ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. ENG-RCAL-028 Rev. 1 Project No. 772030/171 Page 1 of 62
Subject: Transportation Risk Assessment for the Shipment of Unirradiated Uranium
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1.0 OBJECTIVE

The objective of this transportation risk assessment is to determine the impacts of the transportation of unirradiated uranium in the form of metallic billets, UO_3 powder, and finished and unfinished N Reactor fuel elements from the Hanford Site, Washington, to Portsmouth, Ohio. The radiological risk is determined for both incident-free transport and transport involving potential accidents. The toxicological consequences are determined for the case in which a credible accident is assumed to occur, without regard for the frequency, and thus the risk, of such an accident.

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3.0 ASSUMPTIONS, RESULTS, AND CONCLUSIONS

The following assumptions were made in the risk calculations for all payloads.

- Risk calculations were made with the computer code RADTRAN version 4.0.19.SI (Neuhauser and Kanipe 1989 and 1992). Assumptions for specific parameters in the RADTRAN code are given in Section 4.0. Input files are given in Section 5.0.
- Routes were obtained using the computer code Highway version 3.3 (Johnson et al. 1993) for the truck routes, and the computer code Interline version 5.0 (Johnson et al. 1992) for the rail routes. Output files are given in Section 5.0
- Mileage through each zone of population density (rural, suburban, and urban) was aggregated along the entire route, and national average accident rates from Saricks and Kvitek (1994) were applied to each zone.
- Eight accident severity categories and the corresponding severity fractions for truck and rail transport were taken from NRC (1977).
- The shipments were exclusive use based on calculated dose rates.

The following assumptions were made specifically in the risk calculations for the uranium billets.

- Release fractions for Category 1 accident severity were assumed to be zero, and 1.0 for Categories 2 through 8. The Category 2 and 3 release fractions are conservative by a factor of 100 and 10, respectively, compared to values for Type A containers given in NRC (1977).
- Aerosol fractions and respirable fractions were taken from DOE (1994a) for the complete oxidation of uranium metal in a fire.
- The conveyance was a truck, with a trailer of width 3 m.
- The container was assumed to be the G-4255 Wooden Box (FDH 1999), with interior dimensions 8 in. x 24.125 in. x 30.75 in.
- A total of 75 shipments for the campaign of billets was used, based on a total of 234 MTU, 175 kg U per billet, 3 billets per box, 6 boxes per shipment.
- A dose rate of 0.086 mrem/h at 1 m from the edge of the conveyance was used based on the shielding calculation included in the Appendix in Section 5.1.

The following assumptions were made specifically in the risk calculations for the UO_3 powder.

- Release fractions for Category 1 accident severity were assumed to be zero, 0.1 for Category 2, and 1.0 for Categories 3 through 8. The Category 2 and 3 release fractions are conservative by a factor of 10 compared to values for Type A containers given in NRC (1977).
- Aerosol fractions and respirable fractions were taken from DOE (1994a) for powder with particle diameter less than 2 mm in metal containers.
- Both truck and rail conveyances were modeled.
- Two routes were considered, a direct route and an indirect route through Paducah, Kentucky.
- The container was assumed to be the T-Hopper (Lawson 1987), a cone-shaped container enclosed in a 5 ft x 5 ft x 6 ft steel frame.
- A total of 5 shipments for the campaign of powder via rail were modeled, based on a total of 147 T-Hoppers, 10 T-Hoppers per rail car, 3 rail cars per shipment.
- A total of 49 shipments for the campaign of powder via truck were modeled, based on 3 T-Hoppers per truck.
- A dose rate of 0.73 and 0.44 mrem/h at 1 m from the edge of the railcar and truck trailer, respectively, was used based on decay and shielding calculations. A discussion of the shielding calculation is included in the Appendix in Section 5.1.

The following assumptions were made specifically in the risk calculations for the finished and unfinished fuel elements.

- Release fractions for boxes of finished fuel were those recommended for Type A containers. For unfinished fuel, the release fractions were the same as for the UO_3.
- Aerosol and respirable fractions were the same as for the billets.
- Only a direct route by truck was modeled.

- The container was assumed to be the G-4214 Wooden Box (FDH 1999), with interior dimensions 30 in. x 14.125 in. x 8.375 in.
- The campaign of finished fuel was assumed to require a total of 537 shipments; 94 shipments for the campaign of unfinished fuel. Note that these numbers are based on preliminary, unpublished criticality-based shipment limits (Ferrell 1999) for each ^{235}U enrichment content.
- Dose rates at 1 m from the vehicle edge of 0.023 - 0.052 mrem/h for the various ^{235}U enriched fuels were calculated based on an assumed box arrangement, assumed box loadings, box capacity, and shipment limits. The shielding calculation is addressed in Section 5.1.

A small amount of UO_2 is also to be transported. The UO_2 consists of 4.86 metric tons uranium enriched in ^{235}U to levels between 0.2 and 4.31%, with a weighted average of 1.12%. Because a shipping container for this material has not been identified, this payload is not analyzed.

Table 1 gives the total radiological risks from the shipping campaigns of the billets, powder, and fuel payloads. The total radiological risk is broken into contributions from incident free transport, i.e., during which no accidents occur, and from accidents during transport, which account for the probabilities and content releases of accidents of various severity. The total detriment is the number of fatal cancers, non-fatal cancers, and severe hereditary effects weighted by the severity of that effect. Fatal cancers are given the maximum weight of 1.

Table 2 gives the toxicological consequences from a potential accident involving a single shipment. As these values are consequences rather than risk, they cannot be compared directly to the radiological risk values in Table 1, because a risk assessment weights the consequences by the frequency (or probability) of occurrence of the release.

Table 1 Radiological Risk from Uranium Shipments

Payload Description	Incident Free Transportation			Accident in Transport	Total Radiological Risk
	Worker	Public	Total	Total	
Billets -- Hanford to Portsmouth -- Truck					
Total Dose (person-rem)	0.084	0.092	0.176	0.103	0.279
Latent Cancer Fatalities	3.36E-05	4.60E-05	7.96E-05	5.15E-05	1.31E-04
Total Detriment	4.71E-05	6.71E-05	1.14E-04	7.52E-05	1.89E-04
UO3 Powder					
-- Hanford to Portsmouth -- Rail					
Total Dose (person-rem)	0.092	0.429	0.521	0.033	0.554
Latent Cancer Fatalities	3.70E-05	2.14E-04	2.51E-04	1.64E-05	2.68E-04
Total Detriment	5.17E-05	3.13E-04	3.65E-04	2.39E-05	3.89E-04
-- Hanford to Portsmouth -- Truck					
Total Dose (person-rem)	0.372	0.354	0.726	0.059	0.785
Latent Cancer Fatalities	1.49E-04	1.77E-04	3.26E-04	2.94E-05	3.55E-04
Total Detriment	2.08E-04	2.58E-04	4.67E-04	4.29E-05	5.10E-04
-- Hanford to Paducah to Portsmouth -- Rail					
Total Dose (person-rem)	0.106	0.445	0.551	0.041	0.592
Latent Cancer Fatalities	4.24E-05	2.23E-04	2.65E-04	2.05E-05	2.85E-04
Total Detriment	5.94E-05	3.25E-04	3.84E-04	2.99E-05	4.14E-04
-- Hanford to Paducah to Portsmouth -- Truck					
Total Dose (person-rem)	0.422	0.400	0.822	0.069	0.891
Latent Cancer Fatalities	1.69E-04	2.00E-04	3.69E-04	3.43E-05	4.03E-04
Total Detriment	2.36E-04	2.92E-04	5.28E-04	5.01E-05	5.78E-04
Fuel -- Hanford to Portsmouth -- Truck					
Total Dose (person-rem)	0.524	0.081	0.605	0.141	0.746
Latent Cancer Fatalities	2.10E-04	4.05E-05	2.50E-04	7.04E-05	3.21E-04
Total Detriment	2.94E-04	5.92E-05	3.53E-04	1.03E-04	4.56E-04

Table 2 Toxicological Consequences from an Accident

Receptor Location, m	Fuel/Billets, 0.045 g/s release rate			T-Hopper Shipments, 4.1 g total release		
	χ/Q', s/m^3	Concentration, mg/m^3		χ/Q, m^{-3}	Concentration, mg/m^3	
100	3.76E-3	0.170	< TEEL-1	3.14E-4	1.27	< TEEL-3
200	9.68E-4	0.0439	< TEEL-0	4.74E-5	0.192	< TEEL-1
1000	6.63E-5	3.01E-3	< TEEL-0	7.10E-7	2.88E-03	< TEEL-0
100, rare case	2.85E-2	1.29	< TEEL-3	2.65E-3	10.7	> TEEL-3

4.0 EVALUATION

4.1 Methodology

The RADTRAN 4 computer code (Neuhauser and Kanipe 1992) was used to analyze the risks of transporting unirradiated uranium in the form of metallic billets, UO_3 powder, and N Reactor fuel elements from the Hanford Site in Washington State to the DOE site near Portsmouth, Ohio. RADTRAN was originally developed by Sandia National Laboratories (SNL) in conjunction with the preparation of NUREG-0170, *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC 1977). Since then the code has been expanded and refined several times.

4.2 Source Term

Three forms of uranium are considered in this analysis: metallic billets, UO_3 powder, and finished and unfinished N Reactor fuel. The uranium is unirradiated and slightly enriched in ^{235}U. The source terms used in this analysis are listed in Tables 3-5, respectively.

234 metric tons of uranium are in the form of forged billets, each about 175 kg and containing 1.25% ^{235}U. Billets of this enrichment are in the shape of an annular cylinder, 17.73 cm OD, 7.1 cm ID, and 40.64 cm long (FDH 1999). The billets are shipped by truck in the Model G-4255 wooden box, which has a capacity of 3 billets and, when loaded with 1.25% ^{235}U billets, may be shipped six at a time (FDH 1999). This gives a total of 75 shipments [75 shipments = 234,000 kg / (175 kg/billet x 3 billets/box x 6 boxes/shipment)].

669 metric tons of uranium are in the form of UO_3 powder, enriched to 0.87% ^{235}U. The powder is currently stored in 147 T-Hoppers, each of which has a capacity of 4.5 metric tons of uranium. T-Hoppers are to be shipped either by truck three at a time or by rail, ten per railcar, three railcars per shipment. This would require a total of 49 shipments by truck or 5 shipments by rail.

Table 3 Source Term for the Billets

Isotope	Weight Fraction	kg isotope /Billet	Ci/Billet	Ci/Box
^{234}U	1.34E-04	2.35E-02	1.459E-01	4.376E-01
^{235}U	1.256E-02	2.20E+00	4.836E-03	1.451E-02
^{236}U	1.00E-03	1.75E-01	1.132E-02	3.397E-02
^{238}U	9.88E-01	1.73E+02	5.809E-02	1.743E-01
^{241}Pu	4.14E-11	7.25E-09	7.245E-04	2.174E-03
^{99}Tc	2.58E-05	4.52E-03	7.721E-02	2.316E-01
^{90}Sr	1.56E-10	2.73E-08	3.849E-03	1.155E-02

Table 4 Source Term for the T-Hoppers

Isotope	Wt %	kg isotope /T-Hopper	Ci/T-Hopper
^{234}U	0.0080	0.36	2.239E+00
^{235}U	0.87	39.15	8.613E-02
^{236}U	0.069	3.105	2.009E-01
^{238}U	99.06	4457.7	1.498E+00

The N Reactor fuel consists of finished and unfinished inner and outer fuel elements of five different ^{235}U enrichments. Both elements are annular cylinders, the outer element has dimensions of about 2.4 in. OD, 1.8 in. ID; the inner element is about 1.2 in. OD, 0.5 in. ID, with lengths varying between 15 and 26 in. (WHC 1992). A total of 957.3 metric tons of uranium as fuel are to be shipped in the Model G-4214 wooden box, which has a capacity of 544 kg. The unfinished fuel elements are differentiated from the finished fuel in that they do not have the end caps welded on. The enrichment levels of ^{235}U consist of 0.71, 0.95, 1.03, 1.15, and 1.25%. Due to the possibility of forming a critical configuration in the event of an accident, preliminary limits on the total uranium mass in a shipment of the 0.95% and 1.25% enriched fuel have been derived (Ferrell 1999). Mass limits for the 1.03 and 1.15% enriched fuel were interpolated from these limits. The fuel with a ^{235}U content of 0.71% is considered to be natural uranium and is not considered to be fissile material. The criticality based shipment mass limits, total mass of both finished and unfinished fuel to be shipped, and calculated number of shipments of fuel of each ^{235}U content are included in Table 5.

Table 5 Source Term for the Fuel

^{235}U Content	Isotope[a]	Weight Fraction	kg/Shipment	Ci/Shipment	Shipment Limit (kg)	Total Mass (kg)	# Shipments
0.71%	^{234}U	5.50E-05	1.80E-01	1.12E+00	3264 based on 544 kg/box, 6 boxes/ shipment	65,300[f] 8,600[u]	20[f] 3[u]
	^{235}U	7.10E-03	2.32E+01	5.10E-02			
	^{236}U	3.00E-04	9.79E-01	6.34E-02			
	^{238}U	9.93E-01	3.24E+03	1.09E+00			
0.95%	^{234}U	1.33E-04	2.17E-01	1.347E+00	1628	611,800[f] 113,500[u]	376[f] 70[u]
	^{235}U	9.56E-03	1.56E+01	3.424E-02			
	^{236}U	1.00E-03	1.63E+00	1.053E-01			
	^{238}U	9.91E-01	1.61E+03	5.421E-01			
1.03%	^{234}U	1.33E-04	1.83E-01	1.137E+00	1375	9,800[f]	7
	^{235}U	1.106E-02	1.52E+01	3.346E-02			
	^{236}U	1.00E-03	1.38E+00	8.896E-02			
	^{238}U	9.89E-01	1.36E+03	4.569E-01			
1.15%	^{234}U	1.33E-04	1.32E-01	8.240E-01	996	133,700[f]	134
	^{235}U	1.11E-02	1.10E+01	2.423E-02			
	^{236}U	1.00E-03	9.96E-01	6.444E-02			
	^{238}U	9.89E-01	9.85E+02	3.310E-01			
1.25%	^{234}U	1.34E-04	9.11E-02	5.668E-01	680	14,600[u]	22
	^{235}U	1.256E-02	8.54E+00	1.879E-02			
	^{236}U	1.00E-03	6.80E-01	4.400E-02			
	^{238}U	9.88E-01	6.72E+02	2.257E-01			

[a] Three trace isotopes are assumed to be present in the enriched fuels: ^{241}Pu at 4.14E-11, ^{99}Tc at 2.58E-5, and ^{90}Sr at 1.56E-10 weight fractions.
[f] Finished fuel
[u] Unfinished fuel

^{234}U and ^{236}U were not included in RADTRAN's library of radionuclides, so the isotopes were defined in the input file. These isotopic definitions were taken from RADTRAN input files in Green (1995), which used the sources referenced in RADTRAN (Neuhauser and Kanipe 1992) to obtain the required isotopic properties.

4.3 Incident-Free Transportation

The RADTRAN 4 User Guide (Neuhauser and Kanipe 1992) defines incident-free transportation as transportation during which no accident, packaging or handling abnormality, or malevolent attack occurs. The consequence due to incident-free transportation is the dose received by people in the vicinity of the package due to external exposure. These people may include passengers, transportation workers (crew, inspectors, etc.), handlers, population off-link, population on-link, population during stops, and population during storage. The probability of the afore-mentioned consequences is always set to unity, as the probability of an accident is much less than unity. Thus, the risk due to incident-free transportation is numerically equal to the consequences.

Table 6 lists the input parameters common to all shipments made by truck or rail that are used by RADTRAN 4 in the calculation of population dose for incident-free transportation. Many of the values used for these parameters are defaults recommended by the RADTRAN User Guide (Neuhauser and Kanipe 1992). Others are either calculated or assumed and are discussed below. Parameters dependent on the package transported are listed in Table 7.

Table 6 Input Parameters for Incident Free Transport by Truck and Rail

Parameter Description	Truck	Rail
Number of crew members [a]	2	5
Number of handlings per shipment [a]	0	2
Stop time per km (hr/km)	0	0.033 [a]
Minimum stop time per trip (hr)	10.84 - Direct 12.20 - Indirect	10 [a]
Distance-independent stop time per rail trip (hr)[a]	NA	60
Minimum number of rail inspections [a]	NA	2
Number people exposed during a stop [a]	50	100
Average exposure distance during stops [a]	20	20
Storage time per shipment [a]	0	4
Number of persons exposed during storage [a]	100	100
Average exposure distance during storage [a]	100	100
Number of people per vehicle (on-link population) [a]	2	3
Velocity in rural zone [a]	88.49	64.37
Velocity in suburban zone [a]	40.25	40.25
Velocity in urban zone [a]	24.16	24.16
Fraction of urban travel during rush hour	0	0
Fraction of urban travel on city streets	0	1
Fraction of rural and suburban travel on freeways	1	0
One-way hourly traffic count, Rural zone [a]	470	1
One-way hourly traffic count, Suburban zone [a]	780	5
One-way hourly traffic count, Urban zone [a]	2,800	5

[a] Default values taken from RADTRAN 4 User Guide (Neuhauser and Kanipe, 1992)

Table 7 Package-Specific Input Parameters for Incident Free Transport

Parameter Description	Billets - Truck	UO_3 - Truck	UO_3 - Rail	Fuel - Truck
Exclusive use?	YES	YES	YES	YES
Number of shipments	75	49	5	632
Dose rate at one meter from vehicle edge (mrem/hr)	0.086	0.44	0.73	0.71% ^{235}U: 0.052 0.95% ^{235}U: 0.034 1.03% ^{235}U: 0.034 1.15% ^{235}U: 0.023 1.25% ^{235}U: 0.023
Characteristic package dimension (CPD) (m)	3.91	4.57	15.24	0.71% ^{235}U: 2.50 0.95% ^{235}U: 1.08 1.03% ^{235}U: 1.08 1.15% ^{235}U: 0.72 1.25% ^{235}U: 0.72
Source-to-crew distance (m)	8.27	7.71	152.4 [a]	3.10 [a]

[a] Default values taken from RADTRAN 4 User Guide (Neuhauser and Kanipe, 1992)

One of the calculated parameters in Table 7 is the characteristic package dimension (CPD). This is usually the largest dimension of the package. However, when arrays of similar packages are shipped, the RADTRAN User Guide (Neuhauser and Kanipe 1992) suggests treating the array as a single package. The CPD selected for the array of six G-4255 wooden boxes transporting billets was the length of the array, i.e., six box widths, calculated to be 3.91 m (= 6 x 25.625 in.). The lengths of the array of three T-Hoppers by truck, 4.57 m (= 3 x 5 ft), and of the array of ten T-Hoppers by rail, 15.24 m (=10 x 5 ft), were used as the CPD for the powder shipments. The CPD for the G-4214 wooden boxes used to transport the fuel was a multiple of the box width, 16.375 in., and the number of boxes depended on box capacity and the mass limit imposed by criticality constraints for each enrichment. Schematics of the wooden boxes and T-Hopper are included in Section 5.13.

