	1.98	3.09	5.98	11.7	19.2
	1.0	1.87	2.89	5.39	10.2	16.2
	2.0	1.76	2.43	4.13	7.25	10.9
Tin	0.5	1.56	2.08	3.09	4.57	6.04
	1.0	1.64	2.30	3.74	6.17	8.85
	2.0	1.57	2.17	3.53	5.87	8.53
Tungsten	0.5	1.28	1.50	1.84	2.24	2.61
	1.0	1.44	1.83	2.57	3.62	4.64
	2.0	1.42	1.85	2.72	4.09	5.27
Lead	0.5	1.24	1.42	1.69	2.00	2.27
	1.0	1.37	1.69	2.26	3.02	3.74
	2.0	1.39	1.76	2.51	3.66	4.84
Uranium	0.5	1.17	1.30	1.48	1.67	1.85
	1.0	1.31	1.56	1.98	2.50	2.97
	2.0	1.33	1.64	2.23	3.09	3.95
Data from Ref. Ra-1b μx = mass attenuation coefficient [cm^2/g] $\times$ shield thickness [cm] $\times$ shield density [g/cm^3].

Figure A-4. Solution for E_2 . (Taken from Ja-1b.)

028qn1

A rough approximation for $E_2(b)$ can be given by Equation A-15 (the fit for b values greater than 14 was based on data in Ref. Ab-1 and the fit for b values less than 14, obtained by using singular value decomposition (SVD, Ref Sa-2), was based on data in Ref. Ja-1b):

$$E_2(b) = \begin{cases} e^{-b}/(b+2) & \text{if } b > 14 \quad (\text{good for 1\% accuracy}) \\ e^{-(c_1+c_2b+c_3b^2+c_4b^3)} & \text{if } 14 \geq b \geq 1 \quad (\text{good for 7\% accuracy}) \\ e^{-(c_5+c_6b+c_7b^2+c_8b^3)} & \text{if } 1 \geq b \geq 0 \quad (\text{good for 3\% accuracy}) \end{cases} \quad [\text{A-15}]$$

where:

$$\begin{aligned} c_1 &= 5.5565607E-01 & c_5 &= 1.7837543E-02 \\ c_2 &= 1.4190903E+00 & c_6 &= 3.0105850E+00 \\ c_3 &= -3.3941944E-02 & c_7 &= -2.0438538E+00 \\ c_4 &= 1.1209473E-03 & c_8 &= 9.3175783E-01 \end{aligned}$$

Equation A-15 was programmed directly into the computer code SHIELD (see Appendix C) and polynomial fits (obtained with the code COUNTACH, Ref. Sa-2) for attenuation coefficients and buildup factors (also programmed into SHIELD) are presented into Appendix B.

For dose rates (or exposure rates) external to the canister, the reduction in the dose rate relative to the canister surface value is simply the ratio of the canister radius to the distance of the external location from the center line of the canister. Values for this ratio are shown in Figure A-5.

Figure A-5. Solution for external dose ratio due to geometrical spread. (Prototype cask radius is 1.14 meters. Added distance is distance away from the cask surface.)

References

[Ab-1]

Abramowitz, M and I.A. Stegun (Editors); **Handbook of Mathematical Functions With Formulas, Graphs, and Mathematical Tables**; National Bureau of Standards, Applied Mathematics Series, 55, 2nd printing November 1964, pg. 248.

[CRC-1]

Weast, R.C. (Editor); **CRC Handbook of Chemistry and Physics**; 66th Edition, CRC Press, Inc., Boca Raton, Florida, 1985, pg. A-52 (exponential form #519).

[CRC-1b]

Ibid.; pg. A-52 (exponential form #520).

[CRC-1c]

Ibid.; pg. A-104.

[CRC-1d]

Ibid.; pg. D-184 (data for plain carbon steel, AISI-SAE 1020).

[Ic-1]

Radiation Quantities and Units, International Commission on Radiation Units and Measurements Report 19, 1971. (Although Table 2 indicates report 9 as the citation, only Report 19 was identified in the reference list of Ref. La-1e.)

[G1-1]

Glasstone, S and A. Sesonske; **Nuclear Reactor Engineering**; Van Nostrand Reinhold Company; New York; 1967; pp. 580.

[G1-1b]

Ibid.; pp. 568-585.

[Ja-1]

Jaeger, R.G. (Editor), et. al.; **Engineering Compendium on Radiation Shielding, Volume I – Shielding Fundamentals and Methods**; Springer-Verlag; Berlin; 1968; pg. 383.

[Ja-1b]

Ibid.; pg. 412.

[La-1]

Lamarsh, J.R.; **Introduction To Nuclear Engineering**, 2nd Edition; Addison-Wesley; Reading, Massachusetts; 1983; pg. 405, (Equation 9.10).

[La-1b]

Ibid.; pg. 441, (Equations 9.28 and 9.29, Figure 9.10).

[La-1c]

Ibid.; pg. 473, (Equations 10.1, 10.2, and 10.3).

[La-1d]

Ibid.; pg. 404, (Table 9.2).

[La-1e]

Ibid.; pg. 467, (Reference list).

[La-1f]

Ibid.; Appendix II, Table II.5, pg. 649, [Originally from L.T. Templin, Editor, **Reactor Physics Constants**, ANL-5800, 2nd ed., 1963; based on G.W. Grodstein, National Bureau of Standards circular 583, 1957.]

[La-1g]

Ibid.; pg. 474, (Figures 10.2 and 10.3).

[Mo-1]

Morgan, K.Z. and J.E. Turner, **Principles of Radiation Protection**, Wiley, New York, 1967.

[Nc-1]

Basic Radiation Protection Criteria, National Council on Radiation Protection and Measurements Report 39, 1971.

[Ra-1]

Shleien, B. and M.S. Terpilak; **The Health Physics and Radiological Health Handbook**; Nucleon LECTERN Associates, 1984, pp. 125.

[Ra-1b]

Ibid.; pg. 136.

[Ro-1]

Foderaro, A.H. and F. Obenshain; "Effect of Geometry of Radiation Source", Chapter 9 in **Reactor Shielding Design Manual**, ed. by T. Rockwell III, TID 7004 (March 1956); pp. 366/7.

[Sa-2]

Sanchez, L.C. and M.L. Hudson; "Determination of Effective Thermal Conductivities for a Full-Scale Mock-Up of a 217-Element Breeder Reactor Fuel Assembly Subjected to Normal Conditions"; SAND85-2827, TTC 0635, Sandia National Laboratories, Albuquerque, New Mexico, December 1986, Appendix C, pp. 80 → 99.

[Sc-1]

Schaeffer, N.M. (Editor); **Reactor Shielding for Nuclear Engineers**; U.S. Atomic Energy Commission (UC-80), 1973, TID-25951, ISBN 0-87079-004-8, LCCCN 73-600001.

[Sc-1b]

Ibid.; pp.127 (Equation 4.2-8).

7.2 Appendix B – Shielding Parameters

This appendix contains the results of data fits for shielding parameters (i.e., buildup factors, attenuation coefficients, etc.) identified in Appendix A and used in the code SHIELD (see Appendix C).

Table B-1. Listing of Data Fit for Depleted Uranium Buildup Factor

This file contains the data for Buildup factors
for DU (monodirectional source) as a function of mu*thick

THE POLYNOMIAL COEFFICIENTS FOR THE EQUATION

$$F = C1 * \exp(C2 * X + C3 * Y)$$

OR IN REDUCED FORM

$$F = K1 * \exp(K2 * XR + K3 * YR)$$

(WHERE XR = X / (+4.0000000E+00))
(WHERE YR = Y / (+1.5000000E+01))

ARE GIVEN BY :

C(1)= 9.7792223E-01 K(1)= 9.7792223E-01
C(2)= 1.1832534E-01 K(2)= 4.7330137E-01
C(3)= 8.9406006E-02 K(3)= 1.3410901E+00

THE CALCULATED SOLUTIONS ARE

X	Y	ORIGINAL DATA	CALCULATED DATA	RELATIVE ERROR	% ERROR
0.5000000E+00	0.1000000E+01	0.1170000E+01	0.1134558E+01	-0.3544155E-01	3.0292
0.5000000E+00	0.2000000E+01	0.1280000E+01	0.1240668E+01	-0.3933248E-01	3.0729
0.5000000E+00	0.4000000E+01	0.1450000E+01	0.1483585E+01	0.3358516E-01	2.3162
0.5000000E+00	0.7000000E+01	0.1600000E+01	0.1939984E+01	0.3399837E+00	21.2490
0.5000000E+00	0.1000000E+02	0.1730000E+01	0.2536785E+01	0.8067852E+00	46.6350
0.5000000E+00	0.1500000E+02	0.3100000E+01	0.3966673E+01	0.8666727E+00	27.9572
0.1000000E+01	0.1000000E+01	0.1300000E+01	0.1203707E+01	-0.9629269E-01	7.4071
0.1000000E+01	0.2000000E+01	0.1530000E+01	0.1316283E+01	-0.2137165E+00	13.9684
0.1000000E+01	0.4000000E+01	0.1900000E+01	0.1574006E+01	-0.3259936E+00	17.1576
0.1000000E+01	0.7000000E+01	0.2320000E+01	0.2058221E+01	-0.2617785E+00	11.2836
0.1000000E+01	0.1000000E+02	0.2700000E+01	0.2691397E+01	-0.8603305E-02	0.3186
0.1000000E+01	0.1500000E+02	0.3600000E+01	0.4208433E+01	0.6084327E+00	16.9009
0.2000000E+01	0.1000000E+01	0.1330000E+01	0.1354905E+01	0.2490530E-01	1.8726
0.2000000E+01	0.2000000E+01	0.1620000E+01	0.1481622E+01	-0.1383778E+00	8.5418
0.2000000E+01	0.4000000E+01	0.2150000E+01	0.1771718E+01	-0.3782822E+00	17.5945
0.2000000E+01	0.7000000E+01	0.2870000E+01	0.2316755E+01	-0.5532448E+00	19.2768
0.2000000E+01	0.1000000E+02	0.3560000E+01	0.3029464E+01	-0.5305363E+00	14.9027
0.2000000E+01	0.1500000E+02	0.4890000E+01	0.4737055E+01	-0.1529449E+00	3.1277
0.3000000E+01	0.1000000E+01	0.1290000E+01	0.1525095E+01	0.2350953E+00	18.2244
0.3000000E+01	0.2000000E+01	0.1570000E+01	0.1667729E+01	0.9772915E-01	6.2248
0.3000000E+01	0.4000000E+01	0.2130000E+01	0.1994264E+01	-0.1357363E+00	6.3726
0.3000000E+01	0.7000000E+01	0.3020000E+01	0.2607763E+01	-0.4122365E+00	13.6502

0.3000000E+01	0.1000000E+02	0.3990000E+01	0.3409995E+01	-0.5800045E+00	14.5365
0.3000000E+01	0.1500000E+02	0.5940000E+01	0.5332078E+01	-0.6079222E+00	10.2344
0.4000000E+01	0.1000000E+01	0.1250000E+01	0.1716663E+01	0.4666629E+00	37.3330
0.4000000E+01	0.2000000E+01	0.1490000E+01	0.1877213E+01	0.3872130E+00	25.9875
0.4000000E+01	0.4000000E+01	0.2020000E+01	0.2244764E+01	0.2247637E+00	11.1269
0.4000000E+01	0.7000000E+01	0.2940000E+01	0.2935325E+01	-0.4674697E-02	0.1590
0.4000000E+01	0.1000000E+02	0.4060000E+01	0.3838326E+01	-0.2216741E+00	5.4600
0.4000000E+01	0.1500000E+02	0.6470000E+01	0.6001841E+01	-0.4681585E+00	7.2358

SIGMA = 3.9571E-01

THE MAXIMUM ERROR OCCURS AT :

0.5000000E+00	0.1000000E+02	0.1730000E+01	0.2536785E+01	0.8067852E+00	46.6350 %
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Table B-2. Listing of Data Fit for Iron Buildup Factor

This file contains the data for Buildup factors
for Iron (monodirectional source) as a function of $\mu \cdot \text{thick}$

THE POLYNOMIAL COEFFICIENTS FOR THE EQUATION

$$F = C1 * X^{**}C2 * Y^{**}C3$$

OR IN REDUCED FORM

$$F = K1 * XR^{**}K2 * YR^{**}K3$$

(WHERE $XR = X / (+6.0000000E+00)$)

(WHERE $YR = Y / (+1.5000000E+01)$)

ARE GIVEN BY :

C(1)= 1.7572102E+00 K(1)= 8.2472841E+00
C(2)= -2.8696747E-01 K(2)= -2.8696747E-01
C(3)= 7.6081795E-01 K(3)= 7.6081795E-01

THE CALCULATED SOLUTIONS ARE

X	Y	ORIGINAL DATA	CALCULATED DATA	RELATIVE ERROR	% ERROR
0.5000000E+00	0.1000000E+01	0.2070000E+01	0.2143925E+01	0.7392473E-01	3.5712
0.5000000E+00	0.2000000E+01	0.2940000E+01	0.3632775E+01	0.6927755E+00	23.5638
0.5000000E+00	0.4000000E+01	0.4870000E+01	0.6155560E+01	0.1285560E+01	26.3975
0.5000000E+00	0.7000000E+01	0.8310000E+01	0.9422698E+01	0.1112698E+01	13.3899
0.5000000E+00	0.1000000E+02	0.1240000E+02	0.1236026E+02	-0.3974353E-01	0.3205
0.5000000E+00	0.1500000E+02	0.2060000E+02	0.1682677E+02	-0.3773226E+01	18.3166
0.1000000E+01	0.1000000E+01	0.1920000E+01	0.1757210E+01	-0.1627898E+00	8.4786
0.1000000E+01	0.2000000E+01	0.2740000E+01	0.2977507E+01	0.2375066E+00	8.6681
0.1000000E+01	0.4000000E+01	0.4570000E+01	0.5045239E+01	0.4752392E+00	10.3991
0.1000000E+01	0.7000000E+01	0.7810000E+01	0.7723061E+01	-0.8693885E-01	1.1132
0.1000000E+01	0.1000000E+02	0.1160000E+02	0.1013075E+02	-0.1469248E+01	12.6659
0.1000000E+01	0.1500000E+02	0.1890000E+02	0.1379161E+02	-0.5108387E+01	27.0285
0.2000000E+01	0.1000000E+01	0.1690000E+01	0.1440250E+01	-0.2497500E+00	14.7781
0.2000000E+01	0.2000000E+01	0.2350000E+01	0.2440433E+01	0.9043319E-01	3.8482
0.2000000E+01	0.4000000E+01	0.3760000E+01	0.4135195E+01	0.3751945E+00	9.9786
0.2000000E+01	0.7000000E+01	0.6110000E+01	0.6329999E+01	0.2199992E+00	3.6006
0.2000000E+01	0.1000000E+02	0.8780000E+01	0.8303398E+01	-0.4766021E+00	5.4283
0.2000000E+01	0.1500000E+02	0.1370000E+02	0.1130392E+02	-0.2396076E+01	17.4896
0.3000000E+01	0.1000000E+01	0.1580000E+01	0.1282051E+01	-0.2979486E+00	18.8575
0.3000000E+01	0.2000000E+01	0.2130000E+01	0.2172373E+01	0.4237331E-01	1.9894
0.3000000E+01	0.4000000E+01	0.3320000E+01	0.3680980E+01	0.3609802E+00	10.8729
0.3000000E+01	0.7000000E+01	0.5260000E+01	0.5634705E+01	0.3747051E+00	7.1237
0.3000000E+01	0.1000000E+02	0.7410000E+01	0.7391343E+01	-0.1865653E-01	0.2518
0.3000000E+01	0.1500000E+02	0.1140000E+02	0.1006229E+02	-0.1337711E+01	11.7343
0.4000000E+01	0.1000000E+01	0.1480000E+01	0.1180462E+01	-0.2995378E+00	20.2390
0.4000000E+01	0.2000000E+01	0.1900000E+01	0.2000235E+01	0.1002354E+00	5.2755
0.4000000E+01	0.4000000E+01	0.2950000E+01	0.3389301E+01	0.4393009E+00	14.8916
0.4000000E+01	0.7000000E+01	0.4610000E+01	0.5188213E+01	0.5782135E+00	12.5426
0.4000000E+01	0.1000000E+02	0.6460000E+01	0.6805657E+01	0.3456566E+00	5.3507
0.4000000E+01	0.1500000E+02	0.9920000E+01	0.9264957E+01	-0.6550427E+00	6.6033
0.6000000E+01	0.1000000E+01	0.1350000E+01	0.1050799E+01	-0.2992011E+00	22.1630
0.6000000E+01	0.2000000E+01	0.1710000E+01	0.1780527E+01	0.7052732E-01	4.1244

0.6000000E+01	0.4000000E+01	0.2480000E+01	0.3017016E+01	0.5370164E+00	21.6539
0.6000000E+01	0.7000000E+01	0.3810000E+01	0.4618334E+01	0.8083344E+00	21.2161
0.6000000E+01	0.1000000E+02	0.5350000E+01	0.6058116E+01	0.7081157E+00	13.2358
0.6000000E+01	0.1500000E+02	0.8390000E+01	0.8247284E+01	-0.1427159E+00	1.7010

SIGMA = 1.2795E+00

THE MAXIMUM ERROR OCCURS AT :

0.1000000E+01	0.1500000E+02	0.1890000E+02	0.1379161E+02	-0.5108387E+01	27.0285 %
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Table B-3. Listing of Data Fit for Lead Buildup Factor

This file contains the data for Buildup factors
for lead (monodirectional source) as a function of mu*thick

THE POLYNOMIAL COEFFICIENTS FOR THE EQUATION

$$F = C1 * X^{**}C2 * Y^{**}C3$$

OR IN REDUCED FORM
 $F = K1 * XR^{**}K2 * YR^{**}K3$
 (WHERE XR = X/(+4.0000000E+00))
 (WHERE YR = Y/(+1.5000000E+01))

ARE GIVEN BY :

C(1)= 1.0643266E+00 K(1)= 5.6525889E+00
 C(2)= 2.2681979E-01 K(2)= 2.2681979E-01
 C(3)= 5.0048274E-01 K(3)= 5.0048274E-01

THE CALCULATED SOLUTIONS ARE

X	Y	ORIGINAL DATA	CALCULATED DATA	RELATIVE ERROR	% ERROR
0.5000000E+00	0.1000000E+01	0.1240000E+01	0.9094846E+00	-0.3305154E+00	26.6545
0.5000000E+00	0.2000000E+01	0.1390000E+01	0.1286636E+01	-0.1033641E+00	7.4363
0.5000000E+00	0.4000000E+01	0.1630000E+01	0.1820187E+01	0.1901869E+00	11.6679
0.5000000E+00	0.7000000E+01	0.1870000E+01	0.2408531E+01	0.5385315E+00	28.7985
0.5000000E+00	0.1000000E+02	0.2080000E+01	0.2879241E+01	0.7992414E+00	38.4251
0.5000000E+00	0.1500000E+02	0.3100000E+01	0.3527026E+01	0.4270264E+00	13.7750
0.1000000E+01	0.1000000E+01	0.1380000E+01	0.1064327E+01	-0.3156734E+00	22.8749
0.1000000E+01	0.2000000E+01	0.1680000E+01	0.1505689E+01	-0.1743112E+00	10.3757
0.1000000E+01	0.4000000E+01	0.2180000E+01	0.2130078E+01	-0.4992185E-01	2.2900
0.1000000E+01	0.7000000E+01	0.2800000E+01	0.2818590E+01	0.1858985E-01	0.6639
0.1000000E+01	0.1000000E+02	0.3400000E+01	0.3369439E+01	-0.3056067E-01	0.8988
0.1000000E+01	0.1500000E+02	0.4200000E+01	0.4127511E+01	-0.7248864E-01	1.7259
0.2000000E+01	0.1000000E+01	0.1400000E+01	0.1245531E+01	-0.1544692E+00	11.0335
0.2000000E+01	0.2000000E+01	0.1760000E+01	0.1762036E+01	0.2036014E-02	0.1157
0.2000000E+01	0.4000000E+01	0.2410000E+01	0.2492729E+01	0.8272918E-01	3.4327
0.2000000E+01	0.7000000E+01	0.3360000E+01	0.3298462E+01	-0.6153831E-01	1.8315
0.2000000E+01	0.1000000E+02	0.4350000E+01	0.3943095E+01	-0.4069054E+00	9.3541
0.2000000E+01	0.1500000E+02	0.5940000E+01	0.4830230E+01	-0.1109770E+01	18.6830
0.3000000E+01	0.1000000E+01	0.1360000E+01	0.1365512E+01	0.5511766E-02	0.4053
0.3000000E+01	0.2000000E+01	0.1710000E+01	0.1931772E+01	0.2217715E+00	12.9691
0.3000000E+01	0.4000000E+01	0.2420000E+01	0.2732852E+01	0.3128518E+00	12.9278
0.3000000E+01	0.7000000E+01	0.3550000E+01	0.3616200E+01	0.6619988E-01	1.8648
0.3000000E+01	0.1000000E+02	0.4820000E+01	0.4322930E+01	-0.4970702E+00	10.3127
0.3000000E+01	0.1500000E+02	0.7180000E+01	0.5295523E+01	-0.1884477E+01	26.2462
0.4000000E+01	0.1000000E+01	0.1280000E+01	0.1457585E+01	0.1775855E+00	13.8739
0.4000000E+01	0.2000000E+01	0.1560000E+01	0.2062027E+01	0.5020270E+00	32.1812
0.4000000E+01	0.4000000E+01	0.2180000E+01	0.2917122E+01	0.7371224E+00	33.8130
0.4000000E+01	0.7000000E+01	0.3290000E+01	0.3860033E+01	0.5700329E+00	17.3262
0.4000000E+01	0.1000000E+02	0.4690000E+01	0.4614416E+01	-0.7558381E-01	1.6116
0.4000000E+01	0.1500000E+02	0.7700000E+01	0.5652589E+01	-0.2047411E+01	26.5898

SIGMA = 6.4694E-01

THE MAXIMUM ERROR OCCURS AT :

