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APPLICATION OF THE RADTRAN 5 STOP MODEL

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INTRODUCTION

A number of environmental impact analyses with the RADTRAN computer code have shown that dose to persons at stops is one of the largest components of incident-free dose during overland carriage of spent fuel and other radioactive materials (e.g., USDOE, 1994). The input data used in these analyses were taken from a 1983 study that reports actual observations of spent fuel shipments by truck (Madsen and Wilmot, 1983). Early RADTRAN stop models, however, were insufficiently flexible to take advantage of the detailed information in the study. A more recent study of gasoline service stations that specialize in servicing large trucks, which are the most likely stop locations for shipments of Type B packages in the United States, has provided additional, detailed data on refueling/meal stops (Griego et al., 1996). The RADTRAN 5 computer code for transportation risk analysis (Neuhauser and Kanipe, 1995) allows exposures at stops to be more fully modeled than have previous releases of the code and is able to take advantage of detailed data. It is the intent of this paper first to compare results from RADTRAN 4 (Neuhauser and Kanipe, 1992) and RADTRAN 5 for the old, low-resolution form of input data, and then to demonstrate what effect the new data and input format have on stop-dose estimates for an individual stop and for a hypothetical shipment route. Finally, these estimated public doses will be contrasted with doses calculated for a special population group - inspectors.

ACCOUNTING FOR CODE-RELATED COMPUTATIONAL DIFFERENCES

In order to have confidence in the comparisons in this study, any differences in the stop-dose outputs of the two code releases in calculations made with identical input data must be accounted for. This test is performed as a part of the routine quality-assurance process for code development (Kanipe and Neuhauser, 1997). RADTRAN 5 includes the original RADTRAN stop model as an option, mainly for the purpose of providing continuity between RADTRAN 5 and previous releases; using this model, identical outputs result from identical inputs in both releases. Unlike previous releases of the code, however, RADTRAN 5 also allows total stop time to be divided into what are called "stop links." This capability was included to allow the user to model separately individual stops along a route, for example. Subdividing total stop time in the sample case into two or more "stop links" yields the same total stop dose in the RADTRAN 5 output as in the aggregated case, if all other input values are held constant. Again, this

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normalized, with the generic output set to unity. The percentages of the RADTRAN 5 stop dose represented by persons indoors and persons outdoors are also shown.

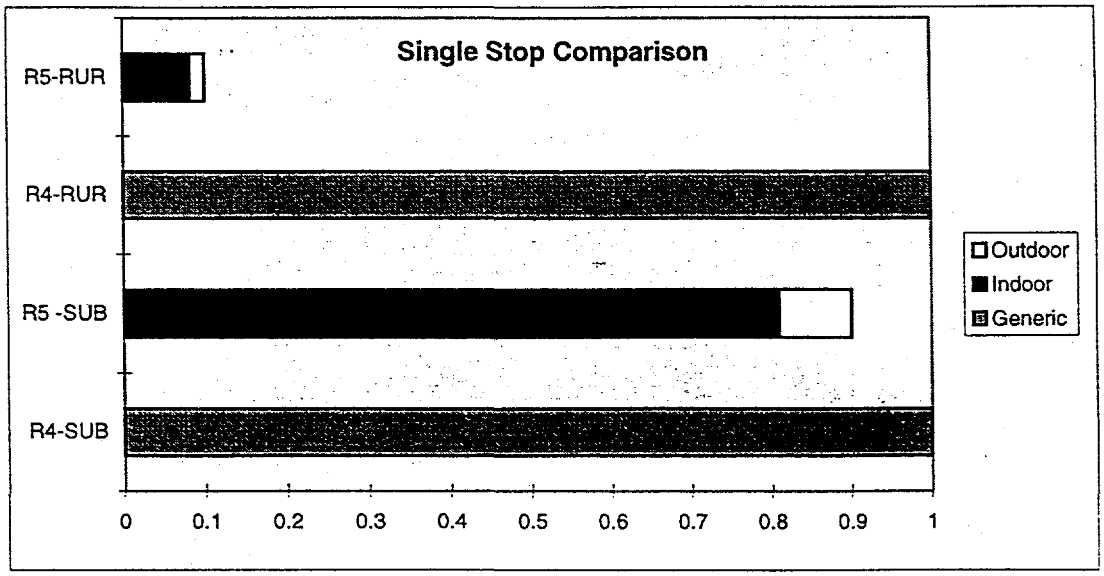

Figure 1. Comparison of RADTRAN 4 (R4) and RADTRAN 5 (R5) Models for Suburban (SUB) and Rural (RUR) Stops