Another parameter in Table 7, the source to crew distance, is calculated for the transport of billets and T-Hoppers by truck. RADTRAN calculates dose rates to the crew by extrapolating the dose rate at the side of the array, without accounting for the fact that the crew is not at the side of the array but at the head of the conveyance. Because the dose rates on the side are larger than at the head of the array, the crew dose rate is overestimated. The RADTRAN User Guide (Neuhauser and Kanipe 1992) suggests fixing this by inflating the source to crew distance. The shielding calculation in Section 5.1 determined the dose rate from the various package arrays for an estimated source to crew spacing of 3.1 m. The equation for the dose rate to the crew given in the RADTRAN Technical Manual (Neuhauser and Kanipe 1989) is

$$DR_c = \frac{(PPS)(DR_p)(1+0.5d_e)^2}{r_c{}^2}$$

where DR_c = dose rate in the crew compartment
r_c = source to crew distance, (m)
PPS = number of packages per shipment
DR_p = dose rate at 1 m, and
d_e = effective package dimension = $\begin{cases} CPD; & \text{if } CPD < 4\,\text{m} \\ 2 \cdot (1+0.5CPD)^{0.75} - 0.55; & \text{if CPD} \geq 4\,\text{m} \end{cases}$

The effective package dimension is a function of the characteristic package dimension (CPD). The CPD of the array of 6 G-4255 boxes is less than 4 m, so d_e is equal to the CPD. The CPD of the array of 3 T-Hoppers is greater than 4 m, so the d_e is calculated to be 4.33 m using the above formula.

Rearranging for the effective source to crew distance gives

$$r_c = (1+0.5d_e)\sqrt{PPS\frac{DR_p}{DR_c}}$$

The parameter values and resulting effective source to crew distances are

Array	d_e	PPS	DR_p	DR_c	r_c
6 G-4255 boxes	3.91	1	0.086	0.011	8.27
3 T-Hoppers	4.33	1	0.44	0.074	7.71

An effective source to crew distance was not calculated for the array of T-Hoppers transported by rail, as the RADTRAN default value for rail shipments is sufficiently large to account for the massive shielding provided by the locomotive. Shipments of fuel also did not require a calculation of the effective source to crew distance, as more of a square footprint was assumed for the arrays of fuel enriched to 0.95 and 1.25% ^{235}U. Consequently, the use of the lateral dose rate was not overly conservative.

Two other parameters in Table 6 for which derived values were used are the stop time per kilometer traveled and the minimum stop time per trip. The computer code HIGHWAY (Johnson et al. 1993) assumes that a two-person truck driving team will move for 4 hr and then stop for a 0.5 hr break, repeating this cycle until the destination is reached. This approach is considered more realistic than the defaults provided in the RADTRAN 4 User Guide (Neuhauser and Kanipe 1992), in which the drivers are assumed to stop for an hour after every 90 km.

However, to be conservative, the stop time using the HIGHWAY approach is multiplied by a factor of 2. The HIGHWAY output files in Section 5.0 give a total road time of 43.3 hr by the direct route and 48.8 hr by the indirect route. The stopover time in Paducah in the indirect route is not included in the total stop time, as the T-Hoppers are removed from the transport vehicle for maintenance. Thus, the total stopover time is 10.8 hr (= 43.3 / 4 x 0.5 x 2) by the direct route and 12.2 hr (= 48.8 / 4 x 0.5 x 2) by the indirect route.

4.4 Transportation Accidents

Accidents occurring during transportation may cause damage to the package's shielding or cause a release of radioactive material from the package. The consequence of an accident during transportation is the dose received by the nearby population from this release by any of six potential exposure pathways considered in RADTRAN. These pathways are direct external irradiation, cloudshine, inhalation, groundshine, resuspension, and ingestion (Neuhauser and Kanipe 1989). The probability of an accident is based on the total distance traveled and on tabulated accident frequencies per unit distance. Thus, knowledge of the transportation route is required for calculating the risks from transportation accidents.

The truck transportation routes between the Hanford Site in Washington and the Portsmouth Site in Ohio were generated using the computer code HIGHWAY 3.3 (Johnson et al. 1993) via the TRANSNET network at Sandia National Laboratories. Two distinct truck transport routes were calculated. One route, which stops in Paducah, Kentucky, is used for the shipment of the T-Hopper packages. All other packages will be shipped via a direct route between the origin and destination. The rail transportation route was generated using the computer code INTERLINE version 5.0 (Johnson et al. 1992), again via TRANSNET. As before, a direct route and an indirect route were obtained. Weighted population densities in the rural, suburban, and urban zones were calculated by HIGHWAY and INTERLINE for the specific routes traveled and used in the RADTRAN input files. The total distance and fraction of distance traveled in each population zone are given in Table 8 for the rail and truck routes. Maps of the routes obtained from HIGHWAY and INTERLINE are included in the Appendix in Section 5.13.

Table 8 Population Breakdown of the Truck and Rail Routes

Route and Mode	Total Distance (km)	Fraction of Total Distance in Each Zone		
		Rural	Suburban	Urban
Direct, Truck	3870.4	0.8783	0.1116	0.0101
Indirect, Truck	4391.8	0.8625	0.1266	0.0109
Direct, Rail	3981.2	0.8590	0.1138	0.0272
Indirect, Rail	4747.0	0.8520	0.1240	0.0240

Nationwide average accident rates were taken from Saricks and Kvitek (1994) for truck and rail shipments. The accident rates per km for rural and urban/suburban truck shipments are 2.03E-7 and 3.58E-7, respectively. The accident rate on mainline railroads per km per railcar is 2.66E-8. Because three railcars will be transported at a time, that rate is multiplied by three. The mainline accident rate is used since the vast majority of the distance traveled is on mainline routes.

Because accidents may vary in terms of their severity, an accident severity classification scheme is required that groups accidents of similar severity together. A scheme of eight severity categories of increasingly severe accidents, defined in terms of mechanical and thermal (fire) loads, for different transportation modes is provided in NUREG-0170 (NRC 1977). Also reported in NUREG-0170 are the fractional occurrences of accidents in each severity category, further subdivided by the fractional occurrence in each of three zones of population density. Accidents of Category 1 are defined to be less serious than the accident performance capabilities of a Type A packaging and are not expected to result in the release of the radioactive material. Similarly, a Type B packaging is expected to survive a Category 2 accident with no release. The probabilities of occurrence of accidents of each severity category and in each population zone are given in Table 9 for truck and rail transportation. Table 10 gives the same data after normalizing the accidents according to population density zone.

Table 9 Fractional Occurrences for Rail and Truck Accidents by Accident Severity Category and by Population Density Zone

Accident Severity Category	Fractional Occurrences via Rail	Fractional Occurrences via Truck	Fractional Occurrences According to Population Density Zones*		
			Low (rural)	Medium (suburban)	High (urban)
1	0.50	0.55	0.1	0.1	0.8
2	0.30	0.36	0.1	0.1	0.8
3	0.18	0.07	0.3	0.4	0.3
4	0.018	0.016	0.3	0.4	0.3
5	0.0018	0.0028	0.5	0.3	0.2
6	1.3E-4	0.0011	0.7	0.2	0.1
7	6.0E-5	8.5E-5	0.8	0.1	0.1
8	1.0E-5	1.5E-5	0.9	0.05	0.05

* These values are the same for truck and rail transportation.
(NRC 1977)

Table 10 Fractional Occurrences for Rail and Truck Accidents Normalized to Population Zone

Accident Category	Rail			Truck		
	Rural	Suburban	Urban	Rural	Suburban	Urban
1	3.56E-01	3.13E-01	5.72E-01	4.62E-01	4.35E-01	5.83E-01
2	2.14E-01	1.88E-01	3.43E-01	3.02E-01	2.85E-01	3.82E-01
3	3.84E-01	4.51E-01	7.72E-02	1.76E-01	2.21E-01	2.78E-02
4	3.84E-02	4.51E-02	7.72E-03	4.03E-02	5.06E-02	6.36E-03
5	6.41E-03	3.38E-03	5.14E-04	1.18E-02	6.64E-03	7.42E-04
6	6.48E-04	1.63E-04	1.86E-05	6.47E-03	1.74E-03	1.46E-04
7	3.42E-04	3.76E-05	8.57E-06	5.71E-04	6.72E-05	1.13E-05
8	6.41E-05	3.13E-06	7.15E-07	1.13E-04	5.93E-06	9.94E-07

With the total distance and the frequency of accidents occurring in each severity category known, the probability of an accident occurring is established. The other half of the risk equation, the consequences of an accident, must now be determined.

The response of a package to an accident of a particular severity is given by the release fraction parameter in RADTRAN 4. The release fraction as used in RADTRAN is the amount of material available for dispersal or exposure in an accident expressed as a fraction of the amount of radioactivity present in the package. NUREG-0170 (NRC 1977) recommends the following release fraction model for Type A containers and LSA drums: 0 release for Category 1, 0.01 for Category 2, 0.1 for Category 3, and 1.0 for Categories 4-8. The Model G-4255 and G-4214 wooden boxes are certified Type AF packagings (FDH 1999), and the T-Hopper is a strong, tight packaging used since the 1950s to transport LSA quantities of materials; therefore, the use of the release fractions in NUREG-0170 is justified. This analysis uses the recommended release fractions for Categories 1 and 4-8 for all payloads. However, to be conservative, larger release fractions are used for Categories 2 and 3 for the billets, powder, and unfinished fuel payloads. The recommended release fractions for all categories are used for the finished fuel payload, as this fuel has a zirconium cladding as an additional containment boundary. For the G-4255 box containing billets, a value of 1.0 is conservatively used for categories 2 and 3. For the T-Hopper and the G-4214 box containing unfinished fuel, release fractions of 0.1 and 1.0 are used for Categories 2 and 3, respectively. Although a detailed structural and thermal evaluation of the various accident scenarios could justify the use of lower fractional releases within Categories 2 through 8, it was not felt to merit the additional time required.

Once the material is released from the container and available for dispersal, it must be in the form of an aerosol to present an inhalation hazard. An accident, such as an impact or fire, will cause a fraction of the contents to form particulate material. This fraction is known as the aerosol fraction. The particulate material that is less than 10 µm aerodynamic equivalent diameter (AED) is assumed to be capable of being inhaled into the human respiratory system.

This fraction is known as the respirable fraction. The aerosol and respirable fractions depend on the severity of the accident and the physical characteristics of the material. The respirable fraction should not be less than the respirable fraction of the pre-accident material. The release, aerosol, and respirable fractions used for the billets, powder, and fuel payloads are summarized in Table 11.

Table 11 Release, Aerosol, and Respirable Fractions for Accident Conditions

Parameter Description		Billets	Powder	Fuel
Release Fraction	Acc. Cat. 1	0	0	0
	Acc. Cat. 2	1	0.1	0.1
	Acc. Cat. 3 - 8	1	1	1
Aerosol Fraction	Acc. Cat. 1	0	0	0
	Acc. Cat. 2	1E-4	3E-4	1E-4
	Acc. Cat. 3 - 8	1E-3	3E-2	1E-3
Respirable Fraction	Acc. Cat. 1	0	0	0
	Acc. Cat. 2	1	1E-2	1
	Acc. Cat. 3 - 8	1	1E-2	1

The aerosol and respirable fractions are set to zero for Category 1 accidents because no release is anticipated. The fractions for Category 2 accidents are conservatively based on the maximum credible accident scenarios discussed in the toxicological consequence assessment in Sections 4.6.1 and 4.6.2. The aerosol fractions used for Categories 3 through 8 are a factor of 10 higher than for Category 2 for the billets payload; these values represent bounding values from DOE (1994) for the billets payload in the fire scenario described in Section 4.6.1. The aerosol fractions used for Categories 3 through 8 are a factor of 100 higher than Category 2 for the powder payload; these values are conservatively higher than the bounding values for the powder in the impact scenario described in Section 4.6.2. Because the fuel is in the same physiochemical form as the billets, the same aerosol and respirable fractions are used for both payloads.

4.5 Health Effects

Deleterious health effects ranging from minor to severe arise from exposure of individuals and populations to ionizing radiation. These effects have been correlated to doses by the International Commission on Radiological Protection (ICRP) based on historical exposures and summarized in conversion factors that consider both the probability of occurrence and a judgment of the severity of that effect (ICRP 1991). Values are given in ICRP for the estimated probabilities of a fatal cancer, of a non-fatal cancer, and of a severe hereditary effect per unit effective dose. The total detriment is the sum of these three probabilities. These values are listed in Table 12.

Table 12 Health Effect Conversion Factors (ICRP 1991)

	Worker	Public
Latent Cancer Fatality (per person-rem)	4.0E-4	5.0E-4
Total Detriment (per person-rem)	5.6E-4	7.3E-4

4.5.1 Results of the Radiological Risk Assessment

Table 13 lists the results of the radiological risk analysis. These results are for the total number of shipments made of a particular payload. Four different shipping scenarios were considered in the shipment of UO_3 powder: the combinations of rail vs. truck, and direct route vs. indirect. The risk from each fuel type, i.e., unfinished vs. finished, for each ^{235}U enrichment, is listed separately, as well as a summed risk from all fuel types. The values given for incident-free transportation are the consequences that result from the normal shipment of these radioactive materials. Because the probability of incident-free transportation is unity, the risks of these shipments are also the consequences in person-rem, number of latent cancer fatalities, and total detriment. The values given for accidents in transportation are risk values, as they are the product of the radiological consequences and the probability of occurrence for accidents of various severity. The sum of the risks from incident-free transportation and from accidents in transportation represent the total radiological risk. The summed risk for the entire shipping campaign of all payloads, assuming the worst-case scenario for shipping the UO_3 powder, is 1.92 person-rem, 8.55E-4 latent cancer fatalities, and 1.22E-3 total detriment.

Table 13 Radiological Risks from Uranium Shipments (2 sheets total)

Payload Description	Incident Free Transportation			Accident in Transportation	Total Radiological Risk
	Worker	Public	Total	Total	
Total of all shipments of billets, worst-case powder, and fuel					
Total Dose (person-rem)	1.03	0.57	1.60	0.312	1.92
Latent Cancer Fatalities	4.12E-04	2.86E-04	6.99E-04	1.56E-04	8.55E-04
Total Detriment	5.77E-04	4.18E-04	9.95E-04	2.28E-04	1.22E-03
Billets -- Hanford to Portsmouth -- Truck					
Total Dose (person-rem)	0.084	0.092	0.176	0.103	0.279
Latent Cancer Fatalities	3.36E-05	4.60E-05	7.96E-05	5.15E-05	1.31E-04
Total Detriment	4.71E-05	6.71E-05	1.14E-04	7.52E-05	1.89E-04
UO3 Powder					
-- Hanford to Portsmouth -- Rail					
Total Dose (person-rem)	0.092	0.429	0.521	0.033	0.554
Latent Cancer Fatalities	3.70E-05	2.14E-04	2.51E-04	1.64E-05	2.68E-04
Total Detriment	5.17E-05	3.13E-04	3.65E-04	2.39E-05	3.89E-04
-- Hanford to Portsmouth -- Truck					
Total Dose (person-rem)	0.372	0.354	0.726	0.059	0.785
Latent Cancer Fatalities	1.49E-04	1.77E-04	3.26E-04	2.94E-05	3.55E-04
Total Detriment	2.08E-04	2.58E-04	4.67E-04	4.29E-05	5.10E-04
-- Hanford to Paducah to Portsmouth -- Rail					
Total Dose (person-rem)	0.106	0.445	0.551	0.041	0.592
Latent Cancer Fatalities	4.24E-05	2.23E-04	2.65E-04	2.05E-05	2.85E-04
Total Detriment	5.94E-05	3.25E-04	3.84E-04	2.99E-05	4.14E-04
-- Hanford to Paducah to Portsmouth -- Truck					
Total Dose (person-rem)	0.422	0.400	0.822	0.069	0.891
Latent Cancer Fatalities	1.69E-04	2.00E-04	3.69E-04	3.43E-05	4.03E-04
Total Detriment	2.36E-04	2.92E-04	5.28E-04	5.01E-05	5.78E-04

Table 13 Radiological Risks from Uranium Shipments (continued)

Payload Description	Incident Free Transportation			Accident in Transportation	Total Radiological Risk
	Worker	Public	Total	Total	
Fuel -- Hanford to Portsmouth -- Truck					
-- Total All Fuel Types and Enrichments					
Total Dose (person-rem)	0.524	0.081	0.605	0.141	0.746
Latent Cancer Fatalities	2.10E-04	4.05E-05	2.50E-04	7.04E-05	3.21E-04
Total Detriment	2.94E-04	5.92E-05	3.53E-04	1.03E-04	4.56E-04
-- Unfinished Fuel Assemblies, 1.25% 235U					
Total Dose (person-rem)	9.97E-03	1.53E-03	1.15E-02	5.81E-03	0.017
Latent Cancer Fatalities	3.99E-06	7.65E-07	4.75E-06	2.91E-06	7.66E-06
Total Detriment	5.58E-06	1.12E-06	6.70E-06	4.24E-06	1.09E-05
-- Unfinished Fuel Assemblies, 0.95% 235U					
Total Dose (person-rem)	6.01E-02	9.30E-03	6.94E-02	4.38E-02	0.113
Latent Cancer Fatalities	2.40E-05	4.65E-06	2.87E-05	2.19E-05	5.06E-05
Total Detriment	3.37E-05	6.79E-06	4.04E-05	3.20E-05	7.24E-05
-- Unfinished Fuel Assemblies, 0.71% 235U					
Total Dose (person-rem)	8.41E-03	1.30E-03	9.71E-03	2.45E-03	0.012
Latent Cancer Fatalities	3.36E-06	6.50E-07	4.01E-06	1.23E-06	5.24E-06
Total Detriment	4.71E-06	9.49E-07	5.66E-06	1.79E-06	7.45E-06
-- Finished Fuel Assemblies, 1.15% 235U					
Total Dose (person-rem)	6.07E-02	9.40E-03	7.01E-02	1.49E-02	0.085
Latent Cancer Fatalities	2.43E-05	4.70E-06	2.90E-05	7.45E-06	3.64E-05
Total Detriment	3.40E-05	6.86E-06	4.09E-05	1.09E-05	5.17E-05
-- Finished Fuel Assemblies, 1.03% 235U					
Total Dose (person-rem)	6.01E-03	9.30E-04	6.94E-03	1.07E-03	0.008
Latent Cancer Fatalities	2.40E-06	4.65E-07	2.87E-06	5.35E-07	3.40E-06
Total Detriment	3.37E-06	6.79E-07	4.04E-06	7.81E-07	4.83E-06
-- Finished Fuel Assemblies, 0.95% 235U					
Total Dose (person-rem)	3.23E-01	5.00E-02	3.73E-01	6.80E-02	0.441
Latent Cancer Fatalities	1.29E-04	2.50E-05	1.54E-04	3.40E-05	1.88E-04
Total Detriment	1.81E-04	3.65E-05	2.17E-04	4.96E-05	2.67E-04
-- Finished Fuel Assemblies, 0.71% 235U					
Total Dose (person-rem)	5.61E-02	8.60E-03	6.47E-02	4.73E-03	0.069
Latent Cancer Fatalities	2.24E-05	4.30E-06	2.67E-05	2.37E-06	2.91E-05
Total Detriment	3.14E-05	6.28E-06	3.77E-05	3.45E-06	4.11E-05

4.6 Toxic Chemical Consequence Assessment

This section evaluates the consequences due to the chemical toxicity of uranium that could result from an accidental release during transport of the metallic billets, UO_3 powder, and the worst-case shipment of fuel. The toxicological consequences are given in terms of the concentrations of airborne uranium particulates at various receptor locations. The calculated concentrations are then compared to various exposure limits to evaluate the effects of the release on the public.