0.5000000E+00 0.1000000E+02 0.2080000E+01 0.2879241E+01 0.7992414E+00 38.4251 %

Table B-4. Listing of Data Fit for Exposure-to-Absorbed Dose Conversion Factor

Exposure to absorbed dose conversion ratio
f [rad/R]

THE POLYNOMIAL COEFFICIENTS FOR THE EQUATION

$$F = C1 + C2*X + C3*X**2 + C4*X**3 + \dots$$

$$\begin{array}{c} \text{OR IN REDUCED FORM} \\ F = K1 + K2*XR + K3*XR**2 + K4*XR**3 + \dots \\ \text{(WHERE } XR = X/(+4.0000000E+00) \text{)} \end{array}$$

ARE GIVEN BY :

C(1)= 9.7466174E-01	K(1)= 9.7466174E-01
C(2)= -4.1084113E-02	K(2)= -1.6433645E-01
C(3)= 7.4287014E-03	K(3)= 1.1885922E-01

THE CALCULATED SOLUTIONS ARE

X	ORIGINAL DATA	CALCULATED DATA	RELATIVE ERROR	% ERROR
0.1000000E+00	0.1017000E+01	0.9706276E+00	-0.4637238E-01	4.5597
0.1500000E+00	0.9820000E+00	0.9686663E+00	-0.1333373E-01	1.3578
0.2000000E+00	0.9560000E+00	0.9667421E+00	0.1074207E-01	1.1236
0.3000000E+00	0.9470000E+00	0.9630051E+00	0.1600509E-01	1.6901
0.4000000E+00	0.9360000E+00	0.9594167E+00	0.2341669E-01	2.5018
0.5000000E+00	0.9420000E+00	0.9559769E+00	0.1397686E-01	1.4837
0.6000000E+00	0.9420000E+00	0.9526856E+00	0.1068561E-01	1.1344
0.8000000E+00	0.9410000E+00	0.9465488E+00	0.5548820E-02	0.5897
0.1000000E+01	0.9360000E+00	0.9410063E+00	0.5006330E-02	0.5349
0.1250000E+01	0.9390000E+00	0.9349139E+00	-0.4086053E-02	0.4351
0.1500000E+01	0.9420000E+00	0.9297502E+00	-0.1224985E-01	1.3004
0.2000000E+01	0.9400000E+00	0.9222083E+00	-0.1779168E-01	1.8927
0.3000000E+01	0.9110000E+00	0.9182677E+00	0.7267716E-02	0.7978
0.4000000E+01	0.9280000E+00	0.9291845E+00	0.1184513E-02	0.1276

SIGMA = 1.7869E-02

THE MAXIMUM ERROR OCCURS AT :

0.1000000E+00	0.1017000E+01	0.9706276E+00	-0.4637238E-01	4.5597 %
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Table B-5. Listing of Data Fit for Air Mass Attenuation Coefficient

Mass Energy-Absorption Coefficient
(μ/ρ)_{air} [cm²/g]

THE POLYNOMIAL COEFFICIENTS FOR THE EQUATION

$$F = C1 + C2*X + C3*X**2 + C4*X**3 + \dots$$

$$\begin{array}{c} \text{OR IN REDUCED FORM} \\ F = K1 + K2*XR + K3*XR**2 + K4*XR**3 + \dots \\ \text{(WHERE } XR = X/(+4.000000E+00) \text{)} \end{array}$$

ARE GIVEN BY :

C(1)= 2.7353947E-02 K(1)= 2.7353947E-02
C(2)= 5.5507960E-04 K(2)= 2.2203184E-03
C(3)= -7.1288708E-04 K(3)= -1.1406193E-02

THE CALCULATED SOLUTIONS ARE

X	ORIGINAL DATA	CALCULATED DATA	RELATIVE ERROR	% ERROR
0.1000000E+00	0.2330000E-01	0.2740233E-01	0.4102326E-02	17.6065
0.1500000E+00	0.2510000E-01	0.2742117E-01	0.2321169E-02	9.2477
0.2000000E+00	0.2680000E-01	0.2743645E-01	0.6364470E-03	2.3748
0.3000000E+00	0.2880000E-01	0.2745631E-01	-0.1343689E-02	4.6656
0.4000000E+00	0.2960000E-01	0.2746192E-01	-0.2138084E-02	7.2233
0.5000000E+00	0.2970000E-01	0.2745326E-01	-0.2246735E-02	7.5648
0.6000000E+00	0.2960000E-01	0.2743035E-01	-0.2169645E-02	7.3299
0.8000000E+00	0.2890000E-01	0.2734176E-01	-0.1558237E-02	5.3918
0.1000000E+01	0.2800000E-01	0.2719614E-01	-0.8038609E-03	2.8709
0.1250000E+01	0.2680000E-01	0.2693391E-01	0.1339100E-03	0.4997
0.1500000E+01	0.2560000E-01	0.2658257E-01	0.9825700E-03	3.8382
0.2000000E+01	0.2380000E-01	0.2561256E-01	0.1812557E-02	7.6158
0.3000000E+01	0.2110000E-01	0.2260320E-01	0.1503202E-02	7.1242
0.4000000E+01	0.1940000E-01	0.1816807E-01	-0.1231928E-02	6.3501

SIGMA = 1.9587E-03

THE MAXIMUM ERROR OCCURS AT :

0.1000000E+00 0.2330000E-01 0.2740233E-01 0.4102326E-02 17.6065 %

Table B-6. Listing of Data Fit for Iron Mass Attenuation Coefficient

Mass Energy-Absorption Coefficient
(μ/ρ)_{iron} [cm²/g]

THE POLYNOMIAL COEFFICIENTS FOR THE EQUATION

$$F = C1/X + C2 + C3*X + C4*X**2 + \dots$$

$$\begin{array}{c} \text{OR IN REDUCED FORM} \\ F = K1/XR + K2 + K3*XR + K4*XR**2 + \dots \\ \text{(WHERE } XR = X/(+2.0000000E+00) \text{)} \end{array}$$

ARE GIVEN BY :

C(1)=	3.2906432E-02	K(1)=	1.6453216E-02
C(2)=	1.0391703E-02	K(2)=	1.0391703E-02
C(3)=	1.0415693E-02	K(3)=	2.0831386E-02

THE CALCULATED SOLUTIONS ARE

X	ORIGINAL DATA	CALCULATED DATA	RELATIVE ERROR	% ERROR
0.1000000E+00	0.3440000E+00	0.3404976E+00	-0.3502403E-02	1.0181
0.3000000E+00	0.1060000E+00	0.1232045E+00	0.1720452E-01	16.2307
0.5000000E+00	0.8280000E-01	0.8141241E-01	-0.1387585E-02	1.6758
0.6000000E+00	0.7620000E-01	0.7148517E-01	-0.4714827E-02	6.1874
0.8000000E+00	0.6640000E-01	0.5985730E-01	-0.6542702E-02	9.8535
0.1000000E+01	0.5950000E-01	0.5371383E-01	-0.5786171E-02	9.7247
0.1500000E+01	0.4850000E-01	0.4795286E-01	-0.5471359E-03	1.1281
0.2000000E+01	0.4240000E-01	0.4767631E-01	0.5276305E-02	12.4441

SIGMA = 7.8998E-03

THE MAXIMUM ERROR OCCURS AT :

0.3000000E+00	0.1060000E+00	0.1232045E+00	0.1720452E-01	16.2307 %
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Table B-7. Listing of Data Fit for Lead Mass Attenuation Coefficient

Mass Energy-Absorption Coefficient
(μ/ρ)_{lead} [cm²/g]

THE POLYNOMIAL COEFFICIENTS FOR THE EQUATION

$$F = C1 * X^{**}C2 * \exp(-C3/X)$$

$$\begin{aligned} &\text{OR IN REDUCED FORM} \\ F &= K1 * XR^{**}K2 * \exp(-K3/XR) \\ &(\text{WHERE } XR = X/(+2.0000000E+00)) \end{aligned}$$

ARE GIVEN BY :

C(1)= 5.6077678E-02	K(1)= 3.5233374E-02
C(2)= -6.7048400E-01	K(2)= -6.7048400E-01
C(3)= -3.0495029E-01	K(3)= -1.5247515E-01

THE CALCULATED SOLUTIONS ARE

X	ORIGINAL DATA	CALCULATED DATA	RELATIVE ERROR	% ERROR
0.1000000E+00	0.5400000E+01	0.5541870E+01	0.1418698E+00	2.6272
0.3000000E+00	0.4040000E+00	0.3474022E+00	-0.5659776E-01	14.0093
0.5000000E+00	0.1610000E+00	0.1642488E+00	0.3248827E-02	2.0179
0.6000000E+00	0.1250000E+00	0.1313005E+00	0.6300519E-02	5.0404
0.8000000E+00	0.8850000E-01	0.9534862E-01	0.6848623E-02	7.7386
0.1000000E+01	0.7080000E-01	0.7607260E-01	0.5272599E-02	7.4472
0.1500000E+01	0.5170000E-01	0.5236195E-01	0.6619493E-03	1.2804
0.2000000E+01	0.4550000E-01	0.4103679E-01	-0.4463214E-02	9.8093

SIGMA = 5.7911E-02

THE MAXIMUM ERROR OCCURS AT :

0.3000000E+00	0.4040000E+00	0.3474022E+00	-0.5659776E-01	14.0093 %
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Table B-8. Listing of Data Fit for Average Gamma-Ray Energy as a Function of Time (see Figure 5-2)

Average Photon Energy as a function of Time (PWR)
time[yr] Energy[eV]

THE POLYNOMIAL COEFFICIENTS FOR THE EQUATION

$$F = C1/X + C2 + C3*X + C4*X**2 + \dots$$

$$\begin{array}{|l} \text{OR IN REDUCED FORM} \\ F = K1/XR + K2 + K3*XR + K4*XR**2 + \dots \\ \text{(WHERE } XR = X/(+1.0000000E+02) \text{)} \end{array}$$

ARE GIVEN BY :

$$\begin{array}{ll} C(1)= 4.5839019E-01 & K(1)= 4.5839019E-03 \\ C(2)= 2.1220484E-01 & K(2)= 2.1220484E-01 \end{array}$$

THE CALCULATED SOLUTIONS ARE

X	ORIGINAL DATA	CALCULATED DATA	RELATIVE ERROR	% ERROR
0.5000000E+01	0.3053000E+00	0.3038829E+00	-0.1417120E-02	0.4642
0.1000000E+02	0.2544000E+00	0.2580439E+00	0.3643861E-02	1.4323
0.3000000E+02	0.2300000E+00	0.2274845E+00	-0.2515485E-02	1.0937
0.1000000E+03	0.2165000E+00	0.2167887E+00	0.2887441E-03	0.1334

$$\text{-----}$$

$$\text{SIGMA} = 2.6893E-03$$

THE MAXIMUM ERROR OCCURS AT :

$$0.1000000E+02 \quad 0.2544000E+00 \quad 0.2580439E+00 \quad 0.3643861E-02 \quad 1.4323 \%$$

7.3 Appendix C – Computer Code Used in Shielding Calculations

Table C-1. Listing of Computer Code SHIELD (Version 2.04). (Selected Results From This Code Are Presented in Appendices C, E and F)

[illegible]

C						IL SS THICK = 2.54	CMSHL00201
C						OL SS THICK = 3.81	CMSHL00202
C							SHL00203
C							SHL00204
C							SHL00205
C							SHL00206
C							SHL00207
C							SHL00208
C							SHL00209
C							SHL00210
C							SHL00211
C							SHL00212
							SHL00213
							SHL00214
							SHL00215
							SHL00216
C							SHL00217
C							SHL00218
C							SHL00219
							SHL00220
							SHL00221
C							SHL00222
C							SHL00223
							SHL00224
							SHL00225
							SHL00226
							SHL00227
							SHL00228
							SHL00229
							SHL00230
C							SHL00231
C							SHL00232
							SHL00233
							SHL00234
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							SHL00258
							SHL00259
							SHL00260
							SHL00261
C							SHL00262
							SHL00263
							SHL00264
							SHL00265
							SHL00266
							SHL00267
							SHL00268
							SHL00269
							SHL00270
							SHL00271


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+      //'          |'                                SHL00272
ENDIF                                          SHL00273
IF (CLIMIT.EQ.'50mR/hr ') THEN              SHL00274
LINE(4)=| Regulatory Limit: Exposure Rate = 50 mR/hr at 1 meter' SHL00275
+      //'          |'                                SHL00276
ENDIF                                          SHL00277
IF (CLIMIT.EQ.'10mrem/hr ') THEN            SHL00278
LINE(4)=| Regulatory Limit: Dose Rate = 10 mrem/hr at 2 meter ' SHL00279
+      //'          |'                                SHL00280
ENDIF                                          SHL00281
LINE(5)=|                                          ' SHL00282
+      //'          |'                                SHL00283
LINE(6)=|-----' SHL00284
+      //'-----+'                                SHL00285
LINE(7)=|                                          ' SHL00286
+      //'          |'                                SHL00287
WRITE(IUNIT6,9000) LINE                      SHL00288
9000 FORMAT(A80)                             SHL00289
C                                             SHL00290
C                                             SHL00291
RHOIRO = 8.00D+00      ! Iron/SS Density [gm/cm^3] SHL00292
RHODU  = 18.5D+00      ! DU (depleted uranium) Density [gm/cm^3] SHL00293
RHOLED = 11.35D+00     ! Lead Density [gm/cm^3] SHL00294
PI      = 4.0D+00 * DATAN(1.0D+00) ! Calculate PI from arctan(1) SHL00295
RADIUS  = 182.2D+00 / 2.0D+00 ! Dimension of ID of cask [cm] SHL00296
DOSERA  = 100000.0D+00 ! Dose Rate [R/hr] at surface of HLW SHL00297
WRITE(IUNIT6,9010) DOSERA,RADIUS,RHOIRO,RHOLED,RHODU ! Titles SHL00298
9010 FORMAT(
+  ///,T5,'INITIAL INPUT PARAMETERS', SHL00300
+  /,T10,'SOURCE TERM EXPOSURE RATE = ',F9.1,' [R/HR]', SHL00301
+  /,T10,'INNER CASK RADIUS = ',F5.2,' [CM]', SHL00302
+  /,T10,'DENSITY (SS305L) = ',F5.2,' [G/CC]', SHL00303
+  /,T10,'DENSITY (LEAD ) = ',F5.2,' [G/CC]', SHL00304
+  /,T10,'DENSITY ( DU ) = ',F5.2,' [G/CC]',///) SHL00305
C                                             SHL00306
LINE(1)=|-----' SHL00307
+      //'-----+' SHL00308
LINE(2)=| OUTPUT FROM ONE-DIMENSIONAL SHIELDING CALCULATIONS' SHL00309
+      //'          |' SHL00310
LINE(3)=|-----' SHL00311
+      //'-----+' SHL00312
LINE(4)=| GAMMA | SS SHIELD R1| SHIELDING REGION 2| SS SHI' SHL00313
+      //'ELD R3| SURFACE| WEIGHT|' SHL00314
IF (CLIMIT.EQ.'50mR/hr ') THEN SHL00315
LINE(4)=| GAMMA | SS SHIELD R1| SHIELDING REGION 2| SS SHI' SHL00316
+      //'ELD R3| @ 1 m | WEIGHT|' SHL00317
ENDIF SHL00318
IF (CLIMIT.EQ.'10mrem/hr ') THEN SHL00319
LINE(4)=| GAMMA | SS SHIELD R1| SHIELDING REGION 2| SS SHI' SHL00320
+      //'ELD R3| @ 2 m | WEIGHT|' SHL00321
ENDIF SHL00322
LINE(5)=| ENERGY FLUX | THICK FLUX | THICK FLUX | THICK ' SHL00323
+      //' FLUX |DOSE RATE| ' SHL00324
LINE(6)=| (MEV) (1/CM2S) | (CM) (1/CM2S) | ID (CM) (1/CM2S) | (CM) (1' SHL00325
+      //' /CM2S) | (MREM/H) | (MT/M) | ' SHL00326
IF (CLIMIT.EQ.'50mR/hr ') THEN SHL00327
LINE(5)=| ENERGY FLUX | THICK FLUX | THICK FLUX | THICK ' SHL00328
+      //' FLUX |EXPOSURE| ' SHL00329
LINE(6)=| (MEV) (1/CM2S) | (CM) (1/CM2S) | ID (CM) (1/CM2S) | (CM) (1' SHL00330
+      //' /CM2S) | (MR/HR) | (MT/M) | ' SHL00331
ENDIF SHL00332
LINE(7)=|-----+-----+-----+-----' SHL00333
+      //'-----+-----+-----+-----+' SHL00334
WRITE(IUNIT6,9011) LINE SHL00335
9011 FORMAT(A80) SHL00336
DO 5000 GAMMEV = 0.250D+00, 1.50D+00, 0.25D+00 ! Gamma Energy [MeV] SHL00337
IF (IFLAGD.GE.1) WRITE(IUNIT7,9012) GAMMEV,CD(GAMMEV) !Diagnostic SHL00338
9012 FORMAT(T10,'GAMMA/MEV=',1P1E10.4,' CD()=' ,1P1E10.4) SHL00339
FLUX0=DOSERA/CD(GAMMEV) ! Gamma Flux (gamma/cm^2-sec) SHL00340
DO 4000 STH01 = 0.0D+00, 2.54001D+00, 2.54D+00 ! Region 1 thick SHL00341
RELAX=STH01*RHOIRO*XMURHO_IRON(GAMMEV) ! Relaxation Length SHL00342

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FLUX1=FLUX0*B_IRON(GAMMEV,RELAX)*E2(RELAX) ! Surface 1 G-FluxSHL00343
IF(IFLAGD.GE.1) THEN ! DiagnosticsSHL00344
  WRITE(IUNIT7,9013) GAMMEV,XMURHO_IRON(GAMMEV) SHL00345
9013  FORMAT(T15,'GAMMA/MEV=',1P1E10.4,' MU/RHO()=' ,1P1E10.4) SHL00346
  WRITE(IUNIT7,9014) SHTH01,RHOIRO SHL00347
9014  FORMAT(T15,'SH THICK[CM]=' ,1P1E10.4,' RHO(IRON)=' ,1P1E10.4)SHL00348
  WRITE(IUNIT7,9015) RELAX,FLUX1 SHL00349
9015  FORMAT(T15,'RELAX=' ,1P1E10.4,' FLUX1=' ,1P1E10.4) SHL00350
ENDIF SHL00351
DO 3000 IDMATE = 1, 2, 1 ! Materials, 1-lead, 2-DU, 3-IronSHL00352
DO 2000 SHTH03 =0.0D+00, 3.8101D+00, 3.81D+00 !Regn 2 thickSHL00353
DO 1000 SHTH02 =0.0D+00,20.001D+00,1.0D+00 !Region 3 thickSHL00354
IF(SHTH02.LT.3.0D+00.AND.SHTH02.NE.0.0D+00) GO TO 1000 SHL00355
IF(IDMATE.EQ.1) THEN ! Region 2 material -> LeadSHL00356
  IDNAME='LEAD' ! ID SHL00357
  RHO=RHOLED ! density [gm/cm^3] SHL00358
  XMURHO=XMURHO_LEAD(GAMMEV) ! Product of mu & rhoSHL00359
  RELAX=SHTH02*RHO*XMURHO ! Relaxation length SHL00360
  B=B_LEAD(GAMMEV,RELAX) !Gamma buildup factorSHL00361
ENDIF SHL00362
IF(IDMATE.EQ.2) THEN ! Region 2 material -> DU SHL00363
  IDNAME=' DU ' SHL00364
  RHO=RHODU SHL00365
  XMURHO=XMURHO_DU(GAMMEV) SHL00366
  RELAX=SHTH02*RHO*XMURHO SHL00367
  B=B_DU(GAMMEV,RELAX) SHL00368
ENDIF SHL00369
IF(IDMATE.EQ.3) THEN ! Region 2 material -> IronSHL00370
  IDNAME='IRON' SHL00371
  RHO=RHOIRO SHL00372
  XMURHO=XMURHO_IRON(GAMMEV) SHL00373
  RELAX=SHTH02*RHO*XMURHO SHL00374
  B=B_IRON(GAMMEV,RELAX) SHL00375
ENDIF SHL00376
C ! Write out Headers SHL00377
FLUX2=FLUX1*B*E2(RELAX) !Surface 2 G-flux [1/cm^2-s]SHL00378
IF(IFLAGD.GE.1) THEN ! DiagnosticsSHL00379
  WRITE(IUNIT7,9016) IDNAME,RHO SHL00380
9016  FORMAT(T20,'IDNAME=' ,A4,' RHO=' ,1P1E10.4) SHL00381
  WRITE(IUNIT7,9017) XMURHO,B SHL00382
9017  FORMAT(T20,'MU/RHO=' ,1P1E10.4,' B=' ,1P1E10.4) SHL00383
  WRITE(IUNIT7,9018) SHTH02,RELAX SHL00384
9018  FORMAT(T25,'SHIELD TH=' ,1P1E10.4,' RELAX=' ,1P1E10.4)SHL00385
  WRITE(IUNIT7,9019) FLUX2 SHL00386
9019  FORMAT(T25,'FLUX2=' ,1P1E10.4) SHL00387
ENDIF SHL00388
RELAX=SHTH03*RHOIRO*XMURHO_IRON(GAMMEV) !Region3 relaxSHL00389
FLUX3=FLUX2*B_IRON(GAMMEV,RELAX)*E2(RELAX) ! Region 3SHL00390
DOSERM=FLUX3*CD(GAMMEV)*F(GAMMEV)*1000.0D+00 !Region 3SHL00391
EXPOSU=FLUX3*CD(GAMMEV)*1000.0D+00 SHL00392
SOLUTI=DOSERM SHL00393
IF(CLIMIT.EQ.'50mR/hr ') THEN ! @ 1 Meter SHL00394
  RADTOT=RADIUS+2.540+SHTH02+3.81D0 SHL00395
  EXPOSU=EXPOSU*RADTOT/(RADTOT+100.0D0) SHL00396
  SOLUTI=EXPOSU SHL00397
ENDIF SHL00398
IF(CLIMIT.EQ.'10mrem/hr ') THEN ! @ 2 Meter SHL00399
  RADTOT=RADIUS+2.540+SHTH02+3.81D0 SHL00400
  DOSERM=DOSERM*RADTOT/(RADTOT+200.0D0) SHL00401
  SOLUTI=DOSERM SHL00402
ENDIF SHL00403
SSTH01=2.54D0 ! SS Liner #1 thickness (must always) SHL00404
SSTH03=3.81D0 ! SS Liner #2 thickness (include wt) SHL00405
WEIGHT=RHOIRO*PI*((RADIUS+SSTH01)**2-RADIUS**2)! [g/cm]SHL00406
+RHO*PI*((RADIUS+SHTH02+SSTH01)**2-(RADIUS+SSTH01)**2)SHL00407
+RHOIRO*PI*((RADIUS+SSTH03+SHTH02+SSTH01)**2- SHL00408
+ (RADIUS+SHTH02+SSTH01)**2) SHL00409
WEIGHT=WEIGHT/1.0E+04 ! Linear weight [mt/m]SHL00410
C ! Write OUTPUTSHL00411
IF(SOLUTI.LE.200.0D+00.AND.DOSERM.GT.1.0D+00) THEN SHL00412
  WRITE(IUNIT6,9100) GAMMEV,FLUX0,SHTH01,FLUX1,IDNAME,SHL00413

