SANDIA REPORT
SAND2009-5107
Unlimited Release
Printed: August 2009

Dose Estimates in a Loss of Lead Shielding Truck Accident

Matthew L. Dennis, Ruth F. Weiner, Douglas M. Osborn, and Terence J. Heames*

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under Contract DE-AC04-94AL85000.

*Alion Science & Technology
Albuquerque, New Mexico 87110

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865)576-8401
Facsimile: (865)576-5728
E-Mail: reports@adonis.osti.gov
Online ordering: http://www.osti.gov/bridge

Available to the public from
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Rd
Springfield, VA 22161

Telephone: (800)553-6847
Facsimile: (703)605-6900
E-Mail: orders@ntis.fedworld.gov
Online order: http://www.ntis.gov/help/ordermethods.asp?loc=7-4-0#online

SAND2009-5107
Unlimited Release
Printed August 2009

Dose Estimates in a Loss of Lead Shielding Truck Accident

M.L. Dennis, R.F. Weiner, D.M. Osborn, and T.J. Heames*
Transportation & Environmental Safety Department
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-0718

*Alion Science & Technology
Albuquerque, New Mexico 87110

ABSTRACT

The radiological transportation risk & consequence program, RADTRAN, has recently added an updated loss of lead shielding (LOS) model to it most recent version, RADTRAN 6.0. The LOS model was used to determine dose estimates to first-responders during a spent nuclear fuel transportation accident. Results varied according to the following: type of accident scenario, percent of lead slump, distance to shipment, and time spent in the area. This document presents a method of creating dose estimates for first-responders using RADTRAN with potential accident scenarios. This may be of particular interest in the event of high speed accidents or fires involving cask punctures.

Table of Contents

List of Figures

List of Tables

(This page left intentionally blank.)

1. Introduction

In order to estimate the risks and possible consequences of radioactive-material transportation, the computer code RADTRAN was developed in 1977 (Ref. 1). RADTRAN is used to assess risks from a transportation accident as well as the risks from incident-free transportation. Pending validation, RADTRAN 6.0 will incorporate the capability to calculate doses received by both first responders and the general public for an incident where the transportation cask lead gamma shielding is compromised. Various extra-regulatory accident scenarios could involve the spent nuclear fuel (SNF) cask impacting a stationary object or being fully engulfed in an extremely high temperature, long duration fire. Either scenario could lead to degradation in the lead gamma shielding. In a severe impact, the lead would deform due to the force of the impact. In an engulfing fire that brings the interior temperature to the lead melting point, the lead could melt and flow away. In either case, the void can potentially expose the fuel and is referred to as slump. Figure 1 represents an example of lead slump as a result of a high speed impact.

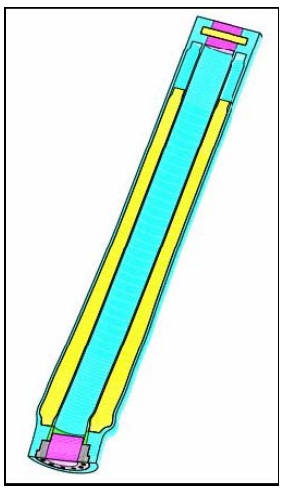

Figure 1. Finite Element Analysis for a Lead-Shielded Truck Cask Involved in 144.8 km/hr Corner Impact Without Impact Limiters[2].

Previous work[2,3] has explored the direct dose received in a loss of shielding (LOS) accident at varying radial and axial positions from a spent fuel cask. To evaluate the potential radiological impact of a LOS accident, an improved LOS model was developed and incorporated into RADTRAN. This paper will present the rationale behind the improved LOS model, its capabilities and limitations, and an example problem which highlights how to setup, run and interpret an LOS simulation.

2. LOS Model

In order to estimate the risks and consequences of a LOS accident, a model was developed in 2005 (Ref. 2). The LOS model estimates the effect on dose receptors outside a transportation cask in the event of an accident that leads to a loss of lead photon shielding. This is done by calculating a dose increase factor *F*, the ratio of the dose (or dose rate) from a damaged cask to that from an undamaged cask for receptor points located at various distances from the cask. Dose increase factors were calculated using a photon shielding and dose assessment program called MicroShield 6.20 ® and compared to earlier results using Monte Carlo N-Particle transport code (MCNP). The comparative results can be found in Ref. 3.