According to DOE (1994), for natural or depleted uranium or uranium enriched < 10% in ^{235}U, the toxicity of uranium as a heavy metal is of greater concern than the radiological hazard. The toxicological hazard results from the accumulation of uranium in the kidneys due to the transport of inhaled, soluble uranium compounds or non-soluble particulates. For non-soluble materials to be an inhalation hazard, the size of the particles/aggregates must be 10 µm AED (more probably 3 µm AED) or less (DOE 1994).

The maximum credible release depends on the physical and chemical form of the payload. Powder and large solid masses respond differently to a given accident scenario; the same applies to oxides and metals. The maximum credible accident scenario for the UO_3 powder is an energetic impact event which damages the T-Hopper container and nearly instantaneously creates a puff of particulates that is released to the atmosphere and transported downwind. On the other hand, an impact event is not expected to significantly damage the solid metal billets or fuel. A fire event is postulated as the maximum credible accident scenario for the billets and fuel, which are engulfed in flames due to the combustion of an external fuel, e.g., the diesel fuel from the truck's fuel tank. The duration of the fire is assumed to last 2 hours. The billets and N Reactor fuel elements are treated together, as they are both uranium metal.

4.6.1 Uranium Billets/Fuel Release Rate

According to DOE (1994), no significant airborne release is postulated for solid metal in an impact event; however, particulates are released during the oxidation of the metal in a fire. Therefore, the maximum credible release is calculated for a fire event.

Massive uranium metal is difficult to ignite, as large amounts of external heat must be supplied and serious heat loss prevented (DOE 1994). This external heat is assumed to arise from the combustion of diesel fuel from the transportation vehicle. DOE (1994, p. 4-3) provides median values of 1E-4 for the airborne release fraction and 1.0 for the respirable fraction for uranium metal subjected to a fire. These values correspond to the complete oxidization of the metal; experimental values reported for a 2 hour burn produced smaller release fractions. Thus, the use of the median release fractions is conservative.

An additional conservatism is introduced by using the two hour fire duration as the duration for the release. Although the uranium will likely not completely oxidize in two hours, assuming this smaller release time increases the release rate. Regardless of the speed at which uranium oxidizes, it is likely that the fuel source will be exhausted before that time. The efforts of emergency responders in mitigating a fire during the assumed burn time is also conservatively neglected.

This analysis conservatively does not consider any removal mechanisms of the particulates, e.g., washout, gravitational settling, or removal through contact with vegetation or buildings. This assumption maximizes the airborne concentration and is conservative. Because the molecular weight of uranium oxide is an order of magnitude greater than air, significant settling would be expected, as DOE (1994b) states that in the absence of strong drafts, uranium oxide smoke tends to deposit in the immediate area of the burning metal.

The worst-case shipment of fuel consists of 0.71% ^{235}U unfinished fuel, as this gives the largest uranium loading. The zirconium cladding on the sides of the unfinished fuel is neglected. The entire truckload of 18 billets or 3264 kg U of fuel is assumed to be engulfed in the fire. A 0.044 g/s release rate of aerosolized, respirable particles from burning uranium billets is calculated. Using the same logic for the fuel gives a 0.045 g/s release rate.

$0.044\ \text{g/s} = (10^{-4})(175\ \text{kg/billet})(1000\ \text{g/kg})(3\ \text{billets/box})(6\ \text{boxes/truck}) / (2\ \text{hr}\ (3600\ \text{s/hr}))$
$0.045\ \text{g/s} = (10^{-4})(3264\ \text{kg/shipment})(1000\ \text{g/kg}) / (2\ \text{hr}\ (3600\ \text{s/hr}))$

For simplicity, the 0.045 g/s release rate will be used for both fuel and billets.

4.6.2 UO_3 Powder Release Rate

Powder can be made airborne by either a fire or an impact event. The airborne release of powder during a fire is due to entrainment caused by the air turbulence induced by the fire. Similarly, during an impact, powder entrainment may be caused by the mechanical disturbance during the dynamics of the impact. Both stresses are considered in the accident scenario involving the T-Hoppers.

The maximum credible accident considered for the UO_3 powder transported by truck is expected to arise from an impact due to a collision. The impact is assumed to cause moderate damage, consisting of rupture of the wall and failure of the gasket, to all the T-Hoppers on the trailer.

For rail transport, the maximum credible accident is due to a collision with a vehicle at a crossing. This scenario would most likely cause considerable damage to the offending vehicle, while the train would sustain minimal damage. However, this analysis conservatively considers the more unlikely scenario in which a vehicle rams the side of a rail car transporting the T-Hoppers. Although the offending vehicle is still likely to sustain the majority of the damage incurred in this accident, the same release rate as calculated for the truck accident is used for simplicity.

DOE (1994, p. 4-87) provides values for the airborne release of powder contained in metal enclosures. The release fractions are dependent on the particle size of the powder. The fraction of the UO_3 powder as a function of particle diameter is not yet known, but it can be assumed that the powder contains particles greater than 0.5 mm in diameter. Experimental measurements involving an impact on steel cans without lids containing powder less than 2 mm in diameter produced an airborne release fraction of 3E-4 and a respirable fraction of 1E-2. If the respirable fraction of the original powder is less than this value, the respirable fraction of the source powder should be used (DOE 1994).

The leakage of aerosolized powder is inhibited by the damaged T-Hopper. Although the rupture from the impact event provides an escape route for the powder, the bulk of the container still encloses the contents. Thus, the amount airborne is reduced by a factor representing the presence of the damaged container. This factor is the leak path factor. This analysis assumes that 10% of the surface area of the container has been compromised in the impact event; thus, 90% of the aerosol undergoes filtration and deposition by the damaged T-Hopper.

The total release of aerosolized, respirable UO_3 particulates is then 4.1 g.

$4.1 \text{ g} = 3*(4.5E6 \text{ g U})*(3E-4)*(1E-2)*(0.1)$

4.6.3 Concentration Calculation

The concentration is related to the release rate in the fire event, or total release in the impact event, by the atmospheric dispersion parameter, χ/Q. This parameter is a function of the receptor location, wind speed, and atmospheric turbulence. χ/Q is normalized either to the release rate of a sustained release (in which case the Q is primed Q') or to the total release of a nearly instantaneous "puff" release. This analysis will determine the uranium airborne concentration at three downwind receptor locations: 100 m, 200 m, and 1000 m. The 100 m distance was assumed to be a reasonable estimate of the distance between an interstate highway and the nearest resident, while the further distances show how the concentration falls off.

Two sets of meteorological conditions are examined. The first consists of worst case conditions of wind speed (1 m/s) and atmospheric turbulence (Pasquill stability class F) that cause a maximum concentration. These conditions tend to disperse the released material very slowly, resulting in the highest possible downwind concentrations. However, these conditions are rarely encountered, except perhaps for night conditions, and tend to overstate the actual impacts. The second case consists of more likely, but still relatively rare, conditions of a wind speed of 2 m/s and neutral stability (Pasquill stability class D). The latter set of conditions will be used to calculate the concentrations at all three potential receptor locations and the former will be used to calculate the worst-case conditions at the shortest distance (100 m).

Green (1995) calculated χ/Q' for the weather conditions and receptor locations described above using the methods of NRC (1982). These values are given below.

- 2.85E-2 s/m^3: χ/Q' for 100 m receptor, Pasquill F, and 1 m/s wind speed
- 3.76E-3 s/m^3: χ/Q' for 100 m receptor, Pasquill D, and 2 m/s wind speed
- 9.68E-4 s/m^3: χ/Q' for 200 m receptor, Pasquill D, and 2 m/s wind speed
- 6.63E-5 s/m^3: χ/Q' for 1000 m receptor, Pasquill D, and 2 m/s wind speed

The computer code GXQ version 4.0 (Hey 1993, 1994) was used to calculate χ/Q for the puff releases for the same meteorological conditions as for the sustained releases. These values are given below. The GXQ output file is given in the appendix.

- 2.65E-3 m^{-3}: χ/Q for 100 m receptor, Pasquill F, and 1 m/s wind speed
- 3.14E-4 m^{-3}: χ/Q for 100 m receptor, Pasquill D, and 2 m/s wind speed
- 4.74E-5 m^{-3}: χ/Q for 200 m receptor, Pasquill D, and 2 m/s wind speed
- 7.10E-7 m^{-3}: χ/Q for 1000 m receptor, Pasquill D, and 2 m/s wind speed

The release rate from the billets in the fire event is multiplied by χ/Q' to obtain the downwind uranium concentration. Similarly, the total release from the UO_3 powder in the impact event is multiplied by χ/Q. Table 14 summarizes the results of the toxic chemical consequence analysis.

Table 14 Uranium Concentrations at Downwind Locations During Accident Conditions

Receptor Location, m	Fuel/Billets, 0.045 g/s release rate			T-Hopper Shipments, 4.1 g total release		
	χ/Q', s/m^3	Concentration, mg/m^3		χ/Q, m^{-3}	Concentration, mg/m^3	
100	3.76E-3	0.170	0.28·TEEL-1	3.14E-4	1.27	2.12 TEEL-2 0.13·TEEL-3
200	9.68E-4	0.0439	0.88·TEEL-0	4.74E-5	0.192	0.32·TEEL-1
1000	6.63E-5	3.01E-3	0.06·TEEL-0	7.10E-7	2.88E-03	0.06·TEEL-0
100, rare case	2.85E-2	1.29	2.15·TEEL-2 0.13·TEEL-3	2.65E-3	10.7	1.07·TEEL-3

The results in Table 14 are then compared with Temporary Emergency Exposure Limits (TEELs) for uranium oxide established by the Department of Energy Subcommittee on Consequence Assessment and Protective Actions (SCAPA) (Craig 1999). Uranium oxide is used because the billets and fuel will oxidize during the fire; also, the limits for oxide are the same or more conservative than for metal. The DOE Emergency Management Guide (DOE 1997) calls for the use of TEELs when Emergency Response Planning Guidelines (ERPGs) are not available. Although ERPGs are the standard community exposure limits approved by the

American Industrial Hygiene Association, less than 100 chemicals have been assigned ERPGs, and none of those include compounds of uranium. The definitions of the TEEL limits are as follows:

- TEEL-0: The threshold concentration below which most people will experience no appreciable risk of health effects. The TEEL-0 for uranium oxide (insoluble compound) is 0.05 mg/m^3.
- TEEL-1: The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient health effects or perceiving a clearly defined objectionable odor. The TEEL-1 is 0.6 mg/m^3.
- TEEL-2: The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. The TEEL-2 is 0.6 mg/m^3.
- TEEL-3: The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects. The TEEL-3 is 10 mg/m^3.

Using these definitions and the results in Table 14, at distances of 200 m and greater from an accident involving any payload, the results are either mild transient health effects (TEEL-1) or nothing at all (TEEL-0). At a distance of 100 m, an accident involving powder could result in an airborne concentration at which irreversible or other serious health effects could occur (twice the TEEL-2). This is about 13% of the level at which most people could be exposed without experiencing life-threatening health effects. At the same distance involving an accident with the fuel or billets payload, only mild transient health effects are expected to occur (TEEL-1). It should be noted that for the very rare weather conditions at 100 m, the TEEL-3 limit is exceeded for an accident involving powder, while for the billets and fuel payloads under the same worst-case meteorological conditions, the downwind concentrations do not exceed TEEL-1.

Table 14 also indicates the dilution of the uranium aerosol with distance. The airborne concentrations of uranium drop by about an order of magnitude from 100 to 200 m, and again from 200 to 1000 m. Although the concentrations at 100 and 200 m are about an order of magnitude less for the fuel or billets payloads than for the powder payload, the concentrations are nearly equal at 1000 m, despite the difference in the releases.

Note that these values are the consequences from an accident, and do not reflect the frequency of occurrence of an accident or the assumed meteorological conditions. As such, they cannot be compared directly to the radiological risk values in Table 1. A risk assessment weights the consequences by the frequency (or probability) of occurrence of the release. The toxicological consequences have not been weighted by the probability of the release.

5.0 APPENDIX

5.1 Dose Rate Calculations for Billets, UO_3 Powder, and N Reactor Fuel

The RADTRAN v. 4 computer code requires as input the dose rate at 1 m from the vertical planes projected by the outer lateral surfaces of the transportation vehicle for exclusive use shipments. This dose rate is then used to extrapolate the dose rate at further distances using the method described in Neuhauser and Kanipe (1992). Shielding calculations were done to estimate the dose rates at 1 m from the outer lateral surfaces of the transportation vehicle loaded with the Model G-4255 Wooden Box, the Model G-4214 Wooden Box, and the T-Hopper.

The billets are transported in the G-4255 wooden box. Six boxes are shipped by truck per shipment, each holding three 175 kg billets in an unknown arrangement. For simplicity, the billets were assumed to be smeared over the entire interior volume of the box. The interior dimensions of the wooden box are taken from FDH (1999), consisting of 30.75 in. L x 24.125 in. W x 8 in. D interior, with a minimum plywood thickness of 0.75 in. A schematic of the box is shown in Section 5.13. The box rests on top of support skids attached to its largest side, while a smaller side faces the lateral surface of the transport vehicle, assumed to be 3 m wide. For this calculation it was assumed that the 30.75 in. x 8 in. side faced the front of the trailer, and the 24.125 in. x 8 in. side faced the lateral side. The six boxes were assumed to be aligned one behind the other, neglecting the shielding between boxes. The dose rate was calculated at 1 m from the edge of the transport vehicle at the midpoint of the lateral surface of the array.

The UO_3 powder is transported in T-Hoppers. An array of three T-Hoppers is shipped by truck, while an array of ten is shipped by rail. The T-Hopper consists of a frame that encloses a conical structure that is widest at the bottom. A schematic of the T-Hopper is shown in Section 5.13. The dose rate was calculated at 1 m from the lateral surface of the transport vehicle, assumed to be 3 m wide. The UO_3 powder is contained in the cone-shaped structure, with a 5 ft diameter cylindrical base at the bottom. This geometry was approximated for simplicity as a cylinder of the height of the T-Hopper (6 ft), with a radius calculated from the powder mass m, density ρ, and height h. Using the equations for density and volume, the radius r was calculated as

$$r = \sqrt{\frac{m}{\rho \pi h}}$$

The density of UO_3 powder is 7.29 g/cm^3 (Lide 1993). Assuming the interstitial void space of the powder results in a packing fraction of 0.68, the bulk density of the powder is 4.96 g/cm^3. For a powder mass of 5454.5 kg, the calculated radius is 43.75 cm.

The fuel elements are transported in the Model G-4214 Wooden Box. The interior dimensions of the wooden box are taken from FDH (1999), consisting of 30 in. L x 14.125 in. W x 8.375 in. H interior, with a minimum thickness of the plywood container of 0.75 in. A schematic of the box is shown in Section 5.13. To prevent the formation of a critical configuration in the event of an accident, limits on the total uranium mass in a shipment of the 0.95% and 1.25% enriched fuel have been derived (Ferrell 1999). Mass limits for the 1.03 and 1.15% enriched fuel were interpolated from these limits. These limits are 1628, 1375, 996, and 680 kg, for fuel containing 0.95, 1.03, 1.15, and 1.25% ^{235}U, respectively. The number of boxes per shipment was assumed based on these criticality based shipment mass limits and the 544 kg capacity of the boxes. Fuel containing 0.71% ^{235}U, the same amount found in natural uranium, is not limited by criticality, in which case 6 boxes per shipment were assumed. The array was assumed to be arranged in a similar fashion as the array of boxes containing billets, i.e., the side with the skids on bottom, the largest lateral face of the box toward the front, and the boxes of the array adjacent to each other centered on the trailer. The dose rate was calculated at 1 m from the lateral sides of the vehicle edge.

The source terms for the billets and fuel are taken from Table 5.2.1-1 of FDH (1999), which gives the photon production in eighteen energy groups at a decay of 1 year. Because of the similarity between the source terms for the 0.95%, 1.10%, and 1.25% ^{235}U enriched fuels, the same source term is used for each enrichment. There are a couple of small differences in the source terms in Table 5.2.1-1 of FDH (1999), reproduced in Table 15; the source term used in the calculations conservatively took the highest photon production of each energy group of the source term of the three enrichments.