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+                               SHTH02,FLUX2,SHTH03,FLUX3,SOLUTI,SHL00414
+                               WEIGHT SHL00415
9100    FORMAT(' ',F4.2,1P,E9.2,0P,' ',F4.2,1P,E9.2,0P,' ',A4SHL00416
+       ,F6.2,1P,E9.2,0P,' ',F4.2,1P,E9.2,0P,' ',1X,F6.2,1X, SHL00417
+       ' ',1P,E7.1,0P,' ') SHL00418
+       ELSE SHL00419
+       WRITE(IUNIT6,9200) GAMMEV,FLUX0,SHTH01,FLUX1,IDNAME,SHL00420
+       SHTH02,FLUX2,SHTH03,FLUX3,SOLUTI,SHL00421
+       WEIGHT SHL00422
9200    FORMAT(' ',F4.2,1P,E9.2,0P,' ',F4.2,1P,E9.2,0P,' ',A4SHL00423
+       ,F6.2,1P,E9.2,0P,' ',F4.2,1P,E9.2,0P,' ',1P,E8.2,0P, SHL00424
+       ' ',1P,E7.1,0P,' ') SHL00425
+       ENDIF SHL00426
IF(SHTH02.LT.2.0D+00.AND.SHTH02.NE.0.0D+00) GO TO 1000 SHL00427
C [The above IF statement is used because the dose con- SHL00428
C version ratios and the flux buildup factors are not SHL00429
C accurate below shielding thicknesses of 2.0cm (and for SHL00430
C gamma energies greater than 1.0 MeV).] SHL00431
C SHL00432
C IUNIT = 0 SHL00433
C 3D-Plot Lead Shielding/no SS Liners/ 0.25 -> 1.5 gammas SHL00434
IF(SHTH01.EQ.0.00D+00.AND.IDMATE.EQ.1.AND. SHL00435
+   SHTH03.EQ.0.00D+00) IUNIT = IUNIT8 SHL00436
C SHL00437
C 3D-Plot Lead Shielding/SS Liners/ 0.25 -> 1.5 gammas SHL00438
IF(SHTH01.EQ.2.54D+00.AND.IDMATE.EQ.1.AND. SHL00439
+   SHTH03.EQ.3.81D+00) IUNIT = IUNIT9 SHL00440
C SHL00441
C 3D-Plot DU Shielding/no SS Liners/ 0.25 -> 1.5 gammas SHL00442
IF(SHTH01.EQ.0.00D+00.AND.IDMATE.EQ.2.AND. SHL00443
+   SHTH03.EQ.0.00D+00) IUNIT = IUNIT10 SHL00444
C SHL00445
C 3D-Plot DU Shielding/SS Liners/ 0.25 -> 1.5 gammas SHL00446
IF(SHTH01.EQ.2.54D+00.AND.IDMATE.EQ.2.AND. SHL00447
+   SHTH03.EQ.3.81D+00) IUNIT = IUNIT11 SHL00448
C SHL00449
C IF(IUNIT.EQ.0) GO TO 1000 SHL00450
C SHL00451
IF(CLIMIT.EQ.'200mrem/hr') THEN ! @ Cask Surface SHL00452
WRITE(IUNIT,9300) GAMMEV,SHTH02,DOSERM SHL00453
ENDIF SHL00454
IF(CLIMIT.EQ.'50mR/hr ') THEN ! @ 1 Meter SHL00455
WRITE(IUNIT,9300) GAMMEV,SHTH02,EXPOSU SHL00456
ENDIF SHL00457
IF(CLIMIT.EQ.'10mrem/hr ') THEN ! @ 2 Meter SHL00458
WRITE(IUNIT,9300) GAMMEV,SHTH02,DOSERM SHL00459
ENDIF SHL00460
C SHL00461
9300    FORMAT(3(2X,1P1E14.7)) SHL00462
1000    CONTINUE SHL00463
2000    CONTINUE SHL00464
3000    CONTINUE SHL00465
4000    CONTINUE SHL00466
5000    CONTINUE SHL00467
C SHL00468
9999    CLOSE(IUNIT8) ! Close OUTPUT files and SHL00469
CLOSE(IUNIT9) ! end program SHL00470
CLOSE(IUNIT10) SHL00471
CLOSE(IUNIT11) SHL00472
IF(IFLAGD.GE.1) CLOSE(IUNIT7) SHL00473
RETURN SHL00474
END SHL00475
C *****SHL00476
C * CD *SHL00477
C *****SHL00478
DOUBLE PRECISION FUNCTION CD(GAMMEV) SHL00479
THIS FUNCTION SUBPROGRAM CALCULATES THE FLUX-TO-DOSE CONVERSION SHL00480
FACTOR (relative to air). SHL00481
IMPLICIT DOUBLE PRECISION (A-H,O-Z) SHL00482
CD = 0.0659D-03*GAMMEV*XMURHO_AIR(GAMMEV) ! [(cm^2-sec/gamma) SHL00483
RETURN ! x (R/hr)] SHL00484

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C                                     SHL00485
C                                     *****SHL00486
C                                     * F *SHL00487
C                                     *****SHL00488
C DOUBLE PRECISION FUNCTION F(GAMMEV) SHL00489
C THIS FUNCTION SUBPROGRAM CALCULATES THE EXPOSURE-TO-ABSORBED DOSE SHL00490
C CONVERSION RATIO. (F IS BASED ON A POLYNOMIAL FIT TO TABULATED SHL00491
C DATA, THIS IS DESCRIBED IN ONE OF THE APPENDICES FOR THE REPORT.) SHL00492
C IMPLICIT DOUBLE PRECISION (A-H,O-Z) SHL00493
C C1 = 9.7466174D-01 SHL00494
C C2 = -4.1084113D-02 SHL00495
C C3 = 7.4287014D-03 SHL00496
C F = C1 + C2*GAMMEV + C3*GAMMEV**2 ! [rad/R] SHL00497
C RETURN SHL00498
C END SHL00499
C                                     *****SHL00500
C                                     * XMURHO_AIR *SHL00501
C                                     *****SHL00502
C DOUBLE PRECISION FUNCTION XMURHO_AIR(GAMMEV) SHL00503
C THIS FUNCTION SUBPROGRAM CALCULATES THE MASS ENERGY-ABSORPTION SHL00504
C COEFFICIENT FOR AIR. (XMURHO_AIR IS BASED ON A POLYNOMIAL FIT TO SHL00505
C TABULATED DATA, THIS IS DESCRIBED IN ONE OF THE APPENDICES FOR THE SHL00506
C REPORT.) SHL00507
C IMPLICIT DOUBLE PRECISION (A-H,O-Z) SHL00508
C C1 = 2.7353947D-02 SHL00509
C C2 = 5.5507960D-04 SHL00510
C C3 = -7.1288708D-04 SHL00511
C XMURHO_AIR = C1 + C2*GAMMEV + C3*GAMMEV**2 ! [cm^2/gm] SHL00512
C RETURN SHL00513
C END SHL00514
C                                     *****SHL00515
C                                     * XMURHO_IRON *SHL00516
C                                     *****SHL00517
C DOUBLE PRECISION FUNCTION XMURHO_IRON(GAMMEV) SHL00518
C THIS FUNCTION SUBPROGRAM CALCULATES THE MASS ENERGY-ABSORPTION SHL00519
C COEFFICIENT FOR IRON. (XMURHO_IRON IS BASED ON A POLYNOMIAL FIT SHL00520
C TO TABULATED DATA, THIS IS DESCRIBED IN ONE OF THE APPENDICES FOR SHL00521
C THE REPORT.) SHL00522
C IMPLICIT DOUBLE PRECISION (A-H,O-Z) SHL00523
C C1 = 3.2906432D-02 SHL00524
C C2 = 1.0391703D-02 SHL00525
C C3 = 1.0415673D-02 SHL00526
C XMURHO_IRON = C1/GAMMEV + C2 + C3*GAMMEV ! [cm^2/gm] SHL00527
C RETURN SHL00528
C END SHL00529
C                                     *****SHL00530
C                                     * XMURHO_LEAD *SHL00531
C                                     *****SHL00532
C DOUBLE PRECISION FUNCTION XMURHO_LEAD(GAMMEV) SHL00533
C THIS FUNCTION SUBPROGRAM CALCULATES THE MASS ENERGY-ABSORPTION SHL00534
C COEFFICIENT FOR LEAD. (XMURHO_LEAD IS BASED ON A POLYNOMIAL FIT SHL00535
C TO TABULATED DATA, THIS IS DESCRIBED IN ONE OF THE APPENDICES FOR SHL00536
C THE REPORT.) SHL00537
C IMPLICIT DOUBLE PRECISION (A-H,O-Z) SHL00538
C C1 = 5.6077678D-02 SHL00539
C C2 = -6.7048400D-01 SHL00540
C C3 = -3.0495029D-01 SHL00541
C XMURHO_LEAD = C1 * GAMMEV**C2 * DEXP(-C3/GAMMEV) ! [cm^2/gm] SHL00542
C RETURN SHL00543
C END SHL00544
C                                     *****SHL00545
C                                     * XMURHO_DU *SHL00546
C                                     *****SHL00547
C DOUBLE PRECISION FUNCTION XMURHO_DU(GAMMEV) SHL00548
C THIS FUNCTION SUBPROGRAM CALCULATES THE MASS ENERGY-ABSORPTION SHL00549
C COEFFICIENT FOR DU. (NOTE! DATA DID NOT EXIST IN THE REFERENCES SHL00550
C FOR DU. THUS VALUES FOR LEAD WERE SUBSTITUTED. THIS IS SHL00551
C CONSIDERED TO BE A VERY REASONABLE ASSUMPTION BECAUSE BOTH SHL00552
C MATERIALS ARE HIGH-Z MATERIALS AND SHOULD HAVE COMPARABLE SHL00553
C SHIELDING PROPERTIES. -- See XMURHO_LEAD.) SHL00554
C IMPLICIT DOUBLE PRECISION (A-H,O-Z) SHL00555

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XMRHO_DU=XMRHO_LEAD(GAMMEV)      ! [cm^2/gm]      SHL00556
RETURN                             SHL00557
END                                SHL00558
C                                  *****SHL00559
C                                  * E2 *SHL00560
C                                  *****SHL00561

DOUBLE PRECISION FUNCTION E2(RELAX)      SHL00562
THIS FUNCTION SUBPROGRAM CALCULATES THE EXPONENTIAL FUNCTION "E2".SHL00563
E2 IS BASED ON A POLYNOMIAL FIT TO TABULATED DATA, THIS IS SHL00564
DESCRIBED IN ONE OF THE APPENDICES FOR THIS FUNCTION IS DESCRIBED SHL00565
IN ONE OF THE APPENDICES FOR THE REPORT.) SHL00566
IMPLICIT DOUBLE PRECISION (A-H,O-Z)      SHL00567
IF(RELAX.GE.14) E2 = (DEXP(-RELAX))/(RELAX+2.0D+00) SHL00568
IF(RELAX.LT.14.AND.RELAX.GE.1) THEN      SHL00569
  C5 = 5.5565607D-01                      SHL00570
  C6 = 1.4190903D+00                      SHL00571
  C7 = -3.3941944D-02                     SHL00572
  C8 = 1.1209473D-03                     SHL00573
  E2 = DEXP(-(C5+C6*RELAX+C7*RELAX**2+C8*RELAX**3)) SHL00574
ENDIF                                     SHL00575
IF(RELAX.LT.1.0D+00.AND.RELAX.GE.0.0D+00) THEN SHL00576
  C9 = 1.7837543D-02                      SHL00577
  C10 = 3.0105850D+00                     SHL00578
  C11 = -2.0438538D+00                     SHL00579
  C12 = 9.3175783D-01                     SHL00580
  E2 = DEXP(-(C9+C10*RELAX+C11*RELAX**2+C12*RELAX**3)) SHL00581
ENDIF                                     SHL00582
IF(RELAX.EQ.0.0D+00) E2 = 1.0D+00      SHL00583
C                                     SHL00584
RETURN                                SHL00585
END                                    SHL00586
C                                  *****SHL00587
C                                  * B_IRON *SHL00588
C                                  *****SHL00589

DOUBLE PRECISION FUNCTION B_IRON(GAMMEV,RELAX) SHL00590
THIS FUNCTION SUBPROGRAM CALCULATES THE GAMMA SHIELDING BUILD-UP SHL00591
FACTOR, AS A FUNCTION OF GAMMA ENERGY, FOR IRON. (B_IRON IS BASED SHL00592
ON A POLYNOMIAL FIT TO TABULATED DATA, THIS IS DESCRIBED IN ONE SHL00593
OF THE APPENDICES FOR THE REPORT.) SHL00594
IMPLICIT DOUBLE PRECISION (A-H,O-Z)      SHL00595
B_IRON=1.0D+00                          SHL00596
IF(RELAX.GT.1.0D+00) THEN                SHL00597
  C1 = 1.7572102D+00                      SHL00598
  C2 = -2.8696747D-01                     SHL00599
  C3 = 7.6081795D-01                     SHL00600
  B_IRON = C1 * GAMMEV**C2 * RELAX**C3    SHL00601
ENDIF                                     SHL00602
RETURN                                    SHL00603
END                                       SHL00604
C                                  *****SHL00605
C                                  * B_DU *SHL00606
C                                  *****SHL00607

DOUBLE PRECISION FUNCTION B_DU(GAMMEV,RELAX) SHL00608
THIS FUNCTION SUBPROGRAM CALCULATES THE GAMMA SHIELDING BUILD-UP SHL00609
FACTOR, AS A FUNCTION OF GAMMA ENERGY, FOR DU. (B_DU IS BASED SHL00610
ON A POLYNOMIAL FIT TO TABULATED DATA, THIS IS DESCRIBED IN ONE SHL00611
OF THE APPENDICES FOR THE REPORT.) SHL00612
IMPLICIT DOUBLE PRECISION (A-H,O-Z)      SHL00613
B_DU=1.0D+00                            SHL00614
IF(RELAX.GT.1.0D+00) THEN                SHL00615
  C1 = 9.7792223D-01                      SHL00616
  C2 = 1.1832534D-01                      SHL00617
  C3 = 8.9406006D-02                      SHL00618
  B_DU = C1 * DEXP(GAMMEV**C2 * RELAX**C3) SHL00619
ENDIF                                     SHL00620
RETURN                                    SHL00621
END                                       SHL00622
C                                  *****SHL00623
C                                  * B_LEAD *SHL00624
C                                  *****SHL00625

DOUBLE PRECISION FUNCTION B_LEAD(GAMMEV,RELAX) SHL00626

```

C	THIS FUNCTION SUBPROGRAM CALCULATES THE GAMMA SHIELDING BUILD-UP	SHL00627
C	FACTOR, AS A FUNCTION OF GAMMA ENERGY, FOR LEAD. (B_LEAD IS BASED	SHL00628
C	ON A POLYNOMINAL FIT TO TABULATED DATA, THIS IS DESCRIBED IN ONE	SHL00629
C	OF THE APPENDICES FOR THE REPORT.)	SHL00630
	IMPLICIT DOUBLE PRECISION (A-H,O-Z)	SHL00631
	B_LEAD=1.0D+00	SHL00632
	IF(RELAX.GT.1.0D+00) THEN	SHL00633
	C1 = 1.0643266D+00	SHL00634
	C2 = 2.2681979D-01	SHL00635
	C3 = 5.0048274D-01	SHL00636
	B_LEAD = C1 * GAMMEV**C2 * RELAX**C3	SHL00637
	ENDIF	SHL00638
	RETURN	SHL00639
	END	SHL00640

7.4 Appendix D – Standard Output From Computer Code

This appendix contains the standard output (screen copy) from the code SHIELD for the computed dose rate at two meters from the cask surface.

Table D-1. Computational Results from SHIELD Code (Version 2.04) for Dose Rate at Two Meters From Cask Surface. (Select Results From This Table Are Presented in Appendices E and F)

[MODULE] INPUT APPLICATION TO BE USED:

```
[1] Reg Limit = 200 mrem/hr at Cask Surface
[2] Reg Limit = 50 mR/hr at 1 meter from Cask
[3] Reg Limit = 10 mrem/hr at 2 meter from Cask
[4] Quit <1> 3
```

Code: S H I E L D Version: 2.04

Regulatory Limit: Dose Rate = 10 mrem/hr at 2 meter

INITIAL INPUT PARAMETERS