The MicroShield 6.20 ® analysis included modeling an intact spent fuel truck cask as well as a set of damaged truck casks, each with a different percentage of slump based on the ten cases specified in Table 1. Table I slump fractions are the result of finite element analysis in accident impacts sufficient to cause lead slump. It was necessary to model and calculate dose rates to receptors for an intact truck cask as well as damaged casks so that a dose increase factor correlation could be established for varying slump fractions.

Table 1. Descriptions of LOS cases[4]

LOS case	LOS accident condition	Fraction of shield lost	Conditional Probability
1	End impact	0.052	1.71E-06
2	End impact	0.158	4.63E-07
3	End impact	0.264	3.21E-08
4	End impact	0.368	2.53E-10
5	Corner impact	0.033	2.20E-05
6	Corner impact	0.096	5.97E-06
7	Corner impact	0.158	4.14E-07
8	Corner impact	0.255	3.27E-09
9	Lead melt (T > 350°C)	0.029	4.90E-05
10	Lead melt with puncture (T > 350°C)	0.5	1.66E-09

The LOS model calculates the dose increase factor *F* based on simulated shielded and unshielded results. Two dose rates were ultimately determined at a range of distances from the cask (1, 2, 3, 4, 5, 10, 20, 50, and 100 meters) and axially averaged along the length of the cask. Averaging was necessary because there is a slight variation in dose rate depending on receptor location along the length of the spent fuel cask. This averaged dose then represents the “AVERAGE RADIOLOGICAL DOSE (P_REM)” in the RADTRAN output. Dose rates beyond the ends of the cask were not used in determining the average dose rate. Equation 1 illustrates how *F* is calculated in the LOS model. It is a simple ratio of the dose rate at a distance *j* with a fraction of lead removed to the intact average dose rate at 1 meter (conversely, 2 meters can be used for maximum radiological dose).

$$F = \frac{DoseRate(slump, j)}{DoseRate(intact, 1)} \qquad (1)$$

This ratio of slumped to unslumped dose rate quantifies the effect of loss of lead shielding and gives a factor which can be multiplied with the vehicle dose rate. The LOS model yields three results: average radiological dose, maximum radiological dose at 2 m from the cask, and the LOS risk.

2.1 Average Radiological Dose

The relationship for LOS dose is given by equation 2.

$$LOSDose = Q \times DR_v \times P_{LOS} \times T_{LOS} \times SF_{LOS} \times F_{a,b} \qquad (2)$$

where

Q = unit conversion factor = 1.0E-03 rem/mrem
DR_v = vehicle dose rate at 1 m from surface (mrem/hr)
P_{LOS} = number of exposed persons at LOS stop
T_{LOS} = stop time (hours)
SF_{LOS} = shielding factor for persons at LOS stop (1= no shielding, 0= full shielding)
$F_{a,b}$ = correlation equation as a function of slump fraction and distance for (a) < 6 meters or (b) ≥ 6 meters

The LOS dose calculation method mirrors the method used for the dose to populations at shipment stops. However, in the LOS model the distance based correlations replace the source-strength terms used in the RADTRAN stop model[5]. The dose increase factor *F* for average radiological dose is found using one of two correlations given in equations 3 and 4.

$$F(fract, dist) = \frac{1}{dist} + 6833\left(\frac{fract}{dist}\right)^{1.16} \qquad 1m \le dist < 6m \qquad (3)$$

$$F(fract, dist) = \left(\frac{2.4}{dist}\right)^{2} + 32140\left(\frac{fract}{dist}\right)^{2.13} \quad for\ dist \ge 6m \qquad (4)$$

2.2 Maximum Radiological Dose at 2 Meters

The peak dose occurs around the zone where the lead has slumped and is reported at 2 meters. The 2 meter distance serves as a comparison to the regulatory limit of 10 mrem/hr at 2 meters stipulated in 10 CFR 71 (Ref. 6). The maximum radiological dose is calculated in the same manner stipulated above in equation 2; however, the dose increase factor *F* is replaced with a correlation multiplication factor $Mult_{max}$. Equations 5 and 6 express this factor based on percent slump.

$$Mult_{\max} = 0.615 + 7600 \times slmp\_frac \quad < 10\% \qquad (5)$$

$$Mult_{\max} = 5280 \times slmp\_frac^{0.84} \quad \ge 10\% \qquad (6)$$

In reality, the slump fraction would rarely ever be larger than 10%; nevertheless, the correlation was separated at 10% to allow for more accuracy at the lower, more likely, slump fractions.