Table 15 Billets and Fuel Source Term from FDH (1999)

Average Energy (MeV)	Photon Production rate (s^{-1})		
	235U enrichment		
	0.95%	1.10%	1.25%
0.01	1.55E+04	1.54E+04	1.55E+04
0.025	1.72E+03	1.70E+03	1.72E+03
0.0375	1.02E+03	1.02E+03	1.02E+03
0.0575	2.02E+03	2.03E+03	2.02E+03
0.085	1.84E+03	1.82E+03	1.84E+03
1.25E-01	7.76E+02	7.58E+02	7.76E+02
0.225	1.32E+03	1.26E+03	1.32E+03
0.375	3.39E+02	3.39E+02	3.39E+02
0.575	1.82E+02	1.82E+02	1.82E+02
0.85	1.14E+02	1.14E+02	1.14E+02
1.25	7.92E+01	7.93E+01	7.92E+01
1.75	1.21E+01	1.21E+01	1.21E+01
2.25	3.50E-03	3.50E-03	3.50E-03
2.75	1.99E-03	1.99E-03	1.99E-03

3.5	1.78E-03	1.78E-03	1.78E-03
5	7.63E-04	7.64E-04	7.63E-04
7	8.78E-05	8.79E-05	8.78E-05
9.5	1.01E-05	1.01E-05	1.01E-05
Total	2.49E+04	2.47E+04	2.49E+04

The source term for the powder is derived from Table 4, decayed 10 years using the computer code ORIGEN-S (Hermann and Westfall 1997) of the SCALE v. 4.3 code package (McCoy 1998). This decay time allows some buildup of daughter products that are part of the long decay chains of uranium and is a conservative estimate of the time since the powder was processed. The most important daughter product in this inventory from a shielding standpoint is ^{234m}Pa, with several low-intensity, high-energy gamma rays and a 2.28 MeV endpoint energy beta particle at 98.6% intensity. The very short-lived daughter products ^{210}Po, ^{211}Po, ^{212}Po, ^{215}Po, ^{216}Po, ^{218}Po, and ^{223}Fr included in the ORIGEN-S output are not included in ISO-PC's data library, but all are of very low activity, energy, or intensity, and so have no effect on the shielding analysis.

The computer code ISO-PC version 2.1 (Rittmann 1995, 1996) was used to calculate the dose rates, summarized in Table 16. Dose rates were calculated at 1 m and 2 m from the vertical plane projected by the outer lateral surface of the transportation vehicle, and at the crew location, assumed to be 3.1 m from the front of the array, which is the RADTRAN default value for trucks (Neuhauser and Kanipe 1992). The anterior-to-posterior flux-to-dose-rate conversion factors from ANS (1991) were used, which are the most conservative and represent radiation entering the front of the body. Buildup was calculated in the uranium source material for all shipments.

Table 16 Dose Rates (mrem/h) from Uranium Payloads

Payload	Lateral - 1 m	Lateral - 2 m	Crew Location
Array of 6 Boxes of Billets	0.086	0.045	0.011
Array of 3 T-Hoppers	0.44	0.24	0.074
Array of 10 T-Hoppers	0.73	0.47	0.074
Array of 6 Boxes of 0.71% enriched fuel	0.052	0.025	9.5E-3
Array of 3 Boxes of 0.95% enriched fuel	0.034	0.016	0.011
Array of 3 Boxes of 1.03% enriched fuel	0.034	0.016	0.011
Array of 2 Boxes of 1.15% enriched fuel	0.023	0.011	0.011
Array of 2 Boxes of 1.25% enriched fuel	0.023	0.011	0.011

The ISO-PC input files for the billets boxes, the T-Hopper, and the fuel boxes follow.

```
0         3 Billets - Uranium TRA - TI Calc
Array of 6 boxes: 1 m and 2 m from vhcl edge
&Input Next=1, Option=0, Ispec=3, Dunit=1, Iconc=0, Ntheta=30, Npsi=20,
 Igeom=10, T=78.11, 1.905, X=289.05, 389.05, Y=20.32, Slth=367.67,
 Nshld=2, Jbuf=1, Weight(31)=3.15E6,
 Source(1,1)=        1.55E+04  0.01    0
                     1.72E+03  0.025   0
                     1.02E+03  0.0375  0
                     2.02E+03  0.0575  0
                     1.84E+03  0.085   0
                     7.76E+02  0.125   0
                     1.32E+03  0.225   0
                     3.39E+02  0.375   0
                     1.82E+02  0.575   0
                     1.14E+02  0.85    0
                     7.92E+01  1.25    0
                     1.21E+01  1.75    0
                     3.50E-03  2.25    0
                     1.99E-03  2.75    0
                     1.78E-03  3.5     0
                     7.63E-04  5       0
                     8.78E-05  7       0
                     1.01E-05  9.5     0 &
 U      15 5.398
 wood-C  6          0.25
1wood-O 23          0.25
Crew location, 3.1 m from front of array
&Input Next=2, T=367.67, 1.905, X=679.58, Slth=78.11 &
End of Input
&Input Next=6 &
  772030/171 - Update NLO Box SARP.
  Source is per gram of 1.25% U235 taken from Table 5.2.1-1 of
    HNF-SD-TP-SARP-019, Rev. K, and is based on (wt%): 1.34E-4 234U,
    1.256E-2 235U, 1.00E-3 236U, 9.88E-1 238U, 4.14E-11 241Pu, 2.58E-5 99Tc,
    and 1.56E-10 90Sr, decayed 1 year.
  Weight(31) scales the photon source groups; 3.15E6 is the weight (g) of the
    U in 6 boxes, 3 billets smeared per box, 175 kg per billet.
  Dimensions of box taken from HNF-SD-TP-SARP-019, Fig. 1.2.1-4, G-4255:
    30.75" L x 24.125" W x 8" D interior, 0.75" thick minimum plywood shld.
  U bulk density = 3 billets/box * 175 kg/billet / InteriorVolume
  Dose pt is at the vehicle edge, assuming the array of 6 boxes is aligned
    on the longitudinal centerline, with the 30.75"x8" face facing the front,
    the 30.75"x24.125" face facing the bottom.  The dose point is at the
    center of the 24.125"x8"x6boxes array, at vhcl edge.
  C:\My Documents\isopc\Urisk\billet2a.in
```

```
0         2 T-Hopper - Uranium TRA - TI Calc - ORIGENS Weights
6 ft H cyl; Odd-Centered; 1 m and 2 m from vhcl edge
&Input Igeom=7, SLTH=182.88, Y=91.44, T=43.75, 0.47, X=250., 350,
 Ntheta=30, Npsi=20, Ispec=3, Dunit=1, Option=0, Iconc=0, Nshld=2,
 Jbuf=1,
 WEIGHT(332) =   2.61E-06 ,    WEIGHT(485) =   4.45E-07 ,
 WEIGHT(414) =   9.38E-12 ,    WEIGHT(488) =   4.15E-11 ,
 WEIGHT(508) =   4.27E-08 ,    WEIGHT(487) =   2.62E-06 ,
 WEIGHT(341) =   2.62E-06 ,    WEIGHT(436) =   4.15E-11 ,
 WEIGHT(524) =   2.61E-11 ,    WEIGHT(364) =   2.59E-06 ,
 WEIGHT(510) =   4.45E-07 ,    WEIGHT(442) =   2.61E-11 ,
```

```
 WEIGHT(483) =   4.27E-08 ,    WEIGHT(518) =   2.06E-04 ,
 WEIGHT(337) =   2.62E-06 ,    WEIGHT(450) =   8.61E-02 ,
 WEIGHT(525) =   2.61E-11 ,    WEIGHT(431) =   9.91E-11 ,
 WEIGHT(511) =   4.45E-07 ,    WEIGHT(530) =   1.50E+00 ,
 WEIGHT(512) =   4.45E-07 ,    WEIGHT(371) =   1.82E-05 ,
 WEIGHT(351) =   2.62E-06 ,    WEIGHT(533) =   1.50E+00 ,
 WEIGHT(523) =   2.61E-11 ,    WEIGHT(441) =   1.95E-03 ,
 WEIGHT(514) =   4.45E-07 ,    WEIGHT(520) =   2.24E+00 ,
 WEIGHT(362) =   2.62E-06 ,    WEIGHT(476) =   8.61E-02 ,
 WEIGHT(522) =   2.61E-11 ,    WEIGHT(398) =   2.01E-01 ,
                               WEIGHT(526) =   1.50E+00  &
 U       15 4.128
 O       23 0.832
1Fe       9          7.86
Contribution from nearest neighbors (odd-centered)
&Input Next=2, X=292.79, 381.74 &
Contribution from 2nd nearest neighbors (odd-centered)
&Input X=394.21, 464.12 &
Contribution from 3rd nearest neighbors (odd-centered)
&Input X=521.09, 575.79 &
Contribution from 4th nearest neighbors (odd-centered)
&Input X=658.87, 702.93 &
Contribution from last nearest neighbor (odd)
&Input X=801.96, 838.54 &
Even-Centered; 1 m and 2 m from vhcl edge
&Input X=261.36, 358.20 &
Contribution from nearest neighbors (even-centered)
&Input X=338.76, 418.04 &
Contribution from 2nd nearest neighbors (even-centered)
&Input X=455.70, 517.36 &
Contribution from 3rd nearest neighbors (even-centered)
&Input X=589.08, 637.98 &
Contribution from 4th nearest neighbors (even-centered)
&Input X=729.95, 769.95 &
Crew location - 3.1 m from front of array
&Input X=386.2 &
End
&Input Next=6 &
  772030/167 - Radtran analysis to support U shipments.
  Inventory is per 1 T-Hopper, decayed 10 years using ORIGENS.
  Case 1 assumed a cylinder of height 6 ft
    with radius calculated from mass, density, and height.
    rho=4.96 g/cc = 7.29 g/cc * 0.68
             UO3 den^^^^        ^^^^powder packing factor assumed
    V=pi*r^2*h=m/rho --> r = SQRT(m/rho/pi/h),
    m=5454.5 kg UO3
  Wall thickness of 3/16" taken from Dwg 47X-5500-M-00006, "T-Hopper
    Ass'y", Westinghouse Mat'ls Co. of Ohio, 1986.
  Width of conveyance assumed 3 m, pkg on centerline of conveyance.
  Case 2, et al, accounts for contribution of adjacent T-Hopper.  The distance
    to the dose pt is calc from a rt triangle:  X=SQRT((5ft)^2+(250cm)^2)
  Case 7 is centered on an array of 10, whereas Case 1 is centered on an
    array of 9.  Hence the names even and odd.
  Other distances: T-Hpr edge, vhcl edge, 1 m from T-Hpr: 76.2, 150., 176.2,
  Other case:
    Smeared over cage volume; same dose pt distances
    &Input Next=1, Igeom=10, SLTH=152.4, Y=182.88, T=151.93,0.47,
     X=152.93, 226.73, 252.4, 326.73 &
     U       15 1.059
     O       23 0.225
    1Fe       9          7.86
```

```
1) 1.25% 235U, 2 boxes: 1 m and 2 m from vhcl edge
&Input Next=1, Option=0, Ispec=3, Dunit=1, Iconc=0, Sfact=1.,
 Igeom=10, Nshld=2, Jbuf=1, Ntheta=30, Npsi=20,
 T=76.2, 1.905, X=288.1, 388.1, Y=21.27, Slth=71.76,
 Weight(31)=0.680E6,
 Source=             1.55E+04  0.01    0
                     1.72E+03  0.025   0
                     1.02E+03  0.0375  0
                     2.03E+03  0.0575  0
                     1.84E+03  0.085   0
                     7.76E+02  0.125   0
                     1.32E+03  0.225   0
                     3.39E+02  0.375   0
                     1.82E+02  0.575   0
                     1.14E+02  0.85    0
                     7.93E+01  1.25    0
                     1.21E+01  1.75    0
                     3.50E-03  2.25    0
                     1.99E-03  2.75    0
                     1.78E-03  3.5     0
                     7.64E-04  5       0
                     8.79E-05  7       0
                     1.01E-05  9.5     0 &
 U      15 5.847
 wood-C  6          0.25
1wood-O 23          0.25
2) Crew location, 3.1 m from front of array
&Input Next=2, T=71.76, 1.905, X=383.66, Slth=76.2 &
3) 0.95% 235U, 3 boxes: 1 m and 2 m from vhcl edge
&Input Next=1, T=76.2, 1.905, X=288.1, 388.1, Y=21.27, Slth=107.63,
 Weight(31)=1.628E6 &
 U      15 9.333
 wood-C  6          0.25
1wood-O 23          0.25
4) Crew location, 3.1 m from front of array
&Input Next=2, T=107.63, 1.905, X=419.54, Slth=76.2 &
5) 1.03% 235U, 3 boxes: 1 m and 2 m from vhcl edge
&Input Next=1, T=76.2, 1.905, X=288.1, 388.1, Y=21.27, Slth=107.63,
 Weight(31)=1.375E6 &
 U      15 7.882
 wood-C  6          0.25
1wood-O 23          0.25
4) Crew location, 3.1 m from front of array
&Input Next=2, T=107.63, 1.905, X=419.54, Slth=76.2 &
6) 1.15% 235U, 2 boxes: 1 m and 2 m from vhcl edge
&Input Next=1, T=76.2, 1.905, X=288.1, 388.1, Y=21.27, Slth=71.76,
 Weight(31)=0.996E6 &
 U      15 8.563
 wood-C  6          0.25
1wood-O 23          0.25
2) Crew location, 3.1 m from front of array
&Input Next=2, T=71.76, 1.905, X=383.66, Slth=76.2 &
End of Input
&Input Next=6 &
  772030/171 - Update NLO Box SARP.
  Source is per gram of 0.95, 1.10, or 1.25% U235 taken from Table 5.2.1-1 of
    HNF-SD-TP-SARP-019, Rev. K, and is based on (wt fraction): 1.00E-3 236U,
    4.14E-11 241Pu, 2.58E-5 99Tc, and 1.56E-10 90Sr, for all enrichments, and
    1.33E-4 234U, 9.56E-3 235U, 9.91E-1 238U, for 0.95% enriched,
    1.33E-4 234U, 1.106E-2 235U, 9.89E-1 238U, for 1.10% enriched, and
    1.34E-4 234U, 1.256E-2 235U, 9.88E-1 238U, for 1.25% enriched.
    These activities are decayed 1 year in Table 5.2.1-1.
    Because the three fuels produce similar photon source terms, the highest
    production rate for each energy group from the three fuels is used.
```

```
Weight(31) scales the photon source groups, which are given per gram;
  1.628E6 is the weight (g) of the 0.95% 235U fuel in 3 boxes;
  1.375E6 is the weight (g) of the 1.03% 235U fuel in 3 boxes;
  0.996E6 is the weight (g) of the 1.15% 235U fuel in 3 boxes;
  0.680E6 is the weight (g) of the 1.25% 235U fuel in 3 boxes;
  Inventory is per shipment based on criticality.
Dimensions of box taken from HNF-SD-TP-SARP-019, Fig. 1.2.1-4, G-4214:
  30" L x 14.125" W x 8.375" D interior, 0.75" thick minimum plywood shld,
  544 kg per box maximum payload weight.
Case 1 is 1.25% 235U payload.
  2 boxes per shipment, 680 kg/shipment.
  5.847 g/cc = 680E3 g / (2x35.88x76.2x21.27) cc
Case 2,4 is to check Radtran's assumption that crew dose rate will not be
  greater than 2 mrem/h.
Case 3 is 0.95% 235U payload.
  3 boxes per shipment, 1628 kg/shipment.
  9.333 g/cc = 1628E3 g / (3x35.88x76.2x21.27) cc
  Dose pt is at the vehicle edge, assuming the array of 3 boxes is aligned
  on the longitudinal centerline, with the 30"x8" face facing the front,
  the 30"x14.125" face facing the bottom.  The dose point is at the
  center of the 14.125"x8.375"x3boxes array, at 1 and 2 m from vhcl edge.
Case 5 is 1.03% 235U payload.
  3 boxes per shipment, 1375 kg/shipment.
  7.882 g/cc = 1375E3 g / (3x35.88x76.2x21.27) cc
Case 6 is 1.15% 235U fuel.
  2 boxes per shipment, 996 kg/shipment.
  8.563 g/cc =  996E3 g / (2x35.88x76.2x21.27) cc
C:\My Documents\isopc\Urisk\fuel2.in
```

The ORIGEN-S input file for the T-Hopper source term

```
#ORIGENS
0$$   E T
DECAY CASE
3$$ 21 1 1 0  A16 4  A33 0  E T
35$$ 0 T
56$$ A2 4  A6 1  A10  0  A13 4  A14 5  A15 3 E
57** 0 E T
THOPPER
THOPPER
60** .3 1 3 10
61** F1E-18
65$$
'GRAM-ATOMS   GRAMS    CURIES     WATTS-ALL  WATTS-GAMMA
  21Z
     3Z         3Z     1  0  0        3Z         3Z         6Z
  21Z
73$$  922340  922350  922360  922380
74** 2.239 8.613E-2 2.009E-1 1.498
75$$  2  2  2  2  T
56$$ F0 T
END
```

(this page reserved for shielding check sheet)