```
SOURCE TERM EXPOSURE RATE = 100000.0 [R/HR]
INNER CASK RADIUS = 91.10 [CM]
DENSITY (SS305L) = 8.00 [G/CC]
DENSITY (LEAD ) = 11.35 [G/CC]
DENSITY ( DU ) = 18.50 [G/CC]
```

OUTPUT FROM ONE-DIMENSIONAL SHIELDING CALCULATIONS

GAMMA		SS SHIELD R1		SHIELDING REGION 2		SS SHIELD R3		@ 2 m	WEIGHT
ENERGY FLUX	THICK FLUX	THICK FLUX	THICK FLUX	THICK FLUX	THICK FLUX	THICK FLUX	THICK FLUX	DOSE RATE	
(MEV) (1/CM2S)	(CM) (1/CM2S)	(CM) (1/CM2S)	ID	(CM) (1/CM2S)	(CM) (1/CM2S)	(CM) (1/CM2S)	(CM) (1/CM2S)	(MREM/H)	(MT/M)
0.25 2.21E+11	0.00 2.21E+11	LEAD	0.00 2.21E+11	0.00 2.21E+11	0.00 2.21E+11	3.16E+07	3.0E+00		
0.25 2.21E+11	0.00 2.21E+11	LEAD	3.00 2.91E+03	0.00 2.91E+03	4.25E-01	5.1E+00			
0.25 2.21E+11	0.00 2.21E+11	LEAD	4.00 1.10E+01	0.00 1.10E+01	1.62E-03	5.8E+00			
0.25 2.21E+11	0.00 2.21E+11	LEAD	5.00 4.27E-02	0.00 4.27E-02	6.31E-06	6.5E+00			
0.25 2.21E+11	0.00 2.21E+11	LEAD	6.00 1.68E-04	0.00 1.68E-04	2.49E-08	7.3E+00			
0.25 2.21E+11	0.00 2.21E+11	LEAD	7.00 6.66E-07	0.00 6.66E-07	9.96E-11	8.0E+00			
0.25 2.21E+11	0.00 2.21E+11	LEAD	8.00 2.66E-09	0.00 2.66E-09	4.01E-13	8.7E+00			
0.25 2.21E+11	0.00 2.21E+11	LEAD	9.00 1.07E-11	0.00 1.07E-11	1.63E-15	9.5E+00			
0.25 2.21E+11	0.00 2.21E+11	LEAD	10.00 4.35E-14	0.00 4.35E-14	6.63E-18	1.0E+01			
0.25 2.21E+11	0.00 2.21E+11	LEAD	11.00 1.77E-16	0.00 1.77E-16	2.71E-20	1.1E+01			
0.25 2.21E+11	0.00 2.21E+11	LEAD	12.00 7.22E-19	0.00 7.22E-19	1.11E-22	1.2E+01			
0.25 2.21E+11	0.00 2.21E+11	LEAD	13.00 2.96E-21	0.00 2.96E-21	4.59E-25	1.3E+01			
0.25 2.21E+11	0.00 2.21E+11	LEAD	14.00 1.21E-23	0.00 1.21E-23	1.90E-27	1.3E+01			
0.25 2.21E+11	0.00 2.21E+11	LEAD	15.00 5.00E-26	0.00 5.00E-26	7.85E-30	1.4E+01			
0.25 2.21E+11	0.00 2.21E+11	LEAD	16.00 2.06E-28	0.00 2.06E-28	3.25E-32	1.5E+01			
0.25 2.21E+11	0.00 2.21E+11	LEAD	17.00 8.51E-31	0.00 8.51E-31	1.35E-34	1.6E+01			
0.25 2.21E+11	0.00 2.21E+11	LEAD	18.00 3.52E-33	0.00 3.52E-33	5.63E-37	1.7E+01			

0.25	2.21E+11	0.00	2.21E+11	LEAD	19.00	1.46E-35	0.00	1.46E-35	2.34E-39	1.7E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	20.00	6.06E-38	0.00	6.06E-38	9.78E-42	1.8E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	0.00	2.21E+11	3.81	3.46E+09	4.95E+05	3.0E+00
0.25	2.21E+11	0.00	2.21E+11	LEAD	3.00	2.91E+03	3.81	4.56E+01	6.65E-03	5.1E+00
0.25	2.21E+11	0.00	2.21E+11	LEAD	4.00	1.10E+01	3.81	1.73E-01	2.54E-05	5.8E+00
0.25	2.21E+11	0.00	2.21E+11	LEAD	5.00	4.27E-02	3.81	6.68E-04	9.87E-08	6.5E+00
0.25	2.21E+11	0.00	2.21E+11	LEAD	6.00	1.68E-04	3.81	2.62E-06	3.90E-10	7.3E+00
0.25	2.21E+11	0.00	2.21E+11	LEAD	7.00	6.66E-07	3.81	1.04E-08	1.56E-12	8.0E+00
0.25	2.21E+11	0.00	2.21E+11	LEAD	8.00	2.66E-09	3.81	4.17E-11	6.28E-15	8.7E+00
0.25	2.21E+11	0.00	2.21E+11	LEAD	9.00	1.07E-11	3.81	1.68E-13	2.55E-17	9.5E+00
0.25	2.21E+11	0.00	2.21E+11	LEAD	10.00	4.35E-14	3.81	6.80E-16	1.04E-19	1.0E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	11.00	1.77E-16	3.81	2.77E-18	4.25E-22	1.1E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	12.00	7.22E-19	3.81	1.13E-20	1.74E-24	1.2E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	13.00	2.96E-21	3.81	4.63E-23	7.18E-27	1.3E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	14.00	1.21E-23	3.81	1.90E-25	2.97E-29	1.3E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	15.00	5.00E-26	3.81	7.82E-28	1.23E-31	1.4E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	16.00	2.06E-28	3.81	3.23E-30	5.09E-34	1.5E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	17.00	8.51E-31	3.81	1.33E-32	2.12E-36	1.6E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	18.00	3.52E-33	3.81	5.51E-35	8.80E-39	1.7E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	19.00	1.46E-35	3.81	2.28E-37	3.67E-41	1.7E+01
0.25	2.21E+11	0.00	2.21E+11	LEAD	20.00	6.06E-38	3.81	9.48E-40	1.53E-43	1.8E+01
0.25	2.21E+11	0.00	2.21E+11	DU	0.00	2.21E+11	0.00	2.21E+11	3.16E+07	3.0E+00
0.25	2.21E+11	0.00	2.21E+11	DU	3.00	5.97E-02	0.00	5.97E-02	8.71E-06	6.4E+00
0.25	2.21E+11	0.00	2.21E+11	DU	4.00	6.40E-06	0.00	6.40E-06	9.40E-10	7.5E+00
0.25	2.21E+11	0.00	2.21E+11	DU	5.00	7.23E-10	0.00	7.23E-10	1.07E-13	8.7E+00
0.25	2.21E+11	0.00	2.21E+11	DU	6.00	8.44E-14	0.00	8.44E-14	1.26E-17	9.9E+00
0.25	2.21E+11	0.00	2.21E+11	DU	7.00	1.01E-17	0.00	1.01E-17	1.51E-21	1.1E+01
0.25	2.21E+11	0.00	2.21E+11	DU	8.00	1.23E-21	0.00	1.23E-21	1.85E-25	1.2E+01
0.25	2.21E+11	0.00	2.21E+11	DU	9.00	1.51E-25	0.00	1.51E-25	2.29E-29	1.3E+01
0.25	2.21E+11	0.00	2.21E+11	DU	10.00	1.88E-29	0.00	1.88E-29	2.87E-33	1.5E+01
0.25	2.21E+11	0.00	2.21E+11	DU	11.00	2.36E-33	0.00	2.36E-33	3.63E-37	1.6E+01
0.25	2.21E+11	0.00	2.21E+11	DU	12.00	2.99E-37	0.00	2.99E-37	4.61E-41	1.7E+01
0.25	2.21E+11	0.00	2.21E+11	DU	13.00	3.81E-41	0.00	3.81E-41	5.91E-45	1.8E+01
0.25	2.21E+11	0.00	2.21E+11	DU	14.00	4.87E-45	0.00	4.87E-45	7.60E-49	2.0E+01
0.25	2.21E+11	0.00	2.21E+11	DU	15.00	6.25E-49	0.00	6.25E-49	9.82E-53	2.1E+01
0.25	2.21E+11	0.00	2.21E+11	DU	16.00	8.07E-53	0.00	8.07E-53	1.27E-56	2.2E+01
0.25	2.21E+11	0.00	2.21E+11	DU	17.00	1.04E-56	0.00	1.04E-56	1.66E-60	2.4E+01
0.25	2.21E+11	0.00	2.21E+11	DU	18.00	1.35E-60	0.00	1.35E-60	2.16E-64	2.5E+01
0.25	2.21E+11	0.00	2.21E+11	DU	19.00	1.76E-64	0.00	1.76E-64	2.83E-68	2.6E+01
0.25	2.21E+11	0.00	2.21E+11	DU	20.00	2.30E-68	0.00	2.30E-68	3.71E-72	2.7E+01
0.25	2.21E+11	0.00	2.21E+11	DU	0.00	2.21E+11	3.81	3.46E+09	4.95E+05	3.0E+00
0.25	2.21E+11	0.00	2.21E+11	DU	3.00	5.97E-02	3.81	9.34E-04	1.36E-07	6.4E+00
0.25	2.21E+11	0.00	2.21E+11	DU	4.00	6.40E-06	3.81	1.00E-07	1.47E-11	7.5E+00
0.25	2.21E+11	0.00	2.21E+11	DU	5.00	7.23E-10	3.81	1.13E-11	1.67E-15	8.7E+00
0.25	2.21E+11	0.00	2.21E+11	DU	6.00	8.44E-14	3.81	1.32E-15	1.96E-19	9.9E+00
0.25	2.21E+11	0.00	2.21E+11	DU	7.00	1.01E-17	3.81	1.58E-19	2.36E-23	1.1E+01
0.25	2.21E+11	0.00	2.21E+11	DU	8.00	1.23E-21	3.81	1.92E-23	2.89E-27	1.2E+01
0.25	2.21E+11	0.00	2.21E+11	DU	9.00	1.51E-25	3.81	2.37E-27	3.58E-31	1.3E+01
0.25	2.21E+11	0.00	2.21E+11	DU	10.00	1.88E-29	3.81	2.95E-31	4.49E-35	1.5E+01
0.25	2.21E+11	0.00	2.21E+11	DU	11.00	2.36E-33	3.81	3.70E-35	5.67E-39	1.6E+01
0.25	2.21E+11	0.00	2.21E+11	DU	12.00	2.99E-37	3.81	4.68E-39	7.22E-43	1.7E+01
0.25	2.21E+11	0.00	2.21E+11	DU	13.00	3.81E-41	3.81	5.95E-43	9.24E-47	1.8E+01
0.25	2.21E+11	0.00	2.21E+11	DU	14.00	4.87E-45	3.81	7.62E-47	1.19E-50	2.0E+01
0.25	2.21E+11	0.00	2.21E+11	DU	15.00	6.25E-49	3.81	9.79E-51	1.54E-54	2.1E+01
0.25	2.21E+11	0.00	2.21E+11	DU	16.00	8.07E-53	3.81	1.26E-54	1.99E-58	2.2E+01
0.25	2.21E+11	0.00	2.21E+11	DU	17.00	1.04E-56	3.81	1.63E-58	2.59E-62	2.4E+01
0.25	2.21E+11	0.00	2.21E+11	DU	18.00	1.35E-60	3.81	2.12E-62	3.39E-66	2.5E+01
0.25	2.21E+11	0.00	2.21E+11	DU	19.00	1.76E-64	3.81	2.76E-66	4.43E-70	2.6E+01
0.25	2.21E+11	0.00	2.21E+11	DU	20.00	2.30E-68	3.81	3.60E-70	5.81E-74	2.7E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	0.00	1.52E+10	0.00	1.52E+10	2.17E+06	3.0E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	3.00	2.00E+02	0.00	2.00E+02	2.92E-02	5.1E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	4.00	7.57E-01	0.00	7.57E-01	1.11E-04	5.8E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	5.00	2.93E-03	0.00	2.93E-03	4.33E-07	6.5E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	6.00	1.15E-05	0.00	1.15E-05	1.71E-09	7.3E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	7.00	4.57E-08	0.00	4.57E-08	6.83E-12	8.0E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	8.00	1.83E-10	0.00	1.83E-10	2.75E-14	8.7E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	9.00	7.36E-13	0.00	7.36E-13	1.12E-16	9.5E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	10.00	2.98E-15	0.00	2.98E-15	4.55E-19	1.0E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	11.00	1.21E-17	0.00	1.21E-17	1.86E-21	1.1E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	12.00	4.95E-20	0.00	4.95E-20	7.64E-24	1.2E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	13.00	2.03E-22	0.00	2.03E-22	3.15E-26	1.3E+01

0.25	2.21E+11	2.54	1.52E+10	LEAD	14.00	8.33E-25	0.00	8.33E-25	1.30E-28	1.3E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	15.00	3.43E-27	0.00	3.43E-27	5.38E-31	1.4E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	16.00	1.41E-29	0.00	1.41E-29	2.23E-33	1.5E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	17.00	5.84E-32	0.00	5.84E-32	9.28E-36	1.6E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	18.00	2.42E-34	0.00	2.42E-34	3.86E-38	1.7E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	19.00	1.00E-36	0.00	1.00E-36	1.61E-40	1.7E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	20.00	4.15E-39	0.00	4.15E-39	6.71E-43	1.8E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	0.00	1.52E+10	3.81	2.37E+08	3.39E+04	3.0E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	3.00	2.00E+02	3.81	3.13E+00	4.56E-04	5.1E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	4.00	7.57E-01	3.81	1.18E-02	1.74E-06	5.8E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	5.00	2.93E-03	3.81	4.58E-05	6.77E-09	6.5E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	6.00	1.15E-05	3.81	1.80E-07	2.68E-11	7.3E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	7.00	4.57E-08	3.81	7.14E-10	1.07E-13	8.0E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	8.00	1.83E-10	3.81	2.86E-12	4.31E-16	8.7E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	9.00	7.36E-13	3.81	1.15E-14	1.75E-18	9.5E+00
0.25	2.21E+11	2.54	1.52E+10	LEAD	10.00	2.98E-15	3.81	4.67E-17	7.12E-21	1.0E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	11.00	1.21E-17	3.81	1.90E-19	2.91E-23	1.1E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	12.00	4.95E-20	3.81	7.75E-22	1.20E-25	1.2E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	13.00	2.03E-22	3.81	3.17E-24	4.93E-28	1.3E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	14.00	8.33E-25	3.81	1.30E-26	2.04E-30	1.3E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	15.00	3.43E-27	3.81	5.36E-29	8.42E-33	1.4E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	16.00	1.41E-29	3.81	2.21E-31	3.49E-35	1.5E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	17.00	5.84E-32	3.81	9.14E-34	1.45E-37	1.6E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	18.00	2.42E-34	3.81	3.78E-36	6.04E-40	1.7E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	19.00	1.00E-36	3.81	1.57E-38	2.52E-42	1.7E+01
0.25	2.21E+11	2.54	1.52E+10	LEAD	20.00	4.15E-39	3.81	6.50E-41	1.05E-44	1.8E+01
0.25	2.21E+11	2.54	1.52E+10	DU	0.00	1.52E+10	0.00	1.52E+10	2.17E+06	3.0E+00
0.25	2.21E+11	2.54	1.52E+10	DU	3.00	4.09E-03	0.00	4.09E-03	5.97E-07	6.4E+00
0.25	2.21E+11	2.54	1.52E+10	DU	4.00	4.39E-07	0.00	4.39E-07	6.45E-11	7.5E+00
0.25	2.21E+11	2.54	1.52E+10	DU	5.00	4.96E-11	0.00	4.96E-11	7.33E-15	8.7E+00
0.25	2.21E+11	2.54	1.52E+10	DU	6.00	5.79E-15	0.00	5.79E-15	8.61E-19	9.9E+00
0.25	2.21E+11	2.54	1.52E+10	DU	7.00	6.92E-19	0.00	6.92E-19	1.04E-22	1.1E+01
0.25	2.21E+11	2.54	1.52E+10	DU	8.00	8.41E-23	0.00	8.41E-23	1.27E-26	1.2E+01
0.25	2.21E+11	2.54	1.52E+10	DU	9.00	1.04E-26	0.00	1.04E-26	1.57E-30	1.3E+01
0.25	2.21E+11	2.54	1.52E+10	DU	10.00	1.29E-30	0.00	1.29E-30	1.97E-34	1.5E+01
0.25	2.21E+11	2.54	1.52E+10	DU	11.00	1.62E-34	0.00	1.62E-34	2.49E-38	1.6E+01
0.25	2.21E+11	2.54	1.52E+10	DU	12.00	2.05E-38	0.00	2.05E-38	3.17E-42	1.7E+01
0.25	2.21E+11	2.54	1.52E+10	DU	13.00	2.61E-42	0.00	2.61E-42	4.05E-46	1.8E+01
0.25	2.21E+11	2.54	1.52E+10	DU	14.00	3.34E-46	0.00	3.34E-46	5.21E-50	2.0E+01
0.25	2.21E+11	2.54	1.52E+10	DU	15.00	4.29E-50	0.00	4.29E-50	6.74E-54	2.1E+01
0.25	2.21E+11	2.54	1.52E+10	DU	16.00	5.53E-54	0.00	5.53E-54	8.74E-58	2.2E+01
0.25	2.21E+11	2.54	1.52E+10	DU	17.00	7.16E-58	0.00	7.16E-58	1.14E-61	2.4E+01
0.25	2.21E+11	2.54	1.52E+10	DU	18.00	9.29E-62	0.00	9.29E-62	1.48E-65	2.5E+01
0.25	2.21E+11	2.54	1.52E+10	DU	19.00	1.21E-65	0.00	1.21E-65	1.94E-69	2.6E+01
0.25	2.21E+11	2.54	1.52E+10	DU	20.00	1.58E-69	0.00	1.58E-69	2.55E-73	2.7E+01
0.25	2.21E+11	2.54	1.52E+10	DU	0.00	1.52E+10	3.81	2.37E+08	3.39E+04	3.0E+00
0.25	2.21E+11	2.54	1.52E+10	DU	3.00	4.09E-03	3.81	6.41E-05	9.35E-09	6.4E+00
0.25	2.21E+11	2.54	1.52E+10	DU	4.00	4.39E-07	3.81	6.87E-09	1.01E-12	7.5E+00
0.25	2.21E+11	2.54	1.52E+10	DU	5.00	4.96E-11	3.81	7.76E-13	1.15E-16	8.7E+00
0.25	2.21E+11	2.54	1.52E+10	DU	6.00	5.79E-15	3.81	9.06E-17	1.35E-20	9.9E+00
0.25	2.21E+11	2.54	1.52E+10	DU	7.00	6.92E-19	3.81	1.08E-20	1.62E-24	1.1E+01
0.25	2.21E+11	2.54	1.52E+10	DU	8.00	8.41E-23	3.81	1.32E-24	1.98E-28	1.2E+01
0.25	2.21E+11	2.54	1.52E+10	DU	9.00	1.04E-26	3.81	1.62E-28	2.46E-32	1.3E+01
0.25	2.21E+11	2.54	1.52E+10	DU	10.00	1.29E-30	3.81	2.02E-32	3.08E-36	1.5E+01
0.25	2.21E+11	2.54	1.52E+10	DU	11.00	1.62E-34	3.81	2.54E-36	3.89E-40	1.6E+01
0.25	2.21E+11	2.54	1.52E+10	DU	12.00	2.05E-38	3.81	3.21E-40	4.95E-44	1.7E+01
0.25	2.21E+11	2.54	1.52E+10	DU	13.00	2.61E-42	3.81	4.08E-44	6.34E-48	1.8E+01
0.25	2.21E+11	2.54	1.52E+10	DU	14.00	3.34E-46	3.81	5.22E-48	8.16E-52	2.0E+01
0.25	2.21E+11	2.54	1.52E+10	DU	15.00	4.29E-50	3.81	6.71E-52	1.05E-55	2.1E+01
0.25	2.21E+11	2.54	1.52E+10	DU	16.00	5.53E-54	3.81	8.66E-56	1.37E-59	2.2E+01
0.25	2.21E+11	2.54	1.52E+10	DU	17.00	7.16E-58	3.81	1.12E-59	1.78E-63	2.4E+01
0.25	2.21E+11	2.54	1.52E+10	DU	18.00	9.29E-62	3.81	1.45E-63	2.32E-67	2.5E+01
0.25	2.21E+11	2.54	1.52E+10	DU	19.00	1.21E-65	3.81	1.89E-67	3.04E-71	2.6E+01
0.25	2.21E+11	2.54	1.52E+10	DU	20.00	1.58E-69	3.81	2.47E-71	3.99E-75	2.7E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	0.00	1.11E+11	0.00	1.11E+11	3.13E+07	3.0E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	3.00	1.16E+08	0.00	1.16E+08	3.35E+04	5.1E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	4.00	1.66E+07	0.00	1.66E+07	4.83E+03	5.8E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	5.00	2.44E+06	0.00	2.44E+06	7.16E+02	6.5E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	6.00	3.59E+05	0.00	3.59E+05	105.88	7.3E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	7.00	5.07E+04	0.00	5.07E+04	15.05	8.0E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	8.00	7.66E+03	0.00	7.66E+03	2.29	8.7E+00

0.50	1.11E+11	0.00	1.11E+11	LEAD	9.00	1.14E+03	0.00	1.14E+03	3.41E-01	9.5E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	10.00	1.69E+02	0.00	1.69E+02	5.10E-02	1.0E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	11.00	2.52E+01	0.00	2.52E+01	7.65E-03	1.1E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	12.00	3.76E+00	0.00	3.76E+00	1.15E-03	1.2E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	13.00	5.64E-01	0.00	5.64E-01	1.74E-04	1.3E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	14.00	8.47E-02	0.00	8.47E-02	2.62E-05	1.3E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	15.00	1.27E-02	0.00	1.27E-02	3.97E-06	1.4E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	16.00	1.92E-03	0.00	1.92E-03	6.01E-07	1.5E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	17.00	2.90E-04	0.00	2.90E-04	9.13E-08	1.6E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	18.00	4.38E-05	0.00	4.38E-05	1.39E-08	1.7E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	19.00	6.63E-06	0.00	6.63E-06	2.11E-09	1.7E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	20.00	1.01E-06	0.00	1.01E-06	3.22E-10	1.8E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	0.00	1.11E+11	3.81	9.72E+09	2.75E+06	3.0E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	3.00	1.16E+08	3.81	1.02E+07	2.95E+03	5.1E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	4.00	1.66E+07	3.81	1.46E+06	4.25E+02	5.8E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	5.00	2.44E+06	3.81	2.15E+05	62.95	6.5E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	6.00	3.59E+05	3.81	3.16E+04	9.31	7.3E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	7.00	5.07E+04	3.81	4.46E+03	1.32	8.0E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	8.00	7.66E+03	3.81	6.74E+02	2.01E-01	8.7E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	9.00	1.14E+03	3.81	9.98E+01	3.00E-02	9.5E+00
0.50	1.11E+11	0.00	1.11E+11	LEAD	10.00	1.69E+02	3.81	1.48E+01	4.48E-03	1.0E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	11.00	2.52E+01	3.81	2.21E+00	6.73E-04	1.1E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	12.00	3.76E+00	3.81	3.31E-01	1.01E-04	1.2E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	13.00	5.64E-01	3.81	4.96E-02	1.53E-05	1.3E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	14.00	8.47E-02	3.81	7.45E-03	2.31E-06	1.3E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	15.00	1.27E-02	3.81	1.12E-03	3.49E-07	1.4E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	16.00	1.92E-03	3.81	1.69E-04	5.29E-08	1.5E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	17.00	2.90E-04	3.81	2.55E-05	8.03E-09	1.6E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	18.00	4.38E-05	3.81	3.86E-06	1.22E-09	1.7E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	19.00	6.63E-06	3.81	5.83E-07	1.86E-10	1.7E+01