2.3 LOS Dose-Risk

The LOS dose-risk mathematically represents the multiplication of LOS dose and accident probability of severity j on link L, thus the term dose-risk. The conditional probability (also referred to as severity fraction) is user-defined and corresponds to a particular slump fraction. The final expression for dose-risk is given in equation 7 summed over all severity categories and uses the average radiological dose obtained from equation 2.

$$RISK_{LOS} = \sum_{j=1}^{\#sev} LOSDose \times ACIDNT\_PRB_{j,L} \times LARAT_L \times NSH_L \times DSTRVL_L \qquad (7)$$

where

LOSDose = average LOS dose per severity j on link L
ACIDNT_PRB = conditional probability of an accident of severity j on link L
LARAT = accident rate on link L (accidents/vehicle-km)
NSH = number of shipments on link L
DSTRVL = length of link L (km)

The method for LOS dose-risk is identical to the original dose-risk calculations outlined in the RADTRAN 5.5 Technical Manual[5].

3. Model Assumptions and Setup

3.1 Model Assumptions

The first and most crucial assumption the model makes is transport cask type. Since all shielding simulations were performed for a generic 5.21 meter long S.S.-Pb-S.S. spent nuclear fuel truck cask, the model discussed in this document should be applied only to truck casks. Ongoing work will include an analogous model with appropriate correlations for rail transport casks.

The model is currently limited to calculating doses and risks at specific distances. In the current model, the dose correlation is only valid between 1 and 100 meters. The lower limitation is due to the absence of simulations below 1 meter from the cask and the upper bound is a consequence of current programming. However, the correlation appears to be valid at distances greater than 100 meters, even up to 1000 meters, but needs to be verified. Once verified, the code will be rewritten to allow for dose estimate distances up to 1000 meters from the LOS accident.

In conjunction with the upper distance bound, an error was found in the interpolation scheme which should have allowed the user to determine the dose at distances other than 1, 2, 3, 4, 5, 10, 20, 50, and 100 meters. Currently, the user may input any range of distances, but the results will only be displayed for the predefined distances. Since the model is limited to the predefined distances, all LOS calculations use the average distance method[5], whereas the RADTRAN stop model incorporates an annular-area method where dose is calculated for a population density within an annular area. The code will allow annular area dose calculations in the future.

3.2 Input Setup

The new RADTRAN 6.0 input deck includes several key changes. The most crucial and mandatory being the inclusion of the command line "RADTRAN 6.0" at the beginning of the input file. Additional, but unnecessary, command changes include commands for unit conversion, economic model defaults and the LOS model, all which depend on if that functionality is being exercised. Only the necessary inputs for the LOS model will be discussed for this paper.

The conditional probabilities and corresponding slump fractions are placed in the input file after the release data. The conditional probabilities indicate the type and probability of accident which will cause a particular slump fraction. This is done for each population zone (rural, suburban, urban) under consideration (NPOP = 1, 2, or 3). Figure 2 provides an example of the required format.

```
LOS_SHIELD
  NPOP=1
  ACIDNT_PRB
    1.71E-06  4.63E-07  3.21E-08  2.53E-10  2.20E-05
    5.97E-06  4.14E-07  3.27E-09  4.90E-05  1.66E-09
  FRAC_LOST
         0.052     0.158     0.264     0.368     0.033
         0.096     0.158     0.255     0.029     0.500
```

Figure 2. LOS conditional probabilities and slump fractions.

The other required declaration is a command line for the LOS stop parameters. This is placed after the link statements prior to the end of the file. The necessary user-defined information includes: LOS stop name, vehicle name, number of persons at LOS stop, radial distances [meters], shielding factor, and exposure time [hours]. Any number of LOS stops can be defined. Figure 3 provides an example of the required format.

```
    NAME           VEHICLE     PEOPLE   DISTANCE  SHLD FCTR  EXPOS TIME
LOS_STOP LOSR  VEHICLE_1  1.00        1.0  800        1.000          0.67
LOS_STOP LOSS   VEHICLE_1   1.00       1.0  100        1.000          0.67
LOS_STOP LOSU   VEHICLE_1  1.00       1.0  50          1.000          0.46
```

Figure 3. LOS input parameters.