5.2 RADTRAN Input File for Billets

```
&& RADTRAN 4 - Unirradiated Uranium EA - Billets
&& J.L. Boles, May  25 2000, 772030/171
&& Accident Severity Categories and Probabilities derived from NUREG-0170 (1977),
&&   Table 5-3.
&& Accident Rates taken from Saricks and Kvitek (1994), US Average, Interstates.
&& Release fraction is 0 for Cat 1, 1 for Cat 2-8.
&& Aerosol and Respirable Fractions are median values for Cat 2, bounding
&&   for Cat 3-8.
&& 75 shipments = 234 MTU / 175 kg/billet / 3 billets/box / 6 boxes/shipment
&& TI = 0.086 from ISO-PC shldg calc, 3/16" Fe wall, src from Table 5.2.1-1,
&&   HNF-SD-TP-SARP-019, Rev. K, at 1 m from the edge of the vehicle carrying
&&   an array of 6 boxes.
&& Crew-source distance DNORML(8)= 8.27 m based on ISO-PC calc crew dose rate
&&   and Eq. 12 of Technical Manual (N&K 1989).
&& Minimum stop time = twice that calculated by Highway code
&& Neutron dose rate negligible
&& CPD = 3.9053 m = length of single layer of 6 boxes/shipment
&& Exclusive use truck shipment
TITLE Uranium EA - Billets - Direct Route - Truck
FORM UNIT
DIMEN 7 8 1 10 18
PARM 1 3 2 1 0
POPDEN     5.9    334.1   2173.7
PACKAGE
   LABGRP
       BILLET
SHIPMENT
   LABISO
       U234     U235    U236    U238    PU241    TC99    SR90
NORMAL
   NMODE=1
       8.783E-01  1.116E-01  1.010E-02  8.849E+01  4.025E+01  2.416E+01
       2.000E+00  8.270E+00  0.000E+00  0.000E+00  1.084E+01  0.000E+00
       0.000E+00  5.000E+01  2.000E+01  0.000E+00  1.000E+02  1.000E+02
       2.000E+00  0.000E+00  0.000E+00  1.000E+00  4.700E+02  7.800E+02
       2.800E+03
ACCIDENT
   ARATMZ
     NMODE=1      2.03E-07   3.58E-07   3.58E-07
   SEVFRC
     NPOP=1
       NMODE=1
       4.62E-01 3.02E-01 1.76E-01 4.03E-02 1.18E-02 6.47E-03 5.71E-04 1.13E-04
     NPOP=2
       NMODE=1
       4.35E-01 2.85E-01 2.21E-01 5.06E-02 6.64E-03 1.74E-03 6.72E-05 5.93E-06
     NPOP=3
       NMODE=1
       5.83E-01 3.82E-01 2.78E-02 6.36E-03 7.42E-04 1.46E-04 1.13E-05 9.94E-07
RELEASE
   RFRAC
      GROUP=1
       0.0  7*1.0E+0
   AERSOL
      DISP=2
       0.0  1.E-4  6*1.0E-3
   RESP
      DISP=2
       0.0  7*1.
DEFINE  U234
      8.93E+07  1.73E-03  2.43E-05  1.30E+08  2.60E+05  0.00E+00
```

```
      0.00E+00  1.00E-02  3.00E+00  8.20E+07  6.50E+04
DEFINE  U236
      8.54E+09  1.57E-03  1.92E-05  6.70E+06  2.50E+05  0.00E+00
      0.00E+00  1.00E-02  3.00E+00  7.70E+07  6.10E+04
EOF
ISOTOPES -1  75  1  0.086  1.  0.  BOXARRAY
        U234       2.625E+00 BILLET  2
        U235       8.704E-02 BILLET  2
        U236       2.038E-01 BILLET  2
        U238       1.046E+00 BILLET  2
        PU241      1.304E-02 BILLET  2
        TC99       1.390E+00 BILLET  2
        SR90       6.929E-02 BILLET  2
PKGSIZ
      BOXARRAY   3.9053
DISTKM
      NMODE=1  3870.4
EOF
EOI
```

5.3 Radtran Input File for UO_3 Powder via Direct Route Truck

```
&& RADTRAN 4 - Unirradiated Uranium EA - UO3 Powder - Truck - Direct
&& J.L. Boles, Aug. 31 1999, 772030/167
&& Accident Severity Categories and Probabilities derived from NUREG-0170
&&   (1977), Table 5-3.
&& Accident Rates taken from Saricks and Kvitek (1994), US Average.
&& Release fraction is 0 for Cat 1, 0.1 for Cat 2, and 1 for Cat 3-8.
&& Aerosol and Respirable Fractions are median values for Cat 2, bounding
&&   for Cat 3-8.
&& 49 shipments = 147 T Hoppers / 3 T Hoppers per truck
&& TI = 0.44 from ISO-PC shldg calc, 3/16" Fe wall, src decayed 10 yrs
&& Crew-source distance DNORML(8)= 7.71 m based on ISO-PC calc crew dose rate
&&   and Eq. 12 of Technical Manual (N&K 1989).
&& Minimum stop time = twice that calculated by Highway code
&& Neutron dose rate negligible;
&& 4.572 m CPD = length of array;
&& Exclusive Use truck shipment
TITLE Uranium EA - Direct Route Truck UO3 powder
FORM UNIT
DIMEN 4 8 1 10 18
PARM 1 3 2 1 0
POPDEN          5.9     334.1   2173.7
PACKAGE
   LABGRP
      POWDER
SHIPMENT
   LABISO
      U234      U235    U236    U238
NORMAL
   NMODE=1
       8.783E-01  1.116E-01  1.010E-02  8.849E+01  4.025E+01  2.416E+01
       2.000E+00  7.710E+00  0.000E+00  0.000E+00  1.084E+01  0.000E+00
       0.000E+00  5.000E+01  2.000E+01  0.000E+00  1.000E+02  1.000E+02
       2.000E+00  0.000E+00  0.000E+00  1.000E+00  4.700E+02  7.800E+02
       2.800E+03
ACCIDENT
   ARATMZ
      NMODE=1   2.03E-7         3.58E-7         3.58E-7
   SEVFRC
```

```
     NPOP=1
       NMODE=1
       4.62E-01 3.02E-01 1.76E-01 4.03E-02 1.18E-02 6.47E-03 5.71E-04 1.13E-04
     NPOP=2
       NMODE=1
       4.35E-01 2.85E-01 2.21E-01 5.06E-02 6.64E-03 1.74E-03 6.72E-05 5.93E-06
     NPOP=3
       NMODE=1
       5.83E-01 3.82E-01 2.78E-02 6.36E-03 7.42E-04 1.46E-04 1.13E-05 9.94E-07
RELEASE
   RFRAC
      GROUP=1
       0.   0.1   6*1.0
   AERSOL
      DISP=5
       0.   3.E-4   6*3.E-2
   RESP
      DISP=5
       0.   7*1.E-2
DEFINE  U234
      8.93E+07  1.73E-03  2.43E-05  1.30E+08  2.60E+05  0.00E+00
      0.00E+00  1.00E-02  3.00E+00  8.20E+07  6.50E+04
DEFINE  U236
      8.54E+09  1.57E-03  1.92E-05  6.70E+06  2.50E+05  0.00E+00
      0.00E+00  1.00E-02  3.00E+00  7.70E+07  6.10E+04
EOF
ISOTOPES  -1  49  1  0.44  1.  0.  THOPARRAY
        U234       6.718E+00 POWDER  5
        U235       2.584E-01 POWDER  5
        U236       6.027E-01 POWDER  5
        U238       4.493E+00 POWDER  5
DISTKM
      NMODE=1  3870.4
PKGSIZ
       THOPARRAY   4.572
EOF
EOI
```

5.4 Radtran Input File for UO$_3$ Powder via Direct Route Rail

```
&& RADTRAN 4 - Unirradiated Uranium EA - UO3 Powder - Rail - Direct
&& J.L. Boles, Aug. 31 1999, 772030/167
&& Accident Severity Categories and Probabilities derived from NUREG-0170 (1977),
&&   Table 5-3.
&& Accident Rates from Saricks and Kvitek (1994), US Mainline Average,
&&   multiplied by 3 (3 railcars/shipment).
&& Release fraction is 0 for Cat 1, 0.1 for Cat 2, and 1 for Cat 3-8.
&& Aerosol and Respirable Fractions are median values for Cat 2, bounding
&&   for Cat 3-8.
&& 5 shipments = 147 T Hoppers / 10 T Hoppers per rail car / 3 cars/shipment
&& TI = 0.73 from ISO-PC shldg calc, 3/16" Fe wall, src decayed 10 yrs
&& Neutron dose rate negligible;
&& 15.24 m CPD = length of array;
&& Exclusive Use rail shipment
TITLE Uranium EA - Direct Route Rail UO3 powder
FORM UNIT
DIMEN 4 8 1 10 18
PARM 1 3 2 1 0
POPDEN      6.900       388.900         2210.000
PACKAGE
```

```
     LABGRP
         POWDER
SHIPMENT
     LABISO
         U234     U235    U236    U238
NORMAL
     NMODE=2
         8.590E-01  1.138E-01  2.720E-02  6.437E+01  4.025E+01  2.416E+01
         5.000E+00  1.524E+02  2.000E+00  3.300E-02  1.000E+01  6.000E+01
         2.000E+00  1.000E+02  2.000E+01  4.000E+00  1.000E+02  1.000E+02
         3.000E+00  0.000E+00  1.000E+00  0.000E+00  1.000E+00  5.000E+00
         5.000E+00
ACCIDENT
     ARATMZ
       NMODE=2      7.98E-08   7.98E-08   7.98E-08
     SEVFRC
       NPOP=1
         NMODE=2
         3.56E-01 2.14E-01 3.84E-01 3.84E-02 6.41E-03 6.48E-04 3.42E-04 6.41E-05
       NPOP=2
         NMODE=2
         3.13E-01 1.88E-01 4.51E-01 4.51E-02 3.38E-03 1.63E-04 3.76E-05 3.13E-06
       NPOP=3
         NMODE=2
         5.72E-01 3.43E-01 7.72E-02 7.72E-03 5.14E-04 1.86E-05 8.57E-06 7.15E-07
RELEASE
     RFRAC
        GROUP=1
         0.   0.1   6*1.0
     AERSOL
        DISP=5
         0.   3.E-4   6*3.E-2
     RESP
        DISP=5
         0.   7*1.E-2
DEFINE  U234
        8.93E+07  1.73E-03  2.43E-05  1.30E+08  2.60E+05  0.00E+00
        0.00E+00  1.00E-02  3.00E+00  8.20E+07  6.50E+04
DEFINE  U236
        8.54E+09  1.57E-03  1.92E-05  6.70E+06  2.50E+05  0.00E+00
        0.00E+00  1.00E-02  3.00E+00  7.70E+07  6.10E+04
EOF
ISOTOPES   -2 5 3 0.73 1.000 0.000 THOPARRAY
        U234       2.239E+001 POWDER  5
        U235       8.613E-001 POWDER  5
        U236       2.009E-000 POWDER  5
        U238       1.498E+001 POWDER  5
DISTKM
         NMODE=2   3981.2
PKGSIZ
         THOPARRAY   15.24
EOF
EOI
```

5.5 Radtran Input File for UO$_3$ Powder via Truck through Paducah, KY

```
&& RADTRAN 4 - Unirradiated Uranium EA - UO3 Powder - Truck - Indirect
&& J.L. Boles, Aug. 31 1999, 772030/167
&& Accident Severity Categories and Probabilities derived from NUREG-0170
&&   (1977), Table 5-3.
```

```
&& Accident Rates taken from Saricks and Kvitek (1994), US Average.
&& Release fraction is 0 for Cat 1, 0.1 for Cat 2, and 1 for Cat 3-8.
&& Aerosol and Respirable Fractions are median values for Cat 2, bounding
&&   for Cat 3-8.
&& 49 shipments = 147 T Hoppers / 3 T Hoppers per truck
&& TI = 0.44 from ISO-PC shldg calc, 3/16" Fe wall, src decayed 10 yrs
&& Crew-source distance DNORML(8)= 7.71 m based on ISO-PC calc crew dose rate
&&   and Eq. 12 of Technical Manual (N&K 1989).
&& Minimum stop time = twice that calculated by Highway code
&& Neutron dose rate negligible;
&& 4.572 m CPD = length of array;
&& Exclusive Use truck shipment
TITLE Uranium EA - Truck Route Via Paducah, KY  UO3 powder
FORM UNIT
DIMEN 4 8 1 10 18
PARM 1 3 2 1 0
POPDEN  7.7   338.4   2112.9
PACKAGE
   LABGRP
      POWDER
SHIPMENT
   LABISO
      U234      U235    U236    U238
NORMAL
   NMODE=1
       8.783E-01  1.116E-01  1.010E-02  8.849E+01  4.025E+01  2.416E+01
       2.000E+00  7.710E+00  0.000E+00  0.000E+00  1.220E+01  0.000E+00
       0.000E+00  5.000E+01  2.000E+01  0.000E+00  1.000E+02  1.000E+02
       2.000E+00  0.000E+00  0.000E+00  1.000E+00  4.700E+02  7.800E+02
       2.800E+03
ACCIDENT
   ARATMZ
      NMODE=1   2.03E-7         3.58E-7         3.58E-7
   SEVFRC
     NPOP=1
       NMODE=1
       4.62E-01 3.02E-01 1.76E-01 4.03E-02 1.18E-02 6.47E-03 5.71E-04 1.13E-04
     NPOP=2
       NMODE=1
       4.35E-01 2.85E-01 2.21E-01 5.06E-02 6.64E-03 1.74E-03 6.72E-05 5.93E-06
     NPOP=3
       NMODE=1
       5.83E-01 3.82E-01 2.78E-02 6.36E-03 7.42E-04 1.46E-04 1.13E-05 9.94E-07
RELEASE
   RFRAC
      GROUP=1
       0.   0.1   6*1.0
   AERSOL
      DISP=5
       0.   3.E-4   6*3.E-2
   RESP
      DISP=5
       0.   7*1.E-2
DEFINE  U234
      8.93E+07  1.73E-03  2.43E-05  1.30E+08  2.60E+05  0.00E+00
      0.00E+00  1.00E-02  3.00E+00  8.20E+07  6.50E+04
DEFINE  U236
      8.54E+09  1.57E-03  1.92E-05  6.70E+06  2.50E+05  0.00E+00
      0.00E+00  1.00E-02  3.00E+00  7.70E+07  6.10E+04
EOF
ISOTOPES  -1  49  1  0.44  1.  0.  THOPARRAY
        U234       6.718E+00 POWDER  5
        U235       2.584E-01 POWDER  5
        U236       6.027E-01 POWDER  5
```

```
        U238       4.493E+00 POWDER  5
DISTKM
      NMODE=1  4391.8
PKGSIZ
      THOPARRAY   4.572
EOF
EOI
```

5.6 Radtran Input File for UO_3 Powder via Rail through Paducah, KY

```
&& RADTRAN 4 - Unirradiated Uranium EA - UO3 Powder - Rail - Indirect
&& J.L. Boles, Aug. 31 1999, 772030/167
&& Accident Severity Categories and Probabilities derived from NUREG-0170 (1977),
&&   Table 5-3.
&& Accident Rates from Saricks and Kvitek (1994), US Mainline Average,
&&   multiplied by 3 (3 railcars/shipment).
&& Release fraction is 0 for Cat 1, 0.1 for Cat 2, and 1 for Cat 3-8.
&& Aerosol and Respirable Fractions are median values for Cat 2, bounding
&&   for Cat 3-8.
&& 5 shipments = 147 T Hoppers / 10 T Hoppers per rail car / 3 cars/shipment
&& TI = 0.73 from ISO-PC shldg calc, 3/16" Fe wall, src decayed 10 yrs
&& ASSUMPTIONS
&&   neutron dose rate negligible;
&&   15.24 m CPD = length of array;
&&   Exclusive Use rail shipment
TITLE Uranium EA - Indirect Route Rail via Paducah UO3 powder
FORM UNIT
DIMEN 4 8 1 10 18
PARM 1 3 2 1 0
POPDEN      8.100       380.100         2068.600
PACKAGE
   LABGRP
       POWDER
SHIPMENT
   LABISO
       U234     U235    U236    U238
NORMAL
   NMODE=2
       8.520E-01  1.240E-01  2.400E-02  6.437E+01  4.025E+01  2.416E+01
       5.000E+00  1.524E+02  2.000E+00  3.300E-02  1.000E+01  6.000E+01
       2.000E+00  1.000E+02  2.000E+01  4.000E+00  1.000E+02  1.000E+02
       3.000E+00  0.000E+00  1.000E+00  0.000E+00  1.000E+00  5.000E+00
       5.000E+00
ACCIDENT
   ARATMZ
     NMODE=2      7.98E-08   7.98E-08   7.98E-08
   SEVFRC
     NPOP=1
       NMODE=2
       3.56E-01 2.14E-01 3.84E-01 3.84E-02 6.41E-03 6.48E-04 3.42E-04 6.41E-05
     NPOP=2
       NMODE=2
       3.13E-01 1.88E-01 4.51E-01 4.51E-02 3.38E-03 1.63E-04 3.76E-05 3.13E-06
     NPOP=3
       NMODE=2
       5.72E-01 3.43E-01 7.72E-02 7.72E-03 5.14E-04 1.86E-05 8.57E-06 7.15E-07
RELEASE
   RFRAC
      GROUP=1
       0.   0.1   6*1.0
```

```
   AERSOL
      DISP=5
       0.   3.E-4   6*3.E-2
   RESP
      DISP=5
       0.   7*1.E-2
DEFINE  U234
      8.93E+07  1.73E-03  2.43E-05  1.30E+08  2.60E+05  0.00E+00
      0.00E+00  1.00E-02  3.00E+00  8.20E+07  6.50E+04
DEFINE  U236
      8.54E+09  1.57E-03  1.92E-05  6.70E+06  2.50E+05  0.00E+00
      0.00E+00  1.00E-02  3.00E+00  7.70E+07  6.10E+04
EOF
ISOTOPES   -2 5 3 0.73 1.000 0.000 THOPARRAY
        U234       2.239E+001 POWDER  5
        U235       8.613E-001 POWDER  5
        U236       2.009E-000 POWDER  5
        U238       1.498E+001 POWDER  5
DISTKM
       NMODE=2   4747.0
PKGSIZ
       THOPARRAY   15.24
EOF
EOI
```