0.50	1.11E+11	0.00	1.11E+11	LEAD	20.00	1.01E-06	3.81	8.84E-08	2.83E-11	1.8E+01
0.50	1.11E+11	0.00	1.11E+11	DU	0.00	1.11E+11	0.00	1.11E+11	3.13E+07	3.0E+00
0.50	1.11E+11	0.00	1.11E+11	DU	3.00	3.30E+06	0.00	3.30E+06	9.53E+02	6.4E+00
0.50	1.11E+11	0.00	1.11E+11	DU	4.00	1.27E+05	0.00	1.27E+05	37.10	7.5E+00
0.50	1.11E+11	0.00	1.11E+11	DU	5.00	5.14E+03	0.00	5.14E+03	1.50	8.7E+00
0.50	1.11E+11	0.00	1.11E+11	DU	6.00	2.13E+02	0.00	2.13E+02	6.28E-02	9.9E+00
0.50	1.11E+11	0.00	1.11E+11	DU	7.00	9.02E+00	0.00	9.02E+00	2.68E-03	1.1E+01
0.50	1.11E+11	0.00	1.11E+11	DU	8.00	3.88E-01	0.00	3.88E-01	1.16E-04	1.2E+01
0.50	1.11E+11	0.00	1.11E+11	DU	9.00	1.69E-02	0.00	1.69E-02	5.07E-06	1.3E+01
0.50	1.11E+11	0.00	1.11E+11	DU	10.00	7.41E-04	0.00	7.41E-04	2.24E-07	1.5E+01
0.50	1.11E+11	0.00	1.11E+11	DU	11.00	3.28E-05	0.00	3.28E-05	9.97E-09	1.6E+01
0.50	1.11E+11	0.00	1.11E+11	DU	12.00	1.46E-06	0.00	1.46E-06	4.47E-10	1.7E+01
0.50	1.11E+11	0.00	1.11E+11	DU	13.00	6.55E-08	0.00	6.55E-08	2.01E-11	1.8E+01
0.50	1.11E+11	0.00	1.11E+11	DU	14.00	2.95E-09	0.00	2.95E-09	9.12E-13	2.0E+01
0.50	1.11E+11	0.00	1.11E+11	DU	15.00	1.33E-10	0.00	1.33E-10	4.15E-14	2.1E+01
0.50	1.11E+11	0.00	1.11E+11	DU	16.00	6.04E-12	0.00	6.04E-12	1.89E-15	2.2E+01
0.50	1.11E+11	0.00	1.11E+11	DU	17.00	2.75E-13	0.00	2.75E-13	8.66E-17	2.4E+01
0.50	1.11E+11	0.00	1.11E+11	DU	18.00	1.26E-14	0.00	1.26E-14	3.97E-18	2.5E+01
0.50	1.11E+11	0.00	1.11E+11	DU	19.00	5.74E-16	0.00	5.74E-16	1.83E-19	2.6E+01
0.50	1.11E+11	0.00	1.11E+11	DU	20.00	2.63E-17	0.00	2.63E-17	8.43E-21	2.7E+01
0.50	1.11E+11	0.00	1.11E+11	DU	0.00	1.11E+11	3.81	9.72E+09	2.75E+06	3.0E+00
0.50	1.11E+11	0.00	1.11E+11	DU	3.00	3.30E+06	3.81	2.90E+05	83.82	6.4E+00
0.50	1.11E+11	0.00	1.11E+11	DU	4.00	1.27E+05	3.81	1.12E+04	3.26	7.5E+00
0.50	1.11E+11	0.00	1.11E+11	DU	5.00	5.14E+03	3.81	4.52E+02	1.32E-01	8.7E+00
0.50	1.11E+11	0.00	1.11E+11	DU	6.00	2.13E+02	3.81	1.87E+01	5.53E-03	9.9E+00
0.50	1.11E+11	0.00	1.11E+11	DU	7.00	9.02E+00	3.81	7.94E-01	2.35E-04	1.1E+01
0.50	1.11E+11	0.00	1.11E+11	DU	8.00	3.88E-01	3.81	3.41E-02	1.02E-05	1.2E+01
0.50	1.11E+11	0.00	1.11E+11	DU	9.00	1.69E-02	3.81	1.48E-03	4.46E-07	1.3E+01
0.50	1.11E+11	0.00	1.11E+11	DU	10.00	7.41E-04	3.81	6.52E-05	1.97E-08	1.5E+01
0.50	1.11E+11	0.00	1.11E+11	DU	11.00	3.28E-05	3.81	2.89E-06	8.77E-10	1.6E+01
0.50	1.11E+11	0.00	1.11E+11	DU	12.00	1.46E-06	3.81	1.29E-07	3.93E-11	1.7E+01
0.50	1.11E+11	0.00	1.11E+11	DU	13.00	6.55E-08	3.81	5.76E-09	1.77E-12	1.8E+01
0.50	1.11E+11	0.00	1.11E+11	DU	14.00	2.95E-09	3.81	2.59E-10	8.02E-14	2.0E+01
0.50	1.11E+11	0.00	1.11E+11	DU	15.00	1.33E-10	3.81	1.17E-11	3.65E-15	2.1E+01
0.50	1.11E+11	0.00	1.11E+11	DU	16.00	6.04E-12	3.81	5.32E-13	1.66E-16	2.2E+01
0.50	1.11E+11	0.00	1.11E+11	DU	17.00	2.75E-13	3.81	2.42E-14	7.61E-18	2.4E+01
0.50	1.11E+11	0.00	1.11E+11	DU	18.00	1.26E-14	3.81	1.10E-15	3.49E-19	2.5E+01
0.50	1.11E+11	0.00	1.11E+11	DU	19.00	5.74E-16	3.81	5.05E-17	1.61E-20	2.6E+01
0.50	1.11E+11	0.00	1.11E+11	DU	20.00	2.63E-17	3.81	2.32E-18	7.41E-22	2.7E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	0.00	2.08E+10	0.00	2.08E+10	5.90E+06	3.0E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	3.00	2.18E+07	0.00	2.18E+07	6.31E+03	5.1E+00

0.50	1.11E+11	2.54	2.08E+10	LEAD	4.00	3.12E+06	0.00	3.12E+06	9.09E+02	5.8E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	5.00	4.60E+05	0.00	4.60E+05	134.78	6.5E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	6.00	6.76E+04	0.00	6.76E+04	19.94	7.3E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	7.00	9.55E+03	0.00	9.55E+03	2.83	8.0E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	8.00	1.44E+03	0.00	1.44E+03	4.31E-01	8.7E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	9.00	2.14E+02	0.00	2.14E+02	6.42E-02	9.5E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	10.00	3.18E+01	0.00	3.18E+01	9.60E-03	1.0E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	11.00	4.74E+00	0.00	4.74E+00	1.44E-03	1.1E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	12.00	7.08E-01	0.00	7.08E-01	2.17E-04	1.2E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	13.00	1.06E-01	0.00	1.06E-01	3.27E-05	1.3E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	14.00	1.59E-02	0.00	1.59E-02	4.94E-06	1.3E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	15.00	2.40E-03	0.00	2.40E-03	7.47E-07	1.4E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	16.00	3.62E-04	0.00	3.62E-04	1.13E-07	1.5E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	17.00	5.46E-05	0.00	5.46E-05	1.72E-08	1.6E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	18.00	8.25E-06	0.00	8.25E-06	2.61E-09	1.7E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	19.00	1.25E-06	0.00	1.25E-06	3.97E-10	1.7E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	20.00	1.89E-07	0.00	1.89E-07	6.05E-11	1.8E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	0.00	2.08E+10	3.81	1.83E+09	5.19E+05	3.0E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	3.00	2.18E+07	3.81	1.92E+06	5.55E+02	5.1E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	4.00	3.12E+06	3.81	2.75E+05	79.94	5.8E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	5.00	4.60E+05	3.81	4.05E+04	11.85	6.5E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	6.00	6.76E+04	3.81	5.95E+03	1.75	7.3E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	7.00	9.55E+03	3.81	8.40E+02	2.49E-01	8.0E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	8.00	1.44E+03	3.81	1.27E+02	3.79E-02	8.7E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	9.00	2.14E+02	3.81	1.88E+01	5.65E-03	9.5E+00
0.50	1.11E+11	2.54	2.08E+10	LEAD	10.00	3.18E+01	3.81	2.79E+00	8.44E-04	1.0E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	11.00	4.74E+00	3.81	4.17E-01	1.27E-04	1.1E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	12.00	7.08E-01	3.81	6.23E-02	1.91E-05	1.2E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	13.00	1.06E-01	3.81	9.34E-03	2.87E-06	1.3E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	14.00	1.59E-02	3.81	1.40E-03	4.34E-07	1.3E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	15.00	2.40E-03	3.81	2.11E-04	6.57E-08	1.4E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	16.00	3.62E-04	3.81	3.18E-05	9.96E-09	1.5E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	17.00	5.46E-05	3.81	4.80E-06	1.51E-09	1.6E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	18.00	8.25E-06	3.81	7.26E-07	2.30E-10	1.7E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	19.00	1.25E-06	3.81	1.10E-07	3.50E-11	1.7E+01
0.50	1.11E+11	2.54	2.08E+10	LEAD	20.00	1.89E-07	3.81	1.66E-08	5.32E-12	1.8E+01
0.50	1.11E+11	2.54	2.08E+10	DU	0.00	2.08E+10	0.00	2.08E+10	5.90E+06	3.0E+00
0.50	1.11E+11	2.54	2.08E+10	DU	3.00	6.21E+05	0.00	6.21E+05	179.46	6.4E+00
0.50	1.11E+11	2.54	2.08E+10	DU	4.00	2.40E+04	0.00	2.40E+04	6.99	7.5E+00
0.50	1.11E+11	2.54	2.08E+10	DU	5.00	9.67E+02	0.00	9.67E+02	2.83E-01	8.7E+00
0.50	1.11E+11	2.54	2.08E+10	DU	6.00	4.01E+01	0.00	4.01E+01	1.18E-02	9.9E+00
0.50	1.11E+11	2.54	2.08E+10	DU	7.00	1.70E+00	0.00	1.70E+00	5.04E-04	1.1E+01
0.50	1.11E+11	2.54	2.08E+10	DU	8.00	7.30E-02	0.00	7.30E-02	2.18E-05	1.2E+01
0.50	1.11E+11	2.54	2.08E+10	DU	9.00	3.18E-03	0.00	3.18E-03	9.54E-07	1.3E+01
0.50	1.11E+11	2.54	2.08E+10	DU	10.00	1.40E-04	0.00	1.40E-04	4.22E-08	1.5E+01
0.50	1.11E+11	2.54	2.08E+10	DU	11.00	6.18E-06	0.00	6.18E-06	1.88E-09	1.6E+01
0.50	1.11E+11	2.54	2.08E+10	DU	12.00	2.75E-07	0.00	2.75E-07	8.42E-11	1.7E+01
0.50	1.11E+11	2.54	2.08E+10	DU	13.00	1.23E-08	0.00	1.23E-08	3.79E-12	1.8E+01
0.50	1.11E+11	2.54	2.08E+10	DU	14.00	5.55E-10	0.00	5.55E-10	1.72E-13	2.0E+01
0.50	1.11E+11	2.54	2.08E+10	DU	15.00	2.51E-11	0.00	2.51E-11	7.81E-15	2.1E+01
0.50	1.11E+11	2.54	2.08E+10	DU	16.00	1.14E-12	0.00	1.14E-12	3.56E-16	2.2E+01
0.50	1.11E+11	2.54	2.08E+10	DU	17.00	5.18E-14	0.00	5.18E-14	1.63E-17	2.4E+01
0.50	1.11E+11	2.54	2.08E+10	DU	18.00	2.36E-15	0.00	2.36E-15	7.48E-19	2.5E+01
0.50	1.11E+11	2.54	2.08E+10	DU	19.00	1.08E-16	0.00	1.08E-16	3.44E-20	2.6E+01
0.50	1.11E+11	2.54	2.08E+10	DU	20.00	4.96E-18	0.00	4.96E-18	1.59E-21	2.7E+01
0.50	1.11E+11	2.54	2.08E+10	DU	0.00	2.08E+10	3.81	1.83E+09	5.19E+05	3.0E+00
0.50	1.11E+11	2.54	2.08E+10	DU	3.00	6.21E+05	3.81	5.46E+04	15.78	6.4E+00
0.50	1.11E+11	2.54	2.08E+10	DU	4.00	2.40E+04	3.81	2.11E+03	6.14E-01	7.5E+00
0.50	1.11E+11	2.54	2.08E+10	DU	5.00	9.67E+02	3.81	8.50E+01	2.49E-02	8.7E+00
0.50	1.11E+11	2.54	2.08E+10	DU	6.00	4.01E+01	3.81	3.53E+00	1.04E-03	9.9E+00
0.50	1.11E+11	2.54	2.08E+10	DU	7.00	1.70E+00	3.81	1.49E-01	4.43E-05	1.1E+01
0.50	1.11E+11	2.54	2.08E+10	DU	8.00	7.30E-02	3.81	6.42E-03	1.92E-06	1.2E+01
0.50	1.11E+11	2.54	2.08E+10	DU	9.00	3.18E-03	3.81	2.79E-04	8.39E-08	1.3E+01
0.50	1.11E+11	2.54	2.08E+10	DU	10.00	1.40E-04	3.81	1.23E-05	3.71E-09	1.5E+01
0.50	1.11E+11	2.54	2.08E+10	DU	11.00	6.18E-06	3.81	5.43E-07	1.65E-10	1.6E+01
0.50	1.11E+11	2.54	2.08E+10	DU	12.00	2.75E-07	3.81	2.42E-08	7.40E-12	1.7E+01
0.50	1.11E+11	2.54	2.08E+10	DU	13.00	1.23E-08	3.81	1.08E-09	3.34E-13	1.8E+01
0.50	1.11E+11	2.54	2.08E+10	DU	14.00	5.55E-10	3.81	4.88E-11	1.51E-14	2.0E+01
0.50	1.11E+11	2.54	2.08E+10	DU	15.00	2.51E-11	3.81	2.21E-12	6.87E-16	2.1E+01
0.50	1.11E+11	2.54	2.08E+10	DU	16.00	1.14E-12	3.81	1.00E-13	3.13E-17	2.2E+01
0.50	1.11E+11	2.54	2.08E+10	DU	17.00	5.18E-14	3.81	4.56E-15	1.43E-18	2.4E+01

0.50	1.11E+11	2.54	2.08E+10	DU	18.00	2.36E-15	3.81	2.08E-16	6.58E-20	2.5E+01
0.50	1.11E+11	2.54	2.08E+10	DU	19.00	1.08E-16	3.81	9.51E-18	3.03E-21	2.6E+01
0.50	1.11E+11	2.54	2.08E+10	DU	20.00	4.96E-18	3.81	4.36E-19	1.40E-22	2.7E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	0.00	7.39E+10	0.00	7.39E+10	3.11E+07	3.0E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	3.00	8.16E+08	0.00	8.16E+08	3.50E+05	5.1E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	4.00	2.35E+08	0.00	2.35E+08	1.01E+05	5.8E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	5.00	6.86E+07	0.00	6.86E+07	2.98E+04	6.5E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	6.00	2.04E+07	0.00	2.04E+07	8.94E+03	7.3E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	7.00	6.18E+06	0.00	6.18E+06	2.72E+03	8.0E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	8.00	1.88E+06	0.00	1.88E+06	8.33E+02	8.7E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	9.00	5.73E+05	0.00	5.73E+05	2.55E+02	9.5E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	10.00	1.73E+05	0.00	1.73E+05	77.41	1.0E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	11.00	5.11E+04	0.00	5.11E+04	23.05	1.1E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	12.00	1.47E+04	0.00	1.47E+04	6.67	1.2E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	13.00	4.79E+03	0.00	4.79E+03	2.19	1.3E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	14.00	1.46E+03	0.00	1.46E+03	6.71E-01	1.3E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	15.00	4.46E+02	0.00	4.46E+02	2.06E-01	1.4E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	16.00	1.36E+02	0.00	1.36E+02	6.33E-02	1.5E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	17.00	4.18E+01	0.00	4.18E+01	1.95E-02	1.6E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	18.00	1.28E+01	0.00	1.28E+01	6.01E-03	1.7E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	19.00	3.93E+00	0.00	3.93E+00	1.85E-03	1.7E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	20.00	1.21E+00	0.00	1.21E+00	5.72E-04	1.8E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	0.00	7.39E+10	3.81	1.01E+10	4.22E+06	3.0E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	3.00	8.16E+08	3.81	1.11E+08	4.76E+04	5.1E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	4.00	2.35E+08	3.81	3.19E+07	1.38E+04	5.8E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	5.00	6.86E+07	3.81	9.33E+06	4.05E+03	6.5E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	6.00	2.04E+07	3.81	2.78E+06	1.22E+03	7.3E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	7.00	6.18E+06	3.81	8.40E+05	3.70E+02	8.0E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	8.00	1.88E+06	3.81	2.56E+05	113.27	8.7E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	9.00	5.73E+05	3.81	7.79E+04	34.69	9.5E+00
0.75	7.39E+10	0.00	7.39E+10	LEAD	10.00	1.73E+05	3.81	2.35E+04	10.52	1.0E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	11.00	5.11E+04	3.81	6.95E+03	3.13	1.1E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	12.00	1.47E+04	3.81	2.00E+03	9.07E-01	1.2E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	13.00	4.79E+03	3.81	6.52E+02	2.97E-01	1.3E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	14.00	1.46E+03	3.81	1.99E+02	9.12E-02	1.3E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	15.00	4.46E+02	3.81	6.07E+01	2.80E-02	1.4E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	16.00	1.36E+02	3.81	1.85E+01	8.61E-03	1.5E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	17.00	4.18E+01	3.81	5.68E+00	2.65E-03	1.6E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	18.00	1.28E+01	3.81	1.74E+00	8.17E-04	1.7E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	19.00	3.93E+00	3.81	5.34E-01	2.52E-04	1.7E+01
0.75	7.39E+10	0.00	7.39E+10	LEAD	20.00	1.21E+00	3.81	1.64E-01	7.78E-05	1.8E+01
0.75	7.39E+10	0.00	7.39E+10	DU	0.00	7.39E+10	0.00	7.39E+10	3.11E+07	3.0E+00
0.75	7.39E+10	0.00	7.39E+10	DU	3.00	9.99E+07	0.00	9.99E+07	4.28E+04	6.4E+00
0.75	7.39E+10	0.00	7.39E+10	DU	4.00	1.24E+07	0.00	1.24E+07	5.37E+03	7.5E+00
0.75	7.39E+10	0.00	7.39E+10	DU	5.00	1.64E+06	0.00	1.64E+06	7.11E+02	8.7E+00
0.75	7.39E+10	0.00	7.39E+10	DU	6.00	2.18E+05	0.00	2.18E+05	95.19	9.9E+00
0.75	7.39E+10	0.00	7.39E+10	DU	7.00	2.80E+04	0.00	2.80E+04	12.34	1.1E+01
0.75	7.39E+10	0.00	7.39E+10	DU	8.00	3.95E+03	0.00	3.95E+03	1.75	1.2E+01
0.75	7.39E+10	0.00	7.39E+10	DU	9.00	5.45E+02	0.00	5.45E+02	2.43E-01	1.3E+01
0.75	7.39E+10	0.00	7.39E+10	DU	10.00	7.58E+01	0.00	7.58E+01	3.40E-02	1.5E+01
0.75	7.39E+10	0.00	7.39E+10	DU	11.00	1.06E+01	0.00	1.06E+01	4.79E-03	1.6E+01
0.75	7.39E+10	0.00	7.39E+10	DU	12.00	1.50E+00	0.00	1.50E+00	6.79E-04	1.7E+01
0.75	7.39E+10	0.00	7.39E+10	DU	13.00	2.12E-01	0.00	2.12E-01	9.68E-05	1.8E+01
0.75	7.39E+10	0.00	7.39E+10	DU	14.00	3.02E-02	0.00	3.02E-02	1.39E-05	2.0E+01
0.75	7.39E+10	0.00	7.39E+10	DU	15.00	4.32E-03	0.00	4.32E-03	1.99E-06	2.1E+01
0.75	7.39E+10	0.00	7.39E+10	DU	16.00	6.19E-04	0.00	6.19E-04	2.87E-07	2.2E+01
0.75	7.39E+10	0.00	7.39E+10	DU	17.00	8.90E-05	0.00	8.90E-05	4.15E-08	2.4E+01
0.75	7.39E+10	0.00	7.39E+10	DU	18.00	1.28E-05	0.00	1.28E-05	6.02E-09	2.5E+01
0.75	7.39E+10	0.00	7.39E+10	DU	19.00	1.86E-06	0.00	1.86E-06	8.75E-10	2.6E+01
0.75	7.39E+10	0.00	7.39E+10	DU	20.00	2.69E-07	0.00	2.69E-07	1.28E-10	2.7E+01
0.75	7.39E+10	0.00	7.39E+10	DU	0.00	7.39E+10	3.81	1.01E+10	4.22E+06	3.0E+00
0.75	7.39E+10	0.00	7.39E+10	DU	3.00	9.99E+07	3.81	1.36E+07	5.82E+03	6.4E+00
0.75	7.39E+10	0.00	7.39E+10	DU	4.00	1.24E+07	3.81	1.69E+06	7.30E+02	7.5E+00
0.75	7.39E+10	0.00	7.39E+10	DU	5.00	1.64E+06	3.81	2.22E+05	96.64	8.7E+00
0.75	7.39E+10	0.00	7.39E+10	DU	6.00	2.18E+05	3.81	2.96E+04	12.94	9.9E+00
0.75	7.39E+10	0.00	7.39E+10	DU	7.00	2.80E+04	3.81	3.81E+03	1.68	1.1E+01
0.75	7.39E+10	0.00	7.39E+10	DU	8.00	3.95E+03	3.81	5.37E+02	2.38E-01	1.2E+01
0.75	7.39E+10	0.00	7.39E+10	DU	9.00	5.45E+02	3.81	7.41E+01	3.30E-02	1.3E+01
0.75	7.39E+10	0.00	7.39E+10	DU	10.00	7.58E+01	3.81	1.03E+01	4.62E-03	1.5E+01
0.75	7.39E+10	0.00	7.39E+10	DU	11.00	1.06E+01	3.81	1.44E+00	6.51E-04	1.6E+01
0.75	7.39E+10	0.00	7.39E+10	DU	12.00	1.50E+00	3.81	2.04E-01	9.23E-05	1.7E+01

0.75	7.39E+10	0.00	7.39E+10	DU	13.00	2.12E-01	3.81	2.88E-02	1.32E-05	1.8E+01
0.75	7.39E+10	0.00	7.39E+10	DU	14.00	3.02E-02	3.81	4.11E-03	1.88E-06	2.0E+01
0.75	7.39E+10	0.00	7.39E+10	DU	15.00	4.32E-03	3.81	5.87E-04	2.71E-07	2.1E+01
0.75	7.39E+10	0.00	7.39E+10	DU	16.00	6.19E-04	3.81	8.41E-05	3.90E-08	2.2E+01
0.75	7.39E+10	0.00	7.39E+10	DU	17.00	8.90E-05	3.81	1.21E-05	5.65E-09	2.4E+01
0.75	7.39E+10	0.00	7.39E+10	DU	18.00	1.28E-05	3.81	1.74E-06	8.19E-10	2.5E+01
0.75	7.39E+10	0.00	7.39E+10	DU	19.00	1.86E-06	3.81	2.52E-07	1.19E-10	2.6E+01