More details on the logic behind selecting appropriate LOS stop parameters will be discussed in the next section covering a sample LOS problem involving first-responders and the public.

4. LOS Example Problem

4.1 Background

The LOS model was used to determine dose estimates to first-responders and public during an extreme spent nuclear fuel transportation accident. Results varied according to the following: type of accident scenario, percent of lead slump, distance to shipment, time spent in the area. The RADTRAN 6.0 input file was setup using data obtained from NUREG/CR-6672 (Ref. 4) and three LOS stops were modeled, one each for rural, suburban and urban routes with the same shipment vehicle. Data from Table 1 was used to construct the conditional probability and slump fraction portion of the input. Table 2 provides stop related data used to setup the example problem.

Table 2. LOS Stop Input Parameters

Name	Vehicle	People	Inner Distance [m]	Outer Distance [m]	Shielding Factor	Exposure Time [hr]
LOSR	Vehicle_1	1	1	100	1	0.67
LOSS	Vehicle_1	1	1	50	1	0.67
LOSU	Vehicle_1	1	1	20	1	0.46
LOSR	Vehicle_1	1	1	100	1	1
LOSS	Vehicle_1	1	1	50	1	1
LOSU	Vehicle_1	1	1	20	1	1

The first three LOS stops with exposure durations of 0.46 and 0.67 hours are intended to mimic the resident population dose prior to arrival of first-responders and ultimate evacuation[4]. These times are based on the average emergency response times based on population zone. Therefore, it is assumed that the public will remain exposed to the accident for up to 0.67 hours until emergency crews arrive. The remaining LOS stops are used to express the first-responder dose if the number of personnel and exposure time is normalized to one; hence, the final average radiological dose can be multiplied by time and people to get a final answer. Other important parameters and their values are listed in Table III.

Table 3. Link Parameters

	Route Length [km]	Accident Rate	Vehicle Dose Rate @ 1 m [mrem/hr]	Population Density [pers/km^2]
Rural	1777	4.40E-08	13	6
Suburban	541	4.40E-08	13	720
Urban	35	4.40E-08	13	3800

4.2 Results

Again, the LOS model provides results for average dose, maximum dose at two meters and LOS dose-risk. Given that three output types and six different LOS stops would yield 18 independent results, only a few accident results will be discussed here. Figure 4 presents how the average dose is affected by slump fraction and distance from the accident. All results were normalized to one person and with increasing slump and proximity to the accident the dose received can be sizeable.

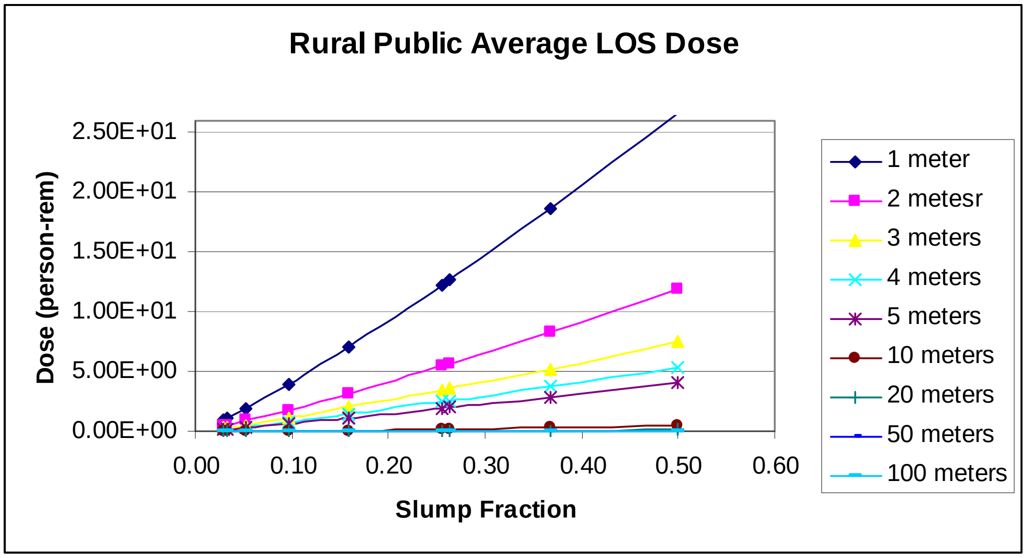

Figure 4. Average Rural Public LOS Dose.