5.7 Representative Radtran Input File for Fuel

```
&& RADTRAN 4 - Unirradiated Uranium EA - Finished Fuel, 0.95% U235
&& J.L. Boles, May  31 2000, 772030/171
&& Accident Severity Categories and Probabilities derived from NUREG-0170 (1977),
&&   Table 5-3.
&& Accident Rates taken from Saricks and Kvitek (1994), US Average.
&& Release fractions are Type A defaults from NUREG-0170.
&& Aerosol and Respirable Fractions are median values for Cat 2, bounding
&&   for Cat 3-8 for burning uranium metal.
&& 376 shipments = 611.8 MTU / 1628 kgU/shipment
&& TI = 0.034 from ISO-PC shldg calc, src from SARP-019, Rev. K, Table 5.2.1-1,
&&   at 1 m from the edge of the vehicle carrying an array of 3 boxes.
&& Source-to-crew distance [DNORML(8)] is default of 3.1 m.
&& Minimum stop time = twice that calculated by Highway code
&& Neutron dose rate negligible
&& CPD = 1.08 m = length of single layer of 3 boxes/shipment
&& Exclusive use truck shipment
TITLE Uranium EA - Billets - Direct Route - Truck
FORM UNIT
DIMEN 7 8 1 10 18
PARM 1 3 2 1 0
POPDEN     5.9     334.1   2173.7
PACKAGE
   LABGRP
       BILLET
SHIPMENT
   LABISO
       U234     U235     U236     U238     PU241     TC99     SR90
NORMAL
   NMODE=1
       8.783E-01  1.116E-01  1.010E-02  8.849E+01  4.025E+01  2.416E+01
       2.000E+00  3.100E+00  0.000E+00  0.000E+00  1.084E+01  0.000E+00
       0.000E+00  5.000E+01  2.000E+01  0.000E+00  1.000E+02  1.000E+02
       2.000E+00  0.000E+00  0.000E+00  1.000E+00  4.700E+02  7.800E+02
```

```
       2.800E+03
ACCIDENT
   ARATMZ
     NMODE=1      2.03E-07   3.58E-07   3.58E-07
   SEVFRC
     NPOP=1
       NMODE=1
       4.62E-01 3.02E-01 1.76E-01 4.03E-02 1.18E-02 6.47E-03 5.71E-04 1.13E-04
     NPOP=2
       NMODE=1
       4.35E-01 2.85E-01 2.21E-01 5.06E-02 6.64E-03 1.74E-03 6.72E-05 5.93E-06
     NPOP=3
       NMODE=1
       5.83E-01 3.82E-01 2.78E-02 6.36E-03 7.42E-04 1.46E-04 1.13E-05 9.94E-07
RELEASE
   RFRAC
      GROUP=1
       0.0  0.01   0.1   5*1.
   AERSOL
      DISP=2
       0.0  1.E-4  6*1.0E-3
   RESP
      DISP=2
       0.0  7*1.
DEFINE  U234
      8.93E+07  1.73E-03  2.43E-05  1.30E+08  2.60E+05  0.00E+00
      0.00E+00  1.00E-02  3.00E+00  8.20E+07  6.50E+04
DEFINE  U236
      8.54E+09  1.57E-03  1.92E-05  6.70E+06  2.50E+05  0.00E+00
      0.00E+00  1.00E-02  3.00E+00  7.70E+07  6.10E+04
EOF
ISOTOPES -1  376  1  0.034  1.  0.  BOXARRAY
        U234       1.347E+00 BILLET  2
        U235       3.424E-02 BILLET  2
        U236       1.053E-01 BILLET  2
        U238       5.421E-01 BILLET  2
        PU241      6.740E-03 BILLET  2
        TC99       7.182E-01 BILLET  2
        SR90       3.581E-02 BILLET  2
PKGSIZ
      BOXARRAY   1.08
DISTKM
      NMODE=1  3870.4
EOF
EOI
```

5.8 Highway Output File for Direct Route from Hanford, WA, to Portsmouth, OH

```
                   *    HIGHWAY 3.3  Highway Routine Program   *
                   *      Oak Ridge National Laboratory        *


                             -----------------
                               HIGHWAY   3.3
                             -----------------

    Portions of this System are licensed for use by the United States
    Government and its contractors under copyrights claimed by Rand
    McNally-TDM, Inc.  Use of this program for day-to-day operational
    purposes by commercial concerns for other than governmental purposes
    incidental to the transport of nuclear and other hazardous
    materials is prohibited.


    Data base version is HW-94.1


From: HANFORD                     WA      Leaving :  6/21/99 at 11:11 PDT
to   : PORTSMOUTH GDP             OH      Arriving:  6/23/99 at  9:31 EDT

Route type: Q with  2 driver(s)                      Total road time: 43:21
  Time bias:  1.00  Mile bias:   .00  Toll bias:  1.00   Total miles: 2405.0

The following constraints are in effect:
 1 - Links prohibiting truck use
 6 - HM-164/State preferred routes
 7 - Avoid ferry crossings
11 - Nonintersecting Interstate Access
Weighting used with preferred highways: 10.0
State mileage:
 OH  168.0  IN  168.0  IL  229.0  IA  302.0  NE  459.0  WY  402.0  UT  148.0
 ID  274.0  OR  209.0  WA   46.0
Mileage by highway sign type:
    Interstate: 2330.0   U.S.:   64.0  State:    7.0  Turnpike:     .0
        County:     .0  Local:    4.0  Other:     .0
Mileage by highway lane type:
    Limited Access Multilane: 2332.0  Limited Access Single Lane:     .0
           Multilane Divided:   62.0         Multilane Undivided:     .0
    Principal Highway:    7.0    Through Highway:     .0   Other:    4.0


From: HANFORD                     WA      Leaving :  6/21/99 at 11:11 PDT
to   : PORTSMOUTH GDP             OH      Arriving:  6/23/99 at  9:31 EDT


  Routing through:
    .0             HANFORD                     WA      .0   0:00   6/21 @ 11:11
   1.0 LR4S        NORTH RICHLAND    LR10 LR4S WA     1.0   0:02   6/21 @ 11:13
   3.0 LR4S        RICHLAND      N  S240 LR4S WA     4.0   0:08   6/21 @ 11:19
   1.0 S240        RLD AIRPORT                 WA     5.0   0:10   6/21 @ 11:21
   4.0 S240        RICHLAND                    WA     9.0   0:18   6/21 @ 11:29
   2.0 S240        RICHLAND      SE I182 X5   WA    11.0   0:22   6/21 @ 11:33
   5.0 I182        WEST RICHLAND  S  I182 I182 WA    16.0   0:27   6/21 @ 11:39
  10.0 I82         KENNEWICK      SW I82  X113 WA    26.0   0:37   6/21 @ 11:49
  19.0 I82         PLYMOUTH          I82  X131 WA    45.0   0:56   6/21 @ 12:08
   2.0 I82         UMATILLA          I82  X1   OR    47.0   0:58   6/21 @ 12:09
  10.0 I82         HERMISTON      SW I82  I84  OR    57.0   1:08   6/21 @ 12:19
   9.0 I84         STANFIELD      SE I84  X188 OR    66.0   1:16   6/21 @ 12:27
  19.0 I84         PDT AIRPORT       I84  X207 OR    85.0   1:33   6/21 @ 12:44
```

```
 2.0 I84         PENDLETON         I84  X209 OR   87.0   1:35   6/21 @ 12:46
52.0 I84         LA GRANDE         I84  X261 OR  139.0   2:23   6/21 @ 13:34
41.0 I84         BAKER CITY     NE I84  X302 OR  180.0   3:01   6/21 @ 14:12
54.0 I84         HUNTINGTON     SE I84  X356 OR  234.0   3:51   6/21 @ 15:02
18.0 I84         ONTARIO        N  I84  X374 OR  252.0   4:08   6/21 @ 16:18
 2.0 I84         ONTARIO        E  I84  X376 OR  254.0   4:40   6/21 @ 16:51
 4.0 I84         FRUITLAND      S  I84  X3   ID  258.0   4:43   6/21 @ 16:54
24.0 I84         CALDWELL          I84  X28  ID  282.0   5:06   6/21 @ 17:16
 8.0 I84         NAMPA          N  I84  X35  ID  290.0   5:13   6/21 @ 17:24
14.0 I84         BOISE          SW I184 I84  ID  304.0   5:26   6/21 @ 17:37
 4.0 I84         BOI AIRPORT       I84  X53  ID  308.0   5:30   6/21 @ 17:41
 1.0 I84         BOISE          S  I84  X54  ID  309.0   5:31   6/21 @ 17:42
41.0 I84         MTN HOME       NE I84  X95  ID  350.0   6:10   6/21 @ 18:21
46.0 I84         BLISS             I84  X141 ID  396.0   6:53   6/21 @ 19:04
24.0 I84         JEROME         W  I84  X165 ID  420.0   7:15   6/21 @ 19:26
 8.0 I84         TWIN FALLS     N  I84  X173 ID  428.0   7:22   6/21 @ 19:33
35.0 I84         BURLEY         N  I84  X208 ID  463.0   7:55   6/21 @ 20:06
 9.0 I84         RUPERT         SE I84  X216 ID  472.0   8:03   6/21 @ 20:14
 5.0 I84         RAFT RIVER     W  I84  I86  ID  477.0   8:08   6/21 @ 20:18
57.0 I84         SNOWVILLE      W  I84  X5   UT  534.0   9:30   6/21 @ 21:41
35.0 I84         TREMONTON      W  I15  I84  UT  569.0  10:04   6/21 @ 22:15
18.0 I15   I84   BRIGHAM CITY   SW I15  X364 UT  587.0  10:21   6/21 @ 22:32
19.0 I15   I84   OGDEN          W  I15  X344 UT  606.0  10:40   6/21 @ 22:51
 2.0 I15   I84   OGDEN          S  I15  I84  UT  608.0  10:42   6/21 @ 22:53
 7.0 I84         UINTAH            I84  X87  UT  615.0  10:48   6/21 @ 22:59
32.0 I84         ECHO              I80  I84  UT  647.0  11:18   6/21 @ 23:29
48.0 I80         EVANSTON       NE I80  X18  WY  695.0  12:02   6/22 @  0:13
48.0 I80         LITTLE AMERICA W  I80  X66  WY  743.0  12:46   6/22 @  0:57
26.0 I80         GREEN RIVER    E  I80  X91  WY  769.0  13:10   6/22 @  1:21
 7.0 I80         ROCK SPRINGS   SW I80  X99  WY  776.0  13:47   6/22 @  1:58
 5.0 I80         ROCK SPRINGS   N  I80  X104 WY  781.0  13:52   6/22 @  2:02
 7.0 I80         ROCK SPRINGS   E  I80  X111 WY  788.0  13:58   6/22 @  2:09
76.0 I80         CRESTON JCT    NE I80  X187 WY  864.0  15:08   6/22 @  3:19
25.0 I80         RAWLINS        W  I80  X211 WY  889.0  15:31   6/22 @  3:42
 4.0 I80         RAWLINS        E  I80  X215 WY  893.0  15:35   6/22 @  3:46
19.0 I80         WALCOTT        S  I80  X235 WY  912.0  15:52   6/22 @  4:03
76.0 I80         LARAMIE        W  I80  X311 WY  988.0  17:03   6/22 @  5:13
 2.0 I80         LARAMIE        S  I80  X313 WY  990.0  17:04   6/22 @  5:15
46.0 I80         CHEYENNE       SW I25  I80  WY 1036.0  17:47   6/22 @  5:58
 3.0 I80         CHEYENNE       S  I80  X362 WY 1039.0  18:20   6/22 @  6:30
60.0 I80         KIMBALL        S  I80  X20  NE 1099.0  19:15   6/22 @  7:26
35.0 I80         SIDNEY         SW I80  X55  NE 1134.0  19:47   6/22 @  7:58
 4.0 I80         SIDNEY         SE I80  X59  NE 1138.0  19:51   6/22 @  8:02
43.0 I80         BIG SPRINGS    SW I76  I80  NE 1181.0  20:31   6/22 @  8:41
24.0 I80         OGALLALA       S  I80  X126 NE 1205.0  20:53   6/22 @  9:04
51.0 I80         NORTH PLATTE   S  I80  X177 NE 1256.0  21:40   6/22 @  9:51
61.0 I80         LEXINGTON      S  I80  X237 NE 1317.0  22:36   6/22 @ 11:47
19.0 I80         ELM CREEK      S  I80  X257 NE 1336.0  23:24   6/22 @ 12:34
16.0 I80         KEARNEY        S  I80  X272 NE 1352.0  23:39   6/22 @ 12:49
39.0 I80         DONIPHAN       N  I80  X312 NE 1391.0  24:15   6/22 @ 13:25
20.0 I80         AURORA         S  I80  X332 NE 1411.0  24:33   6/22 @ 13:44
21.0 I80         YORK           S  I80  X353 NE 1432.0  24:52   6/22 @ 14:03
26.0 I80         SEWARD         S  I80  X379 NE 1458.0  25:16   6/22 @ 14:27
18.0 I80         LINCOLN        W  I80  X396 NE 1476.0  25:33   6/22 @ 14:44
  .0 I80         LINCOLN        W  I80  X397 NE 1476.0  25:33   6/22 @ 14:44
 2.0 I80         LNK AIRPORT       I80  X399 NE 1478.0  25:35   6/22 @ 14:45
 2.0 I80         LINCOLN        N  I180 I80  NE 1480.0  25:37   6/22 @ 14:48
 5.0 I80         LINCOLN        NE I80  X405 NE 1485.0  25:42   6/22 @ 14:52
 4.0 I80         WAVERLY        SW I80  X409 NE 1489.0  25:45   6/22 @ 14:56
30.0 I80         PAPILLION      W  I80  X440 NE 1519.0  26:13   6/22 @ 15:24
 4.0 I80         OMAHA          SW I80  X445 NE 1523.0  26:18   6/22 @ 15:28
 1.0 I80         OMAHA          SW I680 I80  NE 1524.0  26:19   6/22 @ 15:29
12.0 I680        OMAHA          NW I680 X12  NE 1536.0  26:32   6/22 @ 15:42
 1.0 I680        OMAHA          N  I680 X13  NE 1537.0  27:03   6/22 @ 16:13
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  4.0 I680        CRESCENT       W  I29   I680 IA  1541.0  27:07   6/22 @ 16:18
 10.0 I29   I680  LOVELAND       SW I29   I680 IA  1551.0  27:16   6/22 @ 16:27
 16.0 I680        MINDEN         NW I680  I80  IA  1567.0  27:31   6/22 @ 16:42
 13.0 I80         AVOCA          N  I80   X40  IA  1580.0  27:43   6/22 @ 16:54
 20.0 I80         BRAYTON        S  I80   X60  IA  1600.0  28:02   6/22 @ 17:12
 50.0 I80         DE SOTO        NW I80   X110 IA  1650.0  28:48   6/22 @ 17:58
 13.0 I80         DES MOINES     W  I235  I35  IA  1663.0  29:00   6/22 @ 18:10
  4.0 I35   I80   URBANDALE      NW I80   X127 IA  1667.0  29:04   6/22 @ 18:14
 10.0 I35   I80   DES MOINES     N  I235  I35  IA  1677.0  29:15   6/22 @ 18:25
  5.0 I80         ALTOONA        NW I80   X142 IA  1682.0  29:19   6/22 @ 18:30
 13.0 I80         COLFAX         N  I80   X155 IA  1695.0  29:31   6/22 @ 18:42
  9.0 I80         NEWTON         SW I80   X164 IA  1704.0  29:40   6/22 @ 18:50
 27.0 I80         MALCOM         S  I80   X191 IA  1731.0  30:05   6/22 @ 19:15
 29.0 I80         WILLIAMSBURG   N  I80   X220 IA  1760.0  30:31   6/22 @ 19:42
  5.0 I80         HOMESTEAD      SW I80   X225 IA  1765.0  30:36   6/22 @ 19:46
 14.0 I80         TIFFIN         E  I380  I80  IA  1779.0  30:49   6/22 @ 19:59
  7.0 I80         IOWA CITY      NE I80   X246 IA  1786.0  30:57   6/22 @ 20:07
 44.0 I80         DAVENPORT      NW I280  I80  IA  1830.0  31:37   6/22 @ 20:47
  7.0 I280        DAVENPORT      SW I280  X6   IA  1837.0  32:14   6/22 @ 21:24
  4.0 I280        ROCK ISLAND    SW I280  X11  IL  1841.0  32:18   6/22 @ 21:28
  4.0 I280        MILAN          E  I280  X15  IL  1845.0  32:23   6/22 @ 21:33
  3.0 I280        MLI AIRPORT       I280  I74  IL  1848.0  32:26   6/22 @ 21:36
  9.0 I74         GREEN ROCK     SE I74   I80  IL  1857.0  32:36   6/22 @ 21:46
 32.0 I74         GALESBURG      NE I74   X46  IL  1889.0  33:11   6/22 @ 22:21
  8.0 I74         KNOXVILLE      NE I74   X54  IL  1897.0  33:19   6/22 @ 22:30
 18.0 I74         BRIMFIELD      NW I74   X71  IL  1915.0  33:39   6/22 @ 22:49
 15.0 I74         PEORIA         NW I474  I74  IL  1930.0  33:55   6/22 @ 23:06
  5.0 I474        PIA AIRPORT       I474  X5   IL  1935.0  34:01   6/22 @ 23:11
  2.0 I474        BARTONVILLE       I474  X6   IL  1937.0  34:03   6/22 @ 23:13
  3.0 I474        CREVE COEUR       I474  X9   IL  1940.0  34:06   6/22 @ 23:16
  5.0 I474        EAST PEORIA    SE I474  I74  IL  1945.0  34:12   6/22 @ 23:22
  2.0 I74         MORTON         NW I155  I74  IL  1947.0  34:14   6/22 @ 23:24
 27.0 I74         NORMAL         NW I55   I74  IL  1974.0  34:43   6/22 @ 23:53
  7.0 I55   I74   BLOOMINGTON    SW I55   I74  IL  1981.0  34:51   6/23 @  0:01
  2.0 I74         RANDOLPH       N  I74   X135 IL  1983.0  34:53   6/23 @  0:03
 17.0 I74         LEROY          SE I74   X152 IL  2000.0  35:12   6/23 @  0:22
  7.0 I74         FARMER CITY    E  I74   X159 IL  2007.0  35:19   6/23 @  0:29
 13.0 I74         MAHOMET        NE I74   X172 IL  2020.0  35:33   6/23 @  0:44
  7.0 I74         CHAMPAIGN      NW I57   I74  IL  2027.0  36:11   6/23 @  1:21
  2.0 I74         CHAMPAIGN      N  I74   X181 IL  2029.0  36:13   6/23 @  1:23
  5.0 I74         URBANA         NE I74   X185 IL  2034.0  36:19   6/23 @  1:29
 25.0 I74         DANVILLE       W  I74   X210 IL  2059.0  36:46   6/23 @  1:56
  4.0 I74         DANVILLE       S  I74   X215 IL  2063.0  36:50   6/23 @  2:00
 10.0 I74         COVINGTON      W  I74   X4   IN  2073.0  37:01   6/23 @  2:11
 11.0 I74         VEEDERSBURG    NE I74   X15  IN  2084.0  37:12   6/23 @  2:22
 19.0 I74         CRAWFORDSVILLE N  I74   X34  IN  2103.0  37:31   6/23 @  2:41
  5.0 I74         SMARTSBURG     E  I74   X39  IN  2108.0  37:36   6/23 @  2:46
 35.0 I74         SPEEDWAY       NW I465  I74  IN  2143.0  38:11   6/23 @  3:21
  3.0 I465  I74   TREMONT        E  I465  X13  IN  2146.0  38:15   6/23 @  3:25
  2.0 I465  I74   IND AIRPORT       I465  X11  IN  2148.0  38:17   6/23 @  3:27
  2.0 I465  I74   INDIANAPOLIS   SW I465  I70  IN  2150.0  38:19   6/23 @  3:29
  1.0 I465  I74   VALLEY MILLS   NE I465  X8   IN  2151.0  38:20   6/23 @  3:30
  4.0 I465  I74   GLENNS VALLEY  N  I465  X4   IN  2155.0  38:24   6/23 @  3:34
  4.0 I465  I74   INDIANAPOLIS   S  I465  I65  IN  2159.0  38:29   6/23 @  3:39
  5.0 I465  I74   INDIANAPOLIS   SE I465  I74  IN  2164.0  38:34   6/23 @  3:44
  2.0 I465        JULIETTA       W  I465  X47  IN  2166.0  38:36   6/23 @  3:46
  4.0 I465        INDIANAPOLIS   E  I465  I70  IN  2170.0  38:41   6/23 @  3:51
 14.0 I70         GREENFIELD     N  I70   X104 IN  2184.0  38:55   6/23 @  4:05
 20.0 I70         SPICELAND      NE I70   X123 IN  2204.0  39:15   6/23 @  4:25
 26.0 I70         RICHMOND       NW I70   X149 IN  2230.0  39:41   6/23 @  4:51
  2.0 I70         RICHMOND       N  I70   X151 IN  2232.0  39:43   6/23 @  4:53
  5.0 I70         RICHMOND       E  I70   X156 IN  2237.0  39:48   6/23 @  4:58
  2.0 I70         NEW WESTVILLE  NE I70   X1   OH  2239.0  39:50   6/23 @  6:00
  8.0 I70         LEWISBURG      W  I70   X10  OH  2247.0  39:59   6/23 @  6:09
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  14.0 I70         CLAYTON           I70  X24  OH  2261.0  40:14   6/23 @  6:24
   2.0 I70         CLAYTON        E  I70  X26  OH  2263.0  40:46   6/23 @  6:56
   6.0 I70         VANDALIA       SW I70  X32  OH  2269.0  40:53   6/23 @  7:03
   2.0 I70         VANDALIA       S  I70  I75  OH  2271.0  40:55   6/23 @  7:05
   7.0 I70         SULPHUR GROVE  E  I70  X41  OH  2278.0  41:02   6/23 @  7:12
   3.0 I70         FAIRBORN       N  I675 I70  OH  2281.0  41:06   6/23 @  7:16
   4.0 I70         ENON              I70  X47  OH  2285.0  41:10   6/23 @  7:20
   5.0 I70         BEATTY         NW I70  X52  OH  2290.0  41:16   6/23 @  7:25
  19.0 I70         SUMMERFORD     NW I70  X72  OH  2309.0  41:36   6/23 @  7:46
   6.0 I70         LAFAYETTE      NE I70  X79  OH  2315.0  41:43   6/23 @  7:53
   2.0 I70         LAFAYETTE      E  I70  X80  OH  2317.0  41:45   6/23 @  7:55
   5.0 I70         WEST JEFFERSON N  I70  X85  OH  2322.0  41:50   6/23 @  8:00
   8.0 I70         COLUMBUS       W  I270 I70  OH  2330.0  41:59   6/23 @  8:09
   9.0 I270        COLUMBUS       SW I270 I71  OH  2339.0  42:09   6/23 @  8:19
   2.0 I270        SHADEVILLE     N  I270 X52  OH  2341.0  42:11   6/23 @  8:21
   3.0 U23         SHADEVILLE        U23  S317 OH  2344.0  42:14   6/23 @  8:24
  16.0 U23         CIRCLEVILLE    W  U22  U23  OH  2360.0  42:32   6/23 @  8:42
  18.0 U23         CHILLICOTHE    NE U23  U35  OH  2378.0  42:52   6/23 @  9:01
   1.0 U23   U35   CHILLICOTHE    E  U23  U50  OH  2379.0  42:53   6/23 @  9:02
   1.0 U23   U35   CHILLICOTHE    SE U23  U35  OH  2380.0  42:54   6/23 @  9:04
  22.0 U23         PIKETON        S  U23  S32  OH  2402.0  43:18   6/23 @  9:28
   3.0 U23         PORTSMOUTH GDP              OH  2405.0  43:21   6/23 @  9:31


Population Density from: HANFORD                     WA
                   to : PORTSMOUTH GDP               OH

         ------------------  Mileage within Density Levels  -------------------
               <0.0   5.0  22.7  59.7   139   326   821  1861  3326  5815
St Miles    0  -5.0 -22.7 -59.7  -139  -326  -821 -1861 -3326 -5815 -9996 >9996
-------------------------------------------------------------------------------

OH 168.0 11.8  10.0  27.9  28.6  31.7  24.2  15.7   6.9   4.4   4.7   1.5    .5
IN 168.0 11.3  20.0  33.7  36.5  18.7  14.5  10.0  10.9   7.7   2.9   1.9    .0
IL 229.0 17.3  56.2  56.3  25.8  22.4  18.9  14.7   9.5   5.2   2.0    .5    .1
IA 302.0 40.3  97.6  89.6  33.2  13.3  13.2   8.8   4.3   1.6    .2    .0    .0
NE 459.0 48.8 207.1 130.0  31.5  12.0  10.9   6.5   2.9   5.1   3.1   1.1    .0
WY 402.0 78.8 253.4  30.8  12.5   4.6   6.7   6.1   4.7   3.1    .5    .7    .0
UT 148.0 32.1  73.4  11.4   6.2  11.9   5.0   2.3   2.2   2.2    .9    .5    .0
ID 274.0 43.9  97.4  53.6  45.5  10.0   9.3   4.3   4.6   3.5   1.6    .2    .0
OR 209.0 11.1 132.4  31.5  13.8  10.8   4.0   1.4   3.0    .7    .4    .0    .0
WA  46.0  3.7  21.1   5.0   2.4   3.0   1.1   2.3   2.2   4.2    .7    .4    .0

Totals
  2405.0299.0 968.7 469.7 236.2 138.5 107.7  72.1  51.1  37.5  16.9   6.7    .6
Percentages
         12.4  40.3  19.5   9.8   5.8   4.5   3.0   2.1   1.6    .7    .3    .0
Basis: 1990 Census

   RADTRAN Input Data       Rural  Suburban    Urban

   Weighted Population
        People/sq. mi.       15.3     865.2   5630.0
        People/sq. km.        5.9     334.1   2173.7

   Distance                                           Total
        Miles              2112.1     268.4     24.3  2405.0
        Kilometers         3398.9     432.0     39.0  3870.4
        Percentage           87.8      11.2      1.0

   Basis (people/sq. mi.)    <139  139-3326    >3326   1990 Census

   Note: Due to rounding, the sum of the mileages in the individual
         population categories may not equal the total mileage shown
```