COMPARISON OF DATA - SAMPLE ROUTE

Madsen and Wilmot includes data for a spent-fuel shipment from Fort St. Vrain in Colorado to Idaho National Engineering Laboratory (INEL) in Idaho on a route a little over 1000 km in length. During the shipment there were a total of 12 stops, including 5 inspection stops and an estimated 5 brief rest stops (5 min or less) for dispatcher call-ins and similar short-duration activities. Inspections would include tie-down inspections, weigh-station activities at state border crossings, etc. The number of brief rest-stops was derived by application of Madsen and Wilmot's estimate that 40% of all stops were 5 min or less in duration. The remaining 2 stops can then be assumed to be refueling/meal stops. The total stop time for the trip was approximately 2.75 h; 0.5 h can be assigned to short stops (5 @ 5 min each). The average inspection time is estimated at about 23 min if the Griego et al. data for suburban refueling/meal stop time are used.

The Fort St. Vrain-to-INEL route was used in this study as an example. For the sake of simplicity the route was assumed to be exactly 1000 km long. The package was assigned a unit dose rate of 1 mrem/h to further simplify the calculation. A RADTRAN 4 dose was calculated with the Madsen and Wilmot "generic" values described previously, and a RADTRAN 5 dose was calculated with the following input values:

- 2 refueling/meal stops- both assumed to be in suburban locations with the maximum number of persons indoors (65) and outdoors (7) recorded for suburban locations by Griego et al.; both assumed to last 32 min each, the largest average stop time in Griego et al.

test was part of the routine quality-assurance process for code development Therefore, no adjustments need to be made when comparing stop results from the two code releases.

PREVIOUS STOP-TIME ESTIMATES

RADTRAN 4 required total trip stop time as a direct input value, whereas RADTRAN 5 requires stop time to be entered separately for each discrete stop described in the analysis. Total stop time for cross-country truck shipments in the United States was computed from empirical data collected by Madsen and Wilmot (1983), who found it to be approximately 0.01 h/km or about 10 h per 1000 km of travel. Although this appears to be a large value, it includes inspections, refueling, meals, and overnight sleep. The Madsen and Wilmot data can be used to develop rough estimates of individual stop times. Detailed data were recorded for 24 separate shipments of various radioactive materials. The 8 shipments in Madsen and Wilmot with total elapsed transit times of 18 h or less (which eliminates overnight rest stops) encompass 42 stops and a collective elapsed stop time of about 23h (1380 min). Since Madsen and Wilmot also estimate that 40% of all stops last 5 min or less, it follows that approximately 17 of the 48 stops were of this type. Assigning the maximum value of 5 min to each such stop yields a total of 110 min. Seven more stops were inspection stops, which implies that the remaining 27 were refueling/meal stops. However, the data in Madsen and Wilmot do not allow differentiation between the latter two stop types. The collective elapsed time for inspections and refueling/meal stops is 1130 min. Thus, the best estimate that can be developed from the Madsen and Wilmot paper is an average stop time per inspection/refueling/meal stop of about 37 min.

Madsen & Wilmot, 1983 Values:
Avg. Distance (m) = 20
Avg. No. of Persons = 50
Stop Time = .01h/km

SUMMARY OF NEW STOP DATA

Griego et al. (1996) examined truck service stations located near Interstate 40 in suburban and rural areas in the states of Arizona and New Mexico. Their main purpose was to develop data on refueling/meal stops. All stations studied were easily accessed from the Interstate. No truck service stations were found to be located in densely populated urban areas in the study area.

Griego et al. (1996) spent more than 60 hours anonymously observing these stations, following a pre-determined protocol. Data on combination-truck stop times and other variables were collected as written notes and documented with videotape. Table 1 summarizes their findings; distances given in the table represent distances from the stopped shipment to members of the public; each is a practical minimum based on station layout. Station attendants were found to spend relatively little time in close proximity to an individual truck. There were several reasons for this, chief among them being the facts that (1) dual tanks were filled simultaneously instead of one at a time and (2) not all of the total stop time was spent in actual refueling. Trucks were parked while drivers purchased meals, filled out logbooks, etc. The trucks observed at the stations during 9 separate observation periods were randomly selected, by a method developed in the protocol, and they carried all types of cargo.