Since the LOS model, when determining average or maximum dose, makes no automatic account for population zone, the only differentiating factor between the rural and urban results is the response time explained in the previous section. Figure 5 compares the average dose at 20 meters between the rural and urban public population zones.

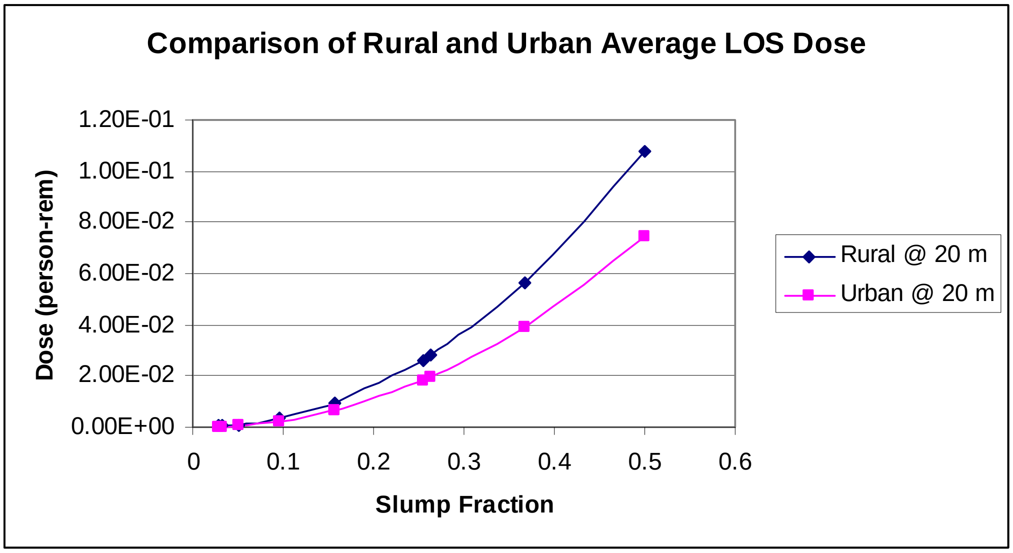

Figure 5. Average Public Dose Comparison between Rural and Urban populations.

The separation in the two lines is due to the shorter response time in an urban environment, thus the dose will be lower for all slump fractions.

The remaining results will focus on the first-responder and cover the maximum dose and dose-risk outputs. Note, the first-responder results are normalized for number of people and time. Therefore, all population zones yield the same values based on the previous assumptions. Figure 6 illustrates the expected maximum dose at two meters for a first-responder.

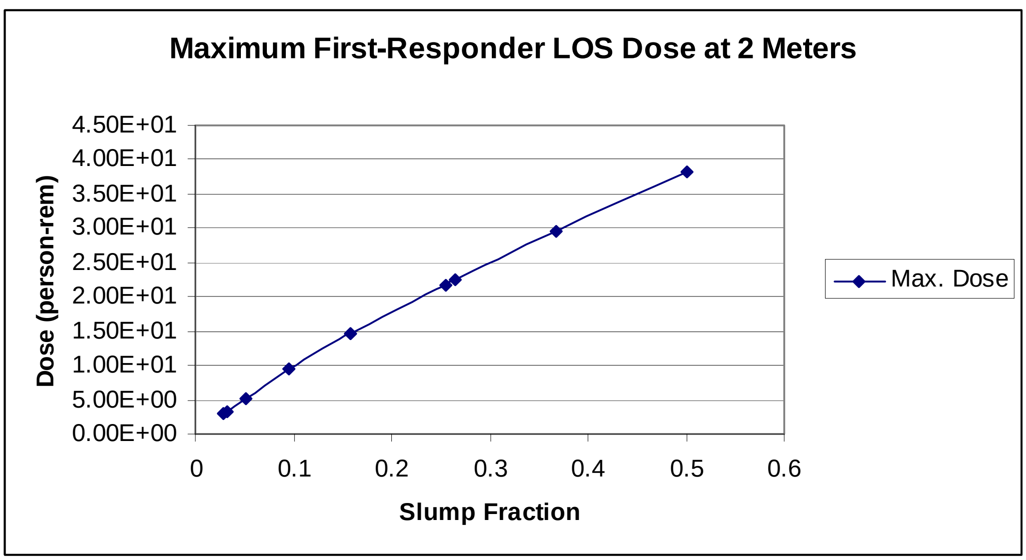

Figure 6. Maximum First-Responder Dose.