0.75	7.39E+10	0.00	7.39E+10	DU	20.00	2.69E-07	3.81	3.65E-08	1.73E-11	2.7E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	0.00	1.70E+10	0.00	1.70E+10	7.13E+06	3.0E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	3.00	1.87E+08	0.00	1.87E+08	8.04E+04	5.1E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	4.00	5.39E+07	0.00	5.39E+07	2.33E+04	5.8E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	5.00	1.58E+07	0.00	1.58E+07	6.85E+03	6.5E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	6.00	4.70E+06	0.00	4.70E+06	2.05E+03	7.3E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	7.00	1.42E+06	0.00	1.42E+06	6.25E+02	8.0E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	8.00	4.32E+05	0.00	4.32E+05	191.37	8.7E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	9.00	1.32E+05	0.00	1.32E+05	58.60	9.5E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	10.00	3.97E+04	0.00	3.97E+04	17.78	1.0E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	11.00	1.17E+04	0.00	1.17E+04	5.29	1.1E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	12.00	3.38E+03	0.00	3.38E+03	1.53	1.2E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	13.00	1.10E+03	0.00	1.10E+03	5.02E-01	1.3E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	14.00	3.36E+02	0.00	3.36E+02	1.54E-01	1.3E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	15.00	1.02E+02	0.00	1.02E+02	4.73E-02	1.4E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	16.00	3.13E+01	0.00	3.13E+01	1.45E-02	1.5E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	17.00	9.59E+00	0.00	9.59E+00	4.48E-03	1.6E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	18.00	2.94E+00	0.00	2.94E+00	1.38E-03	1.7E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	19.00	9.02E-01	0.00	9.02E-01	4.26E-04	1.7E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	20.00	2.77E-01	0.00	2.77E-01	1.31E-04	1.8E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	0.00	1.70E+10	3.81	2.31E+09	9.70E+05	3.0E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	3.00	1.87E+08	3.81	2.55E+07	1.09E+04	5.1E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	4.00	5.39E+07	3.81	7.33E+06	3.16E+03	5.8E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	5.00	1.58E+07	3.81	2.14E+06	9.31E+02	6.5E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	6.00	4.70E+06	3.81	6.39E+05	2.79E+02	7.3E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	7.00	1.42E+06	3.81	1.93E+05	84.91	8.0E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	8.00	4.32E+05	3.81	5.88E+04	26.02	8.7E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	9.00	1.32E+05	3.81	1.79E+04	7.97	9.5E+00
0.75	7.39E+10	2.54	1.70E+10	LEAD	10.00	3.97E+04	3.81	5.39E+03	2.42	1.0E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	11.00	1.17E+04	3.81	1.60E+03	7.20E-01	1.1E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	12.00	3.38E+03	3.81	4.59E+02	2.08E-01	1.2E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	13.00	1.10E+03	3.81	1.50E+02	6.83E-02	1.3E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	14.00	3.36E+02	3.81	4.56E+01	2.09E-02	1.3E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	15.00	1.02E+02	3.81	1.39E+01	6.43E-03	1.4E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	16.00	3.13E+01	3.81	4.26E+00	1.98E-03	1.5E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	17.00	9.59E+00	3.81	1.30E+00	6.09E-04	1.6E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	18.00	2.94E+00	3.81	4.00E-01	1.88E-04	1.7E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	19.00	9.02E-01	3.81	1.23E-01	5.79E-05	1.7E+01
0.75	7.39E+10	2.54	1.70E+10	LEAD	20.00	2.77E-01	3.81	3.77E-02	1.79E-05	1.8E+01
0.75	7.39E+10	2.54	1.70E+10	DU	0.00	1.70E+10	0.00	1.70E+10	7.13E+06	3.0E+00
0.75	7.39E+10	2.54	1.70E+10	DU	3.00	2.30E+07	0.00	2.30E+07	9.84E+03	6.4E+00
0.75	7.39E+10	2.54	1.70E+10	DU	4.00	2.86E+06	0.00	2.86E+06	1.23E+03	7.5E+00
0.75	7.39E+10	2.54	1.70E+10	DU	5.00	3.76E+05	0.00	3.76E+05	163.26	8.7E+00
0.75	7.39E+10	2.54	1.70E+10	DU	6.00	5.00E+04	0.00	5.00E+04	21.86	9.9E+00
0.75	7.39E+10	2.54	1.70E+10	DU	7.00	6.44E+03	0.00	6.44E+03	2.83	1.1E+01
0.75	7.39E+10	2.54	1.70E+10	DU	8.00	9.07E+02	0.00	9.07E+02	4.02E-01	1.2E+01
0.75	7.39E+10	2.54	1.70E+10	DU	9.00	1.25E+02	0.00	1.25E+02	5.57E-02	1.3E+01
0.75	7.39E+10	2.54	1.70E+10	DU	10.00	1.74E+01	0.00	1.74E+01	7.80E-03	1.5E+01
0.75	7.39E+10	2.54	1.70E+10	DU	11.00	2.44E+00	0.00	2.44E+00	1.10E-03	1.6E+01
0.75	7.39E+10	2.54	1.70E+10	DU	12.00	3.44E-01	0.00	3.44E-01	1.56E-04	1.7E+01
0.75	7.39E+10	2.54	1.70E+10	DU	13.00	4.87E-02	0.00	4.87E-02	2.22E-05	1.8E+01
0.75	7.39E+10	2.54	1.70E+10	DU	14.00	6.94E-03	0.00	6.94E-03	3.18E-06	2.0E+01
0.75	7.39E+10	2.54	1.70E+10	DU	15.00	9.91E-04	0.00	9.91E-04	4.57E-07	2.1E+01
0.75	7.39E+10	2.54	1.70E+10	DU	16.00	1.42E-04	0.00	1.42E-04	6.60E-08	2.2E+01
0.75	7.39E+10	2.54	1.70E+10	DU	17.00	2.04E-05	0.00	2.04E-05	9.54E-09	2.4E+01
0.75	7.39E+10	2.54	1.70E+10	DU	18.00	2.95E-06	0.00	2.95E-06	1.38E-09	2.5E+01
0.75	7.39E+10	2.54	1.70E+10	DU	19.00	4.26E-07	0.00	4.26E-07	2.01E-10	2.6E+01
0.75	7.39E+10	2.54	1.70E+10	DU	20.00	6.17E-08	0.00	6.17E-08	2.93E-11	2.7E+01
0.75	7.39E+10	2.54	1.70E+10	DU	0.00	1.70E+10	3.81	2.31E+09	9.70E+05	3.0E+00
0.75	7.39E+10	2.54	1.70E+10	DU	3.00	2.30E+07	3.81	3.12E+06	1.34E+03	6.4E+00
0.75	7.39E+10	2.54	1.70E+10	DU	4.00	2.86E+06	3.81	3.89E+05	167.67	7.5E+00
0.75	7.39E+10	2.54	1.70E+10	DU	5.00	3.76E+05	3.81	5.11E+04	22.20	8.7E+00
0.75	7.39E+10	2.54	1.70E+10	DU	6.00	5.00E+04	3.81	6.80E+03	2.97	9.9E+00
0.75	7.39E+10	2.54	1.70E+10	DU	7.00	6.44E+03	3.81	8.76E+02	3.85E-01	1.1E+01

0.75	7.39E+10	2.54	1.70E+10	DU	8.00	9.07E+02	3.81	1.23E+02	5.46E-02	1.2E+01
0.75	7.39E+10	2.54	1.70E+10	DU	9.00	1.25E+02	3.81	1.70E+01	7.58E-03	1.3E+01
0.75	7.39E+10	2.54	1.70E+10	DU	10.00	1.74E+01	3.81	2.37E+00	1.06E-03	1.5E+01
0.75	7.39E+10	2.54	1.70E+10	DU	11.00	2.44E+00	3.81	3.32E-01	1.50E-04	1.6E+01
0.75	7.39E+10	2.54	1.70E+10	DU	12.00	3.44E-01	3.81	4.68E-02	2.12E-05	1.7E+01
0.75	7.39E+10	2.54	1.70E+10	DU	13.00	4.87E-02	3.81	6.63E-03	3.02E-06	1.8E+01
0.75	7.39E+10	2.54	1.70E+10	DU	14.00	6.94E-03	3.81	9.43E-04	4.33E-07	2.0E+01
0.75	7.39E+10	2.54	1.70E+10	DU	15.00	9.91E-04	3.81	1.35E-04	6.22E-08	2.1E+01
0.75	7.39E+10	2.54	1.70E+10	DU	16.00	1.42E-04	3.81	1.93E-05	8.97E-09	2.2E+01
0.75	7.39E+10	2.54	1.70E+10	DU	17.00	2.04E-05	3.81	2.78E-06	1.30E-09	2.4E+01
0.75	7.39E+10	2.54	1.70E+10	DU	18.00	2.95E-06	3.81	4.01E-07	1.88E-10	2.5E+01
0.75	7.39E+10	2.54	1.70E+10	DU	19.00	4.26E-07	3.81	5.79E-08	2.73E-11	2.6E+01
0.75	7.39E+10	2.54	1.70E+10	DU	20.00	6.17E-08	3.81	8.39E-09	3.98E-12	2.7E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	0.00	5.58E+10	0.00	5.58E+10	3.08E+07	3.0E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	3.00	1.71E+09	0.00	1.71E+09	9.65E+05	5.1E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	4.00	6.75E+08	0.00	6.75E+08	3.83E+05	5.8E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	5.00	2.66E+08	0.00	2.66E+08	1.52E+05	6.5E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	6.00	1.06E+08	0.00	1.06E+08	6.09E+04	7.3E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	7.00	4.26E+07	0.00	4.26E+07	2.47E+04	8.0E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	8.00	1.73E+07	0.00	1.73E+07	1.01E+04	8.7E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	9.00	7.09E+06	0.00	7.09E+06	4.15E+03	9.5E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	10.00	2.92E+06	0.00	2.92E+06	1.72E+03	1.0E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	11.00	1.20E+06	0.00	1.20E+06	7.14E+02	1.1E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	12.00	4.97E+05	0.00	4.97E+05	2.96E+02	1.2E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	13.00	2.04E+05	0.00	2.04E+05	122.22	1.3E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	14.00	8.28E+04	0.00	8.28E+04	50.00	1.3E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	15.00	3.33E+04	0.00	3.33E+04	20.20	1.4E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	16.00	1.31E+04	0.00	1.31E+04	8.02	1.5E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	17.00	5.76E+03	0.00	5.76E+03	3.54	1.6E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	18.00	2.38E+03	0.00	2.38E+03	1.47	1.7E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	19.00	9.82E+02	0.00	9.82E+02	6.10E-01	1.7E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	20.00	4.06E+02	0.00	4.06E+02	2.53E-01	1.8E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	0.00	5.58E+10	3.81	8.74E+09	4.83E+06	3.0E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	3.00	1.71E+09	3.81	2.68E+08	1.51E+05	5.1E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	4.00	6.75E+08	3.81	1.06E+08	6.00E+04	5.8E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	5.00	2.66E+08	3.81	4.17E+07	2.38E+04	6.5E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	6.00	1.06E+08	3.81	1.66E+07	9.54E+03	7.3E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	7.00	4.26E+07	3.81	6.67E+06	3.86E+03	8.0E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	8.00	1.73E+07	3.81	2.71E+06	1.58E+03	8.7E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	9.00	7.09E+06	3.81	1.11E+06	6.50E+02	9.5E+00
1.00	5.58E+10	0.00	5.58E+10	LEAD	10.00	2.92E+06	3.81	4.57E+05	2.69E+02	1.0E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	11.00	1.20E+06	3.81	1.89E+05	111.85	1.1E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	12.00	4.97E+05	3.81	7.78E+04	46.38	1.2E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	13.00	2.04E+05	3.81	3.19E+04	19.14	1.3E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	14.00	8.28E+04	3.81	1.30E+04	7.83	1.3E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	15.00	3.33E+04	3.81	5.21E+03	3.16	1.4E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	16.00	1.31E+04	3.81	2.06E+03	1.26	1.5E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	17.00	5.76E+03	3.81	9.03E+02	5.54E-01	1.6E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	18.00	2.38E+03	3.81	3.72E+02	2.30E-01	1.7E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	19.00	9.82E+02	3.81	1.54E+02	9.55E-02	1.7E+01
1.00	5.58E+10	0.00	5.58E+10	LEAD	20.00	4.06E+02	3.81	6.36E+01	3.97E-02	1.8E+01
1.00	5.58E+10	0.00	5.58E+10	DU	0.00	5.58E+10	0.00	5.58E+10	3.08E+07	3.0E+00
1.00	5.58E+10	0.00	5.58E+10	DU	3.00	4.11E+08	0.00	4.11E+08	2.32E+05	6.4E+00
1.00	5.58E+10	0.00	5.58E+10	DU	4.00	8.19E+07	0.00	8.19E+07	4.65E+04	7.5E+00
1.00	5.58E+10	0.00	5.58E+10	DU	5.00	1.72E+07	0.00	1.72E+07	9.84E+03	8.7E+00
1.00	5.58E+10	0.00	5.58E+10	DU	6.00	3.76E+06	0.00	3.76E+06	2.16E+03	9.9E+00
1.00	5.58E+10	0.00	5.58E+10	DU	7.00	8.36E+05	0.00	8.36E+05	4.84E+02	1.1E+01
1.00	5.58E+10	0.00	5.58E+10	DU	8.00	1.86E+05	0.00	1.86E+05	108.37	1.2E+01
1.00	5.58E+10	0.00	5.58E+10	DU	9.00	4.07E+04	0.00	4.07E+04	23.87	1.3E+01
1.00	5.58E+10	0.00	5.58E+10	DU	10.00	9.31E+03	0.00	9.31E+03	5.49	1.5E+01
1.00	5.58E+10	0.00	5.58E+10	DU	11.00	2.12E+03	0.00	2.12E+03	1.26	1.6E+01
1.00	5.58E+10	0.00	5.58E+10	DU	12.00	4.85E+02	0.00	4.85E+02	2.89E-01	1.7E+01
1.00	5.58E+10	0.00	5.58E+10	DU	13.00	1.11E+02	0.00	1.11E+02	6.69E-02	1.8E+01
1.00	5.58E+10	0.00	5.58E+10	DU	14.00	2.57E+01	0.00	2.57E+01	1.55E-02	2.0E+01
1.00	5.58E+10	0.00	5.58E+10	DU	15.00	5.96E+00	0.00	5.96E+00	3.62E-03	2.1E+01
1.00	5.58E+10	0.00	5.58E+10	DU	16.00	1.39E+00	0.00	1.39E+00	8.46E-04	2.2E+01
1.00	5.58E+10	0.00	5.58E+10	DU	17.00	3.23E-01	0.00	3.23E-01	1.98E-04	2.4E+01
1.00	5.58E+10	0.00	5.58E+10	DU	18.00	7.56E-02	0.00	7.56E-02	4.67E-05	2.5E+01
1.00	5.58E+10	0.00	5.58E+10	DU	19.00	1.77E-02	0.00	1.77E-02	1.10E-05	2.6E+01
1.00	5.58E+10	0.00	5.58E+10	DU	20.00	4.16E-03	0.00	4.16E-03	2.59E-06	2.7E+01
1.00	5.58E+10	0.00	5.58E+10	DU	0.00	5.58E+10	3.81	8.74E+09	4.83E+06	3.0E+00

1.00	5.58E+10	0.00	5.58E+10	DU	3.00	4.11E+08	3.81	6.43E+07	3.63E+04	6.4E+00
1.00	5.58E+10	0.00	5.58E+10	DU	4.00	8.19E+07	3.81	1.28E+07	7.28E+03	7.5E+00
1.00	5.58E+10	0.00	5.58E+10	DU	5.00	1.72E+07	3.81	2.70E+06	1.54E+03	8.7E+00
1.00	5.58E+10	0.00	5.58E+10	DU	6.00	3.76E+06	3.81	5.89E+05	3.38E+02	9.9E+00
1.00	5.58E+10	0.00	5.58E+10	DU	7.00	8.36E+05	3.81	1.31E+05	75.73	1.1E+01
1.00	5.58E+10	0.00	5.58E+10	DU	8.00	1.86E+05	3.81	2.91E+04	16.97	1.2E+01
1.00	5.58E+10	0.00	5.58E+10	DU	9.00	4.07E+04	3.81	6.38E+03	3.74	1.3E+01
1.00	5.58E+10	0.00	5.58E+10	DU	10.00	9.31E+03	3.81	1.46E+03	8.59E-01	1.5E+01
1.00	5.58E+10	0.00	5.58E+10	DU	11.00	2.12E+03	3.81	3.32E+02	1.97E-01	1.6E+01
1.00	5.58E+10	0.00	5.58E+10	DU	12.00	4.85E+02	3.81	7.59E+01	4.53E-02	1.7E+01
1.00	5.58E+10	0.00	5.58E+10	DU	13.00	1.11E+02	3.81	1.75E+01	1.05E-02	1.8E+01
1.00	5.58E+10	0.00	5.58E+10	DU	14.00	2.57E+01	3.81	4.03E+00	2.43E-03	2.0E+01
1.00	5.58E+10	0.00	5.58E+10	DU	15.00	5.96E+00	3.81	9.34E-01	5.67E-04	2.1E+01
1.00	5.58E+10	0.00	5.58E+10	DU	16.00	1.39E+00	3.81	2.17E-01	1.33E-04	2.2E+01
1.00	5.58E+10	0.00	5.58E+10	DU	17.00	3.23E-01	3.81	5.06E-02	3.11E-05	2.4E+01
1.00	5.58E+10	0.00	5.58E+10	DU	18.00	7.56E-02	3.81	1.18E-02	7.31E-06	2.5E+01
1.00	5.58E+10	0.00	5.58E+10	DU	19.00	1.77E-02	3.81	2.77E-03	1.72E-06	2.6E+01
1.00	5.58E+10	0.00	5.58E+10	DU	20.00	4.16E-03	3.81	6.51E-04	4.06E-07	2.7E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	0.00	1.33E+10	0.00	1.33E+10	7.34E+06	3.0E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	3.00	4.07E+08	0.00	4.07E+08	2.30E+05	5.1E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	4.00	1.61E+08	0.00	1.61E+08	9.11E+04	5.8E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	5.00	6.34E+07	0.00	6.34E+07	3.62E+04	6.5E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	6.00	2.52E+07	0.00	2.52E+07	1.45E+04	7.3E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	7.00	1.01E+07	0.00	1.01E+07	5.87E+03	8.0E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	8.00	4.12E+06	0.00	4.12E+06	2.40E+03	8.7E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	9.00	1.69E+06	0.00	1.69E+06	9.89E+02	9.5E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	10.00	6.95E+05	0.00	6.95E+05	4.10E+02	1.0E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	11.00	2.87E+05	0.00	2.87E+05	170.03	1.1E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	12.00	1.18E+05	0.00	1.18E+05	70.51	1.2E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	13.00	4.85E+04	0.00	4.85E+04	29.10	1.3E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	14.00	1.97E+04	0.00	1.97E+04	11.90	1.3E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	15.00	7.92E+03	0.00	7.92E+03	4.81	1.4E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	16.00	3.13E+03	0.00	3.13E+03	1.91	1.5E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	17.00	1.37E+03	0.00	1.37E+03	8.42E-01	1.6E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	18.00	5.66E+02	0.00	5.66E+02	3.49E-01	1.7E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	19.00	2.34E+02	0.00	2.34E+02	1.45E-01	1.7E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	20.00	9.66E+01	0.00	9.66E+01	6.03E-02	1.8E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	0.00	1.33E+10	3.81	2.08E+09	1.15E+06	3.0E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	3.00	4.07E+08	3.81	6.38E+07	3.60E+04	5.1E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	4.00	1.61E+08	3.81	2.51E+07	1.43E+04	5.8E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	5.00	6.34E+07	3.81	9.92E+06	5.67E+03	6.5E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	6.00	2.52E+07	3.81	3.95E+06	2.27E+03	7.3E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	7.00	1.01E+07	3.81	1.59E+06	9.19E+02	8.0E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	8.00	4.12E+06	3.81	6.45E+05	3.76E+02	8.7E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	9.00	1.69E+06	3.81	2.64E+05	154.79	9.5E+00
1.00	5.58E+10	2.54	1.33E+10	LEAD	10.00	6.95E+05	3.81	1.09E+05	64.13	1.0E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	11.00	2.87E+05	3.81	4.49E+04	26.63	1.1E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	12.00	1.18E+05	3.81	1.85E+04	11.04	1.2E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	13.00	4.85E+04	3.81	7.59E+03	4.56	1.3E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	14.00	1.97E+04	3.81	3.09E+03	1.86	1.3E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	15.00	7.92E+03	3.81	1.24E+03	7.53E-01	1.4E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	16.00	3.13E+03	3.81	4.90E+02	2.99E-01	1.5E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	17.00	1.37E+03	3.81	2.15E+02	1.32E-01	1.6E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	18.00	5.66E+02	3.81	8.87E+01	5.47E-02	1.7E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	19.00	2.34E+02	3.81	3.66E+01	2.27E-02	1.7E+01
1.00	5.58E+10	2.54	1.33E+10	LEAD	20.00	9.66E+01	3.81	1.51E+01	9.44E-03	1.8E+01
1.00	5.58E+10	2.54	1.33E+10	DU	0.00	1.33E+10	0.00	1.33E+10	7.34E+06	3.0E+00
1.00	5.58E+10	2.54	1.33E+10	DU	3.00	9.78E+07	0.00	9.78E+07	5.51E+04	6.4E+00
1.00	5.58E+10	2.54	1.33E+10	DU	4.00	1.95E+07	0.00	1.95E+07	1.11E+04	7.5E+00
1.00	5.58E+10	2.54	1.33E+10	DU	5.00	4.10E+06	0.00	4.10E+06	2.34E+03	8.7E+00
1.00	5.58E+10	2.54	1.33E+10	DU	6.00	8.95E+05	0.00	8.95E+05	5.14E+02	9.9E+00