Table 1. Stop Model Input Values Based on Griego et al. 1996 for Three Service Stations

Station	Parameter Values			
	Distance (m)	Stop Time (h)	Persons Outside	Persons Inside
Suburban #1	23	0.32 (σ = .10 h)	7 (σ = 0.2)	33 (σ = 8.4)
Suburban #2	23	0.30 (σ = .13 h)	7 (σ = 2.6)	65 (σ =15.5)
Rural	46	0.25 (σ = .23 h)	5 (σ = 0.5)	44 (σ = 3.2)

Like Madsen and Wilmot, Griego et al. collected data on persons located indoors and out of doors, even though earlier releases of RADTRAN were unable to accept such data. RADTRAN 5 now allows the two population groups to be separately identified. A shielding factor also may be applied to the indoor subpopulation. Like the service stations observed by Madsen and Wilmot, the service stations observed by Griego et al. (1996) were of masonry construction; a shielding factor of 0.83 was used in the current analysis. Madsen and Wilmot suggested a similar factor.

COMPARISON OF DATA - INDIVIDUAL STOP

The 37-min average from Madsen and Wilmot is higher than any of the Griego et al. averages but still well within the statistical range computed by Griego et al. The average source-to-public distance of 23 m for suburban stops in Griego et al. also is comparable to the 20 m value from Madsen and Wilmot. Stops in the relatively built-up suburban areas studied by Griego et al. occupied less total acreage and were more compactly laid out than the rural stops. Since Madsen and Wilmot does not distinguish between rural and suburban locations, their recommended values, which are intended to be applied in all population densities, appear to be somewhat conservative. It should be noted, however, that the single rural station studied quantitatively in Griego et al. may not be representative of all rural truck-service stations.

Griego et al. observed somewhat lower numbers of persons outside buildings than did Madsen and Wilmot (5 to 7 versus 17 to 25); they also observed higher numbers of persons inside buildings than did Madsen and Wilmot (33 to 65 versus 17 to 21). The differences cannot be attributed to seasonal or diurnal factors since all observations by Griego et al. were made during daylight hours in the months of July, August, and September.

Figure 1 illustrates the differences in population doses calculated for a single refueling stop with RADTRAN 4 "generic" values and with Greigo et al. values for a 32-min stop calculated with RADTRAN 5. All values were calculated for a package with a unit dose rate (i.e., 1 mrem/hr); the RADTRAN 4 output was for a 1000 km trip with Madsen and Wilmot's generic values used as inputs. The raw output values for population dose were

- 5 inspection stops- each assumed to last 23 min, with 1 inspector at 1.5 m. from the center of the package.
- 5 short rest stops - each assumed to last 5 min and to have a population profile resembling the rural location in Griego et al.

The RADTRAN 4 stop dose for the route was 2.8E-03 person-rem; the corresponding RADTRAN 5 calculation was 2.2E-03 person-rem, or 82% of the RADTRAN 4 value. Table 2 shows both raw output values and the percentages of the total represented by each stop type in the RADTRAN 5 calculation. Even with the conservative assumption that both of the refueling/meal stops occurred in suburban areas, this dose category still only represents 13% of the total stop dose.

Table 2 Contribution to Total Stop Dose of the Three Stop Categories for an Idealized 1000-km Spent Fuel Shipment

Data Type	Refueling/Meal	Inspection	Short (rural)	Total Stops
Raw Output (person-rem)	2.9E-04	1.9E-03	1.9E-05	2.2E-03
Percentage Value	13	86	1	100

CONCLUSIONS

Two independent Sandia studies of truck stops, performed more than a decade apart, have been shown to yield remarkably consistent values. The inability of the stop models in previous releases of RADTRAN to accept detailed location-specific data forced the authors of the earlier study to develop conservative "generic" values for input variables, including the important stop-time parameter. The result has been a tendency to overestimate stop dose, for short trips in particular. The older data also may overestimate rural stop doses by as much as a factor of 10, but suburban stop doses are essentially unchanged.

When the impact of stop-specific data on dose estimates for a hypothetical shipment with very little rural stop time was examined for an idealized sample route, the results were again remarkably comparable. However, if the rural stop values reported by Griego et al. can be confirmed, then RADTRAN 5 estimates ultimately may be significantly lower than the RADTRAN 4 baseline, since 70 to 85% of most Interstate routes in the United States traverse rural areas. The RADTRAN 5 results contain a previously unavailable breakdown by stop type (Table 3) that reveals that inspection stops are probably the dominant source of stop dose for truck shipments of spent fuel. This is not surprising since inspectors spend more time relatively close to the shipment than do other individuals at any type of stop. This is also consistent with the finding that inspector dose is dominant for maritime shipments of spent fuel entering the United States (Neuhauser and Weiner, 1992).

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