It is unlikely that in an accident scenario the first-responder would ever approach the cask at such proximity, but this value serves as a comparison to how the LOS maximum deviates from the regulatory maximum.

Finally, dose-risk is dependent on link parameters such as accident rate, conditional probability and distance traveled. Since each route accident rate and conditional probability is identical, the only differentiating factor is the route length as stipulated in Table 3. Figure 7 shows the dose-risk for first-responders at various distances for each population zone.

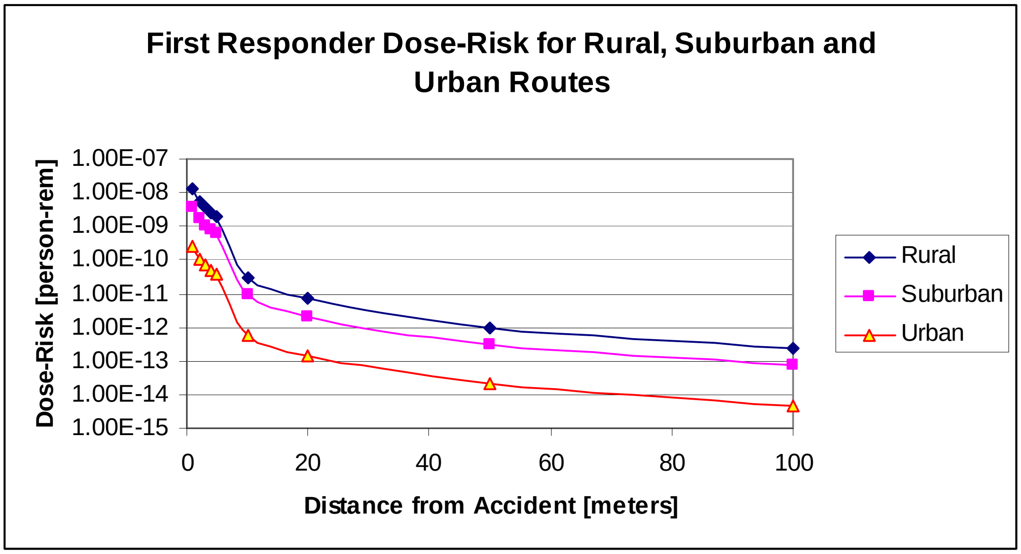

Figure 7. First-Responder Dose Risk.

As expected, the dose-risk is extremely low, even at close distances. At farther distances, the dose-risk approaches zero becoming 4.63E-15 in the urban route at 100 meters.

5. Conclusion

Barring the obvious limitation that the new model is only valid for truck spent nuclear fuel casks, the method improves previous LOS treatments because the new model uses actual dose rates calculated from shielded and unshielded full volume sources. Additionally, we note the contention that under fire accidents the lead shielding is less likely to create an annular void at one end of the cask cavity and more likely to deform creating thinning near the top of the cask. The application of lead thinning is under consideration for analysis and in the meantime, can be roughly approximated using the current model and very small slump fractions.

The new LOS model allows the user to treat an LOS accident similar to a RADTRAN stop, giving the user great flexibility in analyzing numerous accident scenarios on a variety of links with differing accident severities. While extreme conditions could cause lead slump, the model shows that depending on the fraction of shielding lost and distance from the accident, unnecessary doses can be mitigated.

6. References

1. Neuhauser, K.S., F.L Kanipe, and R.F. Weiner. (2000). RADTRAN 5, Technical manual, SAND2000-1256, Sandia National Laboratories, Albuquerque, NM.

2. B.M. O'Donnell, S.C. James, R.F. Weiner, and K.J. Kearfott. (2005). External dose increase from partial loss of lead shielding in a spent fuel cask. Sandia National Laboratories, Albuquerque, NM.

3. Boyd, A.M., D.K. Worthy, R.F. Weiner, and D.M. Osborn. (2006). Benchmarking RADTRAN loss of shielding model for a SNF cask. IHLRWM Conference.

4. J.L. Sprung, D.J. Ammerman, R.J. Dukart, et al., "Reexamination of Spent Fuel Shipment Risk Estimates", NUREG/CR-6672, Two volumes, U.S. Nuclear Regulatory Commission, Washington, D.C., (2000).