1.00	5.58E+10	2.54	1.33E+10	DU	7.00	1.99E+05	0.00	1.99E+05	115.14	1.1E+01
1.00	5.58E+10	2.54	1.33E+10	DU	8.00	4.43E+04	0.00	4.43E+04	25.80	1.2E+01
1.00	5.58E+10	2.54	1.33E+10	DU	9.00	9.70E+03	0.00	9.70E+03	5.68	1.3E+01
1.00	5.58E+10	2.54	1.33E+10	DU	10.00	2.22E+03	0.00	2.22E+03	1.31	1.5E+01
1.00	5.58E+10	2.54	1.33E+10	DU	11.00	5.04E+02	0.00	5.04E+02	2.99E-01	1.6E+01
1.00	5.58E+10	2.54	1.33E+10	DU	12.00	1.15E+02	0.00	1.15E+02	6.88E-02	1.7E+01
1.00	5.58E+10	2.54	1.33E+10	DU	13.00	2.65E+01	0.00	2.65E+01	1.59E-02	1.8E+01
1.00	5.58E+10	2.54	1.33E+10	DU	14.00	6.13E+00	0.00	6.13E+00	3.70E-03	2.0E+01
1.00	5.58E+10	2.54	1.33E+10	DU	15.00	1.42E+00	0.00	1.42E+00	8.62E-04	2.1E+01
1.00	5.58E+10	2.54	1.33E+10	DU	16.00	3.30E-01	0.00	3.30E-01	2.01E-04	2.2E+01

1.00	5.58E+10	2.54	1.33E+10	DU	17.00	7.70E-02	0.00	7.70E-02	4.72E-05	2.4E+01
1.00	5.58E+10	2.54	1.33E+10	DU	18.00	1.80E-02	0.00	1.80E-02	1.11E-05	2.5E+01
1.00	5.58E+10	2.54	1.33E+10	DU	19.00	4.22E-03	0.00	4.22E-03	2.62E-06	2.6E+01
1.00	5.58E+10	2.54	1.33E+10	DU	20.00	9.90E-04	0.00	9.90E-04	6.18E-07	2.7E+01
1.00	5.58E+10	2.54	1.33E+10	DU	0.00	1.33E+10	3.81	2.08E+09	1.15E+06	3.0E+00
1.00	5.58E+10	2.54	1.33E+10	DU	3.00	9.78E+07	3.81	1.53E+07	8.63E+03	6.4E+00
1.00	5.58E+10	2.54	1.33E+10	DU	4.00	1.95E+07	3.81	3.05E+06	1.73E+03	7.5E+00
1.00	5.58E+10	2.54	1.33E+10	DU	5.00	4.10E+06	3.81	6.42E+05	3.67E+02	8.7E+00
1.00	5.58E+10	2.54	1.33E+10	DU	6.00	8.95E+05	3.81	1.40E+05	80.55	9.9E+00
1.00	5.58E+10	2.54	1.33E+10	DU	7.00	1.99E+05	3.81	3.12E+04	18.03	1.1E+01
1.00	5.58E+10	2.54	1.33E+10	DU	8.00	4.43E+04	3.81	6.94E+03	4.04	1.2E+01
1.00	5.58E+10	2.54	1.33E+10	DU	9.00	9.70E+03	3.81	1.52E+03	8.90E-01	1.3E+01
1.00	5.58E+10	2.54	1.33E+10	DU	10.00	2.22E+03	3.81	3.47E+02	2.05E-01	1.5E+01
1.00	5.58E+10	2.54	1.33E+10	DU	11.00	5.04E+02	3.81	7.90E+01	4.68E-02	1.6E+01
1.00	5.58E+10	2.54	1.33E+10	DU	12.00	1.15E+02	3.81	1.81E+01	1.08E-02	1.7E+01
1.00	5.58E+10	2.54	1.33E+10	DU	13.00	2.65E+01	3.81	4.15E+00	2.49E-03	1.8E+01
1.00	5.58E+10	2.54	1.33E+10	DU	14.00	6.13E+00	3.81	9.59E-01	5.79E-04	2.0E+01
1.00	5.58E+10	2.54	1.33E+10	DU	15.00	1.42E+00	3.81	2.22E-01	1.35E-04	2.1E+01
1.00	5.58E+10	2.54	1.33E+10	DU	16.00	3.30E-01	3.81	5.17E-02	3.16E-05	2.2E+01
1.00	5.58E+10	2.54	1.33E+10	DU	17.00	7.70E-02	3.81	1.21E-02	7.40E-06	2.4E+01
1.00	5.58E+10	2.54	1.33E+10	DU	18.00	1.80E-02	3.81	2.82E-03	1.74E-06	2.5E+01
1.00	5.58E+10	2.54	1.33E+10	DU	19.00	4.22E-03	3.81	6.60E-04	4.10E-07	2.6E+01
1.00	5.58E+10	2.54	1.33E+10	DU	20.00	9.90E-04	3.81	1.55E-04	9.67E-08	2.7E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	0.00	4.51E+10	0.00	4.51E+10	3.06E+07	3.0E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	3.00	2.45E+09	0.00	2.45E+09	1.70E+06	5.1E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	4.00	1.16E+09	0.00	1.16E+09	8.12E+05	5.8E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	5.00	5.47E+08	0.00	5.47E+08	3.84E+05	6.5E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	6.00	2.57E+08	0.00	2.57E+08	1.82E+05	7.3E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	7.00	1.22E+08	0.00	1.22E+08	8.67E+04	8.0E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	8.00	5.80E+07	0.00	5.80E+07	4.15E+04	8.7E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	9.00	2.78E+07	0.00	2.78E+07	2.01E+04	9.5E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	10.00	1.34E+07	0.00	1.34E+07	9.74E+03	1.0E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	11.00	6.52E+06	0.00	6.52E+06	4.75E+03	1.1E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	12.00	3.18E+06	0.00	3.18E+06	2.33E+03	1.2E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	13.00	1.55E+06	0.00	1.55E+06	1.14E+03	1.3E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	14.00	7.57E+05	0.00	7.57E+05	5.62E+02	1.3E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	15.00	3.69E+05	0.00	3.69E+05	2.75E+02	1.4E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	16.00	1.79E+05	0.00	1.79E+05	134.50	1.5E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	17.00	8.65E+04	0.00	8.65E+04	65.33	1.6E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	18.00	4.15E+04	0.00	4.15E+04	31.49	1.7E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	19.00	1.97E+04	0.00	1.97E+04	15.03	1.7E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	20.00	9.24E+03	0.00	9.24E+03	7.09	1.8E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	0.00	4.51E+10	3.81	7.33E+09	4.98E+06	3.0E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	3.00	2.45E+09	3.81	3.99E+08	2.77E+05	5.1E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	4.00	1.16E+09	3.81	1.89E+08	1.32E+05	5.8E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	5.00	5.47E+08	3.81	8.89E+07	6.25E+04	6.5E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	6.00	2.57E+08	3.81	4.18E+07	2.96E+04	7.3E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	7.00	1.22E+08	3.81	1.98E+07	1.41E+04	8.0E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	8.00	5.80E+07	3.81	9.43E+06	6.75E+03	8.7E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	9.00	2.78E+07	3.81	4.52E+06	3.26E+03	9.5E+00
1.25	4.51E+10	0.00	4.51E+10	LEAD	10.00	1.34E+07	3.81	2.18E+06	1.58E+03	1.0E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	11.00	6.52E+06	3.81	1.06E+06	7.73E+02	1.1E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	12.00	3.18E+06	3.81	5.16E+05	3.79E+02	1.2E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	13.00	1.55E+06	3.81	2.52E+05	185.93	1.3E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	14.00	7.57E+05	3.81	1.23E+05	91.30	1.3E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	15.00	3.69E+05	3.81	6.00E+04	44.76	1.4E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	16.00	1.79E+05	3.81	2.91E+04	21.87	1.5E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	17.00	8.65E+04	3.81	1.41E+04	10.62	1.6E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	18.00	4.15E+04	3.81	6.74E+03	5.12	1.7E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	19.00	1.97E+04	3.81	3.20E+03	2.44	1.7E+01
1.25	4.51E+10	0.00	4.51E+10	LEAD	20.00	9.24E+03	3.81	1.50E+03	1.15	1.8E+01
1.25	4.51E+10	0.00	4.51E+10	DU	0.00	4.51E+10	0.00	4.51E+10	3.06E+07	3.0E+00
1.25	4.51E+10	0.00	4.51E+10	DU	3.00	8.82E+08	0.00	8.82E+08	6.12E+05	6.4E+00
1.25	4.51E+10	0.00	4.51E+10	DU	4.00	2.31E+08	0.00	2.31E+08	1.61E+05	7.5E+00
1.25	4.51E+10	0.00	4.51E+10	DU	5.00	6.30E+07	0.00	6.30E+07	4.43E+04	8.7E+00
1.25	4.51E+10	0.00	4.51E+10	DU	6.00	1.78E+07	0.00	1.78E+07	1.26E+04	9.9E+00
1.25	4.51E+10	0.00	4.51E+10	DU	7.00	5.16E+06	0.00	5.16E+06	3.67E+03	1.1E+01
1.25	4.51E+10	0.00	4.51E+10	DU	8.00	1.52E+06	0.00	1.52E+06	1.09E+03	1.2E+01
1.25	4.51E+10	0.00	4.51E+10	DU	9.00	4.51E+05	0.00	4.51E+05	3.25E+02	1.3E+01
1.25	4.51E+10	0.00	4.51E+10	DU	10.00	1.33E+05	0.00	1.33E+05	96.77	1.5E+01
1.25	4.51E+10	0.00	4.51E+10	DU	11.00	3.90E+04	0.00	3.90E+04	28.45	1.6E+01

1.25	4.51E+10	0.00	4.51E+10	DU	12.00	1.11E+04	0.00	1.11E+04	8.18	1.7E+01
1.25	4.51E+10	0.00	4.51E+10	DU	13.00	3.54E+03	0.00	3.54E+03	2.61	1.8E+01
1.25	4.51E+10	0.00	4.51E+10	DU	14.00	1.07E+03	0.00	1.07E+03	7.94E-01	2.0E+01
1.25	4.51E+10	0.00	4.51E+10	DU	15.00	3.24E+02	0.00	3.24E+02	2.42E-01	2.1E+01
1.25	4.51E+10	0.00	4.51E+10	DU	16.00	9.86E+01	0.00	9.86E+01	7.40E-02	2.2E+01
1.25	4.51E+10	0.00	4.51E+10	DU	17.00	3.01E+01	0.00	3.01E+01	2.27E-02	2.4E+01
1.25	4.51E+10	0.00	4.51E+10	DU	18.00	9.19E+00	0.00	9.19E+00	6.98E-03	2.5E+01
1.25	4.51E+10	0.00	4.51E+10	DU	19.00	2.82E+00	0.00	2.82E+00	2.15E-03	2.6E+01
1.25	4.51E+10	0.00	4.51E+10	DU	20.00	8.65E-01	0.00	8.65E-01	6.64E-04	2.7E+01
1.25	4.51E+10	0.00	4.51E+10	DU	0.00	4.51E+10	3.81	7.33E+09	4.98E+06	3.0E+00
1.25	4.51E+10	0.00	4.51E+10	DU	3.00	8.82E+08	3.81	1.43E+08	9.95E+04	6.4E+00
1.25	4.51E+10	0.00	4.51E+10	DU	4.00	2.31E+08	3.81	3.75E+07	2.62E+04	7.5E+00
1.25	4.51E+10	0.00	4.51E+10	DU	5.00	6.30E+07	3.81	1.02E+07	7.20E+03	8.7E+00
1.25	4.51E+10	0.00	4.51E+10	DU	6.00	1.78E+07	3.81	2.89E+06	2.05E+03	9.9E+00
1.25	4.51E+10	0.00	4.51E+10	DU	7.00	5.16E+06	3.81	8.39E+05	5.97E+02	1.1E+01
1.25	4.51E+10	0.00	4.51E+10	DU	8.00	1.52E+06	3.81	2.47E+05	177.04	1.2E+01
1.25	4.51E+10	0.00	4.51E+10	DU	9.00	4.51E+05	3.81	7.33E+04	52.85	1.3E+01
1.25	4.51E+10	0.00	4.51E+10	DU	10.00	1.33E+05	3.81	2.17E+04	15.73	1.5E+01
1.25	4.51E+10	0.00	4.51E+10	DU	11.00	3.90E+04	3.81	6.34E+03	4.62	1.6E+01
1.25	4.51E+10	0.00	4.51E+10	DU	12.00	1.11E+04	3.81	1.81E+03	1.33	1.7E+01
1.25	4.51E+10	0.00	4.51E+10	DU	13.00	3.54E+03	3.81	5.76E+02	4.25E-01	1.8E+01
1.25	4.51E+10	0.00	4.51E+10	DU	14.00	1.07E+03	3.81	1.74E+02	1.29E-01	2.0E+01
1.25	4.51E+10	0.00	4.51E+10	DU	15.00	3.24E+02	3.81	5.27E+01	3.94E-02	2.1E+01
1.25	4.51E+10	0.00	4.51E+10	DU	16.00	9.86E+01	3.81	1.60E+01	1.20E-02	2.2E+01
1.25	4.51E+10	0.00	4.51E+10	DU	17.00	3.01E+01	3.81	4.89E+00	3.69E-03	2.4E+01
1.25	4.51E+10	0.00	4.51E+10	DU	18.00	9.19E+00	3.81	1.49E+00	1.13E-03	2.5E+01
1.25	4.51E+10	0.00	4.51E+10	DU	19.00	2.82E+00	3.81	4.58E-01	3.50E-04	2.6E+01
1.25	4.51E+10	0.00	4.51E+10	DU	20.00	8.65E-01	3.81	1.41E-01	1.08E-04	2.7E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	0.00	1.06E+10	0.00	1.06E+10	7.19E+06	3.0E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	3.00	5.77E+08	0.00	5.77E+08	4.00E+05	5.1E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	4.00	2.73E+08	0.00	2.73E+08	1.91E+05	5.8E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	5.00	1.28E+08	0.00	1.28E+08	9.03E+04	6.5E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	6.00	6.05E+07	0.00	6.05E+07	4.28E+04	7.3E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	7.00	2.86E+07	0.00	2.86E+07	2.04E+04	8.0E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	8.00	1.36E+07	0.00	1.36E+07	9.76E+03	8.7E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	9.00	6.54E+06	0.00	6.54E+06	4.71E+03	9.5E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	10.00	3.16E+06	0.00	3.16E+06	2.29E+03	1.0E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	11.00	1.53E+06	0.00	1.53E+06	1.12E+03	1.1E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	12.00	7.46E+05	0.00	7.46E+05	5.47E+02	1.2E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	13.00	3.64E+05	0.00	3.64E+05	2.69E+02	1.3E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	14.00	1.78E+05	0.00	1.78E+05	131.92	1.3E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	15.00	8.66E+04	0.00	8.66E+04	64.68	1.4E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	16.00	4.21E+04	0.00	4.21E+04	31.59	1.5E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	17.00	2.03E+04	0.00	2.03E+04	15.35	1.6E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	18.00	9.74E+03	0.00	9.74E+03	7.40	1.7E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	19.00	4.63E+03	0.00	4.63E+03	3.53	1.7E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	20.00	2.17E+03	0.00	2.17E+03	1.67	1.8E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	0.00	1.06E+10	3.81	1.72E+09	1.17E+06	3.0E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	3.00	5.77E+08	3.81	9.37E+07	6.50E+04	5.1E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	4.00	2.73E+08	3.81	4.44E+07	3.10E+04	5.8E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	5.00	1.28E+08	3.81	2.09E+07	1.47E+04	6.5E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	6.00	6.05E+07	3.81	9.83E+06	6.95E+03	7.3E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	7.00	2.86E+07	3.81	4.65E+06	3.31E+03	8.0E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	8.00	1.36E+07	3.81	2.22E+06	1.59E+03	8.7E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	9.00	6.54E+06	3.81	1.06E+06	7.66E+02	9.5E+00
1.25	4.51E+10	2.54	1.06E+10	LEAD	10.00	3.16E+06	3.81	5.13E+05	3.72E+02	1.0E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	11.00	1.53E+06	3.81	2.49E+05	181.57	1.1E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	12.00	7.46E+05	3.81	1.21E+05	88.96	1.2E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	13.00	3.64E+05	3.81	5.92E+04	43.67	1.3E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	14.00	1.78E+05	3.81	2.89E+04	21.45	1.3E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	15.00	8.66E+04	3.81	1.41E+04	10.51	1.4E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	16.00	4.21E+04	3.81	6.84E+03	5.14	1.5E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	17.00	2.03E+04	3.81	3.30E+03	2.50	1.6E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	18.00	9.74E+03	3.81	1.58E+03	1.20	1.7E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	19.00	4.63E+03	3.81	7.52E+02	5.74E-01	1.7E+01
1.25	4.51E+10	2.54	1.06E+10	LEAD	20.00	2.17E+03	3.81	3.53E+02	2.71E-01	1.8E+01
1.25	4.51E+10	2.54	1.06E+10	DU	0.00	1.06E+10	0.00	1.06E+10	7.19E+06	3.0E+00
1.25	4.51E+10	2.54	1.06E+10	DU	3.00	2.07E+08	0.00	2.07E+08	1.44E+05	6.4E+00
1.25	4.51E+10	2.54	1.06E+10	DU	4.00	5.42E+07	0.00	5.42E+07	3.79E+04	7.5E+00
1.25	4.51E+10	2.54	1.06E+10	DU	5.00	1.48E+07	0.00	1.48E+07	1.04E+04	8.7E+00
1.25	4.51E+10	2.54	1.06E+10	DU	6.00	4.18E+06	0.00	4.18E+06	2.96E+03	9.9E+00

1.25	4.51E+10	2.54	1.06E+10	DU	7.00	1.21E+06	0.00	1.21E+06	8.63E+02	1.1E+01
1.25	4.51E+10	2.54	1.06E+10	DU	8.00	3.57E+05	0.00	3.57E+05	2.56E+02	1.2E+01
1.25	4.51E+10	2.54	1.06E+10	DU	9.00	1.06E+05	0.00	1.06E+05	76.36	1.3E+01
1.25	4.51E+10	2.54	1.06E+10	DU	10.00	3.14E+04	0.00	3.14E+04	22.73	1.5E+01
1.25	4.51E+10	2.54	1.06E+10	DU	11.00	9.16E+03	0.00	9.16E+03	6.68	1.6E+01
1.25	4.51E+10	2.54	1.06E+10	DU	12.00	2.62E+03	0.00	2.62E+03	1.92	1.7E+01
1.25	4.51E+10	2.54	1.06E+10	DU	13.00	8.32E+02	0.00	8.32E+02	6.14E-01	1.8E+01
1.25	4.51E+10	2.54	1.06E+10	DU	14.00	2.51E+02	0.00	2.51E+02	1.87E-01	2.0E+01
1.25	4.51E+10	2.54	1.06E+10	DU	15.00	7.62E+01	0.00	7.62E+01	5.69E-02	2.1E+01
1.25	4.51E+10	2.54	1.06E+10	DU	16.00	2.32E+01	0.00	2.32E+01	1.74E-02	2.2E+01
1.25	4.51E+10	2.54	1.06E+10	DU	17.00	7.06E+00	0.00	7.06E+00	5.33E-03	2.4E+01
1.25	4.51E+10	2.54	1.06E+10	DU	18.00	2.16E+00	0.00	2.16E+00	1.64E-03	2.5E+01
1.25	4.51E+10	2.54	1.06E+10	DU	19.00	6.62E-01	0.00	6.62E-01	5.05E-04	2.6E+01
1.25	4.51E+10	2.54	1.06E+10	DU	20.00	2.03E-01	0.00	2.03E-01	1.56E-04	2.7E+01
1.25	4.51E+10	2.54	1.06E+10	DU	0.00	1.06E+10	3.81	1.72E+09	1.17E+06	3.0E+00
1.25	4.51E+10	2.54	1.06E+10	DU	3.00	2.07E+08	3.81	3.37E+07	2.34E+04	6.4E+00
1.25	4.51E+10	2.54	1.06E+10	DU	4.00	5.42E+07	3.81	8.82E+06	6.16E+03	7.5E+00
1.25	4.51E+10	2.54	1.06E+10	DU	5.00	1.48E+07	3.81	2.41E+06	1.69E+03	8.7E+00
1.25	4.51E+10	2.54	1.06E+10	DU	6.00	4.18E+06	3.81	6.80E+05	4.81E+02	9.9E+00
1.25	4.51E+10	2.54	1.06E+10	DU	7.00	1.21E+06	3.81	1.97E+05	140.26	1.1E+01
1.25	4.51E+10	2.54	1.06E+10	DU	8.00	3.57E+05	3.81	5.81E+04	41.59	1.2E+01
1.25	4.51E+10	2.54	1.06E+10	DU	9.00	1.06E+05	3.81	1.72E+04	12.41	1.3E+01
1.25	4.51E+10	2.54	1.06E+10	DU	10.00	3.14E+04	3.81	5.10E+03	3.70	1.5E+01
1.25	4.51E+10	2.54	1.06E+10	DU	11.00	9.16E+03	3.81	1.49E+03	1.09	1.6E+01
1.25	4.51E+10	2.54	1.06E+10	DU	12.00	2.62E+03	3.81	4.26E+02	3.12E-01	1.7E+01
1.25	4.51E+10	2.54	1.06E+10	DU	13.00	8.32E+02	3.81	1.35E+02	9.98E-02	1.8E+01
1.25	4.51E+10	2.54	1.06E+10	DU	14.00	2.51E+02	3.81	4.09E+01	3.03E-02	2.0E+01
1.25	4.51E+10	2.54	1.06E+10	DU	15.00	7.62E+01	3.81	1.24E+01	9.25E-03	2.1E+01
1.25	4.51E+10	2.54	1.06E+10	DU	16.00	2.32E+01	3.81	3.77E+00	2.83E-03	2.2E+01
1.25	4.51E+10	2.54	1.06E+10	DU	17.00	7.06E+00	3.81	1.15E+00	8.67E-04	2.4E+01
1.25	4.51E+10	2.54	1.06E+10	DU	18.00	2.16E+00	3.81	3.51E-01	2.67E-04	2.5E+01
1.25	4.51E+10	2.54	1.06E+10	DU	19.00	6.62E-01	3.81	1.08E-01	8.21E-05	2.6E+01