on this report.

5.9 Highway Output File for Indirect Route through Paducah, KY

```
                   *    HIGHWAY 3.3  Highway Routine Program   *
                   *      Oak Ridge National Laboratory        *


                             -----------------
                               HIGHWAY   3.3
                             -----------------

    Portions of this System are licensed for use by the United States
    Government and its contractors under copyrights claimed by Rand
    McNally-TDM, Inc.  Use of this program for day-to-day operational
    purposes by commercial concerns for other than governmental purposes
    incidental to the transport of nuclear and other hazardous
    materials is prohibited.


    Data base version is HW-94.1


From: HANFORD                     WA      Leaving :  6/22/99 at  9:35 PDT
to  : PADUCAH GDP                 KY      Arriving:  6/24/99 at  2:34 CDT

Route type: Q with  2 driver(s)                      Total road time: 39:01
  Time bias:  1.00  Mile bias:   .00  Toll bias:  1.00   Total miles: 2180.0

The following constraints are in effect:
 1 - Links prohibiting truck use
 6 - HM-164/State preferred routes
 7 - Avoid ferry crossings
11 - Nonintersecting Interstate Access
Weighting used with preferred highways: 10.0
State mileage:
 KY   16.0  IL  178.0  MO  250.0  KS  432.0  CO  260.0  WY  367.0  UT  148.0
 ID  274.0  OR  209.0  WA   46.0
Mileage by highway sign type:
    Interstate: 2158.0   U.S.:    8.0  State:    7.0  Turnpike:     .0
        County:     .0  Local:    7.0  Other:     .0
Mileage by highway lane type:
    Limited Access Multilane: 2158.0  Limited Access Single Lane:     .0
           Multilane Divided:     .0          Multilane Undivided:     .0
    Principal Highway:   15.0    Through Highway:     .0    Other:    7.0


From: HANFORD                     WA      Leaving :  6/22/99 at  9:35 PDT
to  : PADUCAH GDP                 KY      Arriving:  6/24/99 at  2:34 CDT


  Routing through:
    .0             HANFORD                     WA      .0   0:00   6/22 @  9:35
   4.0 LR4S        RICHLAND       N  S240 LR4S WA     4.0   0:08   6/22 @  9:43
   7.0 S240        RICHLAND       SE I182 X5   WA    11.0   0:22   6/22 @  9:57
   5.0 I182        WEST RICHLAND  S  I182 I82  WA    16.0   0:27   6/22 @ 10:02
  41.0 I82         HERMISTON      SW I82  I84  OR    57.0   1:08   6/22 @ 10:42
 512.0 I84         TREMONTON      W  I15  I84  UT   569.0  10:04   6/22 @ 20:38
  39.0 I15   I84   OGDEN          S  I15  I84  UT   608.0  10:42   6/22 @ 21:16
  39.0 I84         ECHO              I80  I84  UT   647.0  11:18   6/22 @ 21:52
```

```
 389.0 I80          CHEYENNE       SW I25  I80  WY  1036.0  17:47   6/23 @  4:21
  91.0 I25          COMMERCE CITY  W  I25  I76  CO  1127.0  19:44   6/23 @  6:18
   1.0 I76          COMMERCE CITY  NW I270 I76  CO  1128.0  19:45   6/23 @  6:20
   5.0 I270         DENVER         NE I270 I70  CO  1133.0  19:51   6/23 @  6:25
 526.0 I70          TOPEKA         W  I470 I70  KS  1659.0  29:01   6/23 @ 16:35
   7.0 I470         TOPEKA         S  I335 I470 KS  1666.0  29:15   6/23 @ 16:49
   5.0 I470$ TKST$ TOPEKA          E  I470 I70  KS  1671.0  29:25   6/23 @ 16:59
  42.0 I70 $ TKST$ BONNER SPRINGS  N  I70  X224 KS  1713.0  30:04   6/23 @ 17:38
   4.0 I70          KANSAS CITY    W  I435 I70  KS  1717.0  30:08   6/23 @ 17:41
  31.0 I435         KANSAS CITY    SE I435 I70  MO  1748.0  30:41   6/23 @ 18:15
 224.0 I70          ST LOUIS       NW I270 I70  MO  1972.0  34:40   6/23 @ 22:14
  22.0 I270         EDWARDSVILLE   SW I255 I270 IL  1994.0  35:04   6/23 @ 22:38
  11.0 I255         WASHINGTON PK  SE I255 I64  IL  2005.0  35:16   6/23 @ 22:50
  67.0 I64          MT VERNON      NW I57  I64  IL  2072.0  36:59   6/24 @  0:33
   5.0 I57    I64   MT VERNON      SW I57  I64  IL  2077.0  37:05   6/24 @  0:38
  48.0 I57          PULLEYS MILL   W  I24  I57  IL  2125.0  37:57   6/24 @  1:30
  44.0 I24          PADUCAH        W  I24  X4   KY  2169.0  38:45   6/24 @  2:18
   8.0 U60          KEVIL          E  U60  LOCL KY  2177.0  38:55   6/24 @  2:28
   3.0 LOCAL        PADUCAH GDP                 KY  2180.0  39:01   6/24 @  2:34


Population Density from: HANFORD                     WA
                    to : PADUCAH GDP                 KY

         ------------------  Mileage within Density Levels  -------------------
                 <0.0    5.0  22.7  59.7    139    326    821  1861  3326  5815
St Miles    0   -5.0 -22.7 -59.7   -139   -326   -821 -1861 -3326 -5815 -9996 >9996
-------------------------------------------------------------------------------

KY  16.0  1.9     .0   2.4    .4    8.8    1.7     .2     .6    .0    .0    .0    .0
IL 178.0 27.4   44.1  34.2  31.6   14.1   10.9    7.8    4.6   1.7   1.0    .5    .0
MO 250.0 20.5   43.0  74.5  22.1   15.2   10.4   17.6   22.4  12.7   7.5   3.0   1.0
KS 432.0 25.3  206.9  93.7  43.8   18.7   15.3    9.3    8.9   3.9   4.9    .8    .2
CO 260.0 34.3  134.6  33.3  17.9   14.3   12.0    4.5    4.3   1.9   2.4    .3    .0
WY 367.0 69.3  239.7  23.2  12.3    4.2    5.3    5.6    4.3   2.5    .1    .5    .0
UT 148.0 32.1   73.4  11.4   6.2   11.9    5.0    2.3    2.2   2.2    .9    .5    .0
ID 274.0 43.9   97.4  53.6  45.5   10.0    9.3    4.3    4.6   3.5   1.6    .2    .0
OR 209.0 11.1  132.4  31.5  13.8   10.8    4.0    1.4    3.0    .7    .4    .0    .0
WA  46.0  3.7   21.1   5.0   2.4    3.0    1.1    2.3    2.2   4.2    .7    .4    .0

Totals
  2180.0269.5 992.7 362.8 195.9 111.0   75.0   55.3   57.1  33.2  19.6   6.2   1.1
Percentages
         12.4   45.5  16.6   9.0    5.1    3.4    2.5    2.6   1.5    .9    .3    .1
Basis:  1990 Census

   RADTRAN Input Data      Rural Suburban    Urban

   Weighted Population
        People/sq. mi.      13.8    960.2   5566.3
        People/sq. km.       5.3    370.7   2149.1

   Distance                                          Total
        Miles             1932.0    220.6     26.9  2180.0
        Kilometers        3109.1    355.0     43.3  3508.3
        Percentage          88.6     10.1      1.2

   Basis (people/sq. mi.)   <139 139-3326    >3326   1990 Census

   Note: Due to rounding, the sum of the mileages in the individual
         population categories may not equal the total mileage shown
         on this report.
```

```
From: PADUCAH GDP                 KY      Leaving :  6/22/99 at  9:36 CDT
to  : PORTSMOUTH GDP              OH      Arriving:  6/22/99 at 20:22 EDT

Route type: Q with  2 driver(s)                      Total road time:  9:47
  Time bias:  1.00  Mile bias:   .00  Toll bias:  1.00   Total miles:  549.0

The following constraints are in effect:
 1 - Links prohibiting truck use
 6 - HM-164/State preferred routes
 7 - Avoid ferry crossings
11 - Nonintersecting Interstate Access
Weighting used with preferred highways: 10.0
State mileage:
 OH   20.0  KY  452.0  TN   77.0
Mileage by highway sign type:
    Interstate:  478.0   U.S.:   68.0  State:     .0  Turnpike:     .0
        County:     .0  Local:    3.0  Other:     .0
Mileage by highway lane type:
    Limited Access Multilane:  478.0  Limited Access Single Lane:     .0
           Multilane Divided:   60.0         Multilane Undivided:     .0
    Principal Highway:    8.0    Through Highway:     .0   Other:    3.0


From: PADUCAH GDP                 KY      Leaving :  6/22/99 at  9:36 CDT
to  : PORTSMOUTH GDP              OH      Arriving:  6/22/99 at 20:22 EDT


  Routing through:
    .0              PADUCAH GDP                KY      .0   0:00   6/22 @  9:36
   3.0 LOCAL        KEVIL          E  U60  LOCL KY     3.0   0:06   6/22 @  9:42
   8.0 U60          PADUCAH        W  I24  X4   KY    11.0   0:16   6/22 @  9:51
 135.0 I24          INGLEWOOD      W  I24  I65  TN   146.0   2:20   6/22 @ 11:56
 157.0 I65          OKOLONA        SW I265 I65  KY   303.0   5:17   6/22 @ 15:52
  15.0 I265         MIDDLETOWN     SE I265 I64  KY   318.0   5:31   6/22 @ 16:06
  55.0 I64          LEXINGTON      N  I64  I75  KY   373.0   6:22   6/22 @ 16:58
   7.0 I64    I75   LEXINGTON      E  I64  I75  KY   380.0   6:30   6/22 @ 17:05
 109.0 I64          CATLETTSBURG   S  I64  X191 KY   489.0   8:10   6/22 @ 18:46
  60.0 U23          PORTSMOUTH GDP              OH   549.0   9:47   6/22 @ 20:22


Population Density from: PADUCAH GDP                  KY
                    to : PORTSMOUTH GDP               OH

         ------------------  Mileage within Density Levels  -------------------
               <0.0    5.0  22.7  59.7   139   326   821  1861  3326  5815
St Miles    0  -5.0  -22.7 -59.7  -139  -326  -821 -1861 -3326 -5815 -9996 >9996
-------------------------------------------------------------------------------

OH  20.0  1.6   3.5   2.2   5.0   3.6    .9   1.8    .5    .8    .1    .0    .0
KY 452.0 14.6  44.4  59.6 122.5 111.4  53.3  21.1  11.8  10.7   2.3    .0    .0
TN  77.0  8.2   4.2   8.9  13.2  18.1  10.3   4.6   7.8   1.3    .3    .0    .0

Totals
   549.0 24.4  52.1  70.7 140.7 133.2  64.4  27.6  20.1  12.8   2.8    .0    .0
Percentages
          4.5   9.5  12.9  25.6  24.3  11.7   5.0   3.7   2.3    .5    .0    .0
Basis: 1990 Census

   RADTRAN Input Data       Rural Suburban    Urban

   Weighted Population
        People/sq. mi.       47.8    728.5   4570.5
        People/sq. km.       18.5    281.3   1764.7
```

```
Distance                                                Total
     Miles                421.2    124.9       2.8    549.0
     Kilometers           677.8    201.0       4.5    883.5
     Percentage            76.7     22.8        .5

Basis (people/sq. mi.)   <139 139-3326    >3326   1990 Census

Note: Due to rounding, the sum of the mileages in the individual
      population categories may not equal the total mileage shown
      on this report.
```