5. K. S. Neuhauser, F. L. Kanipe, and R. F. Weiner, *RADTRAN 5 Technical Manual*, SAND2000-1256, Sandia National Laboratories, p. 47-48 (2000).

6. "External Radiation Standards for all Packages", *Code of Federal Regulations*, Title 10, Pt. 71.47, (2007).

Appendix A

Example Problem RADTRAN 6.0 Input

```
RADTRAN 6        November 2007
&& Truck Transport from 6672 Ch. 8
&& Package Dimensions: p. 4-3 Steel-Pb-Steel PWR
&& Radionuclide inventory: p. 7-17
TITLE 6672 Based LOS
INPUT STANDARD
OUTPUT CI_REM
FORM UNIT
DIMEN 19 10 18
PARM 1 3 4 0
SEVERITY
   NPOP=1
      NMODE=1
       1.53E-8
 5.88E-5 1.18E-6 7.49E-8 4.65E-7 3.31E-9
 0.0 1.13E-8 8.03E-11 0.0 1.44E-10
 1.02E-12 0.0 7.49E-11 0.0 0.0
 0.0 5.86E-6 0.99993
   NPOP=2
      NMODE=1
       1.53E-8
 5.88E-5 1.18E-6 7.49E-8 4.65E-7 3.31E-9
 0.0 1.13E-8 8.03E-11 0.0 1.44E-10
 1.02E-12 0.0 7.49E-11 0.0 0.0
 0.0 5.86E-6 0.99993
   NPOP=3
      NMODE=1
       1.53E-8
 5.88E-5 1.18E-6 7.49E-8 4.65E-7 3.31E-9
 0.0 1.13E-8 8.03E-11 0.0 1.44E-10
 1.02E-12 0.0 7.49E-11 0.0 0.0
 0.0 5.86E-6 0.99993
RELEASE
   GROUP=Crud
      RFRAC
         0.0020
 0.0014 0.0018 0.0032 0.0018 0.0021
 0.0031 0.0020 0.0022 0.0025 0.0020
 0.0022 0.0025 0.0064 0.0059 0.0033
 0.0033 0.0025 0.0.0
      AERSOL
         1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0
      RESP
         1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0
```

```
    DEPVEL 0.1
  GROUP=Kr
    RFRAC
      0.8
0.14 0.18 0.84 0.43 0.49
0.85 0.82 0.89 0.91 0.82
0.89 0.91 0.84 0.85 0.91
0.91 0.84 0.0
    AERSOL
      1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0
    RESP
      1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0
    DEPVEL 0.0
  GROUP=Ruth
    RFRAC
      6.0E-7
1.0E-07 1.3E-07 3.8E-06 3.2E-07 3.7E-07
2.1E-06 6.1E-07 6.7E-07 6.8E-07 6.1e-07
6.7E-07 6.8E-07 8.4E-05 5.0E-05 6.4E-06
6.4E-06 6.7E-08 0.0
    AERSOL
      1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0
    RESP
      1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0
    DEPVEL 0.1
  GROUP=Cs
    RFRAC
      2.4E-8
4.1E-09 5.4E-09 3.6E-05 1.3E-08 1.5E-08
2.7E-05 2.4E-08 2.7E-08 5.9E-06 2.4E-08
2.7E-08 5.9E-06 9.6E-05 5.5E-05 5.9E-06
5.9E-06 1.7E-05 0.0
    AERSOL
      1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0
    RESP
      1.0
```

```
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0
     DEPVEL 0.1
   GROUP=Part
     RFRAC
       6.0E-7
 1.0E-07 1.3E-07 3.8E-06 3.2E-07 3.7E-07
 2.1E-06 6.1E-07 6.7E-07 6.8E-07 6.1e-07
 6.7E-07 6.8E-07 1.8E-05 9.0E-06 6.8E-07
 6.8E-07 6.7E-08 0.0
     AERSOL
       1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0
     RESP
       1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0 1.0 1.0
 1.0 1.0 1.0
     DEPVEL 0.1
LOS_SHIELD
    NPOP=1
    ACIDNT_PRB  *From 6672 Table 8.12
       1.71E-06  4.63E-07  3.21E-08  2.53E-10  2.20E-05
       5.97E-06  4.14E-07  3.27E-09  4.90E-05  1.66E-09
    FRAC_LOST