1.25	4.51E+10	2.54	1.06E+10	DU	20.00	2.03E-01	3.81	3.30E-02	2.53E-05	2.7E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	0.00	3.81E+10	0.00	3.81E+10	3.05E+07	3.0E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	3.00	3.00E+09	0.00	3.00E+09	2.45E+06	5.1E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	4.00	1.61E+09	0.00	1.61E+09	1.32E+06	5.8E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	5.00	8.49E+08	0.00	8.49E+08	7.03E+05	6.5E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	6.00	4.47E+08	0.00	4.47E+08	3.72E+05	7.3E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	7.00	2.36E+08	0.00	2.36E+08	1.97E+05	8.0E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	8.00	1.25E+08	0.00	1.25E+08	1.05E+05	8.7E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	9.00	6.63E+07	0.00	6.63E+07	5.62E+04	9.5E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	10.00	3.54E+07	0.00	3.54E+07	3.02E+04	1.0E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	11.00	1.90E+07	0.00	1.90E+07	1.63E+04	1.1E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	12.00	1.03E+07	0.00	1.03E+07	8.86E+03	1.2E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	13.00	5.55E+06	0.00	5.55E+06	4.82E+03	1.3E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	14.00	3.01E+06	0.00	3.01E+06	2.63E+03	1.3E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	15.00	1.64E+06	0.00	1.64E+06	1.44E+03	1.4E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	16.00	8.90E+05	0.00	8.90E+05	7.87E+02	1.5E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	17.00	4.84E+05	0.00	4.84E+05	4.30E+02	1.6E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	18.00	2.63E+05	0.00	2.63E+05	2.35E+02	1.7E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	19.00	1.42E+05	0.00	1.42E+05	127.71	1.7E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	20.00	7.65E+04	0.00	7.65E+04	69.16	1.8E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	0.00	3.81E+10	3.81	6.14E+09	4.91E+06	3.0E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	3.00	3.00E+09	3.81	4.84E+08	3.95E+05	5.1E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	4.00	1.61E+09	3.81	2.59E+08	2.13E+05	5.8E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	5.00	8.49E+08	3.81	1.37E+08	1.13E+05	6.5E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	6.00	4.47E+08	3.81	7.21E+07	6.00E+04	7.3E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	7.00	2.36E+08	3.81	3.80E+07	3.18E+04	8.0E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	8.00	1.25E+08	3.81	2.01E+07	1.70E+04	8.7E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	9.00	6.63E+07	3.81	1.07E+07	9.07E+03	9.5E+00
1.50	3.81E+10	0.00	3.81E+10	LEAD	10.00	3.54E+07	3.81	5.71E+06	4.88E+03	1.0E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	11.00	1.90E+07	3.81	3.07E+06	2.63E+03	1.1E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	12.00	1.03E+07	3.81	1.65E+06	1.43E+03	1.2E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	13.00	5.55E+06	3.81	8.95E+05	7.78E+02	1.3E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	14.00	3.01E+06	3.81	4.86E+05	4.25E+02	1.3E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	15.00	1.64E+06	3.81	2.64E+05	2.32E+02	1.4E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	16.00	8.90E+05	3.81	1.44E+05	126.97	1.5E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	17.00	4.84E+05	3.81	7.80E+04	69.40	1.6E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	18.00	2.63E+05	3.81	4.23E+04	37.86	1.7E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	19.00	1.42E+05	3.81	2.29E+04	20.60	1.7E+01
1.50	3.81E+10	0.00	3.81E+10	LEAD	20.00	7.65E+04	3.81	1.23E+04	11.15	1.8E+01

1.50	3.81E+10	0.00	3.81E+10	DU	0.00	3.81E+10	0.00	3.81E+10	3.05E+07	3.0E+00
1.50	3.81E+10	0.00	3.81E+10	DU	3.00	1.42E+09	0.00	1.42E+09	1.16E+06	6.4E+00
1.50	3.81E+10	0.00	3.81E+10	DU	4.00	4.45E+08	0.00	4.45E+08	3.66E+05	7.5E+00
1.50	3.81E+10	0.00	3.81E+10	DU	5.00	1.44E+08	0.00	1.44E+08	1.19E+05	8.7E+00
1.50	3.81E+10	0.00	3.81E+10	DU	6.00	4.82E+07	0.00	4.82E+07	4.01E+04	9.9E+00
1.50	3.81E+10	0.00	3.81E+10	DU	7.00	1.65E+07	0.00	1.65E+07	1.38E+04	1.1E+01
1.50	3.81E+10	0.00	3.81E+10	DU	8.00	5.74E+06	0.00	5.74E+06	4.84E+03	1.2E+01
1.50	3.81E+10	0.00	3.81E+10	DU	9.00	2.03E+06	0.00	2.03E+06	1.72E+03	1.3E+01
1.50	3.81E+10	0.00	3.81E+10	DU	10.00	7.21E+05	0.00	7.21E+05	6.16E+02	1.5E+01
1.50	3.81E+10	0.00	3.81E+10	DU	11.00	2.57E+05	0.00	2.57E+05	2.21E+02	1.6E+01
1.50	3.81E+10	0.00	3.81E+10	DU	12.00	9.12E+04	0.00	9.12E+04	78.78	1.7E+01
1.50	3.81E+10	0.00	3.81E+10	DU	13.00	3.20E+04	0.00	3.20E+04	27.82	1.8E+01
1.50	3.81E+10	0.00	3.81E+10	DU	14.00	1.11E+04	0.00	1.11E+04	9.66	2.0E+01
1.50	3.81E+10	0.00	3.81E+10	DU	15.00	4.18E+03	0.00	4.18E+03	3.67	2.1E+01
1.50	3.81E+10	0.00	3.81E+10	DU	16.00	1.51E+03	0.00	1.51E+03	1.33	2.2E+01
1.50	3.81E+10	0.00	3.81E+10	DU	17.00	5.47E+02	0.00	5.47E+02	4.86E-01	2.4E+01
1.50	3.81E+10	0.00	3.81E+10	DU	18.00	1.99E+02	0.00	1.99E+02	1.78E-01	2.5E+01
1.50	3.81E+10	0.00	3.81E+10	DU	19.00	7.23E+01	0.00	7.23E+01	6.50E-02	2.6E+01
1.50	3.81E+10	0.00	3.81E+10	DU	20.00	2.63E+01	0.00	2.63E+01	2.38E-02	2.7E+01
1.50	3.81E+10	0.00	3.81E+10	DU	0.00	3.81E+10	3.81	6.14E+09	4.91E+06	3.0E+00
1.50	3.81E+10	0.00	3.81E+10	DU	3.00	1.42E+09	3.81	2.29E+08	1.87E+05	6.4E+00
1.50	3.81E+10	0.00	3.81E+10	DU	4.00	4.45E+08	3.81	7.18E+07	5.90E+04	7.5E+00
1.50	3.81E+10	0.00	3.81E+10	DU	5.00	1.44E+08	3.81	2.33E+07	1.93E+04	8.7E+00
1.50	3.81E+10	0.00	3.81E+10	DU	6.00	4.82E+07	3.81	7.77E+06	6.47E+03	9.9E+00
1.50	3.81E+10	0.00	3.81E+10	DU	7.00	1.65E+07	3.81	2.66E+06	2.23E+03	1.1E+01
1.50	3.81E+10	0.00	3.81E+10	DU	8.00	5.74E+06	3.81	9.26E+05	7.81E+02	1.2E+01
1.50	3.81E+10	0.00	3.81E+10	DU	9.00	2.03E+06	3.81	3.27E+05	2.78E+02	1.3E+01
1.50	3.81E+10	0.00	3.81E+10	DU	10.00	7.21E+05	3.81	1.16E+05	99.35	1.5E+01
1.50	3.81E+10	0.00	3.81E+10	DU	11.00	2.57E+05	3.81	4.15E+04	35.61	1.6E+01
1.50	3.81E+10	0.00	3.81E+10	DU	12.00	9.12E+04	3.81	1.47E+04	12.70	1.7E+01
1.50	3.81E+10	0.00	3.81E+10	DU	13.00	3.20E+04	3.81	5.16E+03	4.49	1.8E+01
1.50	3.81E+10	0.00	3.81E+10	DU	14.00	1.11E+04	3.81	1.78E+03	1.56	2.0E+01
1.50	3.81E+10	0.00	3.81E+10	DU	15.00	4.18E+03	3.81	6.73E+02	5.92E-01	2.1E+01
1.50	3.81E+10	0.00	3.81E+10	DU	16.00	1.51E+03	3.81	2.43E+02	2.15E-01	2.2E+01
1.50	3.81E+10	0.00	3.81E+10	DU	17.00	5.47E+02	3.81	8.82E+01	7.84E-02	2.4E+01
1.50	3.81E+10	0.00	3.81E+10	DU	18.00	1.99E+02	3.81	3.20E+01	2.86E-02	2.5E+01
1.50	3.81E+10	0.00	3.81E+10	DU	19.00	7.23E+01	3.81	1.17E+01	1.05E-02	2.6E+01
1.50	3.81E+10	0.00	3.81E+10	DU	20.00	2.63E+01	3.81	4.25E+00	3.84E-03	2.7E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	0.00	5.85E+09	0.00	5.85E+09	4.68E+06	3.0E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	3.00	4.61E+08	0.00	4.61E+08	3.77E+05	5.1E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	4.00	2.47E+08	0.00	2.47E+08	2.03E+05	5.8E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	5.00	1.30E+08	0.00	1.30E+08	1.08E+05	6.5E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	6.00	6.87E+07	0.00	6.87E+07	5.72E+04	7.3E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	7.00	3.62E+07	0.00	3.62E+07	3.03E+04	8.0E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	8.00	1.92E+07	0.00	1.92E+07	1.62E+04	8.7E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	9.00	1.02E+07	0.00	1.02E+07	8.64E+03	9.5E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	10.00	5.44E+06	0.00	5.44E+06	4.65E+03	1.0E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	11.00	2.92E+06	0.00	2.92E+06	2.51E+03	1.1E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	12.00	1.58E+06	0.00	1.58E+06	1.36E+03	1.2E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	13.00	8.53E+05	0.00	8.53E+05	7.42E+02	1.3E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	14.00	4.63E+05	0.00	4.63E+05	4.05E+02	1.3E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	15.00	2.52E+05	0.00	2.52E+05	2.21E+02	1.4E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	16.00	1.37E+05	0.00	1.37E+05	121.00	1.5E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	17.00	7.44E+04	0.00	7.44E+04	66.14	1.6E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	18.00	4.04E+04	0.00	4.04E+04	36.08	1.7E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	19.00	2.18E+04	0.00	2.18E+04	19.63	1.7E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	20.00	1.18E+04	0.00	1.18E+04	10.63	1.8E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	0.00	5.85E+09	3.81	9.43E+08	7.55E+05	3.0E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	3.00	4.61E+08	3.81	7.44E+07	6.07E+04	5.1E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	4.00	2.47E+08	3.81	3.98E+07	3.27E+04	5.8E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	5.00	1.30E+08	3.81	2.10E+07	1.74E+04	6.5E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	6.00	6.87E+07	3.81	1.11E+07	9.23E+03	7.3E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	7.00	3.62E+07	3.81	5.84E+06	4.89E+03	8.0E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	8.00	1.92E+07	3.81	3.09E+06	2.61E+03	8.7E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	9.00	1.02E+07	3.81	1.64E+06	1.39E+03	9.5E+00
1.50	3.81E+10	2.54	5.85E+09	LEAD	10.00	5.44E+06	3.81	8.78E+05	7.50E+02	1.0E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	11.00	2.92E+06	3.81	4.71E+05	4.05E+02	1.1E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	12.00	1.58E+06	3.81	2.54E+05	2.20E+02	1.2E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	13.00	8.53E+05	3.81	1.38E+05	119.58	1.3E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	14.00	4.63E+05	3.81	7.47E+04	65.27	1.3E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	15.00	2.52E+05	3.81	4.06E+04	35.68	1.4E+01

1.50	3.81E+10	2.54	5.85E+09	LEAD	16.00	1.37E+05	3.81	2.21E+04	19.51	1.5E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	17.00	7.44E+04	3.81	1.20E+04	10.67	1.6E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	18.00	4.04E+04	3.81	6.51E+03	5.82	1.7E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	19.00	2.18E+04	3.81	3.52E+03	3.17	1.7E+01
1.50	3.81E+10	2.54	5.85E+09	LEAD	20.00	1.18E+04	3.81	1.90E+03	1.71	1.8E+01
1.50	3.81E+10	2.54	5.85E+09	DU	0.00	5.85E+09	0.00	5.85E+09	4.68E+06	3.0E+00
1.50	3.81E+10	2.54	5.85E+09	DU	3.00	2.18E+08	0.00	2.18E+08	1.78E+05	6.4E+00
1.50	3.81E+10	2.54	5.85E+09	DU	4.00	6.84E+07	0.00	6.84E+07	5.63E+04	7.5E+00
1.50	3.81E+10	2.54	5.85E+09	DU	5.00	2.22E+07	0.00	2.22E+07	1.84E+04	8.7E+00
1.50	3.81E+10	2.54	5.85E+09	DU	6.00	7.41E+06	0.00	7.41E+06	6.17E+03	9.9E+00
1.50	3.81E+10	2.54	5.85E+09	DU	7.00	2.53E+06	0.00	2.53E+06	2.12E+03	1.1E+01
1.50	3.81E+10	2.54	5.85E+09	DU	8.00	8.83E+05	0.00	8.83E+05	7.45E+02	1.2E+01
1.50	3.81E+10	2.54	5.85E+09	DU	9.00	3.12E+05	0.00	3.12E+05	2.65E+02	1.3E+01
1.50	3.81E+10	2.54	5.85E+09	DU	10.00	1.11E+05	0.00	1.11E+05	94.68	1.5E+01
1.50	3.81E+10	2.54	5.85E+09	DU	11.00	3.95E+04	0.00	3.95E+04	33.93	1.6E+01
1.50	3.81E+10	2.54	5.85E+09	DU	12.00	1.40E+04	0.00	1.40E+04	12.11	1.7E+01
1.50	3.81E+10	2.54	5.85E+09	DU	13.00	4.92E+03	0.00	4.92E+03	4.28	1.8E+01
1.50	3.81E+10	2.54	5.85E+09	DU	14.00	1.70E+03	0.00	1.70E+03	1.48	2.0E+01
1.50	3.81E+10	2.54	5.85E+09	DU	15.00	6.42E+02	0.00	6.42E+02	5.64E-01	2.1E+01
1.50	3.81E+10	2.54	5.85E+09	DU	16.00	2.32E+02	0.00	2.32E+02	2.05E-01	2.2E+01
1.50	3.81E+10	2.54	5.85E+09	DU	17.00	8.40E+01	0.00	8.40E+01	7.47E-02	2.4E+01
1.50	3.81E+10	2.54	5.85E+09	DU	18.00	3.05E+01	0.00	3.05E+01	2.73E-02	2.5E+01
1.50	3.81E+10	2.54	5.85E+09	DU	19.00	1.11E+01	0.00	1.11E+01	9.98E-03	2.6E+01
1.50	3.81E+10	2.54	5.85E+09	DU	20.00	4.05E+00	0.00	4.05E+00	3.66E-03	2.7E+01
1.50	3.81E+10	2.54	5.85E+09	DU	0.00	5.85E+09	3.81	9.43E+08	7.55E+05	3.0E+00
1.50	3.81E+10	2.54	5.85E+09	DU	3.00	2.18E+08	3.81	3.52E+07	2.87E+04	6.4E+00
1.50	3.81E+10	2.54	5.85E+09	DU	4.00	6.84E+07	3.81	1.10E+07	9.07E+03	7.5E+00
1.50	3.81E+10	2.54	5.85E+09	DU	5.00	2.22E+07	3.81	3.58E+06	2.96E+03	8.7E+00
1.50	3.81E+10	2.54	5.85E+09	DU	6.00	7.41E+06	3.81	1.19E+06	9.95E+02	9.9E+00
1.50	3.81E+10	2.54	5.85E+09	DU	7.00	2.53E+06	3.81	4.09E+05	3.42E+02	1.1E+01
1.50	3.81E+10	2.54	5.85E+09	DU	8.00	8.83E+05	3.81	1.42E+05	120.08	1.2E+01
1.50	3.81E+10	2.54	5.85E+09	DU	9.00	3.12E+05	3.81	5.03E+04	42.66	1.3E+01
1.50	3.81E+10	2.54	5.85E+09	DU	10.00	1.11E+05	3.81	1.79E+04	15.27	1.5E+01
1.50	3.81E+10	2.54	5.85E+09	DU	11.00	3.95E+04	3.81	6.37E+03	5.47	1.7E+01
1.50	3.81E+10	2.54	5.85E+09	DU	12.00	1.40E+04	3.81	2.26E+03	1.95	1.8E+01
1.50	3.81E+10	2.54	5.85E+09	DU	13.00	4.92E+03	3.81	7.93E+02	6.89E-01	1.9E+01
1.50	3.81E+10	2.54	5.85E+09	DU	14.00	1.70E+03	3.81	2.74E+02	2.39E-01	2.0E+01
1.50	3.81E+10	2.54	5.85E+09	DU	15.00	6.42E+02	3.81	1.04E+02	9.10E-02	2.1E+01
1.50	3.81E+10	2.54	5.85E+09	DU	16.00	2.32E+02	3.81	3.74E+01	3.31E-02	2.2E+01
1.50	3.81E+10	2.54	5.85E+09	DU	17.00	8.40E+01	3.81	1.36E+01	1.20E-02	2.4E+01
1.50	3.81E+10	2.54	5.85E+09	DU	18.00	3.05E+01	3.81	4.92E+00	4.40E-03	2.5E+01
1.50	3.81E+10	2.54	5.85E+09	DU	19.00	1.11E+01	3.81	1.79E+00	1.61E-03	2.6E+01
1.50	3.81E+10	2.54	5.85E+09	DU	20.00	4.05E+00	3.81	6.53E-01	5.90E-04	2.7E+01

OUTPUT FILES GENERATED

SHIELD_9.DAT: LEAD SHIELD/NO LINERS/.25->1.5 GAMMAS
 SHIELD_10.DAT: LEAD SHIELD/ LINERS/.25->1.5 GAMMAS
 SHIELD_11.DAT: DU SHIELD/NO LINERS/.25->1.5 GAMMAS
 SHIELD_12.DAT: DU SHIELD/ LINERS/.25->1.5 GAMMAS

7.5 Appendix E – Results for Lead Shield Material

Dose Rate at Cask Surface for Lead Shielding (0.00 & 0.00 cm SS liners)

Figure E-1. 3D plot of dose rate at cask surface as a function of gamma-ray energy and lead shielding thickness without shielding credit for stainless steel liners. Plot floor corresponds to cask surface dose rate limit of 200 mrem/hr limit.

Dose Rate at Cask Surface for Lead Shielding (2.54 & 3.81 cm SS liners)

Figure E-2. 3D plot of dose rate at cask surface as a function of gamma-ray energy and lead shielding thickness with shielding credit for stainless steel liners. Plot floor corresponds to cask surface dose rate limit of 200 mrem/hr limit.

Exposure Rate at 1m from Cask Surface for Lead Shielding
(0.00 & 0.00 cm SS liners)

Figure E-3. 3D plot of exposure rate at one meter from the cask surface as a function of gamma-ray energy and lead shielding thickness without shielding credit for stainless steel liners. Plot floor corresponds to exposure rate of 50 mR/hr at one meter from cask surface.

Exposure Rate at 1m from Cask Surface for Lead Shielding
(2.54 & 3.81 cm SS liners)

Figure E-4. 3D plot of exposure rate at one meter from the cask surface as a function of gamma-ray energy and lead shielding thickness with shielding credit for stainless steel liners. Plot floor corresponds to exposure rate of 50 mR/hr at one meter from cask surface.

Dose Rate at 2m from Cask Surface for Lead Shielding
(0.00 & 0.00 cm SS liners)

Figure E-5. 3D plot of dose rate at two meters from the cask surface as a function of gamma-ray energy and lead shielding thickness without shielding credit for stainless steel liners. Plot floor corresponds to dose rate of 10 mrem/hr at two meters from cask surface.

Dose Rate at 2m from Cask Surface for Lead Shielding (2.54 & 3.81 cm SS liners)

Figure E-6. 3D plot of dose rate at two meters from the cask surface as a function of gamma-ray energy and lead shielding thickness with shielding credit for stainless steel liners. Plot floor corresponds to dose rate of 10 mrem/hr at two meters from cask surface.

7.6 Appendix F – Results for Depleted Uranium Material

This appendix contains 3D plots generated from selected SHIELD results, for depleted uranium shielding material only.

Dose Rate at Cask Surface for DU Shielding (0.00 & 0.00 cm SS liners)

Figure F-1. 3D plot of dose rate at cask surface as a function of gamma-ray energy and depleted uranium shielding thickness without shielding credit for stainless steel liners. Plot floor corresponds to cask surface dose rate limit of 200 mrem/hr limit.

Dose Rate at Cask Surface for DU Shielding (2.54 & 3.81 cm SS liners)

Figure F-2. 3D plot of dose rate at cask surface as a function of gamma-ray energy and depleted uranium shielding thickness with shielding credit for stainless steel liners. Plot floor corresponds to cask surface dose rate limit of 200 mrem/hr limit.

Exposure Rate at 1m from Cask Surface for DU Shielding (0.00 & 0.00 cm SS liners)

Figure F-3. 3D plot of exposure rate at one meter from the cask surface as a function of gamma-ray energy and depleted uranium shielding thickness without shielding credit for stainless steel liners. Plot floor corresponds to exposure rate of 50 mR/hr at one meter from cask surface.

Exposure Rate at 1m from Cask Surface for DU Shielding (2.54 & 3.81 cm SS liners)

Figure F-4. 3D plot of exposure rate at one meter from the cask surface as a function of gamma-ray energy and depleted uranium shielding thickness with shielding credit for stainless steel liners. Plot floor corresponds to exposure rate of 50 mR/hr at one meter from cask surface.

Dose Rate at 2m from Cask Surface for DU Shielding (0.00 & 0.00 cm SS liners)

Figure F-5. 3D plot of dose rate at two meters from the cask surface as a function of gamma-ray energy and depleted uranium shielding thickness without shielding credit for stainless steel liners. Plot floor corresponds to dose rate of 10 mrem/hr at two meters from cask surface.

Dose Rate at 2m from Cask Surface for DU Shielding (2.54 & 3.81 cm SS liners)

Figure F-6. 3D plot of dose rate at two meters from the cask surface as a function of gamma-ray energy and depleted uranium shielding thickness with shielding credit for stainless steel liners. Plot floor corresponds to dose rate of 10 mrem/hr at two meters from cask surface.

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