5.10 Interline Output File from Hanford, WA, to Portsmouth, OH, via Rail

```
ROUTE FROM:  USG  16215-HANFORD WORKS       WA     LENGTH:  2473.9 MILES
        TO:  NS    3170-PORTSMOUTH          OH  POTENTIAL:  3745.0


MILEAGE SUMMARY BY RAILROAD           A-M    B-M    A-BR   B-BR   OTHER
                     BN    1966.8   1966.8    .0     .0     .0      .0
                     NS     449.1    449.1    .0     .0     .0      .0
                     UP       8.6       .0    .0    6.0    2.6      .0
                     IHB     24.0     24.0    .0     .0     .0      .0
                     USG     25.4       .0    .0     .0   25.4      .0
                     WCRC      .0       .0    .0     .0     .0      .0
                          - - -   - - -   - -   - -   - - -   - -
                   TOTAL   2473.9   2439.9    .0    6.0   28.0      .0
 MILEAGE SUMMARY BY STATE
         101.0-ID    183.2-IL    156.3-IN    279.8-MN    672.0-MT
         385.0-ND    290.8-OH    203.8-WA    202.0-WI


  RR      NODE              STATE  DIST
 USG  16215-HANFORD WORKS    WA     0.
 USG  13941-RICHLAND         WA    25.
- - - - - - - - - - - - - - - - - - - - - - - TRANSFER
 UP   13941-RICHLAND         WA    25.
 UP   13964-KENNEWICK        WA    34.
- - - - - - - - - - - - - - - - - - - - - - - TRANSFER
 WCRC 13964-KENNEWICK        WA    34.
- - - - - - - - - - - - - - - - - - - - - - - TRANSFER
 BN   13964-KENNEWICK        WA    34.
 BN   13890-PASCO            WA    35.
 BN   13828-SPOKANE          WA   187.
 BN   13300-SANDPOINT        ID   250.
 BN   13089-SHELBY           MT   587.
 BN   13168-HAVRE            MT   688.
 BN   15740-WILLISTON        ND  1007.
 BN   10936-MINOT            ND  1119.
 BN   10935-SURREY           ND  1125.
 BN   11134-CASSELTON        ND  1340.
 BN   11132-FARGO            ND  1360.
 BN   11131-MOORHEAD         MN  1363.
 BN    9663-STAPLES          MN  1477.
 BN    9671-SAUK RAPIDS      MN  1542.
 BN    9826-COON CREEK       MN  1592.
 BN    9798-NORTHTOWN        MN  1597.
 BN   15603-EAST MINNEAPOLISMN  1603.
 BN    9793-SOO LINE JCT     MN  1610.
 BN    9830-ST PAUL          MN  1612.
 BN    5736-LA CROSSE        WI  1734.
```

```
  BN    4327-EAST DUBUQUE    IL  1845.
  BN    4317-SAVANNA         IL  1885.
  BN    4190-AURORA          IL  1976.
  BN    4170-LA GRANGE       IL  2001.
 - - - - - - - - - - - - - - - - - - - - - - - TRANSFER
  IHB   4170-LA GRANGE       IL  2001.
  IHB   4172-ARGO            IL  2005.
  IHB   4163-BLUE ISLAND     IL  2017.
  IHB   4228-BURNHAM / CALUMEIL  2025.
 - - - - - - - - - - - - - - - - - - - - - - - TRANSFER
  NS    4228-BURNHAM / CALUMEIL  2025.
  NS    4076-HAMMOND         IN  2027.
  NS    4064-HOBART          IN  2043.
  NS    4020-ARGOS           IN  2106.
  NS    3548-FORT WAYNE      IN  2165.
  NS    3002-FOSTORIA        OH  2254.
  NS    2995-BELLEVUE        OH  2285.
  NS    3402-MARION          OH  2334.
  NS    3094-COLUMBUS (4TH STOH  2374.
  NS    3162-CHILLICOTHE     OH  2425.
  NS    3170-PORTSMOUTH      OH  2474.


   POPULATION DENSITY FROM:  USG  16215-HANFORD WORKS       WA
                       TO:  NS    3170-PORTSMOUTH          OH

         ------------------  MILEAGE WITHIN DENSITY LEVELS  -------------------
               <0.0   5.0  22.7  59.7   139   326   821  1861  3326  5815
St Miles    0  -5.0 -22.7 -59.7  -139  -326  -821 -1861 -3326 -5815 -9996 >9996
------------------------------------------------------------------------------

ID 101.0 14.8  22.4  36.5  10.0   8.9   4.1   1.9   1.2    .6    .6    .0    .0
IL 183.2 10.5  34.7  44.7  22.6  14.9   8.8   6.4   8.4  10.6  14.1   5.7   1.8
IN 156.3  7.2  16.0  24.2  38.1  31.2  11.2   8.1   6.5   6.4   4.8   2.2    .4
MN 279.8 16.7  49.1  58.6  47.4  30.7  18.3  18.9  16.5  12.5   9.1   1.9    .1
MT 672.0 21.2 536.5  86.3  18.7   5.4   2.3    .3    .7    .6    .0    .0    .0
ND 385.0 33.6 247.5  62.3  12.8   7.9   6.3   5.5   2.2   4.9   1.7    .2    .0
OH 290.8 12.3  39.3  39.9  69.8  46.3  32.1  16.2   8.3  11.2   8.4   3.1   3.6
WA 203.8 30.3  74.5  50.6   3.7   6.7   4.7  11.9   7.3   6.7   7.0    .5    .0
WI 202.0 17.6  38.4  45.4  53.6  24.8  10.2   3.2   4.0   2.6   2.0    .2    .0

Totals
  2473.9164.31058.3 448.3 276.7 176.6  98.0  72.5  55.0  56.1  47.7  13.8   5.8
Percentages
          6.6  42.8  18.1  11.2   7.1   4.0   2.9   2.2   2.3   1.9    .6    .2
Basis: 1990 Census data

   RADTRAN Input Data       Rural Suburban    Urban

   Weighted Population
        People/sq. mi.        17.8    1007.2   5723.8
        People/sq. km.         6.9     388.9   2210.0

   Distance                                          Total
        Miles               2124.3     281.6     67.4  2473.9
        Kilometers          3418.6     453.2    108.4  3981.2
        Percentage            85.9      11.4      2.7

   Basis (people/sq. mi.)    <139 139-3326    >3326

   Note: Due to rounding, the sum of the mileages in the individual
         population categories may not equal the total mileage shown
         on this report.
```

5.11 Interline Output File for Indirect Route through Paducah, KY

```
ROUTE FROM:  USG  16215-HANFORD WORKS       WA     LENGTH:  2415.5 MILES
        TO:  PAL   7075-PADUCAH             KY  POTENTIAL:  4002.2


MILEAGE SUMMARY BY RAILROAD            A-M   B-M   A-BR  B-BR  OTHER
                     BN    1966.8   1966.8    .0    .0    .0     .0
                     CSXT   316.7    316.7    .0    .0    .0     .0
                     UP       8.6       .0    .0   6.0   2.6     .0
                     IHB     20.0     20.0    .0    .0    .0     .0
                     PAL     78.0       .0  78.0    .0    .0     .0
                     USG     25.4       .0    .0    .0  25.4     .0
                     WCRC      .0       .0    .0    .0    .0     .0
                           - - -   - - -   - -   - -   - -    - -
                   TOTAL  2415.5   2303.5  78.0   6.0  28.0     .0
 MILEAGE SUMMARY BY STATE
         101.0-ID    290.9-IL    164.2-IN    116.8-KY    279.8-MN
         672.0-MT    385.0-ND    203.8-WA    202.0-WI



  RR       NODE              STATE  DIST
 USG  16215-HANFORD WORKS     WA      0.
 USG  13941-RICHLAND          WA     25.
- - - - - - - - - - - - - - - - - - - - - - - TRANSFER
 UP   13941-RICHLAND          WA     25.
 UP   13964-KENNEWICK         WA     34.
- - - - - - - - - - - - - - - - - - - - - - - TRANSFER
 WCRC 13964-KENNEWICK         WA     34.
- - - - - - - - - - - - - - - - - - - - - - - TRANSFER
 BN   13964-KENNEWICK         WA     34.
 BN   13890-PASCO             WA     35.
 BN   13828-SPOKANE           WA    187.
 BN   13300-SANDPOINT         ID    250.
 BN   13089-SHELBY            MT    587.
 BN   13168-HAVRE             MT    688.
 BN   15740-WILLISTON         ND   1007.
 BN   10936-MINOT             ND   1119.
 BN   10935-SURREY            ND   1125.
 BN   11134-CASSELTON         ND   1340.
 BN   11132-FARGO             ND   1360.
 BN   11131-MOORHEAD          MN   1363.
 BN    9663-STAPLES           MN   1477.
 BN    9671-SAUK RAPIDS       MN   1542.
 BN    9826-COON CREEK        MN   1592.
 BN    9798-NORTHTOWN         MN   1597.
 BN   15603-EAST MINNEAPOLISMN   1603.
 BN    9793-SOO LINE JCT      MN   1610.
 BN    9830-ST PAUL           MN   1612.
 BN    5736-LA CROSSE         WI   1734.
 BN    4327-EAST DUBUQUE      IL   1845.
 BN    4317-SAVANNA           IL   1885.
 BN    4190-AURORA            IL   1976.
 BN    4170-LA GRANGE         IL   2001.
- - - - - - - - - - - - - - - - - - - - - - - TRANSFER
 IHB   4170-LA GRANGE         IL   2001.
 IHB   4172-ARGO              IL   2005.
 IHB   4163-BLUE ISLAND       IL   2017.
 IHB   4223-DOLTON / RIVERDAIL   2021.
```

```
 - - - - - - - - - - - - - - - - - - - - - - - TRANSFER
  CSXT  4223-DOLTON / RIVERDAIL   2021.
  CSXT  4206-CHICAGO HEIGHTS IL   2031.
  CSXT  4636-WATSEKA         IL   2082.
  CSXT  4642-DANVILLE        IL   2127.
  CSXT  3863-TERRE HAUTE     IN   2184.
  CSXT  3812-VINCENNES       IN   2237.
  CSXT  3838-EVANSVILLE      IN   2287.
  CSXT  3839-HENDERSON       KY   2300.
  CSXT  7059-MADISONVILLE    KY   2338.
 - - - - - - - - - - - - - - - - - - - - - - - TRANSFER
  PAL   7059-MADISONVILLE    KY   2338.
  PAL   7075-PADUCAH         KY   2416.


 POPULATION DENSITY FROM:  USG  16215-HANFORD WORKS       WA
                      TO:  PAL   7075-PADUCAH             KY

      ------------------  MILEAGE WITHIN DENSITY LEVELS  -------------------
            <0.0   5.0  22.7  59.7   139   326   821  1861  3326  5815
St Miles    0  -5.0 -22.7 -59.7  -139  -326  -821 -1861 -3326 -5815 -9996 >9996
-------------------------------------------------------------------------------

ID 101.0 14.8  22.4  36.5  10.0   8.9   4.1   1.9   1.2    .6    .6    .0    .0
IL 290.9 14.1  53.7  64.4  44.7  30.3  16.5  13.1  14.4  13.6  18.4   5.8   1.8
IN 164.2  5.0  14.3  29.0  42.5  23.6  16.6  13.0  12.8   3.8   2.4    .8    .1
KY 116.8  2.5   9.9  15.7  59.8  12.3   6.6   5.3   3.3   1.2    .1    .0    .0
MN 279.8 16.7  49.1  58.6  47.4  30.7  18.3  18.9  16.5  12.5   9.1   1.9    .1
MT 672.0 21.2 536.5  86.3  18.7   5.4   2.3    .3    .7    .6    .0    .0    .0
ND 385.0 33.6 247.5  62.3  12.8   7.9   6.3   5.5   2.2   4.9   1.7    .2    .0
WA 203.8 30.3  74.5  50.6   3.7   6.7   4.7  11.9   7.3   6.7   7.0    .5    .0
WI 202.0 17.6  38.4  45.4  53.6  24.8  10.2   3.2   4.0   2.6   2.0    .2    .0

Totals
  2415.5155.91046.3 448.6 293.2 150.3  85.7  73.2  62.4  46.5  41.5   9.4   2.0
Percentages
           6.5  43.3  18.6  12.1   6.2   3.5   3.0   2.6   1.9   1.7    .4    .1
Basis: 1990 Census data

   RADTRAN Input Data       Rural Suburban    Urban

   Weighted Population
        People/sq. mi.       17.1    993.7   5366.3
        People/sq. km.        6.6    383.7   2071.9

   Distance                                           Total
        Miles              2094.4    267.7     52.9  2415.5
        Kilometers         3370.5    430.8     85.1  3887.3
        Percentage           86.7     11.1      2.2

   Basis (people/sq. mi.)   <139 139-3326    >3326

   Note: Due to rounding, the sum of the mileages in the individual
         population categories may not equal the total mileage shown
         on this report.


 ROUTE FROM:  PAL    7075-PADUCAH            KY     LENGTH:    534.2 MILES
         TO:  NS     3170-PORTSMOUTH         OH  POTENTIAL:  926.33


 MILEAGE SUMMARY BY RAILROAD           A-M    B-M    A-BR   B-BR   OTHER
```

```
                        NS    310.0    123.0  96.0  91.0    .0     .0
                        PAL   224.2       .0 224.2    .0    .0     .0
                              -  -  -  -  -  -  -  -  -  -  -  -  -  -
                      TOTAL   534.2    123.0 320.2  91.0    .0     .0
   MILEAGE SUMMARY BY STATE
           427.5-KY    106.7-OH


     RR      NODE           STATE  DIST
    PAL   7075-PADUCAH         KY     0.
    PAL   7008-LOUISVILLE      KY   224.
   - - - - - - - - - - - - - - - - - - - - - - - TRANSFER
    NS    7008-LOUISVILLE      KY   224.
    NS    6850-LEXINGTON       KY   353.
    NS    3228-CINCINNATI      OH   428.
    NS    3234-IVORYDALE       OH   434.
    NS    3237-RED BANK        OH   441.
    NS    3170-PORTSMOUTH      OH   534.


   POPULATION DENSITY FROM:  PAL    7075-PADUCAH              KY
                        TO:  NS     3170-PORTSMOUTH           OH

         ------------------  MILEAGE WITHIN DENSITY LEVELS  -------------------
               <0.0   5.0  22.7  59.7   139   326   821  1861  3326  5815
St Miles    0  -5.0 -22.7 -59.7  -139  -326  -821 -1861 -3326 -5815 -9996 >9996
-------------------------------------------------------------------------------

KY 427.5 10.9  28.3  64.0 179.5  64.2  25.6  16.4  13.9  11.8   9.7   2.9    .3
OH 106.7 12.3  13.6  20.2  15.7  11.0   8.2   9.3   7.6   4.3   3.8    .7    .0

Totals
   534.2 23.2  41.9  84.2 195.2  75.2  33.8  25.7  21.5  16.1  13.5   3.5    .3
Percentages
          4.3   7.8  15.8  36.5  14.1   6.3   4.8   4.0   3.0   2.5    .7    .0
Basis: 1990 Census data

   RADTRAN Input Data      Rural Suburban    Urban

   Weighted Population
        People/sq. mi.      40.0    959.1   5332.2
        People/sq. km.      15.4    370.3   2058.7

   Distance                                           Total
        Miles              419.7     97.1     17.3    534.2
        Kilometers         675.4    156.2     27.9    859.7
        Percentage          78.6     18.2      3.2

   Basis (people/sq. mi.)   <139 139-3326    >3326

   Note: Due to rounding, the sum of the mileages in the individual
         population categories may not equal the total mileage shown
         on this report.
```

5.12 GXQ Output File for Puff Release

```
  Current Input File Name: puffxq.IN
```

```
                        ________________________

                             GXQ Version 4.0
                            December 19, 1994
                        ________________________

General Purpose Atmospheric Dispersion Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-3002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-3003 Rev. 1.
Code Custodian is Brit E. Hey, WHC, ext. 376-2921.

Run Date = 07/26/99
Run Time = 15:43:12.70


INPUT ECHO:
Peak Concentration for Puff Release
c GXQ Version 4.0 Input File
c   mode
    2
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    1     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c  (irise igrnd)iwash igrav
    0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
c       = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c isize = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
```

```
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
c igrav = 1 then gravitational settling model turned on
c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                 reference                     frequency
c   release       anemometer     mixing         to
c   height        height         height         exceed
c   hs(m)         ha(m)          hm(m)          Cx(%)
c   ___________    ___________    ___________    ___________
    0.00000E+00    1.00000E+01    1.00000E+03    5.00000E-01
c
c   initial       initial                                      gravitational
c   plume         plume          release        deposition     settling
c   width         height         duration       velocity       velocity
c   Wb(m)         Hb(m)          trd(hr)        vd(m/s)        vg(m/s)
c   ___________    ___________    ___________    ___________    ___________
    0.00000E+00    0.00000E+00    0.00000E+00    1.00000E-03    1.00000E-03
c
c                 initial        initial                       convective
c   ambient       plume          plume          release        heat release
c   temperature   temperature    flow rate      diameter       rate(1)
c   Tamb(C)       T0(C)          V0(m3/s)       d(m)           qh(w)
c   ___________    ___________    ___________    ___________    ___________
    2.00000E+01    2.20000E+01    1.00000E+00    1.00000E+00    0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q           Wind
c   scaling       Speed
c   factor        Exponent
c   c(?)          a(?)
c   ___________    ___________
    1.00000E+00    7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE     make         RECEPTOR DEPENDENT DATA
c 1 (site specific)         sector distance receptor-height
c 2 (by class & wind speed) class windspeed distance offset receptor-height
c 3 (create plot file)      class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size

MODE:
X/Q calculated by stability class and wind speed.
```

```
LOGICAL CHOICES:

MODELS SELECTED:
Gaussian puff model selected.

WARNING/ERROR MESSAGES:


Peak Concentration for Puff Release


ATM.       WIND                                  RECEPTOR     SCALED
STAB.      SPEED      DISTANCE       OFFSET       HEIGHT       X/Q
CLASS      (m/s)        (m)            (m)          (m)        (1/m3)

______    ________    ________    ________    ________    __________
F             1.00         100           0           0     2.65E-03
D             2.00         100           0           0     3.14E-04
D             2.00         200           0           0     4.74E-05
D             2.00        1000           0           0     7.10E-07
```

5.13 Attachments: Route Maps and Container Schematics

(this page reserved for truck direct route)

(this page reserved for truck indirect route)

(this page reserved for rail direct route)

(this page reserved for rail indirect route)

ENGINEERING ANALYSIS/DESIGN CALCULATION

Doc. No. ENG-RCAL-028 Rev. 1 Project No. 772030/171 Page 59 of 62
Subject: Transportation Risk Assessment for the Shipment of Unirradiated Uranium
Preparer: J. L. Boles Date 5/31/00
Checker: B. B. Peters Date 5/31/00

(this page reserved for G-4255 box schematic)

(this page reserved for G-4214 box schematic)

(this page reserved for T-Hopper schematic)

(this page reserved for Brian’ s check sheet)