        0.052     0.158     0.264     0.368     0.033
       0.096     0.158     0.255     0.029     0.500
    NPOP=2
    ACIDNT_PRB  *(again)
       1.71E-06  4.63E-07  3.21E-08  2.53E-10  2.20E-05
       5.97E-06  4.14E-07  3.27E-09  4.90E-05  1.66E-09
    FRAC_LOST
        0.052     0.158     0.264     0.368     0.033
       0.096     0.158     0.255     0.029     0.500
    NPOP=3
    ACIDNT_PRB  *(again)
       1.71E-06  4.63E-07  3.21E-08  2.53E-10  2.20E-05
       5.97E-06  4.14E-07  3.27E-09  4.90E-05  1.66E-09
    FRAC_LOST
        0.052     0.158     0.264     0.368     0.033
       0.096     0.158     0.255     0.029     0.500
PACKAGE PACKAGE_1 13.0 1.0 0.0 5.21
   CO60              173.4     Crud
   KR85              5220      Kr
   SR90   160800  Part
   Y90    160800  Part
   RU106             132900  Ruth
   CS134             209700  Cs
   CS137             237000  Cs
   CE144             116100  Part
```

```
  PM147         77400  Part
  EU154         25260  Part
  PU238 14430   Part
  PU239 642     Part
  PU240 1284    Part
  PU241 195600  Part
  AM241         1308   Part
  AM242M        39.9   Part
  AM243         75.3   Part
  CM242         1128   Part
  CM243         86.4   Part
  CM244         16860  Part
END
VEHICLE -1 VEHICLE_1 1.30E01 1.0 0.0 5.21 1.0 2.0 3.0 1.0 0.71
    PACKAGE_1 1.0
MODSTD
  DISTOFF FREEWAY 3.00E01 3.00E01 8.00E02
  DISTOFF SECONDARY 2.70E01 3.00E01 8.00E02
  DISTOFF STREET 5.00E00 8.00E00 8.00E02
  DISTON
     FREEWAY 1.50E01
     SECONDARY 3.00E00
     STREET 3.00E00
     ADJACENT 4.00E00
  BDF 5.00E-02
  BRATE 3.30E-04
  CULVL 2.00E-01
  EVACUATION 1.00E00
  GECON 1.00E-04
  INTERDICT 1.0E05
  LCFCON 5.00E-04 4.00E-04
  SURVEY 1.00E01
  UBF 5.20E-01
  USWF 4.80E-01
  CAMPAIGN 8.33E-02
  MITDDIST 3.00E01
  MITDVEL 2.40E01
  RPD 6.00E00
  RR 1.00E00
  RU 1.80E-02
  RS 8.70E-01
  SMALLPKG 5.00E-01
  RPCTHYROID
     I131         1.27E06
FLAGS
  IACC 2
  IUOPT 2
  REGCHECK 0
EOF
LINK LINK_R VEHICLE_1 1777 88.0 2.0 6    460.0  4.4E-08 0.5 R 1 1.0
LINK LINK_S VEHICLE_1 541  72.0 2.0 720  780.0  4.4E-08 0.5 S 1 0.0
LINK LINK_U VEHICLE_1 35   40.0 2.0 3800 2800.0 4.4E-08 0.5 U 1 0.0
*  LOSS OF SHIELDING STOP
*       NAME      VEHICLE     PEOPLE    DISTANCE    SHLD FCTR  Expos TIME
 LOS_STOP PublicLOSR    VEHICLE_1    1.00      1.0  100      1.000     0.67
 LOS_STOP PublicLOSS    VEHICLE_1    1.00      1.0  50       1.000     0.67
```

```
 LOS_STOP PublicLOSU     VEHICLE_1    1.00      1.0  20        1.000     0.46
 LOS_STOP FirstLOSR     VEHICLE_1    1.00      1.0  100       1.000     1.0
 LOS_STOP FirstLOSS     VEHICLE_1    1.00      1.0  50        1.000     1.0
 LOS_STOP FirstLOSU     VEHICLE_1    1.00      1.0  20        1.000     1.0

EOF
EOI
```

Distribution

Sandia Internal:

6765, MS 0718	David Miller
6762, MS 0718	Doug Osborn
6765, MS 0718	Ruth Weiner
6765, MS 0718	Matthew Dennis
9536, MS 0899	Technical Library (1 electronic and 1 paper copy)

Sandia National Laboratories